



**JAPAN INTERNATIONAL COOPERATION AGENCY
DIRECTORATE FOR ROADS OF VIETNAM
MINISTRY OF TRANSPORT
THE SOCIALIST REPUBLIC OF VIET NAM**



THE PROJECT FOR CAPACITY ENHANCEMENT IN ROAD MAINTENANCE PHASE-II

Final Report

VOLUME 3.3: EXPRESSWAY MAINTENANCE MANUAL

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Concept of Development

- (1) Expressway Maintenance Manual is a reference material aiming to provide information on the expressway maintenance procedures to the DRVN, RMBs and SBs staff currently involved in the expressway maintenance and management activities in the field.
- (2) The maintenance management procedures covered in this manual ranges from road facility inspection, diagnosis, maintenance and repair work selection and the implementation of maintenance and repair work to be carried out in conjunction with routine maintenance and periodic repair on the expressway systems.

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1. SCOPE OF APPLICATION

- (1) Expressway Maintenance Manual is a reference material aiming to provide information on the expressway maintenance procedures to the DRVN, RMBs and SBs staff currently involved in the expressway maintenance and management activities in the field.
- (2) Expressway maintenance Manual covers procedures ranging from road facility inspection, diagnosis, maintenance and repair work selection and the implementation of maintenance and repair work to be carried out in conjunction with routine maintenance and periodic repair on the expressway systems.
- (3) The Manual shall not be applied to the investment projects such as rehabilitation and reconstruction projects implemented aiming to upgrade road functions and capacities such as a widening project.
- (4) The Manual shall not be applied to the expressways in operation under BOT or PFI scheme.
- (5) The Manual shall not be applied to large-scale bridges, special bridges, ITS systems, toll systems, vehicle weighing stations and road management facilities on the expressways.

2. QUOTED DOCUMENTS

The following documents are needed for the application of this Manual. For the reference documents indicating year of publication, the version at the date shown below shall be used. For the reference documents without year of publication, the latest edition shall be used, including revisions and amendments (if any).

TCVN 7493/2005	Bitumen - Specifications
TCVN 7887/2008	National Technical Regulation on Road Signs and Signals
TCVN 8786/2011	Traffic Paints - Road marking materials: Water-borne paint - Specifications and test methods
TCVN 8787/2011	Traffic Paints - Road Marking Materials: Solventborne Paint - Specifications and Test Methods
TCVN 8788/2011	Traffic paints. Road marking materials: Solvent-borne and water-borne paint - Procedures construction and acceptance TCVN 8860:2011 Hot Mix Asphalt Concrete Pavement – Specifications on Construction and Acceptance
TCCS 02:2010/TCĐBVN	Bridge Construction Specifications
TCVN 8867 - 2001	Flexible pavement - standard test method for determination of elastic modulus of pavement structure using Benkelman girder
TCCS 07:2013/TCĐBVN	Technical Specifications for Frequent Road Maintenance
TCCS 11-2013/TCĐBVN	Specification for Road Management and Operation

TCCS 12-2013/TCĐBVN	Specification for Construction and Acceptance of Cement Concrete Highway Pavement Structure
TCVN XXXX/2015	Design Standard on Strengthening RC Bridge Structure with Fiber – reinforced plastic
TCVN XXXX/2015	Strengthening RC Bridge Structure with Fiber – reinforced plastic - Specifications on Construction and Acceptance

3. TERMS AND DEFINITIONS

In this Manual, the following terms and definitions shall be used, which are defined in the regulations stipulated in “2. Quoted Document”:

- (1) Expressway means a road reserved exclusively for motor vehicles, with median strips separating carriageways for the two opposite directions of traffic, without at-grade intersection with any road, furnished with adequate support equipment and devices to ensure uninterrupted and safe traffic and shorten travel time, and with certain points for vehicle exits and entries.
- (2) Expressway Administration agency means the Directorate for Roads of Vietnam, the Ministry of Transport; specialized agencies of People’s Committees of provinces and centrally run cities.
- (3) Road Facility Inspection means checking of road facilities by visual or by inspection devices to detect any damages on the facilities and to evaluate the damages for further survey or repair works.
- (4) Work Maintenance means a collection of work to ensure and maintain proper and safe operation of the work as indicated in the design during its lifespan, which includes routine maintenance, periodic repair and emergency repair to keep road structures and properties as near as possible to their as-constructed or renewed condition. Maintenance includes minor repairs and improvements to eliminate the cause of defects and avoid excessive repetition of maintenance efforts.
- (5) Routine Maintenance means the works to be implemented to prevent and promptly fix deficiency or minor damages of road facilities and equipment components in order to enhance the operation quality and prevent further damages and incidents and secure the service life of road facilities. These operations are typically small scale or simple, but widely dispersed, and require skilled or un-skilled manpower.
- (6) Periodical repair is a scheduled remedial activity aiming to recover functions of facilities to initial function and to improve the technical condition of road transport infrastructure assets, which cannot be assured by routine maintenance. Moreover, it includes new replacement of old or aged equipment.
- (7) Emergency repair means the works to be implemented when the components of rod facilities and equipment are damaged by sudden effects from typhoons, floods, earthquakes, crashes, fires and other unexpected affects or there are signs of sudden damages which affect the usage safety and require prompt repair in order to ensure the smooth and safe traffic.

3.1 Organization with legal ownership

- (1) Definitions of functions, tasks, power and organization structure of the organization in charge of expressway maintenance and management are stipulated in the relevant regulations.
- (2) Units carrying out road facility inspection, road routine maintenance, periodic maintenance are those who possess business license in construction and maintenance of transport works and who are assigned and ordered or participated and bid accepted to implement road maintenance and management.
- (3) Road routine maintenance management according to executed method and quantity (MBC - Method Based Contract) is the management type of traditional routine maintenance implementation based on required methods and quantity and certified by Road Management Agency. The management type may follow routine maintenance plan assigned by year or fixed rate of routine maintenance quantity for unit carrying out road routine maintenance.
- (4) Road routine maintenance management as per executed quality (PBC - Performance Based Contract) is the management type of progressive routine maintenance implementation based on road quality and works on the roads which are evaluated periodically according to united norms. This type of management is carried out on the basis of road routine maintenance contracts through bidding, order placing or assignment.

3.2 Abbreviations:

AC:	Asphalt concrete
CC:	Cement concrete
DRVN:	Directorate for Roads of Vietnam
MBC:	Method Based Contract
MOT:	Ministry of Transport
PCI:	Pavement Condition Index
PBC:	Performance Based Contract
PDOT:	Provincial Department of Transport
PSRC:	Pre-stressed reinforced concrete
RC:	Reinforced Concrete
ROW:	Right of Way
RRMB:	Regional Road Management Bureau

4. GENERAL REGULATIONS

Proper maintenance should be given to all expressways during their operation and lifespan. New expressways should be maintained right after the work is put into use. Expressways under repair should be maintained right after the repair work is done.

Expressway concessionaire should have an overall strategy on expressway maintenance, including inspection, maintenance and repair (if necessary).

5. PRINCIPLE OF ROAD FACILITY INSPECTION

This chapter stipulates principle of road facility inspection including procedures, methods and technologies of inspection. Detail implementation guidance of road facility inspection shall be given in each chapter of relevant road facility by facility type.

5.1 Objective of Road Facility Inspection

Road facility inspection is part road maintenance activities and has the following objectives;

- To quickly detect any incidents and abnormalities on the road facilities which may hinder road and traffic functions.
- To provide information to the formulation of medium-term and long-term road asset management plans which aims at optimizing maintenance and repair investment in the long period of road maintenance.

5.2 Classification of Road Facility Inspection

- (1) Road facility inspection for the national roads shall fall into the following five (5) categories; initial inspection; routine inspection; periodic inspection, emergency inspection and detailed inspection.
- (2) Initial inspection is to survey the initial status of road facilities that are taken over from construction stage to maintenance stage.
- (3) Routine inspection is a daily inspection done by traffic patrol staff to quickly find any unusual incidents and defects which may provide negative effects on the road and traffic function of the roadway, thereby maintain the service level of the road.
- (4) Periodic inspection is to regularly survey defects and deterioration of road facilities, to evaluate them in comparison with predetermined judgment criteria, to select the most suitable repair methods for the damages and to preserve data in relevant databases. Periodic inspection provides base information to the road asset management which aims to find out the most appropriate mid-term/long-term investment for road maintenance and repair works.
- (5) Emergency inspection is generally carried out in order to supplement the above inspections and to cope with emergencies, such as unusual weather, traffic accidents and natural disasters.
- (6) Detail inspection shall be implemented based on the decision made by evaluation committee to further study the details of structural defects and deterioration of road facilities after periodic inspection and to specify the causes of structural defects and deterioration. Also, it shall be implemented to provide information for the designs of road repair works, including F/S, basic designs and technical designs needed for repair works.

5.3 Procedures of Road Facility Inspection

Road facility inspection shall include the following tasks; formulation of road facility inspection plans, implementation of road facility inspection, evaluation of inspection results, formulation of repair work plans, formulation of monitoring plans, registration of inspection data into road facility database and reporting. **Figure 5.3-1** shows the flowchart of these procedures.

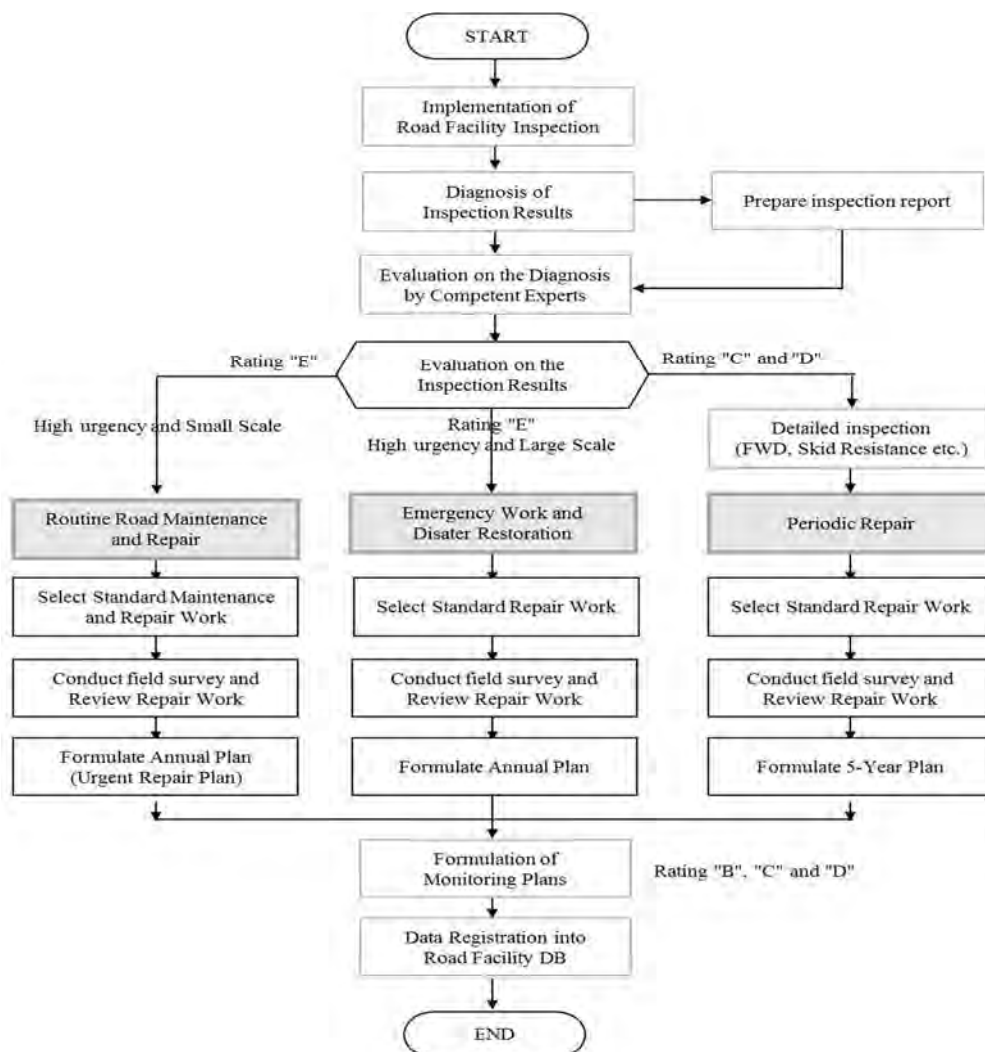


Figure 5.3-1 Implementation Procedures of Road Facility Inspection

5.3.1 Formulation of Road Facility Inspection Plans

Management agency of road facility inspection shall formulate inspection implementation plans for the road facilities under their jurisdiction on the basis of the relevant articles of this guideline. The inspection implementation plans to be formulated shall include the plans for routine inspection and periodic inspection for the national roads under their jurisdiction. Road facility inspection plans shall include the following information:

- Inspection facilities
- Inspection methods

- Inspection devices
- Inspection frequencies
- Inspection schedule
- Inspection team organization
- Safety assurance during inspection
- Evaluation on the inspection results
- Formulation of repair work plans
- Recording of inspection results and reporting

For the implementation of initial road facility inspection on the new road facilities taken over to DRVN for road maintenance and operation, DRVN shall designate a management agency of road facility inspection in the region to implement inspection.

5.3.2 Inspection Facilities

Road facilities for inspection to be selected in this guideline shall include road pavements, slopes, tunnels, box and pipe culverts, traffic safety and management facilities.

5.3.3 Inspection Methods

Inspection methods shall be properly selected for each inspection type. Standard methods of each inspection type are shown in Table 5.3-1.

Table 5.3-1 Standard Inspection Methods

Inspection Type	Inspection Methods
Initial Inspection	● Short-distance visual inspection ● Hammering tests ● Pavement condition survey vehicle
Routine Inspection	● Vehicle on-board visual inspection ● Short-distance visual inspections
Periodic Inspection	● Pavement condition survey vehicle ● Short-distance visual inspection ● Hammering inspection, Crack gage, measuring tape ● Photos
Emergency Inspection	● Short-distance visual inspection ● Hammering inspection, Crack gage, measuring tape ● Photos
Detailed Inspection	● Short-distance visual inspection ● Hammering inspection, Crack gage, measuring tape ● Photos ● Non-destructive test equipment

(Source) Project for capacity enhancement in Road Maintenance Phase-II

5.3.4 Inspection Devices

Inspection devices shall be properly selected and applied to road facility inspection as the need arises. Standard inspection devices are shown below;

- Inspection equipment: crack gauge, gap gauge, dial gauge, hammer (230 grams for hammering),

Schmidt hammer, binoculars, tape measure, metal tape, caliper square, tape, pole, wire-brush, shovel, hand mirror, thermometer, etc.

- Inspection safety gears: goggles (for hammering), mobile phones (for communication), anti-dust masks, safety belts, etc.
- Recording facilities: Digital camera, video recorder, black board, chalk, note pads, etc.;
- Other device: Traffic control facility (traffic cone, arrow signs, flags, etc.), stepladder, paint, cohesive substances

5.3.5 Standard Inspection Frequency

Road facility inspection shall be implemented based on the standard frequencies stipulated in **Table 5.3-2**. However, managing agency of road facility inspection can adjust frequencies of inspection in order to meet local conditions of road facilities and their damages.

Table 5.3-2 Standard Inspection Frequencies

Inspection Type	Frequencies
Initial Inspection	● After the completion of road construction/reconstruction and before the opening of road facilities to the public, or, ● Within one year after the opening of road facilities to the public.
Routine Inspection	● Every day; When traffic volume is more than 10,000 vehicles per day ● Every other day; When traffic volume is less than 10,000 vehicles per day
Periodic Inspection	● Pavement facilities: Once every 3-5 years ● Slope facilities: Once every 5 years ● Tunnel facilities: Once every 5 years ● Box and pipe culvert facilities: Once every 5 years ● Traffic Road safety facilities: Once every 5 years ● Road management facilities: Once every 5 years (Note) a. However, if the facilities are once rated as “C” in the evaluation of the periodic inspection, the next inspection should be carried out no later than two years after the previous inspection. b. Also, if the facilities are once rated as “D” or “E” in the evaluation of the periodic inspection, the inspection should be carried out no later than one year after the previous inspection. c. However, upon completion of repair works, original frequencies stated above are applied for the above two cases.
Emergency Inspection	● Immediately after unexpected incidents occur such as disasters.
Detailed Inspection	● When proposed by periodic inspection ● When proposed for the planning and the designing of road rehabilitation and reconstruction works

(Source) Project for capacity enhancement in Road Maintenance Phase-II

5.3.6 Safety Measures during Inspection

Safety measures during inspection shall be properly taken in order to ensure traffic safety and inspection staff safety.

5.3.7 Evaluation of Inspection Results

Evaluation of inspection results shall be conducted, applying criteria of 5 rating levels consisting of A/B/C/D/E as shown in **Table 5.3-3**. The criteria are based on the following concepts; effects on vehicle traffic and road environment; and the need of further survey.

- Rating “A” is applied when no damage or minor damages are observed, so that no repair work is needed at this stage.
- Rating “B” is applied to the medium structural damages whose rapid progress is not expected within 5 years. Repair work will be needed, but not urgent, so that monitoring is a major activity.
- Rating “C” is applied to medium and heavy structural damages expected to progress within 5 years. Repair works need to be planned within 5 years, so that detailed inspection is necessary to find out the causes of the damages and the detail planning of repair works.
- Rating “D” is applied to heavy structural damages which need urgent repair work, so that detailed inspection is needed to plan and design repair works in detail.
- Rating “E” is applied to the damages expected to give large negative effects on road traffic and road environment. Urgent repair work is needed regardless of damage degree.

Table 5.3-3 Evaluation Criteria

Rating	Evaluation Criteria	Effects on road structural function	Effects on traffic and environment	Need of further study	Measures to be taken
A	• No damage or minor structural damages	Small	-----	-----	• No repair work
B	• Medium structural damages • Progress of damages is not expected within coming 5 years. • Repair works will be needed, but not urgent.	Medium	-----	-----	• Monitoring
C	• Medium to Heavy structural damages • Progress of damages is expected within coming 5 years. • Repair works will be needed within 5 years.	Medium-large	-----	Detailed inspection	• Periodic repair (Planned works) • Monitoring
D	• Heavy structural damages • Urgent repair work is needed.	Large	-----	Detailed inspection	• Periodic repair • Urgent repair • Monitoring
E	• Large effects on road environment are expected.	-----	Large	-----	• Routine maintenance and repair

5.3.8 Implementation of Detailed Inspection

When the evaluation meeting makes a decision that further detailed inspection is needed (a rating level of “C” or “D”), managing agency of road facility inspection shall take immediate actions to conduct detailed inspection for the damages. Detailed inspection shall be implemented aiming to identify the causes of damages, to find out the most appropriate repair works and to design repair works.

5.3.9 Formulation of Monitoring Plans

Road facility inspection is in principle conducted based on the standard frequencies specified in this relevant article of this Guideline. However, if a road facility inspection was conducted and the evaluation was made on some of road facilities with “B”, “C”, “D” and “E” rating, the inspection frequencies until next inspections need to be adjusted in particular for “C” and “D” rating. Managing agency of road facility inspection shall formulate monitoring plans in order to keep watching the progress of damages on the road facilities.

5.3.10 Formulation of Maintenance and Repair Plans

Managing agencies of road facility inspection shall formulate road routine maintenance plans, periodic repair plans and emergency repair plans in accordance with Circular No.52/2013/TT-BGTVT.

5.3.10.1 Selection of Maintenance and Repair Works

Managing agencies of road facility inspection shall select maintenance and repair works for the damages rated as “C”, “D” and “E”. Selection of repair works except those shown in this guideline shall be based on the current practices implemented in the RMB regions. However, in case PMS is applied to the formulation of periodic repair plans for “C” and “D”, repair works shall be automatically selected in the computation processes of PMS model.

The selection of maintenance and repair plans shall be implemented for the small repair in the routine maintenance and for the periodic repair, following the flowchart shown in **Figure 5.3-1**. Users are required to select standard repair plans first for the above both cases, then to conduct detailed surveys to identify local conditions and to review standard repair plans, taking account of local conditions.

5.3.10.2 Formulation of Maintenance Repair Plans

Road routine maintenance plans, which are annual plans, shall include regular routine maintenance works and urgent repair works for the damages rated as “E” during road facility inspection, which are expected to provide large effects to vehicle traffic and road environment. Temporary restoration works for the damages given by disasters shall be included in the routine maintenance and repair plans. Full-scale restoration works shall be registered into emergency repair works stated below.

Periodic repair plans shall include repair plans aiming to repair medium or heavy damages rated as “C” or “D” during road facility inspection. Periodic repair plans shall be classified into annual plans and 3-year plans, depending upon the urgency of repair works. If periodic repair works need urgent implementation, periodic repair plans shall be registered into annual plans. On the other hand, if periodic repair works do not need urgent implementation, periodic repair works shall be registered into 3-year planned repair plans.

Emergency repair plans shall include repair plans for the damages given by disasters which are rated as “D” during road facility inspection.

5.3.10.3 Estimation of Maintenance and Repair Work Volumes

Work volumes for maintenance and repair works shall be estimated for each of the work. Repair work volume estimation for periodic and emergency works shall be based on the results of detailed inspection, design materials conducted in the detailed inspection and field observation. However, in case PMS is applied in the formulation of periodic repair plans for “C” and “D” rating, estimation of work volumes for periodic repair works shall be automatically made in the computation processes of PMS model.

5.3.11 Registration of Inspection Data and Reporting

Inspection results shall be recorded in the data registration forms shown in **Table 5.3-4**. Inspection supervision agency (SB) shall report inspection results to inspection management agency (RMB) and DRVN regularly.

Table 5.3-4 Data Input Form

Inspection type	Data Registration Form	
Pavement inspection (by Road Condition Survey)	ANNEX-I_P1	ANNEX-J
Pavement inspection (by Visual Inspection)	ANNEX-I_P2	ANNEX-J
Slope inspection	ANNEX-I_S-1	ANNEX-J
Tunnel inspection	ANNEX-I_T-1	ANNEX-J
Box and pipe culver inspection	ANNEX-I_C-1	ANNEX-J
Traffic safety facility inspection	ANNEX-I_TS-1	ANNEX-J
Traffic management facility inspection	ANNEX-I_TM-1	ANNEX-J

6. ROAD MAINTENANCE AND REPAIR TECHNOLOGIES

6.1 Road Slope Maintenance Management

6.1.1 Introduction

The Guideline regulates the focus points of road slope maintenance including damage types of road slopes, inspection and diagnosis of slope damages, and maintenance work selection against road slope damages. Road slopes in general fall into the following two types; (1) a natural slope and (2) a structurally protected slope. Cut slopes

It is known that cut slopes including natural slopes and artificially protected slopes shall be weathered and deteriorated and eventually becomes weakened as time passes after construction. Road slope damages shall often provide serious damages to road and traffic functions, often giving a large negative effect to regional socio-economy. A key point of road slope maintenance is to detect any abnormalities arising on the road slopes and to take immediate actions against these changes before leading to serious damages and providing serious effects on traffic safety and regional socio-economy.

6.1.2 Road Slope Protection Technology

6.1.2.1 Natural Slopes with Seeding, Sodding and Planting

Planting including seeding and sodding becomes effective only when plants grow successively for a long term to come and when they are taken care of appropriately. The method of planting falls into two categories: seeding and sodding. **Table 6.1-1** shows the objectives of these technologies.

Table 6.1-1 Planting Technologies and Purposes

Maintenance and Repair Technology	Objectives
Seeds spraying; Sodding mat; Sodding	To prevent rain water causing soil erosion, greening, vegetation around the area
Seed matting; Strip sodding	To prevent rain water causing soil erosion, greening, vegetation around the area, vegetation rows on the mound for embankment
Seed board; Seed packet; Pick-hole seeding	To prevent rain water causing soil erosion, greening, vegetation around the area and partial vegetation on borrow soil in the cut slope.

6.1.2.2 Structurally Protected Slopes

For areas which are not suitable for planting, the areas where planted by tree still not making sure of the stability of slopes, or areas at risk of fracture, erosion, collapse; they should be applied to the method reinforced with structural materials. **Table 6.1-2** shows basic method of reinforcement

Table 6.1-2 Slope Protection Technologies and Purposes

Protection Technologies	Purposes
Mortar spraying Concrete spraying Stone pitching Concrete block pitching Concrete block crib	Against weathering, erosion
Concrete pitching Cast-in-place concrete crib Slope anchor	Against weathering, erosion Preventing sloping surface cracks, anti-fracture, the rock avalanche,
Net hurdling Slope gabion	Preventing landslides in tilt surface layer
Rock fall prevention net Rock fall prevention fence Rock fall shed	Preventing rock slides

6.1.3 Typical Damages Observed

Table 6.1-3 shows the damages arising on the road slope. Slope failures differ depending upon slope types as follows;

Table 6.1-3 Damages of road slope

Classification	Slope Type	Damages on the Slope
Natural slopes	No protection	- Cracks, swelling, subsidence etc. - Gully erosion and falling of surface soils - Debris on slope berm - Spring water - Landslide - Slope collapse

Classification	Slope Type	Damages on the Slope
	Natural slopes with planting or seeding	- Withered plants and grass - Land slide - Slope collapse
Structurally protected slopes	Stone rip-rap, concrete crib work and stone pitching	- Back filling soil flowing - Holes or cave-in in protected slope - Fall of pebbles or crushed stone in the crib works - Sliding, subsidence, bulging or cracking of concrete crib work - Water seepage or spring water - Erosion of foundation
	Concrete or mortar splay	- Cracking and peeling - Swelling and settlement - Water seepage or spring water
	Slope wire net	- Wire corrosion or rupture - Deformation
	Wire cylinder or mat gabion masonry	- Wire corrosion - Falling rocks
	Rock fall prevention work	- Weathering and damage of foundation - Accumulation soil and falling rocks - Corrosion of net and straps - Loosen or missing anchor

6.1.4 Inspection of Road Slope

The Guideline regulates the major points of road slope inspection as shown below. For other points including “Inspection methods and frequencies”, Evaluation of inspection results” and “Data registration and reporting”, users are requested to refer to the relevant Chapter “Inspection”.

- Focus points of inspection
- Inspection points
- Slopes with structural protection
- Monitoring methods of slope damage

6.1.4.1 Focus Points of Inspection

- (1) It is known that general cut slope without protection is weathered and deteriorated and eventually becomes weakened as time passes by during road maintenance, so that it is important not to miss the first symptom of slope failure by facility inspection.
- (2) Focus points of slope inspection are as follows;
 - Status of underground and surface water on the slope
 - Erosion caused by underground or surface water flow
 - Cracks, swelling and uneven settlement of natural and planting slopes
 - Cracks, swelling and uneven settlement of structurally protected slopes
 - Status of growth for planting and seeding slope

In case detecting any slope failures, detailed study shall be implemented immediately for planning slope protections and evaluating the urgency of countermeasures.

- (3) Cut slope cracks emerging on the slopes and forward swelling of cut slopes are the main symptoms of imminent slope failures. Cut slope failures often occur from the upper part of slopes including cut shoulders, so that it is necessary to investigate the existence of cracks in a wider area including natural slopes surrounding the cut slopes under consideration.
- (4) Attention should be paid to any spring water seen on the cut slope and water treatment on the cut shoulders, as heavy rainfall may raise ground water level near the slope and have negative effects on the stability of cut slopes. Care should be directed to any changes of water near the cut slopes including occurrence of spring water, water volume and turbidity,
- (5) Block masonries and concrete frames on the slope often show the first symptom of slope failures, so that it is particularly important to check for deformation of these structures.
- (6) Road embankment constructed with half cutting and half fill on the narrow inclined valleys in the mountainous area should be carefully inspected as rainfalls often causes high concentrations of water in the narrow valleys which has negative effects on the embankment.
- (7) Any changes seen on the surface of the embankment, such as cracks on the slope shoulder, differences in level or swelling, should be carefully inspected.
- (8) Attention should also be paid on whether plants or grasses fully cover the slopes or whether soil erosion has occurred.
- (9) If urgent countermeasures are needed to ensure stability of the embankment by inspection, appropriate measures including the installation of drain borings should be implemented to drain out water from embankments.
- (10) The focus points of embankment and cut slope inspection are shown in **Figure 6.1-1** and **Figure 6.1-2**.

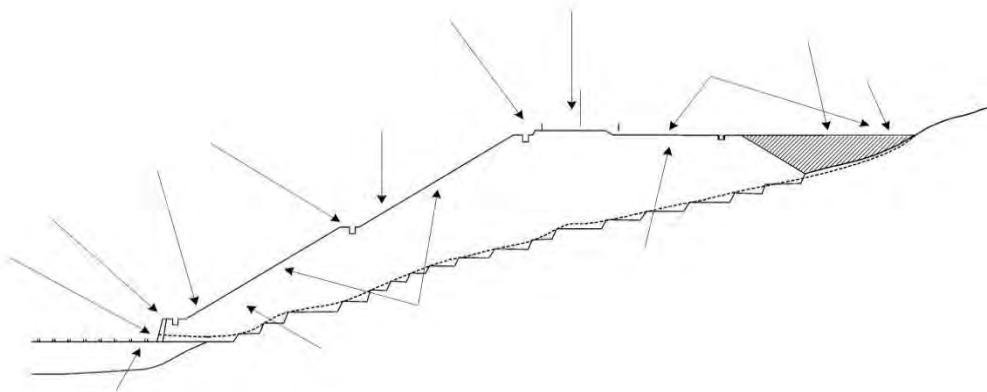


Figure 6.1-1 Focus Points of Inspection on Embankment Slopes

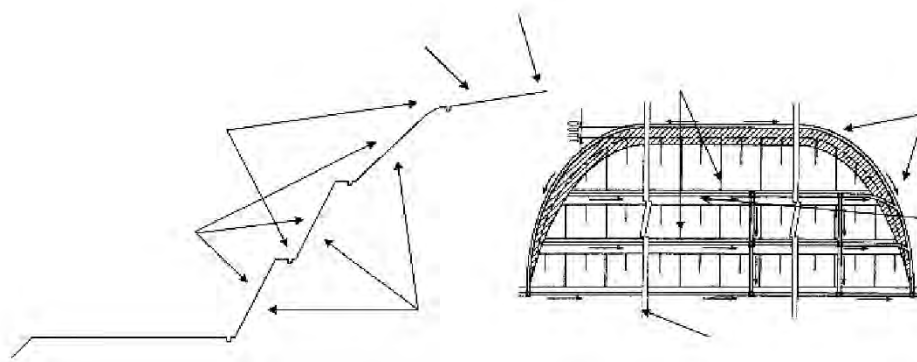


Figure 6.1-2 Focus Points of Inspection on Cut Slopes

6.1.4.2 Inspection Points

Inspection of road slope facilities shall be implemented on the inspection points shown in **Table 6.1-4** for natural slopes with seeding, sodding and planting and **Table 6.1-5** for structurally protected slopes. Tables regulate the minimum requirement of inspection points, so that users can supplement some inspection points whenever needed.

Routine inspection shall be in principle implemented by vehicle-on-board visual inspection. However, when damage is detected, the inspection staff shall get off the patrol car and conduct short-distance visual inspection. In the case of routine inspection which shall be carried out from national road side, the range of the inspection is the area visible from the patrol car on the national road. For the routine inspection on the road side slopes which are invisible from national road side, inspection shall be done within the visible range from the local road accessible by car.

Table 6.1-4 Inspection Points for Natural Slopes

Facility	Member	Damage	Initial inspection	Daily inspection	Periodic inspection	Emergency inspection	Detailed Inspection
Natural slopes with seeding, sodding and planting	Cut slope & Embankment	Slope Failure	X	X	X	X	As required by Routine or Periodic Inspection
		Cracks / swelling /settlement	X	X	X	X	
		Gully erosion	X	X	X	X	
		Debris on the slope steps	X	----	X	X	
		Poor drainage/ Spring water	X	X	X	X	
		Falling rock	X	X	X	X	

Table 6.1-5 Inspection Points for Structurally Protected Slopes

Facility	Member	Damage	Initial inspection	Daily inspection	Periodic inspection	Emergency inspection	Detailed Inspection
Structurally Protected slopes	Concrete block frame in situ	Cracks/ Peeling	X	X	X	X	As required by Routine
		Loosening /Swelling /Settlement	X	X	X	X	

Facility	Member	Damage	Initial inspection	Daily inspection	Periodic inspection	Emergency inspection	Detailed Inspection
	/Concrete frame	Spring water/ Poor drainage	X	X	X	X	or Periodic Inspection
	Mortar spray Concrete spray	Cracks/ Peeling	X	X	X	X	
		Loosen / Swelling /Settlement	X	X	X	X	
		Void	X	X	X	X	
		Spring water/ Poor drainage	X	X	X	X	
Masonries	Concrete Block Masonries	Cracks/ Swelling/ Loosening	X	X	X	X	As required by Routine or Periodic Inspection
		Settlement/ Movement/ Leaning	X	X	X	X	
		Scouring	X	X	X	X	
		Poor drainage or spring water	X	X	X	X	
	Slope gabion works	a. Steel wire rupture or corrosion	X	X	X	X	
		b. Deformation	X	X	X	X	

6.1.4.3 Inspection Methods and Frequencies

Inspection methods and inspection frequencies in principle shall follow the relevant articles of this guideline.

6.1.4.4 Evaluation of Inspection Results

Evaluation of the inspection results obtained in routine inspection, periodic inspection and emergency inspection shall be conducted, following relevant articles in this guideline. Sample criteria of inspection results for general slopes and protected slopes are shown in ANNEX-A. Also, particular notes for the evaluation of some major damages are described below;

- (1) Slope failure of general cut slope gives serious damages to road facility and vehicle traffic, so that it is important not to miss the first symptom of slope failure by facility inspection. When any changes or damages are found on the cut slope such as small collapse, cracks, swelling, spring water and so forth, it is necessary to conduct monitoring of these changes, in particular for those which are expanding and progressing.
- (2) Slope damages which lead to slope failure often appear at the upper part of the cut slope due to heavy rain in the form of tensile cracks or depression. These damages have high potential for large scale slope failures.
- (3) Damages appearing on the structural slope protection are sometimes caused by the damages occurring in the background area, so that inspection area should be carefully selected in order not to miss the main causes of the damages.

6.1.4.5 Registration of Inspection Data and Reporting

Registration of inspection data and reporting shall be conducted, following relevant articles in this guideline.

6.1.5 Planning and Implementation of Maintenance and Repair Work

6.1.5.1 Introduction

Natural slopes become deteriorated as time passes by due to the weathering of slope soils. Based on the evaluation results of road slope inspection specified in the previous section, maintenance and repair works shall be selected for routine maintenance and periodic repair works.

6.1.5.2 Maintenance and Repair Works

(1) Seepage of underground water

- When underground and surface water may have a potential of causing slope collapse or slope erosion, drainage system shall be properly installed to lead water to the downstream drains.

(2) Slope collapse or erosion

- When there are symptoms of slope collapse or erosion, slope protection work shall be selected and implemented together with planting.
- When planting tree to overcome the erosion area, or landslide, the time of implementation and the plant environment are limited that it should be noted about selection of planting technology and crop plants accordingly.

(3) Falling rocks

- When there is a potential hazard of falling rocks in the rainy season, installation of disaster prevention facilities including a wire net and a rock fall prevention wall is needed

(4) Maintenance of sods and plants

- After the completion of covering with vegetation, it needs about 2 to 3 years that leaves, old twigs are decayed into nutrients for plants growing in that period, and the plants should be fertilized at least once a year.
- For the short grasses such as wild sod, korai sodding and Bermuda grass, tall grasses should be removed for better sunshine.
- When planting in hot and dry season, sun light can dry and cause adverse effects to the seeds, so sprouts need to be fully watered until seeds are fully developed.
- It's difficult for plants to develop at the top area that they require more fertilizers and more care.
- If plants grow slowly, there will be high potential of erosion in the rainy season. Therefore, the watering and fertilizer should be added when plans grow so slowly in particular in the hot season.
- At the place where plant and/or grass have been withered, the damaged areas should be excavated and replaced by the new plant and/or grass at suitable season of growing.

(5) Large-scale slope failure

In case slope failure is a large-scale, slope protection shall be planned and implemented in accordance with the guideline shown in the relevant paragraphs of this Guideline.

(6) Potential hazard of large-scale slope failures or landslides

In case there is a potential hazard of landslide, it is necessary to conduct monitoring and conduct a further investigation on the slope movement. In particular, if negative effects on the vehicle traffic in this section is expected to occur, immediate actions shall be taken in particular to ensure the safety of vehicle traffic. Measures to be taken under this situation are shown below;

- To conduct a detailed survey on the causes and on the expected countermeasures against slope failures.
- To install monitoring devices to investigate slope movement.
- To guide spring water to the downstream drainage system. Landslides have very close relation with water permeability and often occur in the area where rainwater concentration occurs.
- To install measures against slope failures and minimize their effect, including counter weight embankment, stacked soil sack, net hurdling, gabion work, rock falling prevention work etc.

(7) Large-scale failures and landslide

When large-scale failures and landslide occurs, road administrator shall take the following actions;

- Emergency maintenance team shall be mobilized to the sites with equipment such as excavator, motor grader and/or bulldozer as soon as possible to clean debris.
- To control traffic, if necessary.
- To implement temporary countermeasures to minimize the effect on the vehicle traffic.
- To implement further investigation to find out the most appropriate countermeasures,
- To implement permanent countermeasures based on the detailed study.

6.1.5.3 Monitoring of Large-scale Slope Damage

When detecting potential danger leading to serious damages such as landslides later on, it is necessary to conduct monitoring and keep watching slope movement. A way of monitoring is to install monitoring devices as shown below such as the installation of strings or piers which shall perform as a base of measurement and to measure the relative position of slope movement (**Figure 6.1-3**).

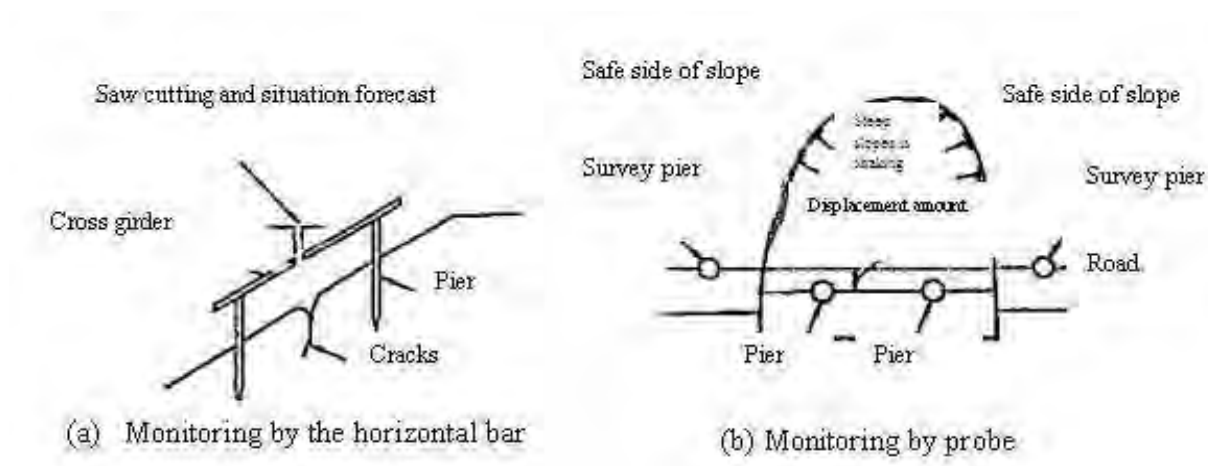


Figure 6.1-3 Monitoring Method of Slope Movements

6.1.5.4 Maintenance and repair reinforced slopes using structural protection with seeding, sodding and planting.

When having maintenance and repairing on works to reinforce slopes used structural materials, the following points should be noted:

- In case protection works are damaged or deformed partially, it is necessary to identify the causes of these damages and carry out repair works on the spots including surrounding parts.

For example: In case of lack of material stuffed inside the concrete frame works, it is needed to supplement such lack materials. In addition, in case the material was stuffed into and swelled out partially, measures need to be taken to repair such as replacing stuffing (including the surrounding parts).

- In case slope itself is at risk of being damaged or slope protection become deteriorated or deformed, it is necessary to conduct a detailed investigation.

For example, there are cases where back of the reinforced slope works do not work properly due to stagnant water, earth mounting and bulging out to the entire system. The main reason of this kind of failure is the improper handling of ground water and pit water. Therefore, special attention shall be paid in maintaining the proper function of drainage system in slope areas on dykes with wide and high structure.

6.1.5.5 Slopes with Structural Protection

6.1.5.5.1 Repair damages of stoned rip-rap, concrete block pitching slope

(1) Back fill soil flow-out

There are cases in which back fill soil is flowed out by surface water or underground water. In order to cope with this problem, drainage shall be installed then, soil shall be filled again after the installation of drainage system. Procedures of implementation are as follows;

- Remove wet or flowed back filling soil
- Provide appropriate drainage system
- Replace new back fill soil by appropriate materials (well-graded soil, sand.) and compact to required density.

(2) Holes or cave-in in protected slope

Holes or cave-in in protected slope can be failures of slope constructions. It also can results from back filling soil flowing. The treatment solution for the first case is holes filling by suitable materials of cement mortar and stones and crushed stone and for the later one is similar with back filling soil flowing treatments as stated above. The general procedure for the first case is:

- Remove loose materials of stabilized slope
- Fill holes and cave-in by appropriate size stone and pitching by mortar.
- Cleaning and maintaining finished surface of treated slope

(3) Flow out of rubbles and crushed stone filled in the concrete block pitting

Fall of rubbles, crushed stone etc. filled in the stone pitching, concrete block pitching slope may occur by weathering which lead to slope instability. Countermeasure against these damages is to place new materials to the damaged area.

(4) Sliding, subsiding, bulging or cracking of slope protection

The protected slope may have problems like sliding, subsidence, bulging or cracking due to various causes including improper design or failure during construction stage. This problem is more often seen on the steeper slope. Improper compaction of back fill soil sometimes causes sliding, bulging and cracking of slope protection facilities.

The single crack of concrete block is deemed independent from subsidence, thus it can be sealed by cement mortar or by bitumen. Replacement of new concrete block shall be applied when concrete block has been cracked or broken.

Implementation of repair works against the sliding of slope protection is as follows;

- Remove sliding stones, concrete block and soil.
- Excavate slope to designed shape (design stable slope or grades)
- Compact slope to the level of quality requirement
- Re-stabilize slope as original design

Implementation of repair works against bulging, cracking caused by subsidence is as follows;

- Excavate subsidence, bulging or cracking areas, and remove excavating materials
- Compact slope to designed slope and density

- Re-stabilize slope as original design

(5) Groundwater seepage and rainwater infiltration into protected slope or slope foundation

The water seepage from the surface of stabilized slope shall be treated properly. It is necessary to install drainage system and guide water out of the slope. Implementation of repair works of water treatment is as follows;

- Check for source of water seepage from the slope and provide appropriate drainage system
- Replace stabilized slope of rip-rap stones or concrete blocks when necessary at provided drainage system area.

6.1.5.5.2 Repair damages of concrete crib works

Concrete crib works shall be damaged due to subsidence of back fill material or erosion/sliding of back fill soil. Also, improper construction often causes the swelling of back fill materials and then cracks on the concrete cribs. Poor concrete construction induce water penetration into concrete crib works, thereby results in the corrosion of reinforcing steel.

(1) Disassemble concrete crib or broken concrete crib due to subsidence

Damages concrete crib works shall be removed and replaced with new crib works. The following shows implementation methods;

- Remove disassemble and broken part of concrete crib by hammer.
- Repair or replace reinforcing steel, connect new reinforcing steel with origin system by appropriate method
- Prepare framework of concrete crib
- Pouring concrete as designed concrete mix and maintain in required time

(2) Erosion or sliding of fill back soil

When erosion or sliding occurred at back of concrete crib, the eroded or sliding materials need to be removed then refilled back by appropriate materials

(3) Cracked and/or swelled out of concrete cribs

- Remove wet or swelled back fill soil
- Break and remove cracked and/or swelled concrete cribs
- Prepare framework of concrete crib
- Pouring concrete as designed concrete mix and maintain in required time
- Refill soil into back of concrete crib works

(4) Reinforcing steel corrosion

Corroded reinforcing steel shall be replaced by following procedure:

- Break and remove cracked and/or swelled concrete cribs
- Prepare framework of concrete crib
- Pouring concrete as designed concrete mix and maintain in required time
- Refill soil into back of concrete crib works

6.1.5.3 Repair damages on the mortar or concrete sprayed slope

Mortal or concrete sprayed slope shall be damaged by underground water seepage, by swelled backfill soil or improper compaction during construction. In particular, underground water or rain water infiltration shall cause the bulging and the cracking of mortar or concrete protection slope. Also, damages shall be caused by damaged drain system on the slope.

Repair works in compliance with damage types are shown below;

(1) Depression, bulging and cracking

- Break and remove damaged mortar area
- Remove wet or swelled back fill soil
- Re-fill back soil and compact to required density
- Re-mortar slope surface

(2) Water seepage

- Break and remove damaged area near seepage position (if any)
- Remove wet or swelled back fill soil
- Check existing drainage system and provide appropriate drainage system if necessary
- Re-fill back soil and compact to required density
- Re-mortar slope surface

(3) Drainage system damages

- Repair drainage system (as in 5.3 Section)

6.1.5.4 Repair damages of grid-frame or slope protection net

Repair works in compliance with damage types are shown below;

(1) Damages of foundation due to weathering

- Check damages of foundation for slope protection net. Depending on the foundation materials, damages shall be repaired by methods stated in the sections relevant to retaining wall maintenance and repair.

(2) Piling of soil, gravel, stone debris at slope foundation caused by sliding and erosion

- Clear foundation from agglomerated soil and debris.
- Clear drains near foundation of slope protection net
- (3) Collapse or corrosion of stakes, piles or pillars
 - Clean corroded piles or pillars of net foundation and repainting the piles or pillars
 - Cut/ remove broken plies, strengthen the piles or pillars by welding or an appropriate method or replace the ne pillars
- (4) Collapse or corrosion of net or wires
 - Clean and paint corroded net
 - Cut broken net area, replace and strengthen the net by appropriate material
- (5) Disassemble of bolt or dowel
 - Remove damaged bolt or dowels and replace by new one

6.1.6 Planning and Implementation of Emergency Repair Work

The following are a few cases of typical urgent repair works against landslide.

- (1) Repair works against landslide occurring at upper slopes

In case cracks or damages are observed on the surface of soil layer as shown in

Figure 6.1-4, it is necessary to evaluate hazard risks to vehicle traffic first and take traffic control measures if needed. If damage is partial and there is no risk of immediate failure, simple countermeasures shown in

Figure 6.1-5 shall be applied. In case there is a potential risk of large-scale landslides and local countermeasures cannot be applied, it is necessary to apply long-term safety measures such as re-cutting of the slopes and the mitigation of slope inclination.

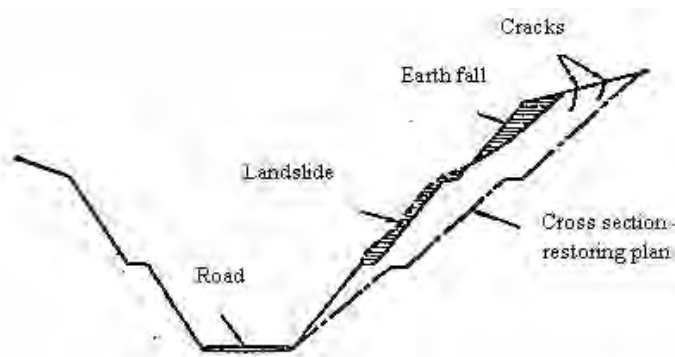


Figure 6.1-4 Landslide at the upper slopes

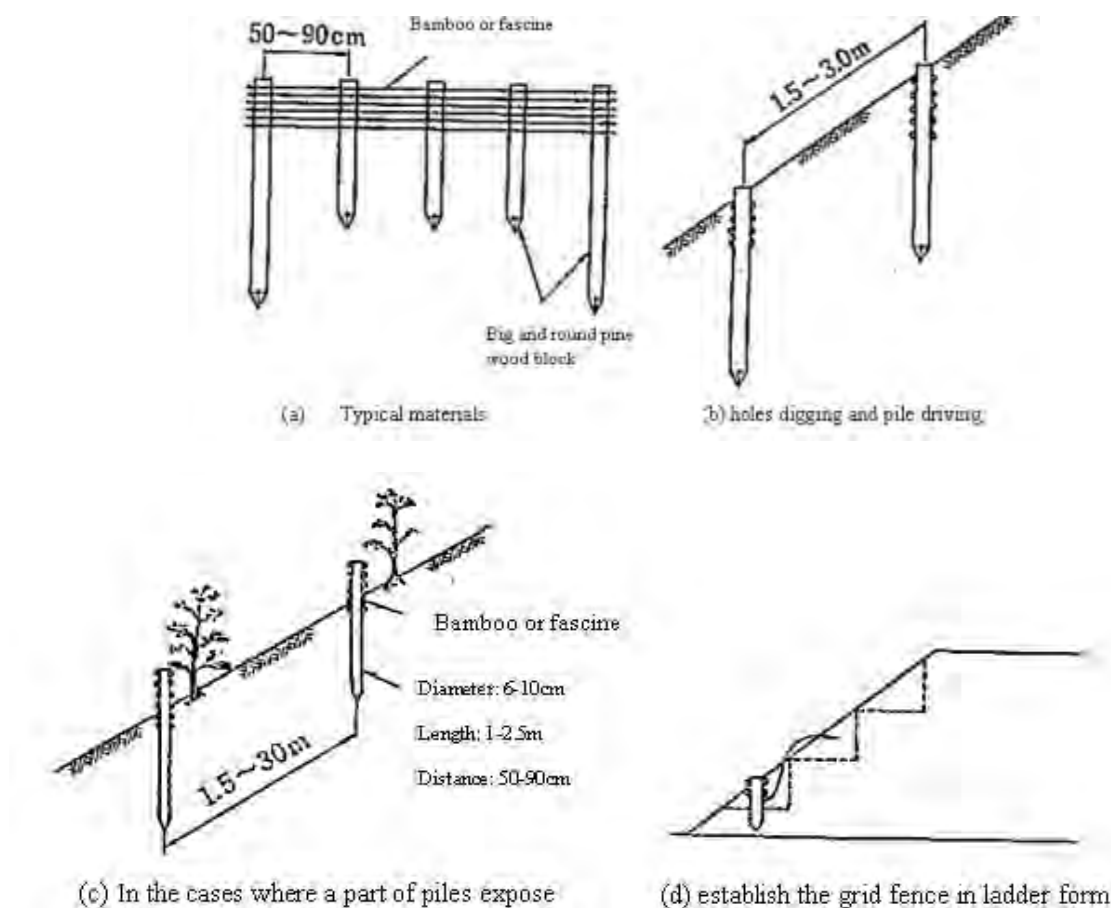


Figure 6.1-5 Simple countermeasures to protect natural slope

(2) Repair works against cracks, damage and water seepage on the surface of slopes

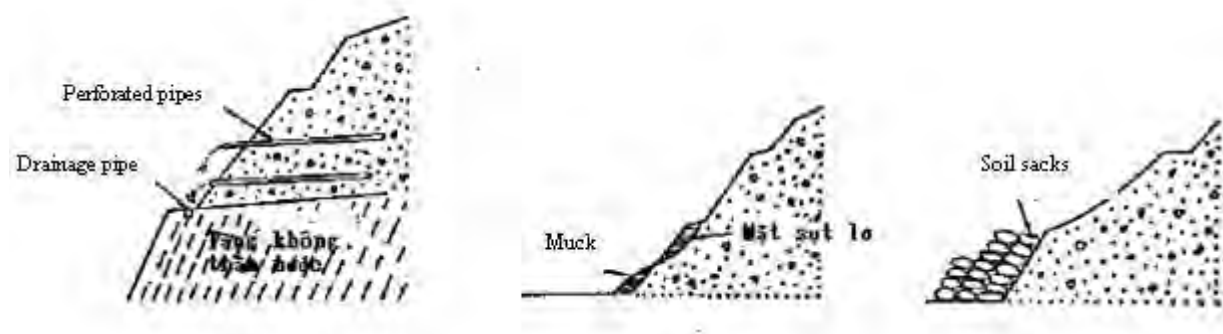


Figure 6.1-6 Drainage with horizontal boring and stacked soil sacks in emergency

Apart from the method described in (1), treatment of underground water should be implemented using measures such as: use bore holes as illustrated in **Figure 6.1-6**. Insert perforated pipes into drilled holes in the ground so that the holes will not be collapsed. In addition, earth filling into cracks on the upper slopes is also necessary to prevent the water infiltration into cracks.

- (3) Repair works against cracks or damages in the lower part of the slopes with underground water seepage

Where the landslide is big, it should be studied carefully how the damages in the lower part of the slopes may influence on the upper slope stability. If attention is not paid, rain water infiltration sometimes causes large-scale landslides. In case potential hazard is detected, temporary works against expected landslide shall be implemented in the field, such as piling of soil sacks at the foot of the slope until long-term countermeasures should be applied such as installation of gabion, wood piles, etc. In the cases that the stability for the entire slope cannot be ensured, re-shaping of cut slope shall be implemented.

- (4) Repair works against falling rocks

In case rocks on the slopes are likely to fall down to the ground, it is necessary to immediately remove floating rocks or take rock erosion control measures, such as the installation of a concrete grid and a steel rock net on the slopes.

- (5) Repair works against the weathering or the deterioration of slopes protected by mortar spray

It is necessary to partially reinforce the slope with concrete or precast concrete frame, or with other measures such as using grid to prevent the rolling stone in the case that the drainage system of the mortar sprayed slopes becomes weak after a long period of time due to the piling of mud, garbage, grass clog etc. In the case of major damage and big steep slopes, in-situ concrete slope protection works should be implemented (**Figure 6.1-7, Figure 6.1-8**).

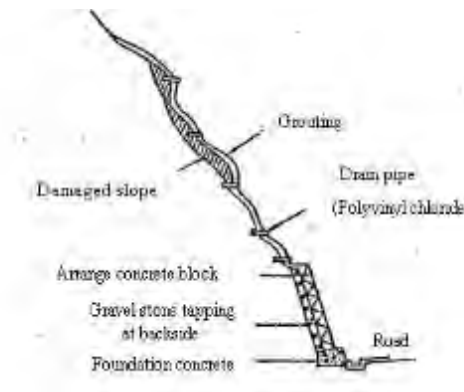


Figure 6.1-7 Cross section of collapse of mortar stabilized slope

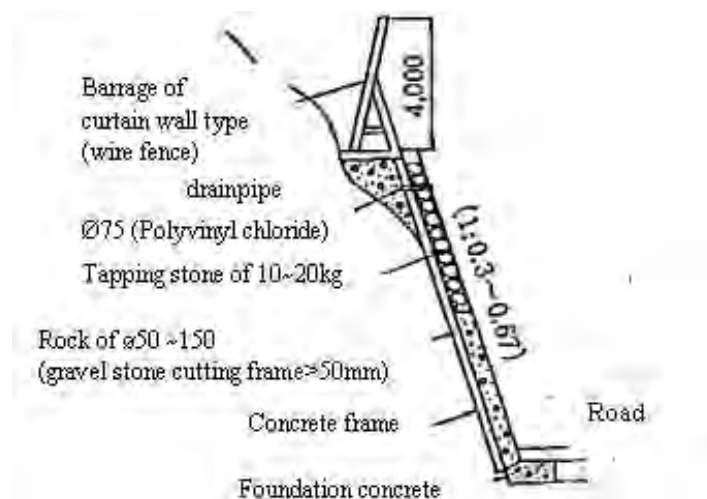


Figure 6.1-8 Example of the recovery using cast in-situ concrete frame

- (6) Repair work against water concentration on the slope which may cause landslides

Heavy rain concentration to specific locations often causes small scale landslides at steep slope. If such condition becomes widened, it may cause damages to the roadbed on the shoulder. In these cases, it is necessary to strengthen the foot of the slopes with soil sacks. Then remove the drifting soil and sand and restore the slopes with good quality soil to the original status of the slopes as seen in **Figure 6.1-9**. In addition, blind drainage conduit shall be installed to remove standing water.

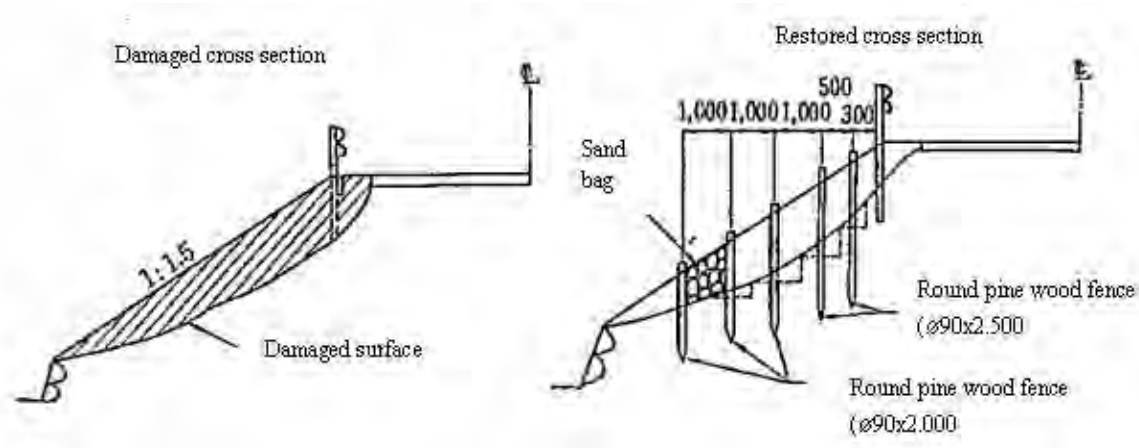


Figure 6.1-9 Examples of damaged steep slope due to standing water restriction method

- (7) Repair work by installing drainage system for surface water

In case there are ponds, swamp on the slopes, effort must be taken to remove standing water. It is necessary to use a nylon cover to protect cracks from water infiltration, temporary drainage by nylon or wooden pipes to lead groundwater out of the slope.

- (8) Repair work by installing drainage system for groundwater

In the case of landslides, a measure of installing horizontal borings is effective. Horizontal boring shall be installed crossing over the cracks on the slope and set perpendicular to the crack direction with the mutual interval of 5 to 10m and the extra length of about 10 to 20m longer than the end of the cracks as shown in **Figure 6.1-10**.

The outlet of water pipe shall be located outside the landslide area with the protection of concrete or gabion around the outlet against soil erosion. Also, a water collect well also shall be applied to treat groundwater when boring does not have sufficient capacity of handling ground water.

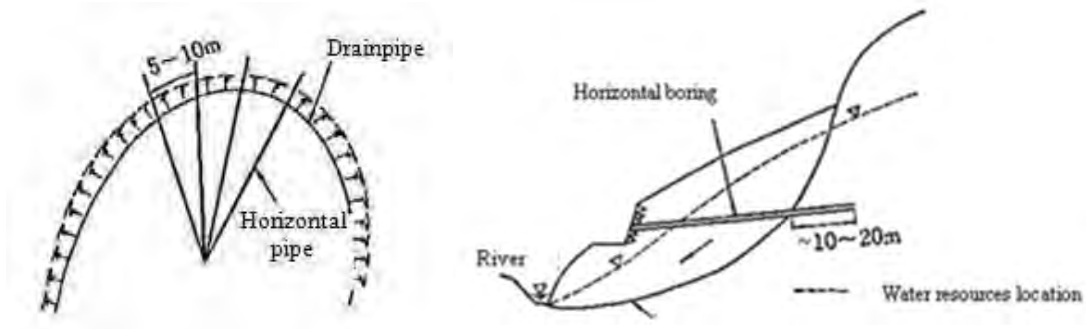


Figure 6.1-10 Drainage with horizontal boring

(9) Protective works against landslides

When the end area of landslides is at risk of subsidence or there is high potential of the widespread of landslides, protective work shall be implemented against landslide force such as the installation of gabions, crib-works, force resistant piles, retaining wall in accordance with the magnitude of land slide power.

(10) Temporary emergency restoration

When road surface subsidence occurs which is small scale but not deep, a leveling work of cracked areas shall be made in order to open vehicle traffic with low-speed as early as possible. In the cases where the subsidence is deep and large scale, new temporary road should be built to ensure operation and safety of vehicle traffic. In any cases, warning devices which can detect the movement of landslide and give warning to vehicle driver shall be installed. Restoration work shall start after landslide movement is settled. In constructing temporary roads, care shall be paid to their designs which can speed up their construction, such as the reduction of soil volume etc.

Despite the implementation of landslide prevention works, it is very hard to stop landslide movement immediately, so attention shall be paid to monitor the movement and take any immediate actions in order to avoid secondary accidents.

6.2 Drainage System Maintenance Management

6.2.1 Introduction

Many damages of road facilities are often caused by improper treatment of water, so maintenance and repair of drainage systems is of critically important.

6.2.2 Classification of Drainage Systems

Drainage facilities in general falls into the following classifications. **Figure 6.2-1** illustrates overall road drainage systems.

a. Road surface drainage system

Road surface drainage system is to prevent the degradation of subgrade bearing capacity which is the softening of subgrade caused by rain.

b. Underground drainage system

Underground drainage system is to prevent underground water infiltration into road structure from nearby area.

c. Road Slope drainage system

Road slope drainage system is to treat rain water or underground water and to prevent damages caused by them.

d. Transverse drainage system

Transverse drainage system is to guide water crossing under road structure.

e. Water discharge drainage

Downstream water outlet is to collect water from road area and discharge water to the drainage system prepared outside of road area.

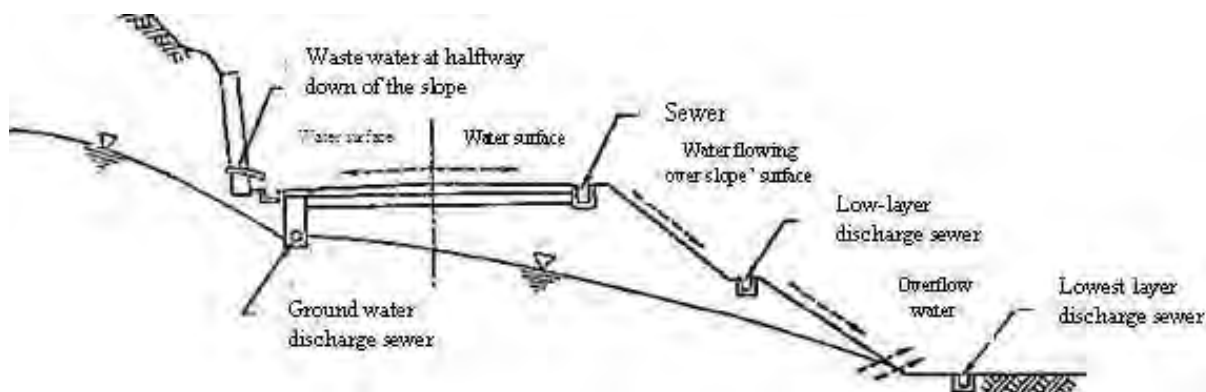


Figure 6.2-1 Overall Road Drainage Systems

(1) Road surface drainage system

Road surface drainage system shall be classified into the following major facilities;

- a. Naked ditch
- b. Stone masonry ditch
- c. Concrete block masonry ditch
- d. Concrete L-shaped ditch
- e. Concrete U-shaped ditch
- f. Rolled gutter
- g. Concrete cast-in-place ditch

(2) Underground drainage System (**Figure 6.2-2**)

There are mainly three types of underground drainage systems as follows;

- a. Underground drainage system is to prevent water infiltration into road body from neighbor areas and lead water to downstream outlet.
- b. Transverse drainage system crossing over road facility
- c. Filter layer installed when groundwater level is high to prevent water infiltration into road body

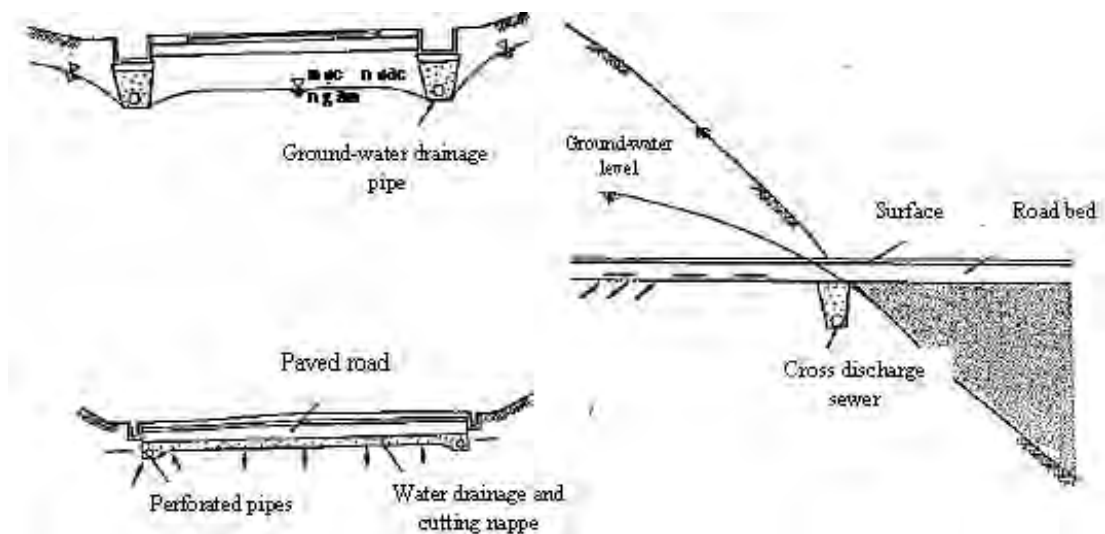


Figure 6.2-2 Underground Drainage System

(3) Road Slope Drainage System

There are mainly four types of slope drainage systems available as shown below. **Figure 6.2-3** illustrates the installation of road slope drainage system.

- a. Slope shoulder drainage system installed at the top of slope
- b. Vertical drainage installed along slope gradient from top to downward
- c. Drainage system installed on berms
- d. Stone filled drain installed horizontally

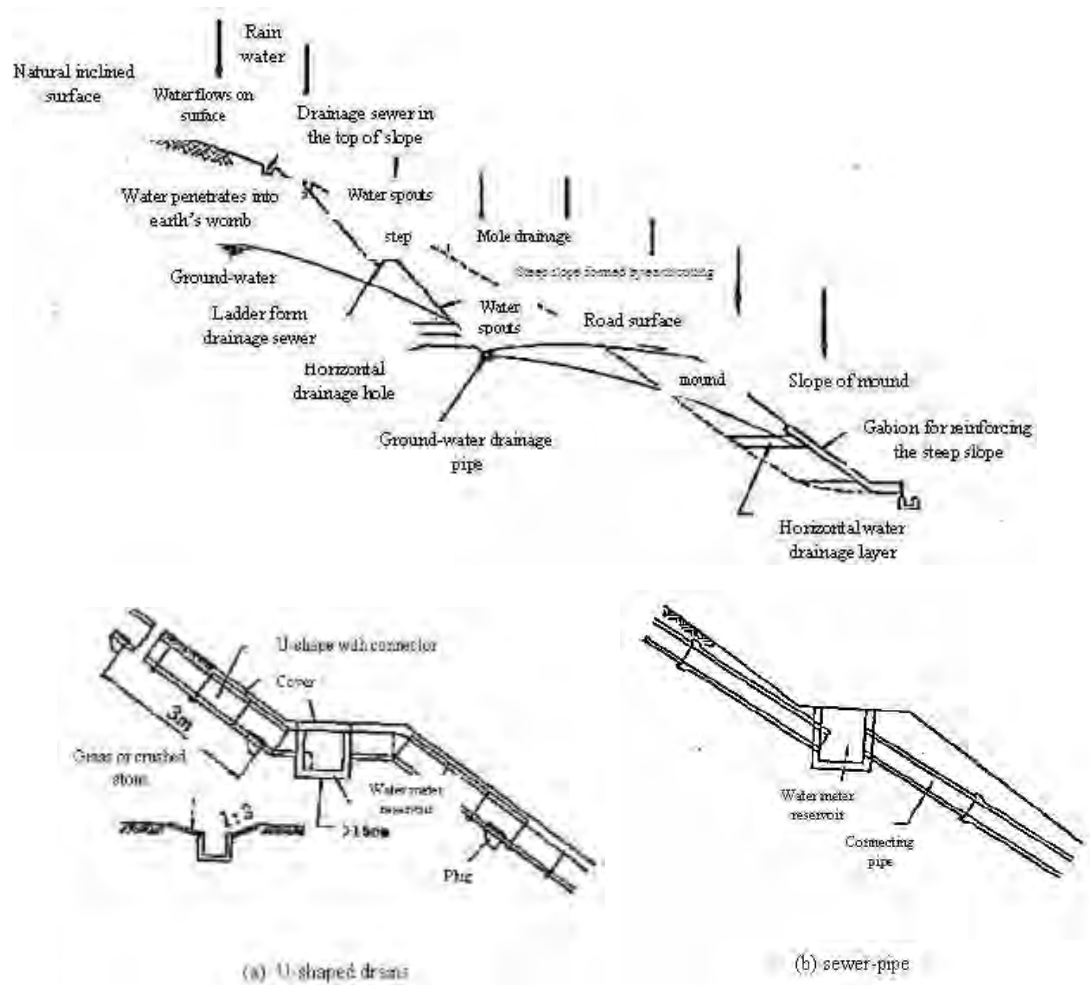


Figure 6.2-3 Slope drainage system

(4) Catch basin and water pit (Figure 6.2-4)

Figure 6.2-4 illustrates the installation of catch-basin and water pit.

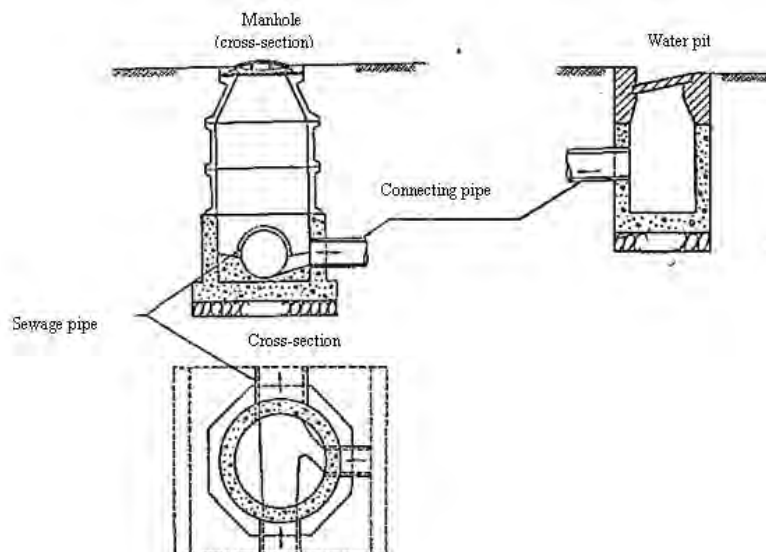


Figure 6.2-4 Catch-basin and Water Pit

6.2.3 Typical Damages Observed

6.2.3.1 Road Surface Drainage System

The following damages are often observed on the road surface drainage system:

- Interruption of water flow due to fallen plants, fallen trees, debris, loose silt or rocks.
- Piling of debris due to insufficient gradient of drainage system
- Pavement surface cracks near road surface drainage system
- Water overflow and puddle due to insufficient gradient or capacity of drainage system
- Water flowing into road surface from surrounding area
- Soil erosion at invert or on the sides of drain due to steep gradient
- Soil erosion at drain exit due to steep water flow

The following are the typical damages for cast-in-place concrete drainage system;

- Cracks or collapse of concrete drain due to the erosion of foundation
- Breakdown of drainage due to high water concentration
- For covered concrete drains, there observed some damages on the drain covers. Concrete covers are sometimes cracked or broken down due to traffic actions.

6.2.3.2 Slope Drainage System

The following are the typical damages for slope drainage system;

- Interruption of water flow due to debris in the drains, dense plants, etc.
- Overflow during heavy rain due to low or narrow capacity caused by piled soil, waste and debris.
- Broken or collapsed drains due to erosion lining
- Damage of joints between drains

6.2.3.3 Underground Drainage System

The following are the typical damages for underground drainage system;

- Cracks or unevenness on road pavement surface
- Water volume fluctuation at water outlet

6.2.3.4 Transverse Drainage System

The following are the typical damages for transverse drainage system;

- Cracks and water leakage
- Piling of debris or garbage

- Damage of joints and water leakage
- Water puddle due to uneven settlement
- Deterioration of drainage system

6.2.3.5 Catch-basin and Water Pit

The damages of catch-basin and water pit include the following;

- Physical damages on the facilities
- Piling of debris in the facilities and malfunction of water flow
- Pavement cracks caused by the damages of catch-basin and water pit.
- High concentration of water and overflow from the facilities

6.2.4 Inspection of Drainage Systems

6.2.4.1 Focus point of inspection

Focus points of inspection are shown below;

- (1) Inspection on the drainage systems on the cut slope is important because any change of cut slope often appears on the drainage systems. Drain systems which are clogged or deformed by debris induce water infiltration into cut slope and cause slope failure in the long run.
- (2) Attention should be paid to any spring water seen on the cut slope and water treatment on the cut shoulders, as heavy rainfall may raise ground water level near the slope and have negative effects on the stability of cut slopes. Care should be directed to any changes of water near the cut slopes including occurrence of spring water, water volume and turbidity.
- (3) It is in general very hard to inspect underground drainage systems, so that their functions shall be inspected after rainfall.
- (4) Attention shall be paid to the inspection on whether the drainage systems including outlets and catch-basis have capacity enough to treat water.

6.2.4.2 Inspection points

Inspection of road slope facilities shall be implemented on the inspection points shown in **Table 6.2-1**. However, the table regulates the minimum requirement of inspection points, so that users can supplement some inspection points whenever needed.

Routine inspection shall be in principle implemented by vehicle-on-board visual inspection. However, when damage is detected, the inspection staff shall get off the patrol car and conduct short-distance visual inspection. In the case of routine inspection which shall be carried out from national road side, the range of the inspection is the area visible from the patrol car on the national road. For the routine inspection on the road side drainages which are invisible from national road side, inspection shall be done within the visible range from the local road accessible by car.

Table 6.2-1 Inspection Points for Drainage System

Facility	Member	Damage	Initial inspection	Daily inspection	Periodic inspection	Emergency inspection	Detailed Inspection
Drainage	All drainage system	Structural damages	X	X	X	X	As required by Routine or Periodic Inspection
		Erosion of foundation	X	X	X	X	
		Joint damage	X	X	X		
		Piling of debris		X	X	X	
		Flow capacity	X	X	X	X	
		Water puddle	X	X	X	X	
		Damages given to nearby road facilities	X	X	X	X	

6.2.4.3 Inspection methods and Frequencies

Inspection methods and inspection frequencies in principle shall follow the relevant articles of this guideline.

6.2.4.4 Evaluation of Inspection Results

Evaluation of the inspection results obtained in routine inspection, periodic inspection and emergency inspection shall be conducted, following relevant articles in this guideline. Sample evaluation criteria for drainage facilities are attached in ANNEX-B.

6.2.4.5 Registration of Inspection Data and Reporting

Registration of inspection data and reporting shall be conducted, following relevant articles in this guideline.

6.2.5 Planning and Implementation of Maintenance and Repair Work

6.2.5.1 Introduction

Road drainages are often caused by improper treatment of water, so that maintenance and repair of road drainage systems shall be properly implemented in order to prevent further progress of damages to road facilities.

6.2.5.2 Road Surface Drainage System

Focus points of maintenance and repair for road surface drainage systems are as follows;

- Care shall be paid to road side drains which are easily filled with debris, garbage, etc. and degraded their functions, so that regular routine maintenance is important.
- Roadside wall of U-shaped concrete drain is vulnerable to vehicle load. If it is broken down, it is necessary to replace it with a new one or to install a support in the drain.
- Damages are often seen at the joint portion of precast concrete drainage due to uneven settlement or breakdown of drainage systems, so that it is necessary to reinstall drainage systems.

- Underground drainage broken by vehicle load under the ground sometimes causes a serious problem, subsidence, due to void caused by water leakage. Early detection is a key for successful maintenance and repair.

The following are the major maintenance and repair methods by damage type.

(1) Interruption of water flow

- Clearing and cleaning drains

(2) Piling of soil

- Cleaning or deepen ditch (de-silting)
- Where deepening is not possible because of topography, new drainage systems shall be constructed.

(3) Ponding

- Deepen ditch
- Install a new drain.

(4) Unlined drain

- Reshape/regrade ditch, line drain.

(5) Erosion at invert and sides of drain

- Provide erosion control
- Regrade/realign drains,
- Provide repair scour protection,
- Line drain slopes and invert,
- Construct cascade

(6) Erosion at drain outfall

- Provide erosion control of:
- Repair lining,
- Realign drain.

(7) Cracked or broken concrete drain

- Removed damaged concrete block.
- Removed lining materials and wet soil
- Refill and replace new material of drain foundation to correct density
- Install new concrete block of drain and fill joints

(8) Wash-out concrete drain block

- Removed lining materials and wet soil
- Refill and replace new material of drain foundation to correct density
- Install new concrete block of drain and fill joints

6.2.5.3 Road Slope Drainage System

Focus points of maintenance and repair for road slope drainage systems are as follows;

- Road slope damages are often caused by improper treatment of water such as improper guidance of rain water, water infiltration and water seepage from slope surface etc. It is very important to lead water to the drainage facilities out of the slope area.
- Road slope drainage is often filled with debris and garbage, so that routine maintenance shall be done in order to maintain drainage facility in good condition.
- Joints of drainage system, in particular precast concrete facility, are often damaged by uneven settlement of drainage system, which causes water leakage from broken joints and then soil erosion shall occur on the foundation of drainage facilities or nearby road structures.

The following are the major maintenance and repair methods by damage type.

- (1) Accumulated waste, debris in the drains, at collectors
 - Regularly clearing and cleaning drains and collector
- (2) Water flow-over during heavy rain
 - Clearing and cleaning silted soil, waste and debris or
 - Provide new drain line to reduce flow charge or increase capacity of whole slope drain system
- (3) Broken drainage facility
 - Removed damaged concrete drain
 - Removed lining materials and wet soil
 - Refill and replace new material of drain foundation to correct density
 - Install new concrete block of drain and fill joints

6.2.5.4 Underground Drainage System

Focus points of maintenance and repair for underground drainage facilities are as follow;

- Underground drainage system is basically unseen from surface, so that attention shall be paid to their outlet facilities. If damage is detected on their function, maintenance and repair shall be conducted quickly.
- In case water leakage occurs on the underground drainage due to drainage joint failures, it may sometimes cause road facility subsidence in the worst case.
- In case inlet of underground drainage facility on the mountain side is filled with debris, fallen

trees etc. and does not function well, it may sometimes give serious damages to road structures. Routine inspection shall be conducted in particular after heavy rainfalls.

- In case water flow function is damaged, it is necessary to construct another underground facility to supplement its capacity.

6.2.5.5 Catch-basin and Drain Pipes

Focus points of maintenance and repair for catch-basin and water pit facilities are as follow;

- Broken cover of catch-basin may cause traffic accidents, so that early replacement shall be conducted.
- (1) Blocked manhole
 - Clear manhole and underground pipes.
 - (2) Manhole cover or grating is missing or damaged
 - Replace manhole cover or grating
 - (3) The manhole is covered with soil and vegetation
 - Clear manhole area.
 - (4) The catch pit sump is completely silted up
 - Clean catch pit sump.
 - (5) Removed broken or collapsed manhole and pipes
 - Removed lining materials and wet soil
 - Refill and replace new material of drain foundation to correct density
 - Reconstruct manholes and pipes Broken or collapsed manhole or pipes

6.3 Road Pavement Maintenance Management

6.3.1 Introduction

Asphalt pavements are worn out due to repeated traffic loading and to the deterioration or aging of the asphalt mixture, or serviceability deterioration owing to the flow of mixtures or friction.

6.3.2 Typical Damages Observed

6.3.2.1 Functional Damage and Structural Damage

Damage to asphalt pavements falls into functional damage and structural damage as follows. **Table 6.3-1** summarizes damage types which belong to the functional and the structural damages. In addition, outlines of pavement damages are shown in the next paragraph.

- (1) Functional Damage

Functional damage, which includes rutting and cracking, is not caused by the reduction of pavement strength. The damage stays at the surface layer in most of the cases. Unless appropriate repair is made immediately, the damage gradually progresses into lower layers including binder, subbase course and base course. Major functional damages include rutting, cracking and the deterioration of skid resistance. Progress of these damages often causes the deterioration of travel performance in terms of safety and driving comfort.

(2) Structural Damage

Structural damage is caused by the reduction of pavement bearing capacity of base course or sub grade, so that it is necessary to consider the repair even of the base and sub grade. Damage related to pavement structure is caused by strength deterioration under repeated loading, insufficient pavement thickness and material strength, strength deterioration in the base or sub grade due to frost heave, etc. Rutting and cracking, which are deemed as the initial stage of functional damages, may also lead to structural damage if they are left unrepaired for a long time. Structural damage is frequently induced by strength reduction in lower layers such as the base and sub grade and by the penetration of damage to lower layers. It is necessary to select the optimal repair method based on the results of structural surveys of pavements.

Table 6.3-1 Damage Classification

Damage type		Status of Damage	Observed Damage Area	Damage Classification	
				Functional	Structural
Rutting	Rutting due to the flow of asphalt mixture	Consolidation and lateral movement of asphalt mixture or settlement at lower layers	Mainly on vehicle swept paths along heavy traffic routes in warm areas	○	○
	Rutting due to friction	Abrasion on vehicle swept paths	In snowy and cold areas	◎	
Cracking	Cracking due to the deterioration of bearing capacity of the base and sub grade	Linear cracks developing to hexagonal	Mainly on vehicle swept paths		◎
	Cracking due to the deterioration or aging of asphalt mixture	Hexagonal	Cracking occurring on vehicle swept paths progressing to the entire pavement.	○	○
	Cracking due to uneven settlement	Linear (longitudinal, transverse or irregular)	Around the structure, at joints made as a result of the widening of lanes, at cut/fill boundaries, etc.		◎
	Cracking due to thermal stress cracking	Linear (transverse). At nearly regular intervals.	In cold areas and in the areas with large variations of temperature	○	○
	Cracking at construction joints	Linear (longitudinal or transverse)	At construction joints	◎	
	Reflective cracking	Linear (longitudinal or transverse)	On concrete slabs and in cases where cement stabilization is applied		◎
	Top-down cracking	Linear (longitudinal) to reticular	On vehicle swept paths	○	○
Deterioration	Longitudinal irregularities and settlement	Longitudinal irregularities with a relatively long	In soft grounds, in the backfill of the structure and near a buried object		◎

Damage type		Status of Damage	Observed Damage Area	Damage Classification	
				Functional	Structural
		wavelength			
	Corrugations	Ripple-like folds on the surface	Near the toll gate and in congested sections	○	○
	Depressions and swells	Local depressions and swells	In parking areas and in congested sections	○	○
Others	Potholes	Holes created on pavement surface. Occurrences of abrasion of aggregates and hexagonal cracking	In cracked sections, poor-drainage sections and sections subjected to raveling by tire chains	○	○
	Deterioration of skid resistance coefficient	freezing and polishing		⊙	
	Bump	Vertical surface displacement or irregularities	At expansion joints on bridges and in the backfill of a structure	○	○
	Pumping	Outflow of water and fine particles of sub grade materials, often accompanied by cracking.	At spots with cracking or abrasion on the base layer or below		⊙
	Raveling	Separation of surface mortar	Mainly on vehicle swept paths	⊙	
	Cutback due to oil leakage	Scattered aggregates. Potholes.	At accident sites and in parking areas	⊙	

(Note) Damage classifications: ⊙; High potential incident, ○; Medium potential incident

6.3.2.2 Damages of Road Pavement

Road asset management has explained that there are two types of pavement repair works; (1) Functional damage and (2) Structural damage as shown below. Functional Damage

- (1) Functional damage stays at the surface layer in most of the cases. Unless appropriate repair is made immediately, the damage gradually progresses into lower layers including binder, subbase course and base course. Major functional damages include rutting, cracking and the deterioration of skid resistance. Progress of these damages often causes the deterioration of travel performance in terms of safety and driving comfort.

(2) Structural Damage

Structural damage is caused by the reduction of pavement bearing capacity of base course or sub grade, so that it is necessary to consider the repair even of the base and sub grade. Damage related to pavement structure is caused by strength deterioration under repeated loading, insufficient pavement thickness and material strength, strength deterioration in the base or sub grade due to frost heave, etc. Rutting and cracking, which are deemed as the initial stage of functional damages, may also lead to structural damage if they are left unrepaired for a long time. Structural damage is frequently caused by the reduction in bearing capacity at lower layers such as the base and sub grade and by the penetration of damage to lower layers. It is necessary to select the optimal repair method based on the results of structural surveys of pavements.

Typical asphalt pavement damages are shown below.

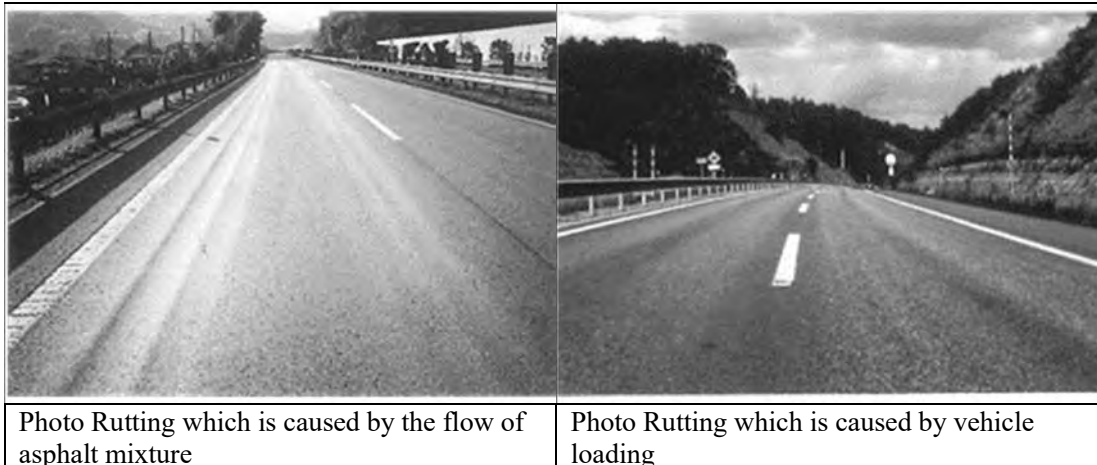
(1) Rutting

Rutting is transverse surface deformation created by vehicle loading. Rutting is caused either by the flow of asphalt mixture or by vehicle loading. Potential external causes of the former rutting, which is caused by the flow of asphalt mixture, are the rise of pavement surface temperature in the summer season and the concentration of heavy vehicles on specific lanes. The mechanical properties of asphalt mixtures are greatly affected by binder properties. Asphalt mixtures behave like an elastic body at low temperature but they behave like a viscos-elastic body under high temperature. Under high temperature, asphalt mixtures are vulnerable to deformation caused by heavy vehicles. Deformation accumulates in the pavement as vehicles run on the same position, thereby becomes permanent deformation in the pavement. One of the internal factors of the rutting is the flow resistance of asphalt mixtures. Flow resistance is affected by the amount of asphalt, asphalt penetration and the grain size of the mixture. Measures to increase flow resistance are listed below.

- Minimize the amount of asphalt as long as an optimum amount is secured.
- Use hard asphalt.
- Use coarse graded materials for mixtures and increase the amount of coarse aggregate.

The external cause of rutting is the travel of vehicles equipped with tire chains or spike tires. A conceivable internal factor is the frictional resistance of asphalt mixtures. Frictional resistance is reduced by the following factors.

- Inadequate density due to insufficient compaction
- Inadequate amount of asphalt
- Low hardness of aggregate



(2) Cracking

Cracking is caused by the deterioration or aging of mixture or by structural factors. Both factors affect the durability of pavements, so that if cracks are left unrepaired, cracks shall grow day by day. Infiltration of water contributes to structural damages. Cracking is roughly divided into linear and planar types. Linear cracking is generally occurs in the initial stage of cracking and mostly belongs to functional damage. Planar cracking usually occurs as linear cracking and develops with the lapse of time into structural damage. The most important external cause of cracking is traffic loading. Cracks

are caused by the tensile stress created by traffic loading (an external force). If the asphalt mixture is assumed to be an elastic body, it is deformed by an external force as shown in **Figure 6.3-1**, and compressive and tensile stresses occur at the top and bottom edges of the mixture respectively. Asphalt mixtures with the tensile strength approximately one-tenth of compressive strength have extremely low resistance to tension. Excessive loads cause the tensile strain on the bottom surface of the asphalt layer to exceed the limit resulting in cracking. Pavements are designed to maintain a mechanical balance. Once the balance is lost, an excessive-deflection induced deformation causes cracking, due to a rapid increase in traffic volume, overloaded heavy-duty vehicles and uneven bearing capacity of roadbed;

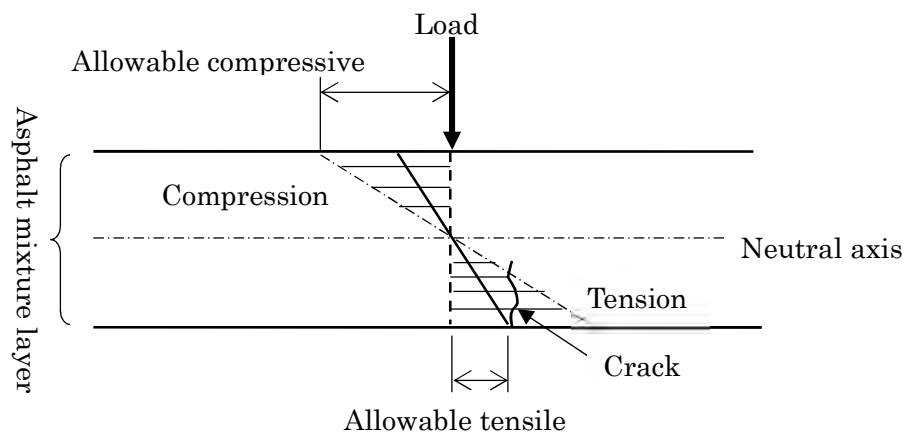
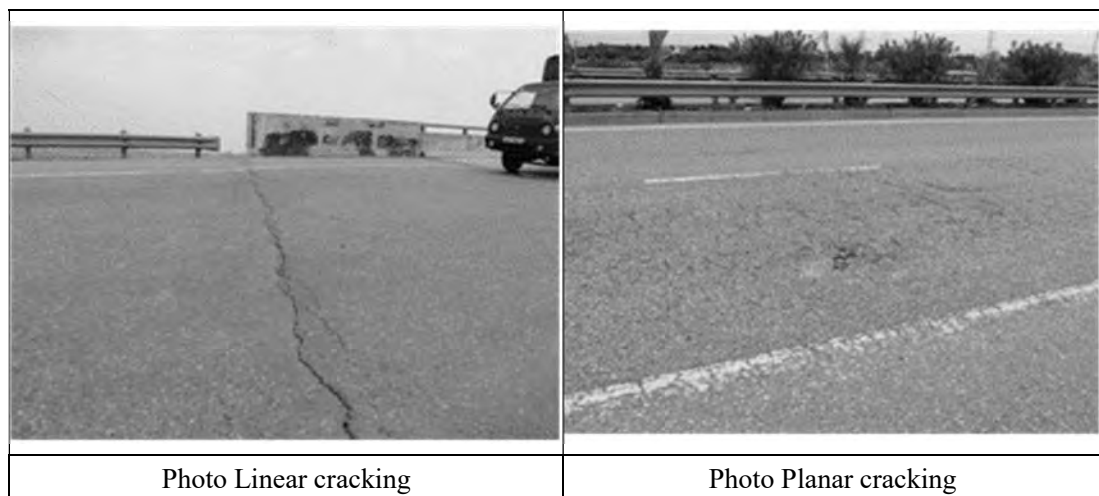


Figure 6.3-1 Tensile Stress of Asphalt Mixture

The internal causes of cracking include the amount and hardness of asphalt. Mixtures with a large amount of asphalt and of fine-graded type are highly resistant to cracking. Mixtures with a small amount of asphalt and of course-graded type are vulnerable to cracking. The hardness of asphalt is affected by thermal degradation during the manufacturing of mixtures.



(3) Deterioration of Smoothness

Smoothness is deteriorated by the local settlement of road surface due to cracking or the development of potholes, insufficient roller compaction in the backfill of the structure during construction, or residual settlement in soft-ground areas. Smoothness greatly affects the driver's comfort.

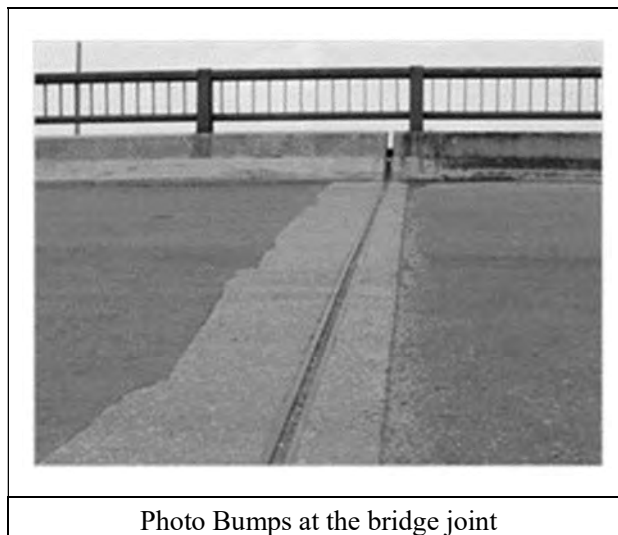
The deterioration of smoothness, in the broad sense, refers to the longitudinal and transverse directions; however, it generally means longitudinal irregularities. For smoothness, a standard value is defined at the completion of construction. Smoothness remains satisfactory in the initial stages of service but deteriorates with the lapse of time. The deterioration frequently occurs with other types of damage such as cracking and surface settlement due to the development of potholes. Bumps and corrugations also lead to the deterioration of smoothness. These phenomena cause the deterioration of smoothness of a short wavelength. The deterioration of smoothness in soft grounds or in the backfill of a structure induces poor smoothness of a relatively long wavelength in numerous cases. The phenomenon is attributable to the slow progress of residual settlement, which is caused mainly by poor soil stabilization during construction or insufficient compaction of backfill materials.

(4) Potholes

Potholes are small holes created on the road surface. The causes of potholes include the leakage of oil from vehicles and poor mixing of asphalt mixture. If potholes are left unattended, damage develops because of the infiltration of storm water or other factors and structural damage may be induced.

(5) Bumps

Bumps are created by vertical displacement of road surface at the connection between the bridge joint and pavement surface or along a buried object, and affect the comfort of vehicle occupants.



6.3.3 Inspection of Road Pavement

The Guideline regulates inspections on the main part of pavement facilities including asphalt pavements, bituminous pavements and cement concrete pavements.

6.3.3.1 Focus Points of Inspection

Pavement inspection are not only to detect pavement damages promptly which may lead to traffic accidents, but also to obtain data for strategic planning of maintenance and repair works of the road pavement. The following are the points to be focused on in implementing pavement inspection.

6.3.3.1.1 Asphalt Concrete Pavement & Bituminous Surface Treatment

- (1) Asphalt pavement cracks induce water infiltration into the pavement body and have a negative effect on the pavement life-cycle. The following are the points to note in carrying out the inspections.
 - Observe pavement cracks from slow moving vehicles on the road shoulder. If needed, stop the car and conduct a visual observation of the cracks.
 - Drying time after rainfall for crack sections is in general much longer than that for the non-crack sections.
 - Brief sketching or photographing crack conditions with measurement scales, which facilitates the computation of crack rates, will help support the evaluation of the defects and deterioration of asphalt pavements
- (2) Potholes, peeling and depression of asphalt pavement often give a serious influence on drivability, in particular to motorcycles and cause traffic accidents, so that inspection needs to be conducted with much attention.
 - Observe the magnitude of damages in depth and in width.
 - Carefully observe influence on vehicle drivability
- (3) Rutting, caused by asphalt flow and abrasion and scattering of aggregate, allows water to puddle and water splash on the pavement surface, causing a decline in skid resistance and visibility during night driving. The following are the points to note in carrying out the inspections.
 - Observe whether car loses driving control
 - Observe steering ability when crossing lanes
 - Observe puddles and splash of water when it rains
- (4) Longitudinal roughness, when it becomes noticeable, often causes a decline in driving comfort and increased driving fatigue to vehicle drivers, thereby lowering driving safety. Large longitudinal corrugations not only cause discomfort to drivers, but cause lateral vibration in the vehicles and thus impair driving safety. Also, impact load often causes noise and vibration of the pavement, bridge structures and roadside environment. It is therefore necessary to carry out inspection carefully.
 - Observe driving comfort and vibration while driving.
 - Observe straightness of guardrails and road markings.
- (5) Bumps often appear at the connection with bridges, at the places where there are crossing structures and at the transition between cut and fill, and often cause big shocks to vehicles. Shocks not only

cause damage to road pavements and bridge concrete decks, but will be a source of noise and vibration to the roadside areas. The following are the points to note in carrying out the inspections.

- Carefully observe roughness in driving and vibration while driving
 - Getting out of the car, carefully observe noise and vibration when vehicles pass
- (6) Edge Break is a break of asphalt pavement wearing surface. Edge breaks generally occur when the road shoulder is worn, when there is inadequate strength of the pavement at the edge, when water scours soft shoulder of road and weaken pavement edge. Significant edge drops narrows lane width and resulting bumps may damage vehicle tires, causing vehicle or motorcycle accidents.
- (7) Other Defects
- Pumping is the phenomenon often observed when water infiltrates into a subgrade layer through pavement layers. With vehicle load, small/fine particles of subgrade or base course materials which contain water will spout out through pavement surface cracks. Inspection should be carefully carried out when fine soil particles or sand in the cracks on the pavement surface are observed. Repair works need to be done promptly before damages develop into serious pavement structural damages.
 - Blistering is a phenomenon often appearing on the bridge pavements. When the water that remains between a bridge deck and the pavement vaporizes, pavement surfaces are often swollen. This often happens in the summer season. Blistered areas easily turn into potholes, so that inspection should be done carefully on the blistered areas of bridge pavements.

6.3.3.1.2 Cement Concrete Pavement

- (1) Bumps often appear at the joints between concrete slabs due to uneven settlement. As a consequence of uneven settlement, tie bars in the pavement are sometimes sheared or bend, causing a difference in the levels at joints between concrete slabs and thus impart shocks to running vehicles. Points of inspection to investigate the voids under the concrete pavements are as follows.
- Take core samples
 - Excavate the side of concrete slabs and confirm voids
 - Measure unevenness of concrete slabs
 - Hammer concrete slabs and listen to the sound
- (2) Concrete pavement cracks, which come out at the end surface of the concrete slabs due to the effects of tie bars, tend to develop in accordance with the growth in the traffic volumes of large vehicles, so that special attention should be directed to the surface of the concrete slabs during inspection. In addition, small cracks observed in the stage of construction tend to be increased by repeated loading of vehicle traffic. Data should be preserved to clarify the progress of cracks comparatively.
- (3) Damages at concrete slab joints occur in accordance with the increase in large vehicle traffic. Concrete slabs are reinforced by tie bars and therefor are not deformed, so that stress concentration

arises at or nearby joint structures between concrete slabs. In general, it is preferable to inspect joints of concrete pavements in winter, since joints gaps become wider in winter.

6.3.3.2 Inspection Points

Road facility inspection for pavement facilities shall be implemented on the inspection points shown in Table 6.3-2.

Table 6.3-2 Inspection Points for Pavement

Facility	Member	Damage	Initial inspection	Routine inspection	Periodic inspection	Emergency Inspection	Detail Inspection
Road Pavement	Asphalt Pavement	Pot holes/Potholes/Peeling/depressions	X	X	---	X	As required by Routine or Periodic Inspection
		Cracks	---	---	XX	---	
		Rutting Depth	---	---	XX	---	
		IRI	---	---	XX	---	
		Edge Break	X	X	---	X	
		Bumps	X	X	---	X	
		Pumping	X	X	---	X	
		Blistering	X	X	---	X	
	Concrete pavement	Bumps	X	X	---	X	As required by Routine or Periodic Inspection
		Cracks	---	---	XX	---	
		IRI	---	---	XX	---	
		Concrete slab joint damages	X	X	X	X	
	Road surface drainage system	Damages of drainage facilities	X	X	X	X	As required by Routine or Periodic Inspection
		Joint damages	X	X	X	X	
		Piling of debris	X	X	X	X	

(Note) X: Inspection items, XX: Inspection items to be measured by pavement condition survey vehicle.

- (1) Routine inspection shall detect pavement damages, in particular focusing on the damages causing unsafety to road traffic such as pot holes, bumps, rutting, water paddle etc.
- (2) Periodic inspection shall cover surveys not only on the asphalt concrete pavement, bituminous surface treatment and cement concrete pavement, but also on the road surface drainage systems.
- (3) In case pavement condition survey vehicle is applied to the periodic inspection, it shall measure pavement condition indexes including crack rate, rut depth and IRIs every 100 meters. Of these pavement condition indexes, rut depth and IRIs are automatically measures by the on-board sensors, on the other hand, crack rate shall be manually calculated by analysing video data recorded all the way during pavement condition survey. Other damages on the concrete slab joint and on the road surface drainage systems shall be separately inspected by patrol staff, following the relevant above articles in this guideline.
- (4) Periodic inspection by pavement condition survey vehicle shall be conducted by professional organization designated by DRVN. Managing agency of road facility inspection shall commit the road condition survey in the region to the professional agency by contract.
- (5) Professional organization shall take responsibilities for carrying out the field survey on pavement conditions, analysing crack data, evaluating the results of inspection, registering data into the

pavement condition database and preparing and submitting inspection reports to the managing agency of road facility inspection.

(6) Detail inspection shall be conducted when proposed by periodic inspection or when proposed for the planning and the designing of road rehabilitation and reconstruction works. Detailed inspection shall apply advance inspection equipment and make professional judgement in finding out the causes of the damages and in planning countermeasures of the damages. The following are the typical tasks for the detailed inspection.

- To evaluate pavement structure by Falling Weight Defectometer (FWD). It is a trailer-mounted device that operates by dropping a weight on to the pavement and measuring the resulting pavement deflections.
- To identify areas or locations where poor skid resistance is observed, thereby many vehicle accidents occur, by applying skid resistance survey equipment.
- To make decisions on the repair work priorities.
- To examine locations where vehicle accident frequently occur.

6.3.3.3 Inspection Methods and Frequencies

Inspection methods and inspection frequencies in principle shall follow the relevant articles of this guideline. However, inspection methods and frequencies specialized for the periodic inspection and the detailed inspection for pavement facility shall follow the methods prescribed in **Table 6.3-3**.

Table 6.3-3 Inspection Methods and Frequencies

Inspection Type	Inspection Method	Inspection Frequency
Periodic inspection	● Pavement condition survey vehicle for cracking, rutting and IRI survey ● Short-distance visual inspections for edge break and other damages	Once every 3~5 years
Detailed Inspection	● NDT testing like: Falling Weight Defect meter (FWD), Benkelman Deflection Beam, Plate loading test, etc. ● DT testing like: sample boring, cutting, excavation in combination with site experiments and testing on samples in laboratory. ● Skid Resistance Survey	Refer to Table 5.3-2

6.3.3.4 Evaluation of Inspection Results

- (1) Evaluation of the results of routine inspection, periodic inspection and emergency inspection shall be conducted, following the relevant articles in this guideline. Sample evaluation criteria for road pavement inspection results are shown in **ANNEX-D**. Also, particular notes for the evaluation of some damages are described below;
- (2) In this guideline, road facility damages expected to give large effects to vehicle traffic are rated as “D”, such as pothole, peeling and depression damages over 20 cm in diameter and 20 mm in depth, crack ratio in area percentage over 40 percent and rutting depth over 40 mm. Pavement depression discussed in this Guideline is a local depression arising in spots.

- (3) In case PMS is applied to the formulation of periodic repair plans for road pavement, evaluation on the inspection results shall be automatically carried out in the computation processes of PMS model. Other damages shall be separately inspected by patrol staff in the routine inspection and evaluated, following the relevant above articles in this guideline.

6.3.4 Planning of Maintenance and Repair

Proper maintenance or repair shall restore the performance of asphalt pavements and reduces overall pavement life cycle costs. In planning maintenance or repair works, the road sections that require maintenance and repairs need to be selected and prioritized based on the diagnosis of pavement inspection. Appropriate maintenance and repair works are then selected for these high-priority road sections. The above process is implemented for each road network and for respective projects. Data needed for the designing of pavement maintenance and repair plans are shown below.

- Initial design conditions
- Pavement configuration (thickness and material property)
- Pavement management level
- Traffic volume and axle load (wheel load)
- History of maintenance and repair
- Surface property and mixture property
- Load bearing capacity and strength of each layer

Asphalt pavements are anytime exposed to weather changes, so that when damage is discovered on the pavement, appropriate measures, e.g. crack seal etc., need to be taken in the initial stage of the damage in order to block water infiltration into pavement layers. Early repair is a key to prolong pavement life until future large-scale repair. The following outlines the data needed for the planning.

In case that target level of pavement management is promulgated, the pavement management level shall be taken into consideration in maintenance and repair work selection. **Table 6.3-4** shows a sample pavement management level currently applied to the Inter-city expressway network management by NEXCO-Central in Japan.

Table 6.3-4 Target Pavement Management Level (Reference)

Rutting (mm)	Faulting		Coefficient of Skid Resistance (μ80)	Longitudinal Roughness (mm) IRI	Crack Rate (%)
	Bridge Approach	Transverse structure approach			
25	20	30	0.25	3.5	20

(Note) Target pavement management level: from NEXCO-Central in Japan.

6.3.4.1 Identification of Design Conditions

When planning repair methods, it is necessary to identify design parameters including load bearing capacity, pavement structure, property of pavement materials and traffic conditions, before going into the designing or selecting the materials for repair works. It is also necessary to get information on the design conditions for initial construction and on maintenance and repair history in the past.

(1) Load bearing capacity and pavement structure

Evaluating the load bearing capacity and pavement structure enables the determination of whether the damage is structural or functional. Estimating the value required for overlay sectional design also becomes possible. Whenever the degree of deflection is found to be extraordinarily higher than usual, it often turns out that the sub grade has insufficient load bearing capacity. In those instances, cut and cover surveys need to be implemented. The depth of layers in which damage prevails and the load bearing capacity of the sub grade are measured to collect data required for identifying the range of layers that requires repair and for designing the cross section.

(2) Properties of pavement materials

For asphalt mixtures, the grain size, amount of asphalt and asphalt property are investigated. Water content and penetration are investigated in the base and sub grade. The material properties of asphalt mixtures are frequently investigated mainly in the case where the damage is determined to be of functional type. Then, identifying the asphalt mixture material properties enables appropriate selection of repair materials.

(3) Traffic loads

Pavements are also damaged in numerous cases as cyclic loading exceeding the design traffic volume or excessive traffic loads act, breaking the equilibrium between the traffic load and the pavement structure. In the case of sectional design in the repair of structural damage in particular, it is desirable to identify not only the sub grade design conditions but also the traffic loads for appropriate sectional design. In the case of functional damage, grasping the extent of traffic load is also important.

(4) Design conditions for initial construction and history of maintenance and repair

The design conditions when the pavement was initially constructed are important at the time of sectional design during the repair of structural damage. The history of maintenance and repair is useful when selecting the repair method or the range of repair.

6.3.4.2 Selection of Maintenance and Repair Work

The following three-step approach shall be applied to the repair work selection. First, to select standard repair work, and second to implement detailed survey and review the standard repair work, taking local conditions into consideration. Each of these approaches will be further discussed in the following sections.

(1) Select routine maintenance or periodic repair based on the results of inspection.

- (2) Select standard pavement maintenance and repair work.
- (3) Conduct detailed surveys including field observation and additional equipment surveys such as FWD, Skid Resistance Survey and so forth.

6.3.4.2.1 Selection of routine maintenance or periodic repair

The selection of maintenance and repair work shall be done based on the results of road facility inspection as shown in **Figure 5.3-1**.

(1) Routine Maintenance

Damages and deterioration evaluated as “E”, which is small-scale, but is to be urgently repaired, shall be repaired by small repair in the routine maintenance or in the emergency work as early as possible in order to mitigate the negative effects given to the road traffic and safety. In case damage area for this repair work shall be fairly limited to the spot or to the narrow range not more than 1.0m x 1.0m, whose repair work scale is manageable by maintenance patrol staff, small repair in the routine maintenance shall be applied.

(2) Periodic Repair

Road pavement becomes deteriorated as time passes by even routine maintenance is properly done. Periodic Repair is a more macroscopic and large-scale measure than routine maintenance to preserve traffic and road infrastructure functions during the long course of road maintenance. Periodic repair is a scheduled road asset management activity, focusing on much wider area than routine maintenance to preserve functions of road transport assets, which cannot be assured by routine maintenance. Work selection of periodic repair shall be made based on the data obtained by pavement condition survey. PMS is often employed as a measure to plan annual and medium term (5-Year) periodic repair plans

In the case of periodic repair, damages and deterioration which are evaluated as “C” or “D” shall be repaired by Periodic Repair, which is planned repair over 5 years with preferential treatment depending upon ABC rating. In case that damage area is larger than 1.0m x 1.0m and widespread, but is rated as “E” in the diagnosis, repair work shall be incorporated into an annual repair plan and implemented together with other repair work. In case that damage area is larger than 1.0m x 1.0m and widespread, but is rated as “C” or “D” in the diagnosis, repair work shall be incorporated into Periodic Repair Plan and implemented over 5 years with preferential treatment depending upon ABC rating.

6.3.4.2.2 Selection of Standard Maintenance and Repair Work

Figure 6.3-2 shows the framework to select standard maintenance and repair work for routine maintenance and periodic repair. **Table 6.3-5** shows the outline of these maintenance and repair work. As seen in the figure and the table, routine maintenance works consist of cutting, crack seal, pothole repair, surface treatment, bump repair and linear replacement. Also, major periodic repair works consists of overlay, local replacement, leveling, cut and overlay and replacement. Users are requested to select standard maintenance and repair work for routine maintenance and periodic repair based on the figure and the table.

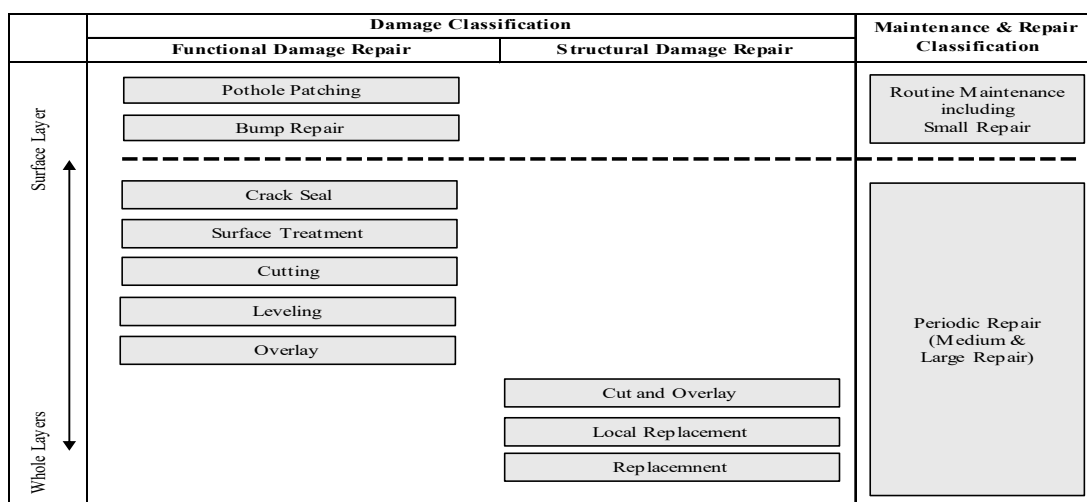


Figure 6.3-2 Major Repair Work for Asphalt Concrete Pavement

Table 6.3-5 Major Maintenance and Repair Works for Asphalt Concrete Pavements

Repair Work		Description
Routine Maintenance	Crack Seal	Joint fillers are injected into relatively wide cracks. Injection materials include emulsified, cutback and resin types. Various materials are used according to the width or depth of the crack.
	Pothole Patching and Bump Repair	Potholes, depressions and irregularities are temporarily filled. For filling, hot asphalt mixtures or cold mixtures using bituminous or resin binder are employed.
	Surface treatment	A sealing layer with a thickness of 3 cm or less is applied over the existing pavement using materials other than hot asphalt mixtures. The seal coat, slurry seal or resin-type seal method is available.
	Linear replacement	The pavement is replaced along linear cracks. Only the hot asphalt mixture layers are replaced.
	Cutting	Bumps on the surface are removed by cutting to eliminate difference in level. The method is often implemented as a preliminary measure before overlaying or surface treatment.
Periodic Repair	Overlay	Hot asphalt mixtures with a thickness of 3 cm or more are laid over an existing pavement. At locally faulty points, if any, replacement should be made first. If overlaying is adopted, the influences on the clearance gauge or the structures at the surface should be examined.
	Leveling	Modifications are made longitudinally by laying additional mixtures in longitudinal depressions on the surface produced by differential settlement. In planning, considerations should be given for guaranteeing the adequate height of safety fence, securing the drainage capacity and selecting appropriate regulation methods.
	Local replacement	In the case where the local damage to an existing pavement is determined to be great and no other method is expected to repair the damage, local replacement is done from the surface layer, base layer or base course. The method is frequently applied together with cutting and overlaying or overlaying in the areas where great cracking occurred locally.
	Cut and overlay	Existing asphalt mixture layers are removed by cutting, and the surface or base layer of the existing pavement is replaced.
	Replacement	The base course or part of the base course of an existing pavement is replaced. The sub grade may be replaced or the sub grade or base course may be stabilized in some cases.

6.3.4.2.3 Conduct Detailed Survey

Following the selection of standard repair work discussed above, users are requested to conduct detail site surveys to get local conditions for the design and the implementation of pavement repair on the sites.

Detail survey may include field visual observation conducted to the damage and deterioration identified in the pavement inspection. Detail survey shall be done by competent engineers. In addition, further survey, such as FWD, skid resistance survey shall be implemented to get numerical data for designing the detail of repair work. The following are the key points of detail survey.

(1) Damage Area

The detail survey on the damage area aims to measure the scale of pavement damage spread, which shall be the base of repair work selection. If damaged area is isolated to the spots or the narrow area of less than 1.0m x 1.0m, small repair in the routine maintenance shall be basically applied. However, if damages spread wider than 1.0m x 1.0m, periodic repair with hot mixture shall be the best selection. Small repair in the routine maintenance should not be applied for this case in principle.

(2) Damage Depth

The detail survey is to know the depth of pavement damage. If damage stays within surface or binder layer (Functional damage), small repair in the routine maintenance shall be basically applied to repair damages. However, if the damage depth reaches to the road bed, small repair in the routine maintenance is no longer effective to this damage, but periodic repair shall be applied.

(3) Damage Type

The detail survey on the damage type is also an important element. If a pothole or a bump is observed on the sites, small repair in the routine maintenance can be basically applicable, but if cracks or rutting is observed, small repair is no longer effective and periodic repair shall be the best selection for this case.

(4) Possibility of water bleeding from road bed

Detail survey on the potential of water bleeding from road bed is important element. If there observed water bleeding from road subgrade, it often causes serious damages to the pavements such as Crocodile Cracks etc. and gives serious negative impacts on the lifecycle of the pavement due to insufficient bearing capacity of subgrade, base course or subbase course. If water bleeding is observed, periodic repair shall be basically applied to the damages and replacement of damages with hot mix shall be the best solution for this case including subgrade, base course or subbase of pavement. Implementation of FWD survey is recommended to design the depth of replacement.

(5) Possibility of Surface Water infiltration

Water infiltration into pavement cracks and pavement construction joints often gives serious damages to road subgrade, base course and subbase course and shortens pavement lifecycle. Water infiltration also occurs when pavement damaged area is depressed in height, causing water concentration to the repair section. To cope with this, it is important to apply water sealing by asphalt emulsion to any cracks created by the small repair in the routine maintenance and by periodic repair.

(6) Traffic Volume

Detail survey on the traffic volume is also an important element to select pavement repair materials, in particular for the small repair in the routine maintenance. Cold mix is in principle applied to the small

repair. Cold mix which in general takes time to get initial strength is subjective to traffic load which often causes the fluidization of asphalt material and the separation of asphalt component. Best solution for the pavement repair work under heavy traffic condition is to apply hot mix, or to apply cold mix to the limited area less than 1.0 square meters (1.0 meter X 1.0 meter).

(7) Emergency Repair until Full Repair

There are special cases in which road operator should implement emergency repair with cold mix until full recovery by periodic repair. This may often occur when traffic serviceability or safety is degraded due to pavement damages and thus urgent repair is needed in particular under the heavy traffic condition in the urban area. However, it should be noted that temporary treatment by cold mix becomes feasible with understanding that performance of this measure becomes fairly degraded and temporal until periodic repair. For this reason, it is not appropriate to apply performance acceptance criteria (such as IRI) to this case. As an alternative measurement for the payment, dimension measurement of the completed shape is in general applied.

(8) Repair Work Method

When doing periodic repair work on the sites, square-cut of damaged area by pavement cutting machine shall be done first in order to ensure uniformity of repair thickness and of compaction effect. However, damage repair without square-cutting shall be also applicable to shorten traffic control time in particular for the small repair in the routine road maintenance. For this case, it is important to understand that degradation of performance may occur as already discussed in the previous section.

6.3.5 Implementation of Routine Maintenance

Routine maintenance is not intended for fundamental restoration from the damage to the pavement but only for the maintenance of serviceability of the pavement by temporary measures. The routine maintenance including small-scale repair in general includes cutting, crack seal, pothole patching, surface treatment, bump repair and linear replacement.

(1) Crack Seal

The objectives of crack seal are to extend pavement service life, thereby to reduce the cost of pavement maintenance and repair. Crack seal is the injection of an asphalt-type sealing material or a resin-type sealing material into cracks, which is applicable at normal temperature. The method is adopted to temporarily prevent the deterioration of load bearing capacity caused by water infiltration into the crack.



Photo Injection of an Asphalt-Type Sealing Material

- Crack Seal with Asphalt-type Sealing Material

The method is to apply a hot-mixed material as a sealing material. Hot-mixed sealing materials are highly cohesive, adhesive and elastic, so that they are flexible to the swelling and the shrinkage of cracks. Asphalt-type sealing materials are more cohesive than resin-type sealing materials that are described later and are suitable for relatively large cracks with the width of 5 to 10 millimeters. Work implementation methods are as follows

- Cleaning the spot to be treated

The faulty spot is cleaned by blowing off the dust or mud in cracks using compressed air. The loosened areas around the crack are removed.

- Melting of sealing material

The sealing material is melted by heating.

- Injection of sealing material

The sealing material is poured into the crack and made to penetrate into the crack using a U-shaped tool. Excess material is scraped off with a tool and the surface is cast. Sand is spread as required to prevent the adhesion to tires.

- Opening of the road to traffic

The road is put into service after confirming that the sealing material has fully hardened.

- Considerations

A wet surface is fully dried by heating with a burner before injection.

- Injection of a Resin-type Sealing Material That Hardens at Room Temperature

The method is used to treat the pavement by injecting a resin-type sealing material that hardens at the room temperature. The sealing material hardens quickly and even at low temperature. Thus the material provides high workability including flexibility and traceability along the crack. The

method is therefore applicable to narrow cracks of 5 mm or less.

- Method of patching

The method similar to that for asphalt-type sealing materials is used. No preparation of a sealing material is, however, required.

- Considerations

When the sealing material penetrates and cause settlement, additional volume of material is injected again according to the degree of settlement. Resin-type sealing materials are generally more costly than the asphalt type. They should be used within the designated working life. A wet surface should completely be dried by heating with a burner or other device before injection.

(2) Pothole Patching & Bump Repair

Pothole patching is to temporarily fill potholes, bumps, local cracks and depressions with asphalt mixtures. The objective is to control the deterioration of load bearing capacity due to water infiltration and to improve vehicle riding quality. A simple method is to embed asphalt mixtures or other materials directly into the damage without applying any pre-treatment (**Figure 6.3-3**). In another method, damage areas are cut out and backfilled with asphalt mixtures. The former is applied to the case where urgency is required. Patching is applied either by hot mixing or by cold mixing.

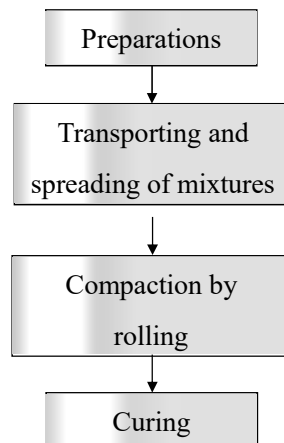


Figure 6.3-3 Flow of Patching Steps

- Patching by Hot Mix

Patching by hot mixing is fitted to the pavement repair of roads that carry heavy large vehicle traffic because it provides excellent adhesive strength with existing pavement and high durability and stability. For the hot asphalt mixtures used by the method, materials similar to those used on the existing pavement should basically be adopted.

- Preparatory work

Damaged and faulty sections are removed using a concrete cutter and their shape is trimmed. When repairing small areas such as potholes, no cutting is required. Then, dust and mud in or around the cut face are removed. Then, a tack coat is laid on the bottom and side surfaces. The excess tack coat staying in depressions are wiped off with a cloth or by other means.

- Transport and spreading of mixtures

Only a small amount of mixture is generally used. The mixture is covered with membranes during the transport to prevent temperature drop. The mixture is spread so that the finished level may be approximately one centimeter higher than the road surface surrounding the faulty spot, taking into account of settlement after the commencement of service.

- Compaction by rolling

Small road rollers or plate compactors are used for compaction.

- Curing

The surface is cured until it becomes possible to touch with a hand.

- Matters to be taken care of

In the above patch work, the point to be repaired needs to be cleaned and a wet surface needs to be completely dried. The work should be carried out quickly to obtain the designated compaction temperature. Heating by burners should be minimized even where necessary.

- Patching by Cold Mix

The method of patching by cold mixing can be implemented at the room temperature. It is easy to implement and is therefore adopted in emergency. The method is inferior to the hot mixing method in initial stability and durability, and moreover, it needs the period of curing.

- Preparatory work

Similar pretreatment is done to that in the method by hot mixing.

- Spreading of mixture

Aggregate mixture is wrapped in bags. The mixture is spread so that the finished level may be approximately one centimeter higher than the road surface surrounding the faulty spot, counting the magnitude of settlement after the commencement of service.

- Compaction by rolling

Small road rollers or plate compactors are used for compaction.

- Curing

The road should not be put into service until the moisture and solvent of the bituminous material vaporize.

- Considerations

The method is temporarily applicable on roads that carry heavy traffic of large vehicles if urgency is demanding.

(3) Surface Treatment

Surface treatment is the method to set a thin layer less than 3 cm on the existing pavement surface. There are some alternative methods available, depending upon material and work types. Surface treatment has been implemented to cope with pavement deterioration, cracks and pavement wear for the purpose of preventive road maintenance. Surface treatment is expected to improve water-blocking performance and skid resistance, thereby to restore and to reinforce existing pavement functions. When the surface treatment is applied to the light damage as a preventive repair, it is expected to enhance pavement life. There are several materials such as emulsion, asphalt mixture and resins. It is necessary to select appropriate materials, taking account of pavement conditions, traffic volume, etc.

- Fog seal

Fog seal is the repair method to restore pavement functions by spraying asphalt emulsion diluted by 1 to 3 times with water (0.5 –0.9 liters per square meters) and filling into the pavement cracks.

Asphalt emulsion, MK- 2 or 3, has been often used. Sometimes it is used to settle aggregates or dust after other treatments are done. It is effective to apply this technology to low traffic roads. It is possible to open traffic in 1 to 2 hours after the repair work. In the case of hastening the opening of traffic, it is good to spray sand on the sprayed emulsion.

- Chip seal

Chip seal is applied only to the asphalt pavement which finishes aggregate into a single or multiple layers using emulsion. The former is called a seal coat and the latter an armor coat. Seal coat is to formulate one layer of emulsion and aggregates, and armor coat is to formulate more than two layers on the pavement surface. The purposes of this method are as follows.

- To fill up small crack and to enhance water resistance and durability with high water tightness
- To prevent aging of the existing pavement
- To restore pavement surface
- To improve wearing resistance

- Slurry seal

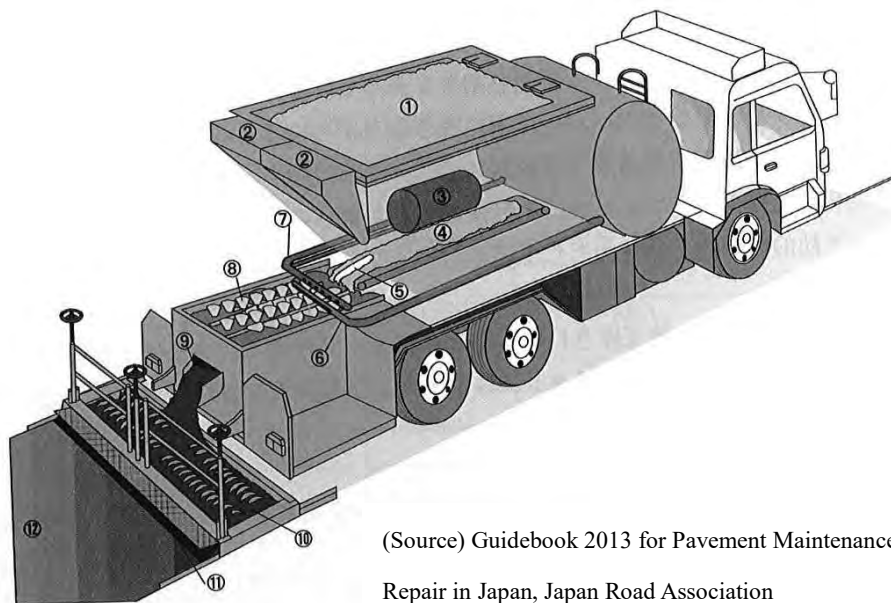
This method is to mix fine aggregate, filler, asphalt emulsion and water together and to put them thin over the asphalt pavement or on the concrete pavement (3 to 10 millimeters). Requirement of asphalt emulsion to the weight of filler and fine aggregate is 13 to 30%, and of water 10 to 15% in general. Slurry seal shall be implemented in the field in the warm climate and should not be implemented in the temperature of less than 15 degrees or in the cloudy days with high humidity.

- Micro surfacing

Micro surfacing is a kind of slurry seal which produce slurry cold mixtures of carefully selected aggregate, modified bitumen with rapid rigidity, asphalt emulsion, cement, water and decomposition regulator and spread them thin over existing pavement by using micro-surfacing paving machine. This method does not need heating in producing mixture and in construction in the field, and is fairly energy saving, thereby contribute to reduce carbon dioxide emission. Micro surfacing has been applied to the asphalt and the concrete pavement to restore pavement functions from aging and rut damage, to improve pavement texture and to conduct preventive maintenance.

Construction of micro-surfacing is in general done with one layer whose thickness is from 3 to 10 millimeters placed on the asphalt and the concrete pavement surface. However, when applied to the pavement whose rut is heavy (15 to 20 millimeters in depth), two layer repair is sometimes applied.

Special equipment is used to produce mixture and to place pavement, which has all necessary functions in the equipment such as those for saving materials, mixing materials and paving materials on the pavement surface, thereby make it possible to conduct continuous work while moving forward (**Figure 6.3-4**).



(Source) Guidebook 2013 for Pavement Maintenance and
Repair in Japan, Japan Road Association

Figure 6.3-4 Micro-surfacing Paving Machine

- Carpet coat

This method is applied to normal asphalt and concrete pavement. Hot asphalt mix is laid on the pavement surface and compacted in 1.5 – 2.5cm thick layer. This method features early open to traffic after the repair work. Compared with other overlay methods, this has thinner layer than it. Carper coat is a hot mixture produced by mixing crusher-run, screening, sand, filler and carbon binder. Maximum grain size of aggregate should be less than half of the pavement thickness and 5 mm aggregate is in principle used.

- Resin-based Surface Treatment

Resin-based surface treatment is not to enhance pavement life-cycle, but to enhance pavement skid-resistance, so that it is often called as a skid-resistance pavement. It has been applied to the places where pavement skid-resistance needs to be improved, such an access portion to school zone and to the toll gates on the expressways. It is in general applied to the normal asphalt pavement and concrete pavement, applying resin thinly and evenly on the pavement surface as a binder and spreading wear resistant hard aggregates on it and fixing them on the pavement surface (**Figure 6.3-5**). Resin-based surface treatment is also used to enhance the skid resistance capacity of pavement surface in particular on the wetted road surface.

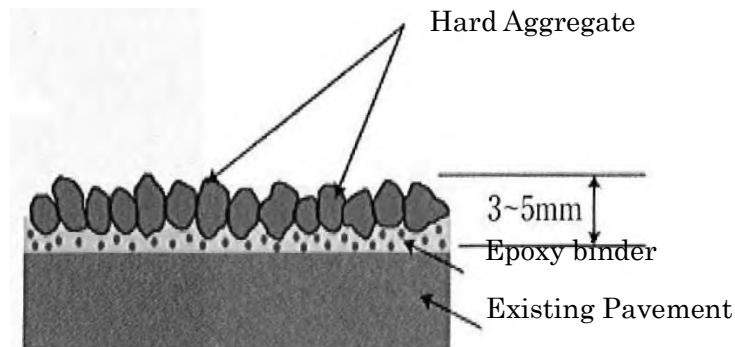


Figure 6.3-5 Cross Sectional View of Resin-based Surface Treatment

- Drainage Topcoat

Drainage top coat is to prevent aggregate dispersion from porous asphalt pavement, keeping water permeability of the pavement. It spreads special resin over the pavement surface and creates hard membrane on the pavement surface without blocking water permeability of the pavement, thereby enhances wearing resistance of the pavement.

(4) Pavement Cutting

Pavement cutting is used to scrape off the uneven or irregular pavement surface. Bumps are scraped off using machines to restore the surface shape. The method is often adopted as a preparatory work before surface treatment or overlaying.

- Preparations

Drainage basins are protected prior to surface cutting to prevent them from being clogged with the materials produced by cutting.

- Cutting

Bumps are scraped for the designated thickness using surface cutters. Sufficient amount of water is sprinkled during cutting to control the production of dust during operation.

- Loading of the pavement waste

The pavement waste produced by cutting is loaded on dump trucks using loading machines for transport to designated sites.

- Cleaning

Road sweepers are used to completely clean the surface while sprinkling water to control the production of dust.

- Considerations

The method is a temporary measure. On the surface where rutting due to the flow of asphalt or corrugations cause problems, therefore, irregularities are likely to recur early. The irregularities that developed in a short time in particular are highly likely to recur.

(5) Linear Replacement

In linear replacement, the pavement is replaced along linear cracking. The method is generally applied only to asphalt mixture layers including the layers stabilized with bituminous materials.

- Linear cutting of pavement

The faulty sections with linear cracks are cut off. For cutting, a cutter is placed along the crack and the section is scraped off with a breaker or backhoe.

- Tack coat

The cut spot is cleaned with a compressor and cured by evenly spreading emulsified asphalt using an engine sprayer. Then, the cut surface in the existing asphalt mixture layer is also fully coated with emulsified asphalt using a brush.

- Laying of a mixture

A hot mixture is manually spread and compacted using a small vibratory roller or tire roller. Joints should be carefully compacted because the joints are likely to be compacted poorly, resulting in weak points.

- Curing

The pavement is cured until the surface temperature drops below 50 C before opening the road to traffic.

6.3.6 Implementation of Periodic Repair

In the case where a pavement has been greatly damaged, a fundamental treatment shall be applied to the pavement through repair work. Asphalt pavement repair methods include overlaying, cutting and overlaying, replacement and local replacement. All are more costly than maintenance. The damage to pavements is caused by various factors. The repair method should therefore be adopted based on the materials including various survey results. The planar scope of the damage, timing of repair, and traffic and roadside conditions need to be examined carefully.

(1) Overlay

In overlaying, an asphalt mixture layer is laid over the existing pavement. The method is applied in the case where the damage is expected to progress throughout the pavement in the near future or the pavement structure has become insufficient to carry ever increasing traffic. The method provides the following benefits.

- Increase in the load bearing capacity of the pavement or restoration of the load bearing capacity of a damaged pavement
- Functional restoration of surface smoothness or skid resistance
- Provision of additional functions

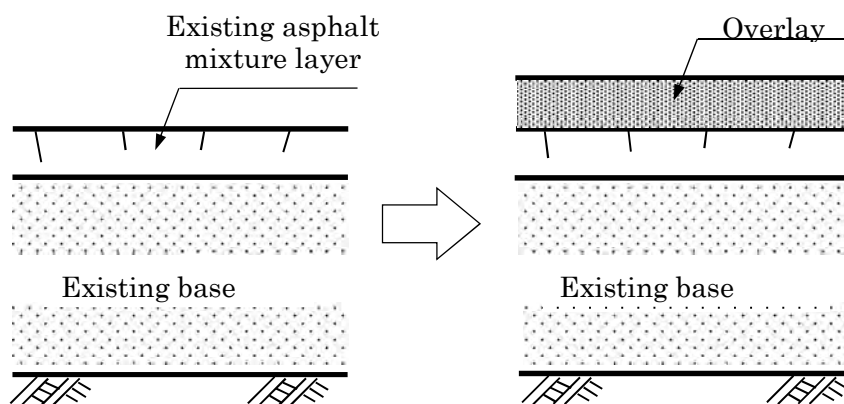


Figure 6.3-6 Conceptual View of Overlay

The thickness of the layer laid by the method is generally 3 to 5 centimeters unlike the thickness of carpet coat (applied by surface treatment) of 1.5 to 2.5 cm. Leveling is applied for restoring from functional damage in the areas subjected to differential settlement, however is not intended for structural reinforcement. In leveling, longitudinal modifications are made by laying new binders over depressions in the longitudinal direction.

The thickness of overlay is designed based on the Pavement Design Standards in Viet Nam. Overlaying is a simple method for reinforcing the pavement structure that enables the improvement of layer equivalency factor by increasing pavement thickness. For adoption, it should be noted that the surface elevation increases and that the causes of damage have yet to be removed fundamentally.

- Preparatory Work

In the case where there are damaged areas or irregularities on an existing pavement, patching, leveling, local replacement or other measure is taken according to the condition before overlaying. For overlaying, the surface is cleaned, dust or mud is removed and a tack coat is applied. In leveling, cutting is required for a depth of approximately 20 mm for connection to secure the minimum pavement thickness at the end.

- Tack coat

A designated amount of emulsified asphalt is evenly spread using distributors or other devices. At the end point of cutting, spreading is done manually or using simple pump spreaders. Care should be exercised to prevent emulsified asphalt from staying on the existing surface.

- Spreading of a mixture

The mixture is usually spread using asphalt finishers, or manually in areas where no finishers can be used. The mixture is spread so as to achieve the designated thickness after compaction. If it starts raining while spreading the mixture, spreading should be suspended. The mixture that has been spread should be compacted quickly and finished.

- Compaction

The mixture that has been spread is compacted so as to obtain the designated density. Compaction generally starts with joint compaction and proceeds to the primary and secondary compaction and ends with finishing. The primary compaction is done by two-time trips, or a back-and-forth trip, of a 10- to 12-ton roller. Compaction is carried out at the highest temperature possible as long as no hair crack occurs. The compaction temperature is generally 110 to 140 C. In order to prevent the mixture from adhering to the roller, a small amount of water may be sprayed thinly over the surface using an atomizer. For the secondary compaction, eight- to 20-ton tire rollers or six- to 10-ton vibratory rollers are generally used. Compacting the mixture by tire rollers improves the interlocking of aggregates owing to the force of compaction as under traffic loading, and is expected to achieve a uniform density in the depth direction. Using vibratory rollers with appropriate loading, frequency of vibration and amplitude produces the designated degree of compaction in smaller numbers of times of rolling than using tire rollers. The secondary compaction is generally carried out at 70 to 90 C. Finishing is done to correct irregularities or eliminate roller marks. Tire rollers or road rollers should travel back and forth once. In the case where vibratory rollers are used for secondary compaction, tire rollers should preferably be employed for finishing. No roller should stay for a long time on the just-finished pavement.

- Curing

The pavement is cured until the surface temperature drops below 50 C before opening the road to traffic.

- Considerations

Overlaying is suitable for controlling relatively moderate cracks that occur on the pavement surface. In the case of the occurrence of numerous cracks that are likely to reach the base course or sub grade, replacement is preferable. After the completion of the leveling work, it is necessary to secure the adequate height of safety fence and the drainage capacity.

(2) Cutting and Overlaying

Cutting and overlaying work involves the cutting of part of the existing asphalt mixture layer followed by overlaying. The repair method - cutting and overlaying- has recently been implemented most because it eliminates the need of increasing the surface elevation and wide availability of high-performance cutters. In cutting and overlaying work, unlike overlaying work, surface cutters are adopted. Surface cutters are classified into wheeled-type and crawler-type devices according to the mode of travel. Surface cutters equipped with a loading machine are generally used

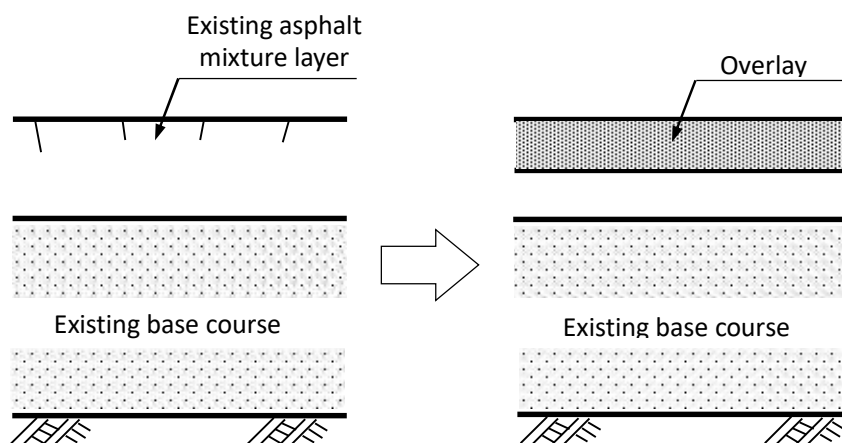


Figure 6.3-7 Conceptual View of Cutting and Overlaying

- Cutting the surface and loading the pavement waste

Cutting the existing surface is generally done by using surface cutters. The areas around cutting should be separated by cutting with concrete cutters. The pavement waste produced by cutting is transported to the designated places on trucks.

- Cleaning

The debris produced by cutting is completely removed while spraying water to prevent drifting. It should be make sure that no debris is left in the ditches created by cutting.

- Tack coat

Construction is carried out as in overlaying. In cutting and overlaying, care should be exercised to prevent the emulsified asphalt that constitutes the tack coat from staying in the ditches created by cutting.

- Spreading of mixture

The spreading work is implemented as it is done in overlaying.

- Compaction

The compaction work is implemented as it is done in overlaying.

- Curing

The curing work is carried out as in overlaying. Spreading Primary compaction by a road roller
Secondary compaction by a tire roller

(3) Replacement

In replacement, the existing pavement is partly or fully removed and a new pavement is constructed. The method is implemented in cases where the pavement has been seriously damaged and the damage has reached the sub grade or base course, or where the surface has a limited elevation. The types of damage to which the method is applied include the deterioration of the load bearing capacity of sub grade or base course and the rutting and cracking ascribable to settlement. The pavement is replaced from the surface to the layer with considerably deteriorated strength. In the case where the base course has suffered from the deterioration of load bearing capacity, the pavement is replaced using excellent materials or is stabilized.

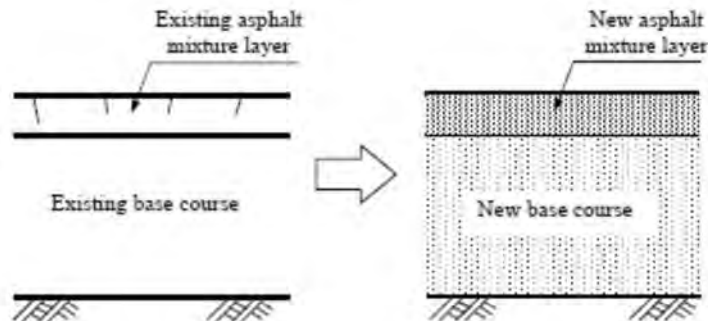


Figure 6.3-8 Conceptual View of Replacement

- Preparations

The points of replacement (e.g. start and end points and longitudinal joints) are specified explicitly.

- Demolition of the existing pavement and transport of the pavement waste

The edge of the area to be replaced is cut to the designated depth by a cutter. The existing asphalt mixture is pulled up with a cutter or breaker and fragmented. The existing asphalt mixture that has been fragmented with a shovel loader or backhoe is loaded on dump trucks and transported to designated places. The sub grade is to be treated carefully so as to finish it as smooth as possible.

- Construction of a sub-base (granular sub-base)

Irregularities on the cut surface are corrected using a bulldozer or grader while confirming the elevation of finished sub grade. The base course materials delivered by dump trucks are spread by bulldozers. Compaction is done using a road roller or a tire roller. The edge is corrected manually and carefully compacted with a rammer or other equipment.

- Prime coat

A designated amount of emulsified asphalt is spread evenly with an engine sprayer and cured. When spreading, protection is provided using concrete panels or other materials to prevent the emulsion from drifting.

- Construction of a base course (base stabilized with bitumen)

Construction is carried out as in overlaying.

- Tack coat work

Emulsified asphalt is evenly spread with a distributor and is cured. When spraying the emulsion, protection is provided using concrete panels or other materials to prevent the emulsion from drifting.

- Construction of wearing course and binder course

Construction is carried out by the same manner as is done in overlaying. When the binder course temperature drops to approximately 50 C, the tack coat works and the wearing course work are undertaken. The work is done as in overlaying. When the wearing course surface temperature drops to approximately 50 C, the pavement is opened to traffic. Then, pavement markings are placed using dedicated machines by a separate work.

(4) Local Replacement

Local replacement of the wearing course, binder course or sub-base is one of the measures employed when the existing pavement is greatly damaged locally by cracking or other factors and suffered from structural damage as revealed by the preliminary survey... The method may sometimes be implemented in areas that suffered serious local damage before overlaying or “cutting and overlaying” is implemented.

- Preparatory work

The points of replacement (e.g. start and end points and longitudinal joints) are to be marked.

- Demolition of existing pavement and transport of the pavement waste

The edge of the area to be replaced is cut to the designated depth by a cutter. The existing asphalt mixture is pulled up with a small cutter or breaker and fragmented. The existing asphalt mixture that has been fragmented with a backhoe or shovel loader is loaded on dump trucks and transported to designated places.

- Construction of a sub-base

Irregularities on the cut surface are corrected manually or using a backhoe while confirming the elevation of finished sub grade. The base course materials that are delivered by dump trucks are spread manually or using a backhoe. Compaction is done carefully with a rammer or plate compactor.

- Prime coat

A designated amount of emulsified asphalt is spread evenly with an engine sprayer and is cured. When spreading, protection is provided using concrete panels or other materials to prevent the emulsion from drifting.

- Construction of a base course (base course stabilized with bitumen)

The mixture is spread manually and compaction is done carefully using a rammer or plate compactor to construct the upper base.

- Tack coat work

A designated amount of emulsified asphalt is spread evenly with an engine sprayer and cured. When spreading, protection is provided using concrete panels or other materials to prevent the emulsion from drifting.

- Construction of wearing course and binder course

The binder course mixture is manually spread, and carefully compacted using a rammer or plate compactor to construct the binder course. Then, a tack coat is applied. The surface layer (wearing course) mixture is manually spread, and carefully compacted using a rammer or plate compactor to construct the surface layer. Pavement markings are placed with a line marker. When the pavement surface temperature drops to approximately 50 C, the pavement is opened to traffic.

- Considerations

Local replacement is prone to cause settlement after the road is opened to traffic. Careful compaction is required in construction. Settlement is likely to occur at the edge in particular. It is therefore desirable to place the finished surface of the surface layer approximately 0.5 cm higher than the existing pavement. When two or more layers are constructed, the overlapping of joints should be avoided and the upper layers should be removed with a wider margin to facilitate compaction (Error! Reference source not found.).

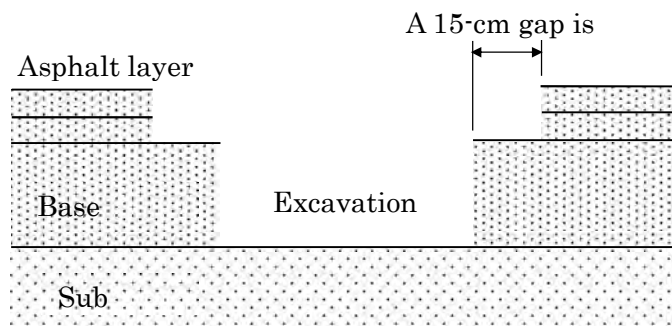


Figure 6.3-9 Excavation in local replacement

6.4 Bridge Pavement Maintenance Management

6.4.1 Introduction

Surface of elevated road or viaduct (hereinafter called bridge pavement surface) is the surface of bridge road and viaduct which have floor slab (concrete floor slab, steel floor). Construction of bridge surface is implemented with the purpose of heavy load resistance, floor protection and high riding quality.

If the surface condition becomes bad, it shall affect traffic and upper structure of the bridge with the increase of vibration and impact on the bridge floor slab, water penetration and so on. In fact, there are a lot of factors influencing on the bridge pavement surface, such as small bridge width resulting to more critical wheel rutting; sharp horizontal curves due to limited space way near the bridge resulting high shear stress from wheel loading; limited overlay due to bridge structure. Therefore, it is required to inspect and maintain to detect incident, find out causes, and settle appropriately.

6.4.2 Typical Defects Observed

In order to repair and improve the bridge surface, it is required to understand failure of the bridge surface clearly. Reasons for bridge surface failure shall be very different with road surface because structures under the surface are made of rigid and impermeable materials. Main failures and the causes are presented in **Table 6.4-1**.

Table 6.4-1 Classification of the bridge pavement surface failures and the causes

Classification			Main causes
Main failure related to surface status	Partial crack	Hair cracks	Quality of compound is not good. Construction temperature is not suitable.
	Roughness	Asperity near expansion joints	Deformation and abrasion is due to difference in strength of pavement surface materials and expansion joints, and unsteady compound.
	Deformation	Rutting	Heavy traffic, low speed traffic or stopping traffic, unsteady surface materials, fixed wheel loading, low quality pavement surface
		Roughness in longitudinal direction, Corrugation, Depression,	Vibration due to dynamic loading from vehicle on the bridge surface, heavy traffic, unsteady mixtures, floor roughness, too much and irregular quantity of tack coat.
		Flushing	Too much asphalt in mix compound; unsuitable asphalt (soft asphalt); too much and/or irregular quantity of tack coat.
	Abrasion	Raveling, Polishing, Peeling	Insufficient compression, lack of asphalt, too hot mixtures resulting to aged asphalt, soft aggregates.
	Broken and surface materials losing	Pot hole Stripping Aging	Low quality mixtures, insufficient compression, water absorption, bolts of steel slab.
	Other	Scratch Uplift	Objects fallen from the vehicles, traffic accidents. Thick mixtures, swollen air under the surface, volatile of tack coat and steam evaporation of concrete slabs.

Classification			Main causes
Main failures related to structure	Crack in scale of the whole bridge surface	Line crack	Bridge with large deflection amount, concentration of partial stress due to vibrating feature of the bridge, warping feature of floor, peeling
		Alligator crack	Vibrating of the bridge, warping, low quality of mixtures aging, and strip of asphalt.

- Notes of bridge pavement surface failures:

(1) Crack

In addition to normal cracks, there are cracks at the middle of expansion joint and curb pavement.

(2) Roughness

Roughness occurs at location at the approaching part from road embankment to bridge structure or at the bordering part of expansion joints. The main reason is lack of compaction due to difficulty of compact work around joints and rutting on earthwork at embankment.

(3) Scratch

Scratches on the bridge surface are normally caused by accidents and objects fallen from the cars. It is required to examine impact of scratches to bridge structure (floor, expansion joints) and scope of impact. In case of large scratch (depth of the scratch is bigger than $\frac{1}{2}$ thickness of the bridge pavement surface), it shall influence on floor. So it is required to examine in area of more than 0.5m from scratch (**Figure 6.4-1**). Moreover, in case the surface is destroyed because of fire, it is also required to examine as above.

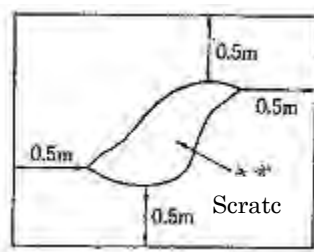


Figure 6.4-1 Scope of examine

6.4.3 Inspection of Bridge Pavement

With respect to repair of the bridge pavement surface, each failure on the surface shall influence largely on the whole bridge, so it is required to individually repair each type of failure. Indexes related to necessity to improve the bridge shall be stated in

Table 6.4-2. In addition, it is necessary to construct bridge pavement surface carefully to avoid impact to the bridge structure. It should consult this table to determine repair method for each type of failure.

Table 6.4-2 Indexes related to necessity to repair and improve the bridge

Items Type of road	Rutting (mm)	Roughness (mm)	Skid resistance coefficient	Crack, space between cracks		Diameter of pot hole (cm)
				Rate (%)	Width (mm)	
Road for cars	15	10	0.25	20	3	10
Normal road with high traffic	20÷30	15÷20	0.25	20	3	10÷20
Normal road low traffic	30÷35	20÷30	-	20	3	20

Note 1: In item of roughness, positions near expansion joint are also included.

Some types of failure (such as crack, pot hole) are caused by bridge structure, so it is required to pay attention to evaluation work.

6.4.4 Planning of Maintenance and Repair Work

Determination of construction, repair and improvement method should be implemented after analyzing, studying generally methods of repair and maintenance for each type of failure as stated in Table 5.9.3 and based on experience.

In case of repair pavement surface on the bridge, some failures are caused by structure, so the repairs might influence on the whole bridge structure if they are neglected. It is required to examine each type of failure and repair basing on examination result regardless of failure dimension.

6.4.5 Implementation of Maintenance and Repair

Repair method of the bridge surface is mostly like pavement. In addition, there are some notes during repairing for bridge pavement:

6.4.5.1 First-aid repair

6.4.5.1.1 Patching

When removing damage part, it is necessary to pay attention not to scratch floor. In addition, it is required to examine the floor status and find out reasons for failures if any.

6.4.5.1.2 Spreading crusher-run and sand

In case the bridge near residential areas, flaking stones that might not be adhered may fly. So it needs to be care as repairing.

Table 6.4-3 Construction and repair method by damage type

Classification			Maintenance/repair work
Main failure related to surface status	Partial crack	Hair crack, space	Sealing Filling
	Roughness	Roughness near expansion joint	Patching, reconstruction

Classification			Maintenance/repair work
	Deformation	Rutting	Scarification, replacing, overlay
		Roughness in longitudinal direction	Scarification, replacing, overlay
		Corrugation	Scarification, replacing, overlay
		Deflection and depression	Scarification and carpet-coat method
		Flush	Spreading crusher-run or sand
	Abrasion	Raveling	Carpet coating, patching
		Polishing	Carpet coating, surface treatment by resin Carpet coating, patching
		Peeling	Coating protecting cover, patching
	Surface materials losing	Pot hole, stripping, aging	Patching, reconstruction
	Others	Scratch	Patching
		Uplift	Patching
Main failures related to structure	All over crack	Line-shape crack, Alligator crack	Filling, overlay, reconstruction Carpet coating, overlay, reconstruction

6.4.5.1.3 Filling

Because rain might intrude into position between the floor and bridge surface through the crack, it is required to check carefully and pour joint sealing compound into the crack. At the space between the bridge surface and bridge structure, after using cutter to fix width of the space, pouring joint sealing compound into such positions shall be implemented.

6.4.5.1.4 Surface treatment

The purpose of the bridge pavement surface repair is not to increase dead load, so it should not use overlaying method but can use carpet coating to make thin protecting cover. As implementing carpet coat, it is required to remove roughness near the joints by following procedure.

6.4.5.1.5 Contact by cutting end

After cutting head of old bridge surface contacting with the expansion joint as in the **Figure 6.4-2**, carpet coat shall be executed to contact with the expansion joint.

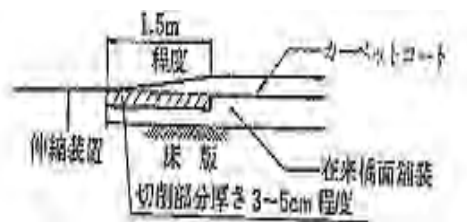


Figure 6.4-2 Contact by cutting end at head of expansion joint

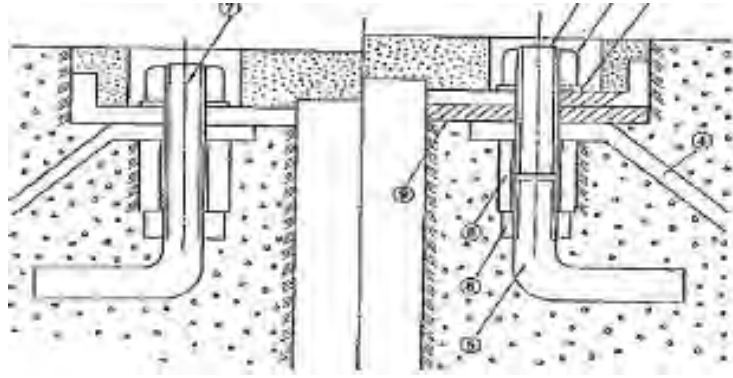


Figure 6.4-3 Lift-up of Expansion Joint

List of materials is as follows: Long bolt, Lock screw, Screw Long bolt, Packing washer, Long screw, Anchor bar, Washer, Anchor bolt

Lifting of the expansion joint shall be implemented as Error! Reference source not found. after putting steel, rubber or resin sheet in suitable thickness with coating cover under the expansion joint. In case of lifting the expansion joint, it needs to replace short bolt by long bolt, then put washer (steel, rubber or plastic washer). If it is lowered, reverse process is done.

6.4.5.1.6 Repair Method

Normally, the repair method is to implement overlay after cutting the bridge surface with appropriate thickness. It is possible to implement like method of asphalt pavement. However, it is required to pay attention to followings:

6.4.5.1.7 Particular Note for Cutting

On the concrete deck, thickness of the surface is not consistent because of irregular floor, so it is required not to cut floor when cutting the old surface.

On the steel floor, it might have screw head, bolt head; therefore, it is required to check carefully and draw this position on the old surface before cutting and this work requires man power.

Cut carefully and pay attention to cut so that concrete floor, steel floor, expansion joint and bridge connecting part, are not destroyed and it needs to construct by machine first, then use man power. On the other hand, it is required to pay attention not to destroy rubber joint by heat.

6.4.5.1.8 Paving

In case of the bridge surface, positions surrounding the bridge connecting part and expansion joint easy to contract and to be lack; therefore, it is required to pay attention to contraction after putting into service. As finishing the expansion joint, it is better to finish at position a little higher than that of the expansion joint (around 2÷3mm).

6.5 Tunnel Pavement Maintenance and Management

With respect to road surface inside the tunnel, because road floor is solid rock in many cases, road surface shall be designed thinner than that of other roads. In addition, because of irregular level of road floor due to excavating and irregular thickness of the road base due to laying drainage culverts, bearing capacity is not identical.

Moreover, after finishing, it is impossible to avoid water leak due to spring water, so it is very difficult to maintain initial status of the road base. Hence, before repairing or upgrading the road surface inside the tunnel, it is required to examine method to prevent water leak.

Abnormal state of the road surface which is paved inside the tunnel might cause traffic accidents, so it is required to pay attention when checking visually by walking. As detecting special incidents, it is necessary to resolve them immediately and appropriately. When repairing the road surface inside the tunnel, it is required to use reconstruction method and reconstruction after scarifying to ensure clearance. In respect to light efficiency and leak resistance, cement concrete pavement is required; however, asphalt pavement is usually used.

6.6 Bridge Maintenance Management

6.6.1 Introduction

Bridge repairing is the process of repairing the damage that is judged to be necessary to repair as a result of the detailed inspection and investigation.

- Bridge repairing is repairing the damaged parts to improve the durability of the bridge. It is different from reinforcing to improve the load bearing capacity of the bridge.
- Repairing is carried out in order to improve the durability and to increase the life of the structure of the bridge, along with avoiding damage propagation.
- If the judge is required to repair, or is likely to cause impaction to the third one, or affect the road traffic, it is necessary to repair in the shortest time.

However, the load bearing capacity and durability of the bridge is often not reduced dramatically so if we want to fix in order to improve the load bearing capacity and durability of the bridge, basing on the actual situation of the bridge, we will select time to carry out the appropriate repairing.

6.6.2 Typical Damages Observed

6.6.2.1 Common damage

Following are common defects and deteriorations to all type of bridges. These defects/deteriorations sometimes affect stability and durability of the bridge.

6.6.2.1.1 Abnormal deflection

Sagging or hogging deflection which is observed due to concrete creep, internal stresses caused by concrete drying shrinkage and inadequate PC wire stresses. Following is the point to note in carrying out the inspections.

- Observe the alignment of the lane marking and the handrail/guardrail.

6.6.2.1.2 Abnormal noise

Abnormal banging noise or creaking noise which are observed due to damage of the joints or internal movement of the joints. Following is the point to note in carrying out the inspections.

- Pay attention on noise carefully near the joints.

6.6.2.1.3 Abnormal vibration

Abnormal vibration is palpably observable. Following is the point to note in carrying out the inspections.

- Pay attention on vibration at the span centre area of the bridge.

6.6.2.1.4 Abnormal expansion gaps

Expansion gaps between girders, abutments and joints which are too narrow or too wide, which caused by tilting of the substructures, lack of consideration on the design, and lack of accuracy of structure dimension at construction stage. Following is the point to note in carrying out the inspections.

- + Measure the expansion gaps when it identified

6.6.2.1.5 Settlement

Settlement is observed on bridge structures including sub structures, foundations and their associated facilities. Uneven settlement observed at joints, which is caused settlement of substructures. Following is the point to note in carrying out the inspections.

- Conduct visual inspection on the joints, and vertical alignment of the handrail/guardrail.

6.6.2.1.6 Movement

Rotation or movement of structures occurs at bridge substructures such as abutments, and piers due to settlement and tilting of substructures. Following is the point to note in carrying out the inspections.

- Conduct measuring of the joint gaps, plumb survey, and elevation survey.

6.6.2.1.7 Scouring

Scouring, which is caused by swift current, exposes structures including footings and foundations of bridges constructed in a river or the sea. Due to scouring bridge foundations expose above the river bed and affects stability of the bridges. Following is the point to note in carrying out the inspections.

- Conduct visual inspection of topographic condition of the river bank, river bed around the

foundation.

6.6.2.2 Concrete bridges

A characteristic of concrete structures is that steel members such as reinforcing bar (hereinafter referred to as “rebar”), and pre-stressing cable (hereinafter referred to as “PC cable”) are embedded in concrete structures, so that repair works and strengthening of structures will become hard if corrosion progresses to steel members inside. Also, the quality of concrete construction may have large impact on the load-bearing capacity of the concrete structures. Environmental conditions around the bridge also have negative impacts on the progress of concrete deterioration, so that early detection of defects and deterioration along with understanding their environment would be a key for the better maintenance of concrete facilities.

The following are typical defects and deterioration often observed during bridge inspection.

6.6.2.2.1 Crack

There are various influential factors causing cracks, such as those including drying shrinkage, tensile stresses, materials, construction methods, environment, designs, external working forces and so forth. Concrete cracks allow water infiltration into the concrete and have a negative effect on the steel members in the concrete and affect life-length of the concrete structures due to losing tensile strength of the structures. In addition, corrosion causes rebar diameter expansion which brings peeling of concrete cover and causes further corrosion of rebar. The following are the points to note in carrying out the inspections. To identify concrete crack following inspection method is commonly implemented.

- Conduct short distance visual inspection.

6.6.2.2.2 Concrete peeling, creep

Concrete peeling is caused by the swelling of rusted rebar, concrete inner stresses and improper treatment of construction joints, causing peeling, spalling and the creep of concrete surfaces. Peeling of concrete causes rebars exposure and develops rebar corrosion and consequently rebars lose its tensile strength. To identify concrete peeling, creep following inspection method is commonly implemented.

- Conduct short distance visual inspection, and conduct short distance visual inspection, if necessary.

6.6.2.2.3 Rebar exposure

Rebar exposure caused by the effects of concrete peeling, creep or improper construction methods. Exposed rebar get rust and develop corrosion easily. To identify rebar exposure following inspection method is commonly implemented.

- Observe surface of the concrete structure body, and conduct short distance visual inspection, if necessary.

6.6.2.2.4 Water leakage and Puddles

Water leakage and puddles occur due to rain water infiltrating through concrete joints, penetrating cracks, expansion joints and damaged drain systems. Water leakage and puddles cause rebar corrosion. To identify rebar exposure following inspection method is commonly implemented.

- Observe surface of the concrete structure body together with concrete crack inspection.

6.6.2.2.5 Free lime

Free lime is a phenomenon causing the lime component of concrete to flow out of construction joints or out of penetrated cracks with water infiltrating into the concrete body. To identify free lime following inspection method is commonly implemented.

- Observe surface of the concrete structure body.

6.6.2.2.6 Rusty fluid

Rusting of rebar buried in the concrete progresses and flows out from concrete cracks, showing the Rusty fluid. To identify rusty fluid following inspection method is commonly implemented.

- Observe surface of the concrete structure body.

6.6.2.2.7 Deterioration and Discoloration

Deterioration of concrete, which may degrade concrete performance, is caused by chemical reactions. Discoloration is a phenomenon changing concrete colour by deterioration.

- Observe surface of the concrete structure body.

6.6.2.2.8 Honey comb, Void

Honey combs, voids are caused by mainly poor quality control during construction stage. These defect cause rebar rusting and corrosion. To identify honey comb and void following inspection method is commonly implemented

- Observe surface of the concrete structure body.

6.6.2.2.9 Chemical attacks

Following are typical chemical attacks;

- (1) Penetrated carbon dioxide into concrete changes concrete property from alkali to neutrality and loose protection function of rebar from rusting.

To identify neutralization depth of the concrete following inspection method is commonly implemented.

- Conduct phenolphthalein solution test on the collected core/powder of the concrete.

- (2) Penetrated chloride particle in the air into concrete causes rebar rusting directly.

To identify chloride penetration depth in the concrete following inspection method is commonly implemented.

- Conduct chloride contents test on the collected core/powder of the concrete.

When alkali reaction aggregate are used as concrete material often crocodile cracks are found on the surface of concrete structures which are facing high possibility of rebar rusting.

- Conduct alkali reaction test on the collected core of the concrete.

6.6.2.3 Steel bridges

Following are typical defects and deterioration often observed during steel bridge inspection.

6.6.2.3.1 Deterioration of paint

Cracks, swelling and peeling are observed on the bridge paint including corrosion due to their effects. To identify deterioration of paint following inspection method is commonly implemented.

- Conduct short distance visual inspections which pay attention on corrosion of steel members, condition of discoloration and chalking, peeling, cracking and swelling of paint film on the steel members.

6.6.2.3.2 Corrosion

Concentrated corrosion is observed on the steel materials or reduction in cross section is observed on steel materials due to the effects of corrosion. To identify corrosion following inspection method is commonly implemented.

- Conduct short distance visual inspections with scaffoldings, if necessary.

6.6.2.3.3 Looseness and falling of rivets and HTBs

Loosening and falling of rivets, bolt-nuts and HTBs are observed at joints. To identify looseness and falling of rivets, bolt-nuts and HTBs following inspection method is commonly implemented.

- Conduct short distance visual inspections and hammering check with scaffoldings, if necessary.

6.6.2.3.4 Cracks

Steel material fatigue cracks are observed at the places where stress concentration occurs, where there are changes in steel material cross section and where welding connection area. Also, cracks are observed, which are caused by over stress due to earthquakes and vehicle collisions or high frequency of over loaded vehicle passages. To identify cracks on the steel members following inspection method is commonly implemented.

- Conduct short distance visual inspections with scaffoldings, if necessary.
- In case crack is unclear in the inspection, the following tests shall be carried out to detect cracks;
 - Penetrant inspection
 - Magnetic particle examination

- Ultrasonic examination

6.6.2.3.5 Deformation, buckling

Deformation or buckling is observed in the steel materials due to over stress caused by earthquakes and vehicle collisions or high frequency of over loaded vehicle passages.

- Pay attention on the shape of steel members during visual inspection.

6.6.2.3.6 Water leakage, puddles

Water infiltration is observed in the places where it is hard to treat pooled water, such as those where steel members cross each other or inside steel piers.

6.6.3 Inspection of Bridge

6.6.3.1 Focus Points of Inspection

Bridge inspection are not only to detect bridge damages promptly which may lead to negative effect to durability of the bridge, but also to obtain data for strategic planning of maintenance and repair works of the bridges. The following are the points to be focused on in implementing bridge inspection.

6.6.3.2 Concrete superstructure

6.6.3.2.1 Girder

The following are the points to be focused on implementing concrete bridge girders inspection.

(1) Girder end support area

Locations where the horizontal force caused by the bearing shoe reaction, earthquakes and changes in temperature. In this area following cracks observed.

- Vertical cracks on the lower side or both sides of a girder on a support.
- Diagonal cracks on the webs of a girder on a support.
- Horizontal cracks on the webs of a girder.

(2) Intermediate supporting area

Locations where negative bending moment and shear forces to be maximum values. Also, stress conditions around the locations become complicated due to the concentrated support reaction force and cracks are prone to emerge.

- Vertical cracks on the upper side of a continuous main girder near support.

(3) Span centre

Locations where bending moments show maximum values and thereby bending cracks are prone to emerge.

- Vertical cracks on the underside or both sides of a girder.
- Longitudinal cracks on the underside of a main girder.

(4) A quarter point of span

Locations where cracks emerge due to the changes in steel bar distribution. Also, improper movement of bearings causes cracks at these points.

- Vertical cracks on the underside or both sides of a girder.

(5) Construction joints

Locations where cracks, peeling and water leakage may be occurring due to concrete drying shrinkage.

(6) Cracks running vertically or horizontally along the segment joints.

Similar cracks to the above arise at the segment joints during concrete casting.

- Cracks near segment joints.

(7) Anchor portions

Around the structures which anchor PC cables, cracks are prone to emerge due to the high concentration of compression stress.

- Crocodile cracks on an anchoring concrete after installing PC cable.
- Vertical or diagonal cracks near the projection of PC cable anchors.
- Cracks near PC cable anchors.
- Cracks on a anchoring concrete at joint portion of cross beams

(8) Notched section

Locations where a girder cross section changes drastically, cracks are prone to emerge due to high concentration of stress.

- Cracks near the cantilever sections where section shape changed drastically.

Focus points on concrete girder cracks inspection are summarised in from

Table 6.6-1 to Table 6.6-9.

Table 6.6-1 Summary of Focus Points on Concrete Girder Crack Inspection

Inspection Points	Outlines of Inspection Points
A. Girder end support	Locations subject to the horizontal forces caused by support reaction force, earthquakes and changes in temperature
B. Central support	Locations where negative bending moment and shear forces show maximum values. Also, stress conditions around the locations become complicated due to the concentrated support reaction force and cracks are prone to emerge.
C. Centre between supports	Locations where bending moments show maximum values and thereby bending cracks are prone to emerge.

Inspection Points	Outlines of Inspection Points
D. A quarter point between supports	Locations where cracks emerge due to the changes in steel bar distribution. Also, improper movement of bearings causes cracks at these points.
E. Concrete joints	Locations where cracks, peeling and water leakage may arise due to concrete drying shrinkage
F. Segment joints	Similar cracks to the above arise at the segment joints during concrete casting.
G. Anchor portions	Around the structures which anchor PC cables, cracks are prone to emerge due to the high concentration of tensile stress.
H. Notched section	Locations where a girder cross section changes drastically, cracks are prone to emerge due to high concentration of stress.

Table 6.6-2 Cracks near the Girder End Supports

Crack Pattern	Outline	Main causes of Cracks
A. Crack pattern near girder end supports	① Vertical cracks observed on the underside or both sides of a girder on a support.	Excessive concentration of stresses on a girder near a support, improper bearing functioning or earthquakes.
	② Diagonal cracks observed on the webs of a girder on a support.	Excessive concentration of stresses or shortage of shear reinforcement steel.
	③ Horizontal cracks observed on the webs of a girder.	Bearing stress around anchor.

Table 6.6-3 Crack near the Intermediate Support

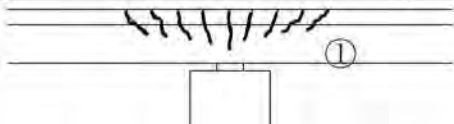
Crack Pattern	Outline	Main causes of Cracks
B. Crack pattern near intermediate support	① Vertical cracks observed on the upper side of a continuous main girder near support.	Lack of reinforcement steel against negative bending moment on the upper flange of a girder near supports.
		

Table 6.6-4 Crack near the Span Center

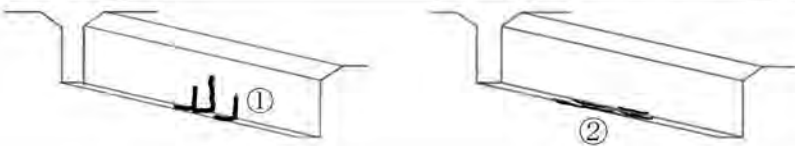
Crack Pattern	Outline	Main causes of Cracks
C. Crack pattern at the centre of the span	① Vertical cracks observed on the underside or both sides of a girder	Excessive bending moment
	② Longitudinal cracks observed on the underside of a main girder.	Lack of cross section or steel bar design volume of a main girder, salt effects or alkaline aggregate reaction.
		

Table 6.6-5 Crack near the Quarter Point of the Span

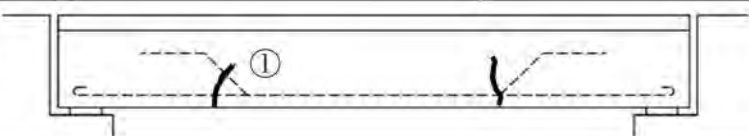
Crack Pattern	Outline	Main causes of Cracks
D. Crack pattern at a quarter point of the span	① Vertical cracks observed on the underside or both sides of a girder	Lack of steel bar design volume
		

Table 6.6-6 Crack near the Construction Joints

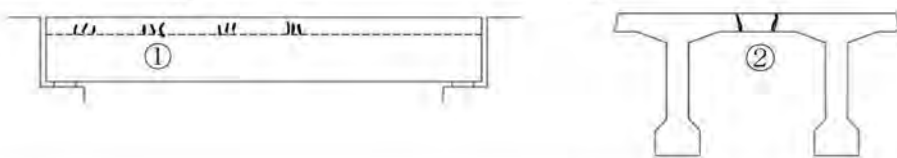
Crack Pattern	Outline	Main causes of Cracks
E. Crack pattern near construction joints	① Cracks running vertically or horizontally along construction joints	Improper concrete adhesive power at cold joints.
	② Cracks near construction joints on the girder or on the concrete slabs	Improper treatment of construction joints or lack of PC material tensile stress
		

Table 6.6-7 Crack near the Segment Joints

Crack Pattern	Outline	Main causes of Cracks
F. Crack pattern near segment joints	① Cracks near segment joints	Lack of PC material tensile force
		

Table 6.6-8 Crack near the PC Cable Anchors

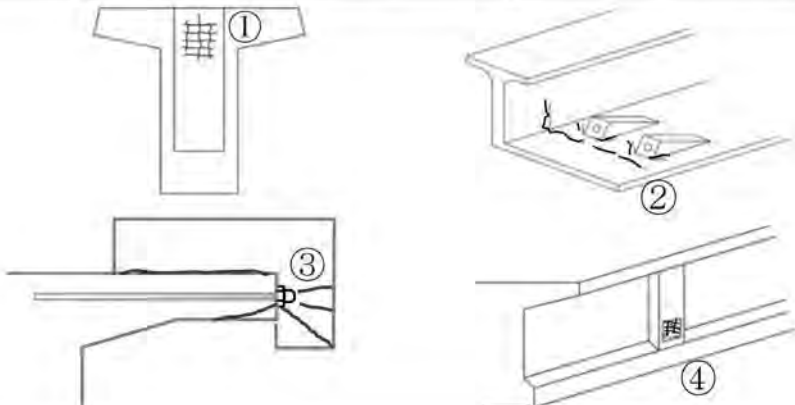
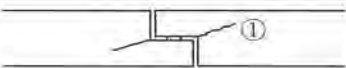
Crack Pattern	Outline	Main causes of Cracks
G. Crack pattern near PC anchors	① Crocodile cracks on an anchoring concrete after installing PC materials.	Concrete drying shrinkage, corrosion of anchor materials, improper treatment of construction joints
	② Vertical or diagonal cracks near the projection of PC material anchors	High concentration of stresses on anchor portions
	③ Cracks near PC material anchors.	Lack of concrete protective covering
	④ Cracks on a anchoring concrete at joint portion of cross beams.	Improper design of concrete, improper construction of anchoring concretes.
		

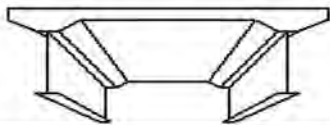
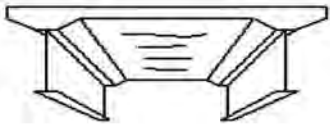
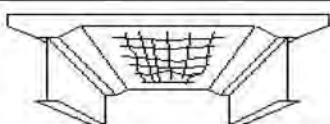
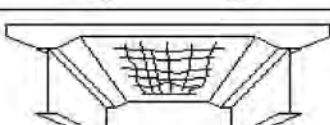
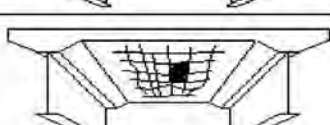
Table 6.6-9 Crack near the Notched Section

Crack Pattern	Outline	Main causes of Cracks
H. Crack pattern near the canti-lever sections	① Cracks near the canti-lever sections	Concentration of stresses due to drastic changes in cross section.
		

6.6.3.2.2 Concrete deck slab inspection

Table 6.6-10 shows the mechanism of crack progress on the concrete decks.

Table 6.6-10 Mechanism of Crack Progress on the Concrete Decks

Crack Damage Progress	Schematic Views
1. Initial Stage, no damage	
2. Cracks, caused by drying shrinkage, appear perpendicular to the bridge axis.	
3. Cracks progress due to traffic load, which comprise longitudinal and perpendicular cracks, forming a grid pattern.	
4. Cracks penetrate the concrete decks to the surface due to traffic load.	
5. Cracks further break down due to interaction between particles, gradually losing shear resistance force.	
6. Due to traffic load which exceeds punching shear force of deck concrete, spalling of concrete material occurs.	

Taking above the mechanism of crack progress on the concrete deck slab into consideration, the following are the points to be focused on implementing concrete bridge deck slab inspection.

(1) Bottom surface of the concrete deck slab

Crack directions, spacing of cracks, water leakage, free lime, traces of rusting, concrete peeling, range of concrete spalling, range of steel bar exposure, range of voids are to be identified through inspection on the bottom of the concrete deck slab. To identify concrete crack on the bottom surface of main body of the concrete deck slab following inspection method is commonly applied.

- Short-distance visual inspection and hammering check standing on the scaffolding installed under the deck slab.

(2) Cantilever section of the concrete deck slab

Crack directions, spacing of cracks, free lime, traces of rusting, concrete peeling, range of concrete spalling, range of steel bar exposure, range of voids are to be identified by the inspection on the cantilever section of the concrete deck slab. These defects emerge on the bottom of the concrete deck slab of the cantilever section. To identify concrete crack on the cantilever section of the concrete deck slab following inspection method is commonly applied.

- Short-distance visual inspection and hammering check standing on the scaffolding installed under the deck slab.

(3) Connection parts with steel girder flange

Free lime, traces of rusting, range of voids, range of concrete peeling and creep are to be identified through the inspection on the connection section between concrete deck slab and steel girder flange. To identify concrete crack on the connection parts with the steel girder flange following inspection method is commonly applied.

- Short-distance visual inspection and hammering check standing on the scaffolding installed under the deck slab.

(4) Pavement surface

Scale of pavement, potholes and repair works in the past, direction of cracks, spacing of cracks are to be inspected. Some of these defects on the pavement are caused by defects on the concrete deck slab. Short distance visual inspection on the road surface is necessary to detect the pavement and concrete deck slab defects.

6.6.3.3 Steel bridge inspection

Following are the points to be focused on in implementing steel bridge inspection.

6.6.3.3.1 Entire steel bridge surface, members

(1) Paint inspection

Inspection on paint condition of the entire of the bridge including inside of the box girder and the steel pier is to be carried out to identify paint condition of the bridge. Visual inspection is common inspection method applied for paint inspection. Following are carried out to identify detailed paint condition;

- Cut and peel check for identifying deterioration progress of the paint film on the steel members.
- Chalking progress check to confirm deterioration progress of the paint film on the steel members.
- Salt particles density check on the surface of the bridges to confirm corrosion condition of surrounding environment of the bridges.
- Impedance test to identify the steel member thickness which reduced due to progress of corrosion.

(2) Corrosion inspection

Inspection method on corrosion including rusting is almost the same with paint inspection. Rust develops to corrosion, therefore, rust inspection on rust location, rust area and rust level is carried out as parts of corrosion inspection to prepare maintenance plan including prevention plan for corrosion. Following area are required much careful inspection due to easy corrosive/restive area.

- Water affects area such as under and surrounding area of drainage facilities.
- Bridge members and other facilities concentrated area where always keeping wet condition due to lack of sun shine and ventilation.

(3) Deformation, buckling inspection

Visual inspection is applicable inspection method for detection of the deformation and buckling of steel members of the bridges. When passing the bridges all ways pay attention upon deformation and buckling of the steel members which are visible from the road surface to find out the defects earlier.

6.6.3.3.2 Welding points

Cracks on the steel members are observed mainly following welding points:

- Welded portions of sole plates and at changes in cross sections
- Welded portions with stiffeners and gusset plates
- Welded portions on the steel deck plates and stiffness members
- Butt welded portions on the lower flanges
- Welded portions on the base of vertical members on the arch ribs
- Welding portion of the base plates with steel pier

Typical crack appearance patterns are shown in the figures from **Figure 6.6-1** to **Figure 6.6-7**.

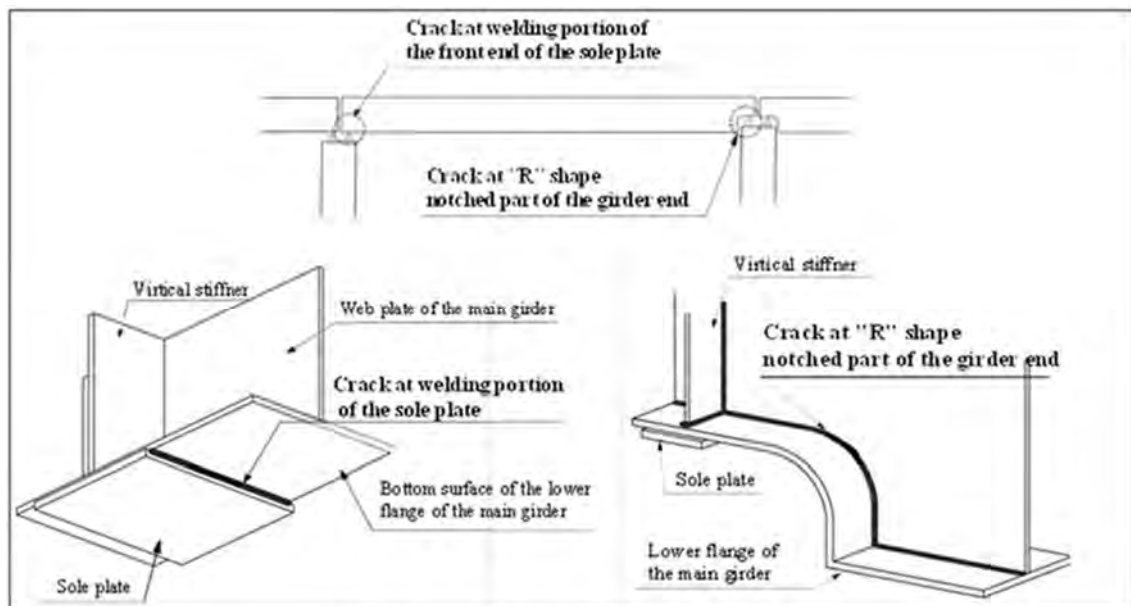


Figure 6.6-1 Crack at Welding Portion of the Front End of the Sole Plate

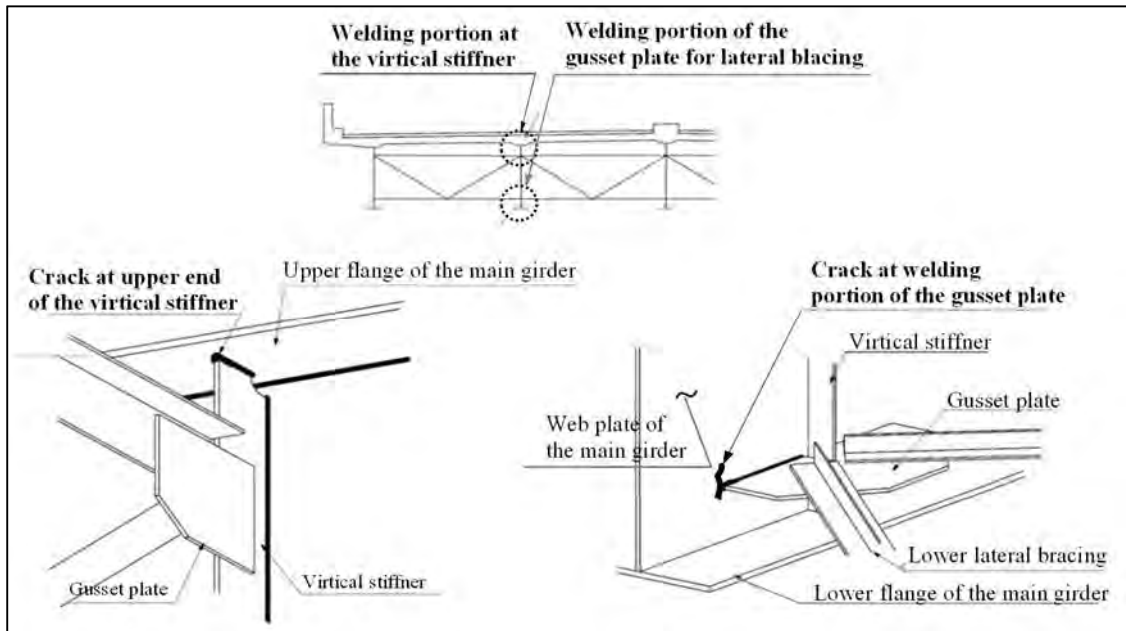


Figure 6.6-2 Crack at Welding Portion at the Vertical Stiffener

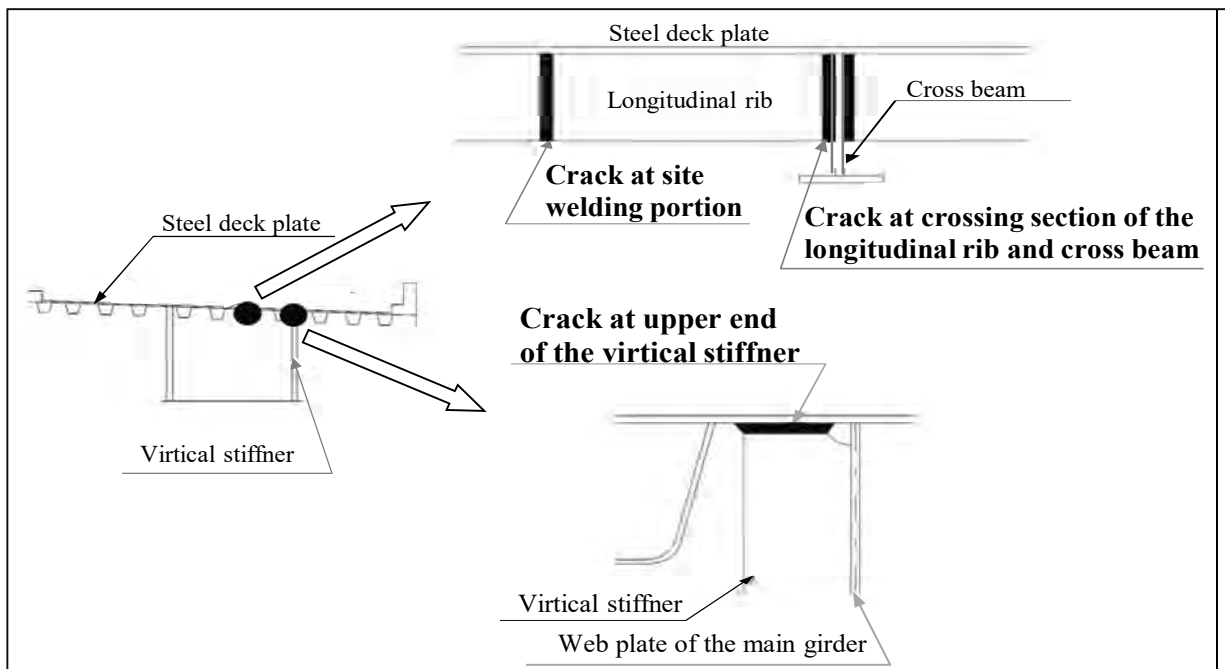


Figure 6.6-3 Crack at Welding Portion of the Steel Deck Plate

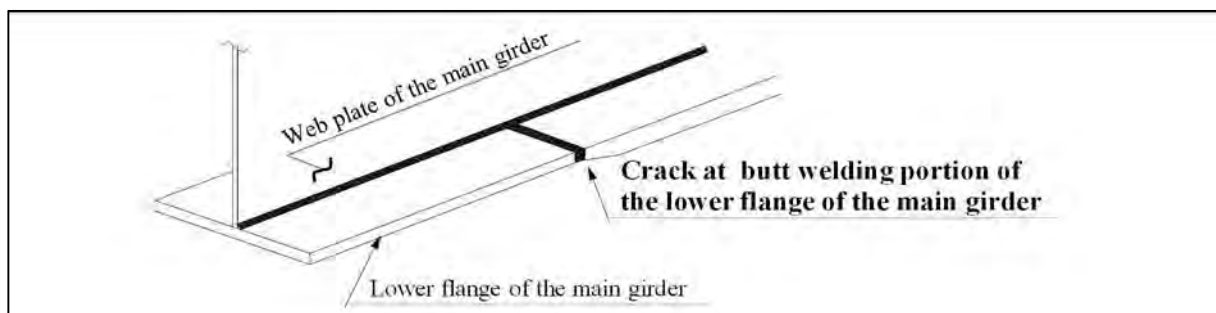


Figure 6.6-4 Crack at Butt Welding Portion of the Lower Flanges

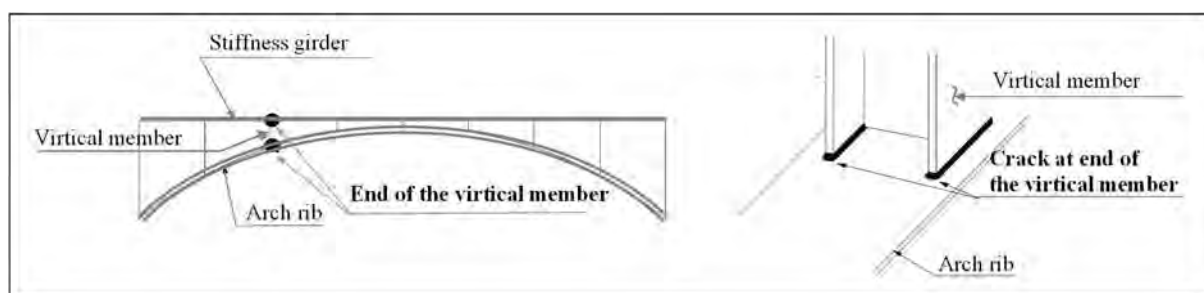


Figure 6.6-5 Crack at the Base of Vertical Members on the Arch Ribs

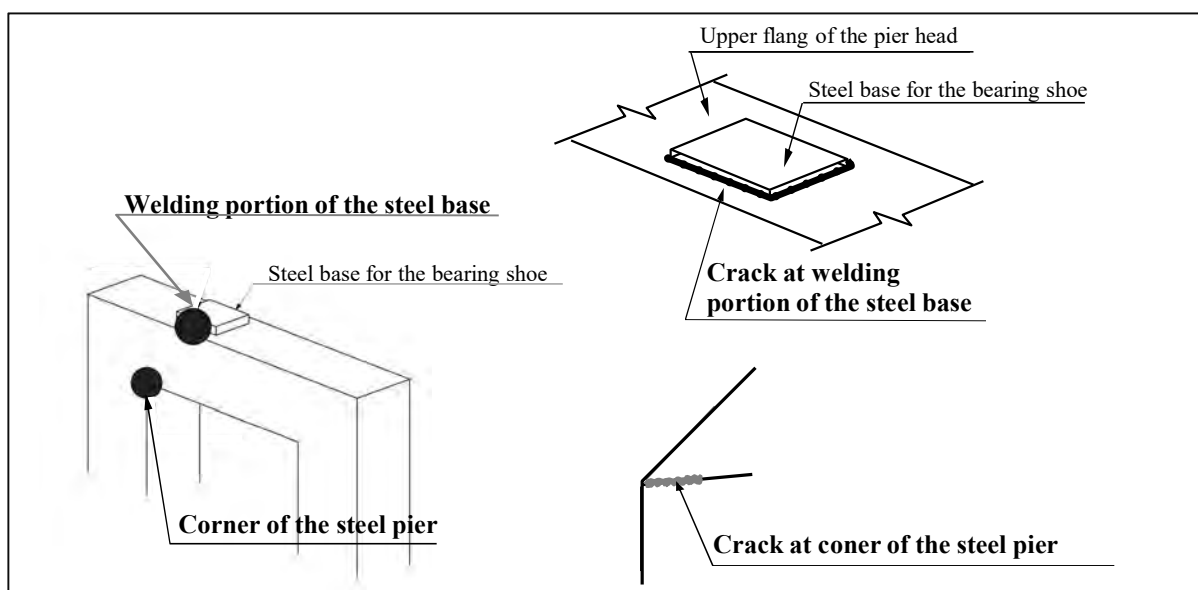


Figure 6.6-6 Crack at the Rigid-frame Piers

6.6.3.3 End of stringers

Cracks are sometimes observed at the end of stringers.

- Pay attention on the corner of the notch for connection to other members and the end of the flange plate of the stringers

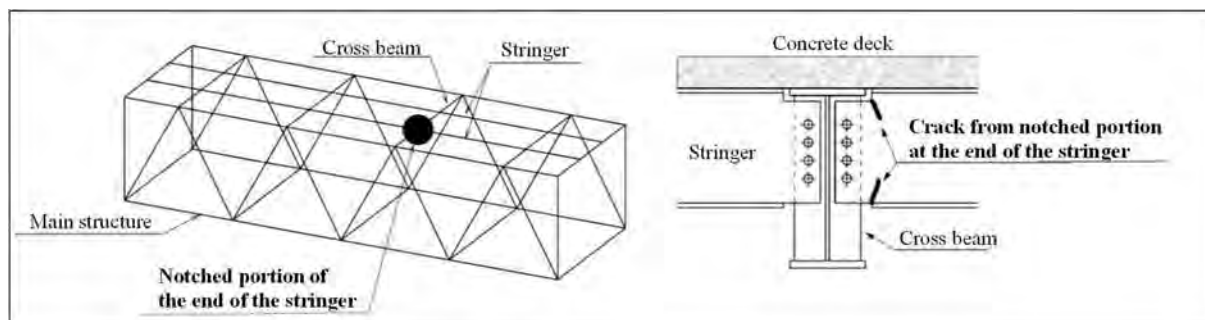


Figure 6.6-7 Crack from End of the Stringers

6.6.3.3.4 Connection and splicing area

Inspection on rivets, bolt-nuts and HTBs are carried out on connecting and splicing portion. In case loosen nuts found it is necessary re-tightening of the nuts. After inspection and re-tightening of bolt-nuts and HTBs, marking on nuts is necessary as parts of quality control of works. Visual inspection and hammering test is effective inspection method.

6.6.3.3.5 Drainage facilities

Visual inspection is applicable inspection method for detection of the water leakage and puddles. The end of the span including expansion joint area, surrounding area of the drainage facilities such as inlet and outlet of the drainage, basin, and cross points of steel materials (in particular for arch and truss bridges) are main inspection points for detecting water leakage and puddles.

6.6.3.4 Substructures and foundations inspection

Following are the points to be focused on in implementing substructures and foundations inspection.

6.6.3.4.1 Tilting, settlement, and movement

Visual inspection is applicable for detecting tilting, settlement and movement of the substructures and foundations. Following are carried out for detect tilting, settlement and movement of the substructures and foundations as supplemental inspections, when required;

- Measuring gap space and elevation difference of the expansion joints
- Levelling survey of the substructure and foundation
- Incline survey of the stem and parapet wall by a plumb

6.6.3.4.2 Scouring

Scouring is caused by swift current of water which brings soil from bottom and surrounding part of the substructures and foundations constructed in a river or sea including the river edge and shore line, exposes substructures and foundations of the bridges. Scouring sometimes affects stability of the bridge seriously. Therefore, it is necessary to confirm scouring condition of the substructures and foundation of the bridges after heavy rain fall by visual inspection. Following are carried out for detect scouring of the substructures and foundations as supplemental inspections, when required;

- Topographic survey of the surrounding area of the substructures by measurement of the depth of water with plumbs
- Topographic survey of the surrounding area of the substructures by a bathy meter

6.6.3.4.3 Collision of a ship and floating objects

When ship and floating object such as logs collides with bridge, safety of the bridge such as the stability of the bridge, strength of the collided members and traffic on the bridge is often threatened. Collision of the ship and floating objects caused due to flooding and strong wind. When collision occurred urgent visual inspection is required to confirm exist of damages and damage level to take necessary countermeasures for ensuring safety traffic.

6.6.3.4.4 Defects of the concrete body

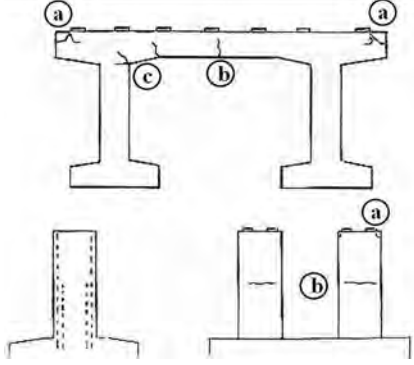
Cracks, peelings, rebar exposure, water leakage and puddling, free lime, trace of corrosion, deterioration and discoloration, honey comb and void, and chemical attacks are observed on the substructure concrete. Short distance visual inspection on the entire substructure body is carried out for the bridge substructure inspection.

- Following points have higher possibility of occurrence of concrete cracks;
 - Bearing shoe beds area
 - Rebar number changed section
 - Construction joints
 - Inside of corners of substructure bodies
 - Member section area changed parts
 - Fixing parts of cantilever members including wing walls
 - Voids under foundations and back fill at behind of stem walls

Table 6.6-11 shows inspection points of bridge substructures and foundations which are specially focused on in these inspections.

Table 6.6-11 Defects of the Concrete Body

Structure	Points to be specially focused	Figures
■ Abutments - Reversed T-type abutment - Rigid-frame abutment	a. Cracks near shoe beds b. Cracks on the sections changing steel bar volume c. Cracks due to lack of construction joints d. Cracks at the corners and on the sections changing cross sections e. Voids in backfill material	

■ Piers - T-type piers - Wall type piers - Rigid-frame piers - Column piers	a. Cracks near shoe bed b. Cracks on the base of cantilevered concrete c. Cracks at the corners and on the sections changing steel bar volumes.	 The diagram illustrates three types of bridge piers: a T-type pier, a wall-type pier, and a column pier. Labels 'a', 'b', and 'c' indicate common crack locations: 'a' at the top corners, 'b' at the base of the pier, and 'c' at the corners and sections where steel bars change volume.
■ Foundations	a. Shortage of gaps between superstructures and substructures due to movement or leaning of substructures. b. Cracks near the base of concrete wings. c. Voids under the foundation d. Scouring and lowered river beds.	 The diagram shows three types of bridge foundations: a single pier foundation, a pier with a wing, and a pier with a wing and a foundation. Labels 'a', 'b', and 'c' indicate common defects: 'a' at the top corners, 'b' at the base of the concrete wings, and 'c' at the corners and sections where steel bars change volume.

6.6.3.5 Bridge accessories

6.6.3.5.1 Bearing shoe

Commonly, visual inspection is carried out for bearing shoe inspection.

Focus points in implementing bearing shoes inspection are as follows;

- Breakdown of bearing body
- Deterioration of rubber
- Corrosion
- Damages to attachments
- Damages to grout concrete or mortar
- Abnormal expansion gaps
- Abnormal sounds
- Piling of dust and sand

Following are major defects of the bearing shoe body and its accessories, and the points to be focused in implementing bearing shoe inspection by types;

(1) Line bearing shoe

- Damages and corrosion on lower shoe
- Damages on side block
- Damages on pinch plate
- Damages on stopper for the upper shoe
- Damages and corrosion of anchor bolts
- Damages to grout concrete or mortar.

(2) Metal plate bearing shoe

- Damages and corrosion on lower shoe

- Damages on bearing plates
- Improper contact of side block and breakage of side block bolts
- Damages on the stopper for the upper shoe
- Breakage of set bolts
- Damages and corrosion of anchor bolts
- Damages to grout concrete or mortar.

(3) Multiple roller bearing shoe

- Damages and corrosion on upper shoe, lower shoe and base plate.
- Improper contact of side block and breakage of side block bolts
- Damages to the lower shoe
- Breakage of set bolts
- Damages to pins that impact functioning
- Damages and corrosion of anchor bolts
- Damages to grout concrete or mortar
- Damages on protective cover.

(4) Rubber bearing shoe

- Damages and deterioration on rubber materials
- Displacement and deviation of rubber materials
- Bulging of rubber materials
- Abnormal space between upper shoe and rubber
- Damages on side block and breakage of set bolts
- Damages on the upper shoe stopper
- Breakage of set bolts
- Damages and corrosion of anchor bolts
- Damages on grout concrete or mortar.

Table 6.6-12 shows the focus points of bearing inspection with illustrations.

Table 6.6-12 Focus Points of Inspection on Bridge Bearings

Bearing Type	Focus points of inspection	Figures
Line Bearing shoe	● Damages and corrosion on lower shoe ● Damages on side block ● Damages on pinch plate ● Damages on stopper for the upper shoe ● Damages and corrosion of anchor bolts ● Damages to grout concrete or mortar.	
Metal bearing plate shoes	● Damages and corrosion on lower shoe ● Damages on bearing plates ● Improper contact of side block and breakage of side block bolts ● Damages on the stopper for the upper shoe ● Breakage of set bolts ● Damages and corrosion of anchor bolts ● Damages to grout concrete or mortar.	
Multiple roller shoe	● Damages and corrosion on upper shoe, lower shoe and base plate. ● Improper contact of side block and breakage of side block bolts ● Damages to the lower shoe ● Breakage of set bolts ● Damages to pins that impact functioning ● Damages and corrosion of anchor bolts ● Damages to grout concrete or mortar ● Damages on protective cover.	
Rubber shoe	● Damages and deterioration on rubber materials ● Displacement and deviation of rubber materials ● Bulging of rubber materials ● Abnormal space between upper shoe and rubber ● Damages on side block and breakage of set bolts ● Damages on the upper shoe stopper ● Breakage of set bolts ● Damages and corrosion of anchor bolts ● Damages on grout concrete or mortar.	

6.6.3.5.2 Expansion joint

Commonly, short distance visual inspection is carried out for expansion joint inspection.

Focus points in implementing expansion joints inspection to be carried out on all types are as follows;

- Deterioration of the face rubber material due to wearing and breakage caused by traffic, deterioration due to time passage
- Deformation of the steel members for load support
- Loosen or breakage of anchor bolt-nuts.
- Break off or breakage of a rubber drainage gutter
- Breakage of filling concrete between the expansion joint and pavement
- Elevation gap between the filling concrete and surface of the expansion joint, and the surface of the pavement
- Infiltration of soil into the expansion joint

6.6.3.5.3 Drainage system

Following facilities are installed on the bridge as the drainage system which facilitates drain of rain water from bridge surface and other parts of the bridge in order to avoid traffic accident due to wet

condition including puddles of rain water and to prevent the bridge deterioration. Main drainage facilities on the bridge are as follows;

- Catch basin
- Drainage gutter
- Horizontal and vertical drainage pipe
- Catch drain under the expansion joint

Short distance inspection is carried out for the drainage system inspection. In order to detect defects of the drainage systems, water leakage from above facilities through inspection of wet condition of the bridge is important focus point of drainage system inspection.

6.6.3.5.4 Guardrail, handrail

Main cause of breakage of guardrails, guard walls and handrails is vehicles collision. Visual inspection is common inspection method for guardrails, guard walls and handrails. Inspection of loosen and missing anchor bolt-nuts, paint condition of guardrails, handrails is carried out as part of guardrails, handrails inspection. Inspection methods, inspection frequencies and damage evaluation criteria of guardrail, handrail in principle shall follow the relevant articles of this guideline.

6.6.3.5.5 Traffic control facilities

Inspection methods, inspection frequencies and damage evaluation criteria of traffic control facilities in principle shall follow the relevant articles of this guideline.

6.6.3.5.6 Pavement

Inspection methods, inspection frequencies and damage evaluation criteria of the pavement on the bridge in principle shall follow the relevant articles of this guideline. However, many of defects of the pavement on the bridge are caused by defects of the deck slab concrete, therefore, when defects of the pavement on the bridge are found it is necessary to carry out further inspection of the deck slab concrete following the relevant articles of this guideline.

6.6.3.5.7 Approach road

Inspection methods, inspection frequencies and damage evaluation criteria of the approach road including the pavement, road embankment behind of the abutments, and foundation of the embankment in principle shall follow the relevant articles of this guideline. Focus points of the approach road other than the pavement are as follows;

- Settlement or deformation of the pavement due to settlement of the embankment
- Settlement of the embankment or slope failure of the embankment due to infiltration of rain water, inadequate quality control of the embankment during construction stage, or damages of the embankment slope foundation due to scouring.
- Erosion or collapse of the embankment slope due to heavy rain fall.

6.6.3.6 Inspection points

6.6.3.6.1 Concrete & Steel superstructure, substructure

Road facility inspection for bridge facilities shall be implemented on the inspection points shown in **Table 6.6-13**.

Table 6.6-13 Inspection Points for Bridge

Structures	Members	Damages	Initial inspection	Routine inspection	Periodic inspection	Emergency inspection	Detailed inspection
All bridge type	•Entire bridge structure	• Abnormal deflection /Under clearance	-----	X	X	X	As required by Routine or Periodic Inspection
		• Abnormal noise	-----	X	X	X	
		• Abnormal vibration	-----	X	X	X	
		• Abnormal expansion gaps	X	X	X	X	
		• Movement	X	-----	X	X	
		• Water leakage and puddles	X	X	X	X	
Concrete •Super-structure •Sub-structure	Structure type •Reinforced concrete bridge	• Cracks	X	-----	X	X	
		• Concrete peeling	X	X	X	X	
		• Honey comb/Voids	X	X	X	X	
	•Pre-stressed concrete bridge	• Free lime	X	-----	X	X	
		• Deterioration /Discoloration	X	-----	X	X	
	•Composite bridge	• Rusty fluid	X	X	X	X	
		• Rebars exposure and corrosion	X	X	X	X	
	Bridge type •I/T girder bridge	• Steel material projection	-----	X	X	X	
		• Missing of drain pipe for cylinder form	X	-----	X	X	
	•Slab girder bridge	• Peeling at repair part	X	X	X	X	
	•Arch bridge		X	X	X	X	
Steel •Super-structure •Sub-structure	Bridge type •I girder bridge	• (Fatigue) cracks	-----	-----	X	X	
		• Deformation /buckling	-----	-----	X	X	
	•Box girder bridge	• Looseness and falling of rivets and HTBs	-----	-----	X	X	
	•Truss bridge	• Deterioration of paint	-----	-----	X	X	
	•Arch bridge	• Corrosion	-----	-----	X	X	

(Note) X: Inspection items, X1: The parts which can be inspected from the patrol car

6.6.3.6.2 Bridge accessories

(1) Bearing shoes

Bearing shoes inspection carried out as part of bridge inspection shall be implemented on the inspection points shown in **Table 6.6-14**.

Table 6.6-14 Inspection Points for Bearing Shoe

Structures	Members	Damages	Initial inspection	Routine inspection	Periodic inspection	Emergency inspection	Detailed Inspection
Steel Bearing Shoes • Line bearing shoe • Metal plate bearing shoe • Multiple roller bearing shoe	Body	Breakage	-----	-----	X	X	As required by Routine or Periodic Inspection
		Corrosion	-----	-----	X	X	
	Accessory including anchor bolt-nuts	Breakage	-----	-----	X	X	
		Corrosion	-----	-----	X	X	
	Shoe base concrete	Breakage	-----	-----	X	X	
	Others	Abnormal gap margin	X	-----	X	X	
		Abnormal sound	-----	-----	X	X	
		Debris or soil piling	-----	-----	X	X	
	Rubber Bearing Shoes	Breakage	-----	-----	X	X	
		Corrosion	-----	-----	X	X	
	Accessory including anchor bolt-nuts	Breakage	-----	-----	X	X	
		Corrosion	-----	-----	X	X	
	Shoe base concrete	Breakage	-----	-----	X	X	
	Others	Abnormal gap margin	X	-----	X	X	
		Debris or soil piling	-----	-----	X	X	

(2) Expansion joint

Expansion joints inspection carried out as part of bridge inspection shall be implemented on the inspection points shown in **Table 6.6-15**.

Table 6.6-15 Inspection Points for Expansion Joint

Structures	Members	Damages	Initial inspection	Routine inspection	Periodic inspection	Emergency inspection	Detailed Inspection
Expansion joint • Load supporting type • Butting type • Buried type	Function Setting condition	Abnormal gap margin	X	X	X	X	As required by Routine or Periodic Inspection
		Elevation gap between face palates or pavement	-----	X	X	X	
		Abnormal noise	-----	X	X	X	
	Rubber face plate	Wearing, Breakage	-----	X	X	X	
	Steel face plate	Corrosion	-----	X	X	X	
		Breakage	-----	X	X	X	
	Anchor bolt-nuts	Corrosion	-----	-----	X	X	
		Missing of nuts	-----	X	X	X	
		Breakage	-----	X	X	X	
	Drainage gutter	Break off, Breakage	-----	X	X	X	
		Accumulation of soil	-----	-----	X	X	
	Filling concrete /Bitumen material	Elevation gap with face plate, or pavement and joint damage	-----	X	X	X	
		Peeling, Spalling	-----	X	X	X	
		Cracking, Breakage	-----	X	X	X	

6.6.3.7 Routine Inspection

Routine inspection shall detect bridge damages, in particular focusing on the damages causing unsafety to road traffic such as expansion gap, guardrail and handrail, deformation of bridge members above the road surface, water paddle etc.

6.6.3.8 Periodic Inspection

Periodic inspection shall cover not only bridge components, members, but also all facilities attached on the bridge such as traffic safety facilities, traffic control facilities, lighting systems, and pavement and approach roads including the embankment.

The chief engineer of the Inspection Team shall evaluate the results of inspection, registering data into the bridge condition database (VBMS) and preparing and submitting inspection reports to the managing agency of road facility inspection.

6.6.3.9 Detail Inspection

Detail inspection shall be conducted when proposed by periodic inspection or when proposed for the planning and the designing of the bridge rehabilitation and reconstruction works. Detailed inspection shall apply advance inspection equipment and make professional judgement in finding out the causes of the damages and in planning countermeasures of the damages. The following are the typical tasks for the detailed inspection.

- Inspection on entire bridge condition

Survey of deflection, settlement, movement and scouring: When some deflection, settlement, movement or scouring of the bridge is found, it is necessary to conduct detailed survey with necessary survey equipment. Periodical monitoring of these abnormalities is necessary.

- Inspection on chemical attack

Detecting depth of penetrated salinity contents into concrete: Salinity contents test on collected concrete powder from each depth is carried out to identify penetration depth of salinity contents into the concrete.

Detecting depth of penetrated carbon dioxide into concrete: Phenolphthalein solution test on the collected core/powder from each depth of the concrete is conducted to identify penetration depth of carbon dioxide into the concrete.

Detecting effect of alkali reaction aggregate: Alkali reaction test on the collected core of the concrete is carried out. However, actual test method is different according to chemical feature of the aggregate. Therefore, chemical feature shall be clarified through laboratory test at first. After then applicable test method will be suggested by chemical researcher.

- Detecting crack on the steel member

To confirm exist of crack on the steel member by;

Penetrant Inspection: It is carried out to paint Fluorescent penetrant on the surface of the steel member at first, then confirming crack by irradiated ultraviolet rays. If there is a crack on the surface of the member, the crack will be highlighted by ultraviolet ray.

Magnetic particle examination: It is carried out to magnetize the detecting area by electro magnet, and scattering magnetic steel particles on the detecting area, after then confirming crack by irradiated ultraviolet rays. If there is a crack on the surface of the member, the crack will be highlighted by ultraviolet ray.

Ultrasonic examination: It is carried out to give ultrasonic to the steel member by detector and catch echo from the steel member. If there is a crack in the steel member the crack will reflect ultrasonic and will be cached as echo.

- To make decisions on the repair work priorities.

6.6.3.10 Inspection Methods and Frequencies

Inspection methods and inspection frequencies in principle shall follow the relevant articles of this guideline. However, inspection methods and frequencies specialized for the periodic inspection and the detailed inspection for bridge facility shall follow the methods prescribed in **Table 6.6-16**.

Table 6.6-16 Inspection Methods and Frequencies

Inspection Type	Inspection Method	Inspection Frequency
Periodic inspection	● Short distance visual inspection on all parts of the bridge ● Hammering inspection for detecting concrete peeling, loosen/missing bolt-nuts etc. ● Measuring of expansion space and elevation gap	Once every 5 years
Detailed Inspection	● Surveying deflection, settlement, movement, and scouring ● Inspection on chemical attack to concrete body ● Inspection on steel member crack	Refer to Table 5.3-2.

6.6.3.11 Evaluation of Inspection Results

Evaluation of the results of routine inspection, periodic inspection and emergency inspection shall be conducted based on intervention levels described below. Sample evaluation criteria for bridge inspection results are shown in **ANNEX-E** and **ANNEX-L**. Also, particular notes for the evaluation of some damages are described as follows.

6.6.3.11.1 Damage level “D”

In this manual, bridge damages anticipated to give large negative effects to stability of the bridge and vehicle traffic are rated as “D”, such as serious girder and deck slab defects, serious deflection,

settlement and movement or scouring, large expansion spacing or elevation gap, and pavement defects described in the relevant articles of this manual.

6.6.3.11.2 Other defects

Other damages shall be separately inspected by patrol staff in the routine inspection and evaluated, following the relevant above articles in this manual.

6.6.3.12 Registration of Inspection Data and Reporting

Registration of inspection data shall be conducted and reported to procuring entities concerned immediately.

6.6.4 Planning and Implementation of Maintenance and Repair Work

6.6.4.1 Repair Policy

The level of improved durability after repair varies depending on the method of repair so it should be based on life-cycle costs to choose the method and time to repair.

After understanding the cause of damage, and considering factors such as the combination of construction methods corresponding to the level and extent of damage, the effectiveness of the repair, construction, economics, and the appropriate repair method should be selected.

When choosing a repair method and execution time, it is necessary to consider service life of repair method, and draw a comparison between methods to reduce to minimum all costs necessary to repairing during the use of the bridge.

The concept of life cycle cost of the bridge is shown in **Figure 6.6-8**.

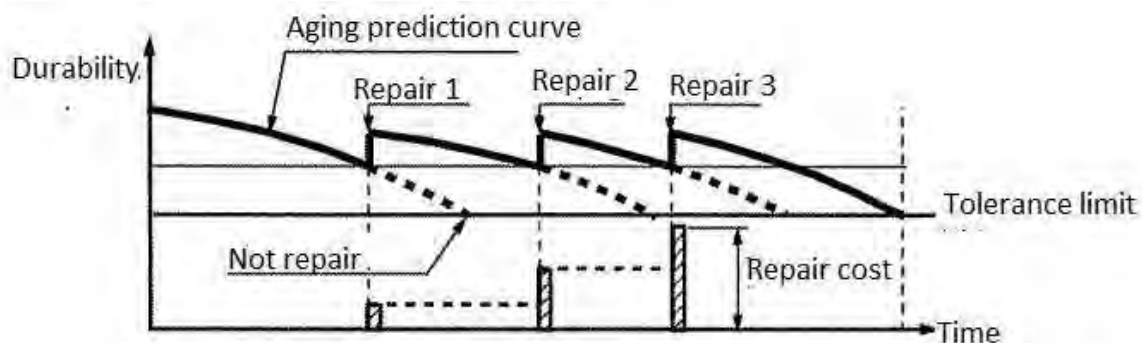


Figure 6.6-8 Concept of life cycle cost

Establishing a durable time of repair methods should be consistent with the time that the road manager requires, and it is necessary to discuss, review priorities and the level of difficulties of the repairs.

Select the scope of repairing should be in accordance with the extent of damage which not has to repair again immediately.

- If it is a local damage and the circumference of that damage is healthy, repairing only that

damage is enough.

- In case of continuous damage affecting adjacent and if it is ignored, the damage will spread and it is necessary to repair whole the damaged area.

When choosing the method of repair, it is necessary to understand the cause of damage in order to select the repair method which is appropriate with that damage.

When making surface covering, it is necessary to pay attention to color and scope of repair in order not make bad influence on the surrounding landscape.

Whether damage is still developed repaired places, it is necessary to check the repaired place regularly, and record the problems and the durability of the repair methods. The recording data is very important to streamline the maintenance management of bridge hereafter.

Particularly, whether to use the new repair technology according to the development of new technologies in recent years, but it is necessary to review carefully to verify the durability of the repair methods.

If the damage is caused by the lack of structural details and the structural durability, even if repaired, it would still be damaged easily. So it is necessary to strengthen the structures before repairing.

6.6.4.2 Repairing methods of steel structures

6.6.4.2.1 Repairing methods selection

When carrying out repair of steel structures, it must consider conditions such as traffic restrictions in the welding position, measures to prevent wind, measures to reduce moist, and must consider the safety of the bridge which was designed such as load capacity while exchanging steel materials, and consideration of construction, capacity of the bridge after repair.

In the typical repair methods of steel structure, there are the following methods:

- Crack repair methods include: welding repair, stop-hole, cover-sheet and shape improvement method
- Element replacement methods include: high strength bolt replacement, whole element replacement, and partial element replacement method
- The heat straightening method
- The paint refinishing method
- The waterproofing method

The causes of damage and repair methods of steel structure are shown in **Table 6.6-17**.

Table 6.6-17 Causes of damages and repair methods of steel structure

Damage	Repair method		Welding repair	Stop-hole Method	Cover Sheet method	Shape improvement	Element replacement d	Heat straightening d	paint refinishing	water proofing method
	Cause of damage									
Corrosion	Due to environment	Salt damage					○		◎	
		Chemical corrosion					○		◎	
	Due to aging of materials	Quality Defect					○		◎	
	Due to production and construction	Bad production and construction					○		◎	
		Bad waterproofing and water draining					○		◎	◎
Crack	Due to external forces	Repeated load	◎	○	◎	◎	○			
		Collision, earthquake	◎		◎		○			
	Due to aging of materials	Quality Defect			○	○	○			
	Due to production and construction	Bad production and construction	◎		○	○	○			
	Due to the structure	Form and shape of the structure is not good				○				
Loose	Due to external forces	Repeated load					◎			
		Collision, earthquake					◎			
	Due to production and construction	Bad production and construction					◎			
	Due to the structure	Form and shape of the structure is not good					◎			
Broken	Due to external forces	Repeated load	○		○		○			
		Collision, earthquake	○		○		◎			
	Due to aging of materials	Quality Defect			○		◎			
	Due to production and construction	Bad production and construction	○		○		○			
Paint aging	Due to external forces	Fire							◎	
	Due to environment	Salt damage							◎	
		Chemical corrosion							◎	
	Due to aging of materials	Quality Defect							◎	
	Due to production and construction	Bad production and construction							◎	
		Bad waterproofing and water draining							◎	◎
	Due to external forces	Repeated load					○			

Damage	Repair method		Welding repair	Stop-hole Method	Cover Sheet method	Shape improve ment	Element replacemen t d	Heat straighte ning d	paint refinishing	water proofing method
	Cause of damage									
De-formation		Collision, earthquake, fire					◎	○		
	Due to production and construction	Bad production and construction					○			
Ab-normal shock	Due to external forces	Repeated load					○			
		Earthquake					○			
	Due to production and construction	Bad production and construction					○			

(Note) ◎: Extremely effective
○: Effective

6.6.4.2.2 Crack treatment

(1) The welding repair method

Use arc air gouging to smooth cracks at the welding position, weld it, and then finish fully the top end of the welding. When cracks are repaired by welding, it is necessary to note the following points:

- The cause of cracks: Because fatigue cracks occurred by stress concentration and occurrence of secondary stress, the welding repair should be conducted after fixing the causes of cracks.
- If the cause of cracks is bad welding work, it means after welding repair, cracks will certainly be improved than before, so just repairing by welding is enough.
- Because welding repair is on-site work, when it is carried in special locations which are difficult of impossible to weld, it can be easy to make weld defects and/or uncompleted repair.
- To increase fatigue strength, the top end of welding should be finished by TIG or grinding.

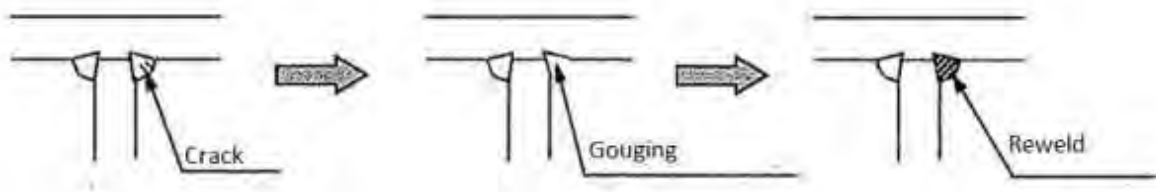


Figure 6.6-9 Welding repair method

(2) The Stop-hole Method

Create a round hole at the tip of the crack to remove the stress concentration of the tip of the crack and prevent the spread of the crack.

This method is used much as a first aid measure, but is also used to prevent the spread of cracks.

Initiation stress at the tip of the crack when stop-hole is effective will reach to 50N/mm^2 compared with the nominal in-plane stress.

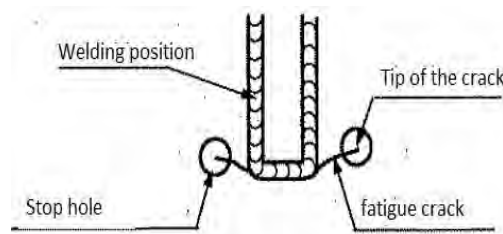


Figure 6.6-10 Stop-hole Method

Use a drill to drill stop hole, and use a grinder to smooth the area around the hole with the main purpose is to reduce stress concentration. Standard diameter of the hole is 24mm.

After creating stop hole, if waiting time to repair that takes a long time, we will insert high strength bolts to tighten in order to limit the spread of the crack.

(3) Cover- sheet repair method

If it is difficult to conduct crack welding repair and for reducing the stress at position arising the crack, it should insert a splice sheet surrounding the position arising the crack and use a high strength bolt to friction joint, called cover-sheet repair method. The expected efficiency of the use of the cover sheet is as follows:

- Reduce the stress arising at cracks position
- Increase the rigidity at the arising crack position
- The stress will be transferred to the cover sheet even when the crack spreads

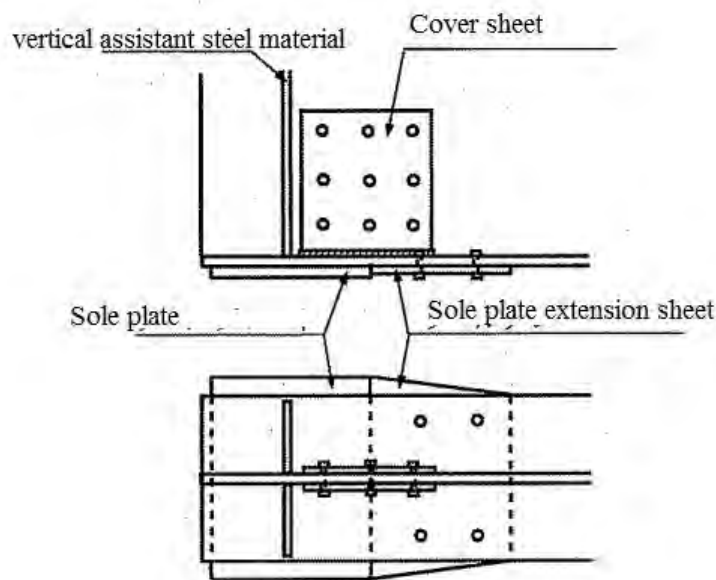


Figure 6.6-11 Example of Cover-sheet Repair Method

There are some cases that the cover-sheet repair method can be used in combination with welding repair methods.

When jointing by welding, it is necessary to note that there is a new stress concentration place and if welding defects occur, fatigue strength may be even lower than before repairing. This method is used much when repairing cracks of sole sheet welding position.

(4) Shape improving method

If cracks occur at the top end of the welding after removing cracks, we grind the shape of the top end of the welding, smoothen by TIG welding and reduce stress concentration.

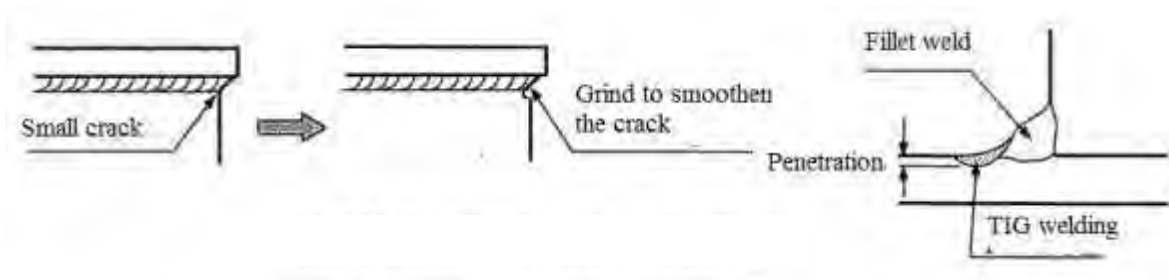


Figure 6.6-12 Example of repairing small cracks by shape improving method

This method will be effective if the cause of cracks is fatigue caused by stress concentration arising from the shape of the welding.

If the crack is small and the stress concentration of the crack is low, it is unnecessary to weld again the position removed the crack.

6.6.4.2.3 Replacing Methods

(1) The high strength bolt replacing method

High strength bolt replacement method is removing broken bolts and rivets of coupling joints and exchange them by new high strength bolts. The method also is used in case of bolts are dropped out or missing. Joint mechanism of rivet and bolt are different. The rivet is bearing pressure joint, and the bolt is friction joint. Replacing a part of rivets with high strength bolts can form admixture of different joints, so it is necessary to check the joints for safety.

In case of replacing all the bolts and rivets of the joints, it should leave the bolts needed for joints and exchange one by one.

As other cases, when there is a gap part between base materials of the back side of the cover sheet, it is necessary to check and replace the cover sheet also if the cover sheet is corroded and the cross section is damaged.

(2) The method of replacing the entire materials

If the secondary materials are damaged by corrosion and the damage of the cross section is severe, it should remove all damaged materials and replace them by new materials.

In case of secondary material is damaged, in order to ensure the safety of the entire bridge, replacing the entire materials is much more optimal than repairing parts.

When replacing the entire materials, it is necessary to check and consider method statement to ensure safety when materials are removed.

If safety cannot be guaranteed, we must use temporary alternative materials.

(3) Partial replacing method

If a portion of the materials was badly damaged by corrosion and collision, etc., those materials should be removed and replaced by new materials and joint by high strength bolts or welding.

In the case of secondary materials, it is necessary to compare the partial replacing method and replacing the entire materials.

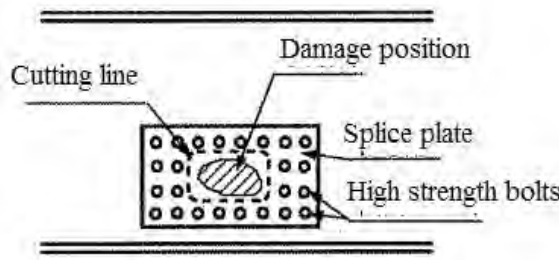


Figure 6.6-13 Example of partial replacing method

When removing damaged materials, the cross section may be damaged so it is necessary to ensure the safety of the entire bridge. The safety also needs to be considered when the stress and tension is reallocated around repaired places to be larger than before.

When removing damaged cross section, the influence of removing to other healthy parts should be considered. It is necessary to carry out appropriate measures such as installing temporary materials before removing.

Both high-strength-bolts using method and on-site welding method can be used for installing new materials. When the joints have made by welding, new defects can be occurred, such as welding defects, so it is necessary to use high strength bolts

6.6.4.2.4 Heat straightening method

If materials are collided and have slight deformation, they should not be replaced but be heated by gas burner and mechanically back to the original shape. This method is suitable for materials with low strength (SS400, SM400). When heating, the specific characteristic of high strength materials would be changed and this method is not suitable.

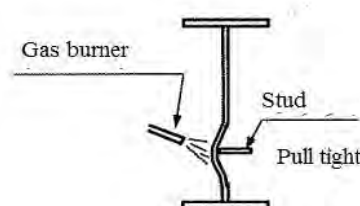


Figure 6.6-14 Example of the heat straightening method

The temperature of heat straightening method is $850\div 950^{\circ}\text{C}$ for alloying steel. When heating, stress redistribution is occurred and the stress around the damaged location will be increased. It should not be neglected and the appropriate measures such as using temporary materials should be taken.

The heat straightening method should not be used when as well deformation, the material is also cracked and torn. In this case, the method of replacing materials is recommended or combination of the heat straightening method and the on-site welding repair method.

6.6.4.2.5 Painting repair method

Painting repair method is to clean the rusted place and repair by painting in order to prevent corrosion of steel materials.

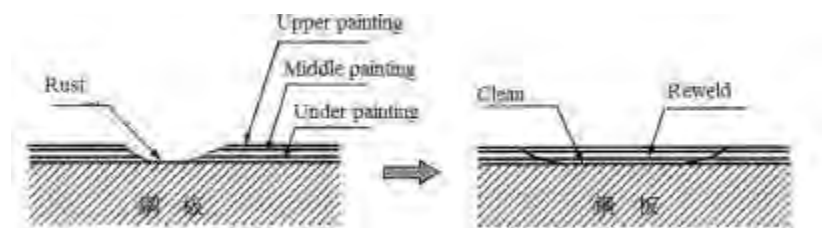


Figure 6.6-15 Example of the Painting Repair Method

This method can be applied for the rusted position, but in case of there is not enough space to paint, the method of replacing materials should be considered. Furthermore, other appropriate measures also should be taken if the cause of rust cannot be removed makes repainting not be eliminated. For example, the cause of rust is leakage of water, the measure to stop water should be conducted before painting.

When it does not reach repainting period and the rusted part affects the entire bridge, there are two reasons as follow:

- First painting is unreasonable
- Type of the first painting is not suitable to the local environment

In the latter case, we must paint with painting which is suitable to the local environment. In areas of extremely severe conditions such as salt damage at coastal areas, sulfurous acid gas from heavy industrial areas, etc., anti-corrosion painting must be conducted in accordance with environmental conditions.

6.6.4.2.6 Waterproofing method

Incomplete waterproofing lets water leakage and cause rust, corrosion of steel materials in areas where water leaks. So the waterproofing method must be conducted completely. Leakage of water from the end of the expansion equipment is the most popular, and expansion equipment becomes undrained.

When water leakage is observed, it must be quickly repaired. Water leaks from floor also corrode steel materials. So the leaked floor should be provided by waterproofing equipment.

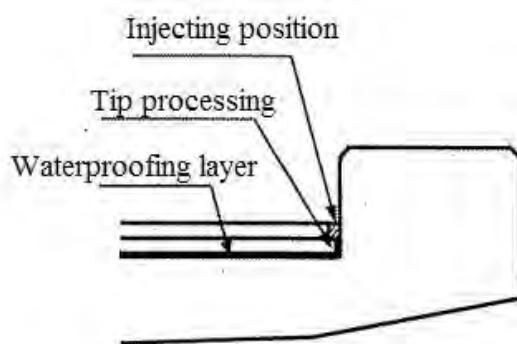


Figure 6.6-16 Example of waterproofing method

The damages of drainage equipment will cause corrosion of steel materials. They should be quickly repaired.

6.6.4.3 Repair methods for concrete structure

6.6.4.3.1 Repair method selection

There are many cases in which the damage of concrete and the cause of damage are complicated, so it is necessary to select a method that is appropriate for any damage. Furthermore, if different damage is contiguous, we must choose a repair method which can counter any damage.

For the cases such as the damage is on a large scale, the method of replacing entire materials with the new one would be used after considering the issues of economy and construction.

There are typical methods for repairing concrete structure as follows:

- Crack repair methods: surface treatment method and crack infusion method
- Cross section repair method: cross section mortar method, prepacked concrete method
- Method of replacement parts
- Surface cover method: the method of covering surface with paint, the method of covering surface aims to prevent peeling paint
- Reinforcing bar anti-rust method: anti-rust treatment method, the method of changing titanium to anode to prevent electric corrosion, the method of changing zinc to anode to prevent electric corrosion.
- Desalting method: (Electro chemical desalting method)
- Re-alkali method (Electrochemical re-alkali method)
- Waterproofing method, water stopping method

- The entire replastering method

Repairing of peeled concrete and exposed reinforcing bar is usually combination of anti-rust treatment, cross section repair and surface cover method. But if the construction is not properly, by the time reinforcing bar inside will expand by corrosion and the efficiency of the repair will be reduced. So conducting anti-rust treatment of reinforcing bar is very important.

After a detailed survey, besides selecting the appropriate repair method with aging mechanism, it is necessary to define intervention level and repairing policy, type of repair materials, cross-section measurement after repairing, and construction methods.

For example, the aging mechanism of the concrete structure and repair plan are shown in **Table 6.6-18**.

Table 6.6-18 Examples of aging mechanisms and repair plan

Aging mechanisms	Repair policies	Possibly appropriate repair methods	Factors need to consider in order to reach repair standard
Neutralization	- Remove the neutral concrete - Restraint the infiltration of CO ₂ and water after repairing	Cross section repair method Surface cover method Re-alkali method	- Degree of removal of neutral concrete - Anti-rust treatment of reinforcing bar - Quality and thickness of surface cover materials
Salt damage	- Remove infiltrated Cl- - Remove aging concrete - Restraint the infiltration of CO ₂ and water after repairing	Cross section repair method Surface cover method Desalting method	- Degree of removal of the infiltrated Cl- - Anti-rust treatment of reinforcing bar - Quality and thickness of surface cover materials -
	- Control electrical potential of reinforcing bar	Prevent electric corrosion	Quality and polarization quantity of anode materials
Frost damage	- Remove aging concrete - Restraint the infiltration of water after repairing - Improve freeze-thaw resistance of concrete	Cross section repair method Crack infusion method Surface cover method	- Freeze-thaw resistance of cross section repair materials - Quality of crack infusion materials and construction method - Quality and thickness of surface cover materials
Chemical corrosion	- Remove aging concrete - Restraint the infiltration of harmful chemical materials	Cross section repair method Surface cover method	- Quality and thickness of surface cover materials - Degree of removal of aging concrete
Alkali-aggregate reaction	- Restraint the supply of water - Increase the dissipation of water inside - Restraint the supply of alkali	Crack infusion method Surface cover method	- Quality of crack infusion materials and construction method - Quality and thickness of surface cover materials
Overload	- Control the spread of cracks		

(Note) Cl: Ion Chloride; CO₂: Carbon Dioxide Causes of damage of concrete structure and repair methods are shown in **Table 6.6-19**

Table 6.6-19 Causes of damage of concrete structure and repair methods

Damage	Cause of damage	Repair method	Crack repair	Cross section repair	Replace-ment parts	Surface cover	Anti-rust treatment	Electric anti-corrosion	De-salting	Re- alkali	Water-proofing
Crack	External forces	Repeated load	○	○		○	○				
		Sustained load	◎	○		○	○				
		Collision, earthquake, fire	◎	○		○	○				
		Unsymmetrical pressure, consolidation settlement, scouring	◎	○		○	○				
	Environment factors	Drying shrinkage, temperature change	◎	○		○	◎				
		Salt damage		◎		○	◎				
		Frost damage	○	◎		○	◎				
		Chemical Corrosion	○	◎							
	Aging of materials	Alkali-aggregate reaction	○	◎		○	◎				
		Neutralization		◎		○	◎				
		Quality defect	○	◎		○	◎				
	Poor production and construction	Bad production and construction	◎	○		○	○				
		Bad waterproof or drainage	◎	◎			○				◎
Stripping, reinforcement exposure	External forces	Repeated load		◎	○	○	◎				
		Collision, earthquake, fire		◎	○	○	◎				
		Unsymmetrical pressure, consolidation settlement, scouring		◎	○	○	◎				
	Environment factors	Drying shrinkage, temperature change		◎	○	○	◎				
		Salt damage		◎	○	◎	◎	○	○		
		Frost damage		◎	○	○	◎				
		Chemical Corrosion		◎	○	◎	◎				
	Aging of materials	Alkali-aggregate reaction		◎	○	○	◎				
		Neutralization		◎	○	◎	◎	○		○	
		Quality defect		◎	○	○	◎				
	Poor production and construction	Bad production and construction		◎	○	○	◎				
		Bad waterproofing and water draining		◎	○		◎				◎
Calcification, water leak	Environment Factors	Drying shrinkage, temperature change	○	◎	○	○	◎				◎
		Salt damage	○	◎	○	◎	◎	○	○		◎

Damage	Cause of damage	Repair method	Crack repair	Cross section repair	Replacement parts	Surface cover	Anti-rust treatment	Electric anti-corrosion	De-salting	Re-alkali	Water-proofing
	Aging of materials	Frost damage	○	◎	○	○	◎				◎
		Alkali-aggregate reaction	○	◎	○	○	◎				◎
		Neutralization	○	◎	○	◎	◎	○		○	◎
		Quality defect	○	◎	○	○	◎				◎
	Poor production and construction	Bad production and construction	○	◎	○	○	◎				◎
		Bad waterproofing and water draining	○	◎	○		◎				◎
Fall out	External forces	Repeated load			◎	○	◎				
		Collision, earthquake			◎	○	◎				
	Environment factors	Salt damage			◎	◎	◎	○	○		
		Frost damage			◎	○	◎				
		Alkali-aggregate reaction			◎	○	◎				
		Neutralization			◎	◎	◎	○		○	
		Quality defect			◎	○	◎				
	Poor production and construction	Bad production and construction			◎	○	◎				
		Bad waterproofing and water draining			◎		◎				◎
A perforated hollowed	Aging of materials	Quality defect		◎		○	◎				
	Poor production and construction	Bad production and construction		◎		○	◎				
		Bad waterproofing and water draining		◎		○	◎				◎
Discoloration , aging	External forces	Fire		◎		○					
	Environment factors	Drying shrinkage, temperature change				○					
		Salt damage				◎		○	○		
		Chemical corrosion				◎					
	Aging of materials	Alkali-aggregate reaction				○					
		Neutralization				◎		○		○	
		Quality defect				○					
	Poor production and construction	Bad production and construction				○					
		Bad waterproofing and water draining									◎

(Note) ◎: Extremely effective
○: Effective

6.6.4.3.2 Cracks treatment methods

(1) The surface treatment method

If small cracks less than 0.2mm are concentrated in the concrete surface, because it is not suitable to use crack infusion method, a waterproofing film along with the crack to prevent water from leaking into is set up. This method is not suitable in cases where it is necessary to remove part of aging around the crack because the damage is caused by salt, neutralization, material defect. In the surface treatment method, polymer cement paste, cement filler, coating elasticity waterproofing materials such as acrylic resin, urethane resin can be used.

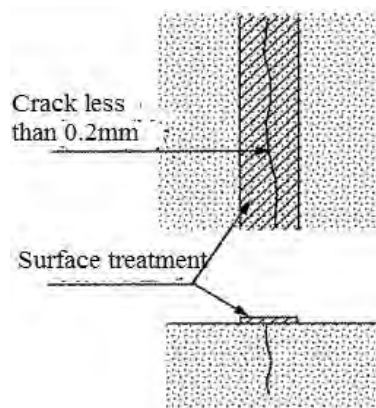


Figure 6.6-17 Example of the surface treatment method

(2) Crack infusion (filling) method

Crack infusion method is infusing or filling repair materials such as epoxy resin, polymer cement, deeply inside the crack in order to prevent the infiltration of water and chloride into the crack.

This method is suitable for the cracks which are stable. If it is necessary to remove the aging concrete around the crack which is caused by salt damage, neutralization, the combination of this method and the cross section repair method is recommended.

Epoxy resin has low viscosity so it is suitable to the crack of about 0.2÷5.0 mm, and is usually infused at low pressure. Polymer cement slurry with low viscosity also can be used.

At temperature below 5°C, epoxy resin cannot harden. This property needs to pay attention to during construction at low temperature.

For the crack more than 5.0mm, dig a hole of U shape along the crack and fill polymer mortar into the hole is the suitable treatment.

Epoxy resin can infiltrate into small cracks and its adhesive property is higher than polymer cement so filling epoxy resin is highly appreciated.

For spreading cracks, it is difficult for materials adhere to the expansion of the cracks, so the crack infusion method is not recommended. If the infusion method is forced to use for spreading crack repair, it must ensure enough materials to absorb the width of the cracks and fill elastic seat into the cracks.

When infusing resin, it is unsuitable to construct in areas with serious water leakage. For repairing the crack at these areas, inorganic cement crystal should be used to increase material to stop water. In this case, repairing materials will react with water in the concrete and produce a cement crystal. This crystallization makes the impermeability of the entire cement.

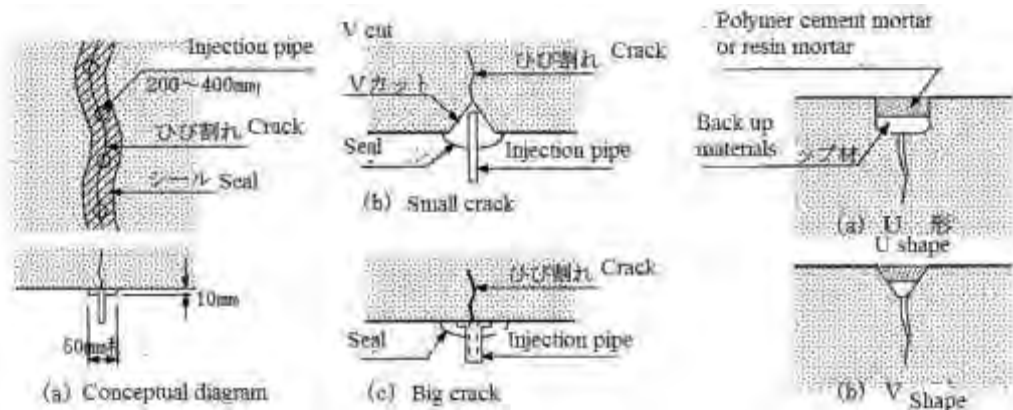


Figure 6.6-18 Example of the crack injecting, (a) and (c), and filling method (b)

6.6.4.3.3 Cross section repair methods

(1) Cross section repair mortar method

Cross section repair mortar method is the method of using trowel, spatula to paint the damaged part of cross section by repair materials many times. This method is also called mortar patching method. This method is used when the cross-section damage is relatively small and the repair depth is below 5cm. When construction condition is convenient which provide sufficient working space, this method can be used at all positions. The materials are used for cross section repair mortar method as polymer cement mortar, concrete, epoxy resin mortar, uncontrived mortar.

- Polymer cement mortar or concrete is cheap, efficient to neutralization and can be worked in wet conditions.
- Polymer SBR has good long-term adhesive property, and PAE polymer has good initial adhesive property.
- Epoxy resin mortar is expensive in comparison with polymer but because of the good adhesion, it is suitable to repair the cross section of relatively thin layer of about 6÷12mm. However, it should not be used at low temperatures of less than 5° C because cannot harden.
- Non-shrinking mortar has thick coating so it is suitable to repair the relatively large cross section. But in comparison with other materials, it has weak adhesion and needs the hydraulic environment.

If reinforcing bar is corroded severely, it should be removed and replaced by the new one. Water jet should be used to remove engaging concrete on a large scale due to salt, neutralization to prevent damage spreading to reinforcing bar and other healthy steel.

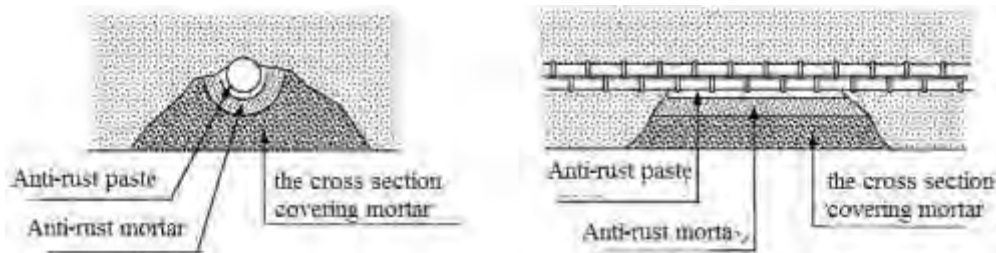


Figure 6.6-19 Example of the cross section repairing

(2) Pre-packing Concrete Method

Pre-packing Concrete Method consists of firstly filling coarse aggregate into a mold and then pouring mortar into that gap to make concrete and repair cross section. This method is suitable to large cross section damage and the inverted construction of filling concrete from bottom to top.

Pouring mortar should have:

- Good fluidity but less bleeding
- High adhesion
- Less shrinkage when hardening
- High solidity when harden
- Has the same coefficient of linear expansion and elastic modulus as concrete
- High durability

Pouring mortar which is often used is polymer cement mortar.

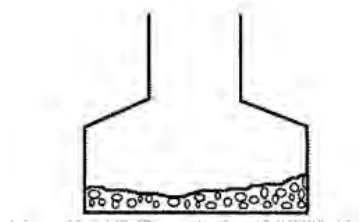


Figure 6.6-20 Example of prepacked method

6.6.4.3.4 The partial filling method

If the cross section of concrete is damaged by peeling and flaking out, it can be repaired by leaving the wrap of reinforcing bar, removing the damaged part, setting new reinforcing bar, and pouring new concrete mortar. This method is suitable to the damages of components that even if remove the structure built as floor system, wall handrail, it will not affect the entire bridge.

Old reinforcing bar and new reinforcing bar need to be connected closely with wrap joint or flare welding. In case of unable to ensure wrap space, this method cannot be used. Furthermore, this method is not suitable to narrow places where cannot assemble reinforcing bar and mold.

6.6.4.3.5 Surface re-covering methods

(1) The method of covering the surface with painting materials

The method of covering the surface with painting materials is using paint materials to cover the concrete surface in order to prevent the infiltration of water, salt, carbonic acid gas and oxygen.

After cleaning and preparing the concrete surface, we adjust the irregularity of the surface and paint middle coating materials, final coating materials on the surface.

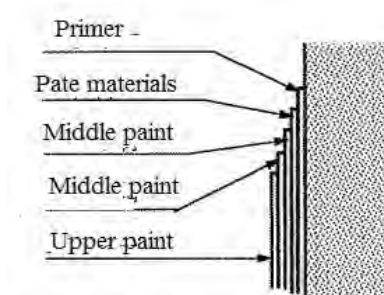


Figure 6.6-21 Example of coating surface by painting

Key points of cover material selection are as follows:

- 1) It is necessary to select appropriate materials for the construction environment as wet environment, tracking of the cracks.
- 2) It is necessary to select appropriate materials for purposes such as measures against aging, salt damage, neutralization, frost damage.
- 3) In the surface cover method, because the moist air inside the concrete usually could not be gone out by itself, so it is necessary to implement methods to prevent infiltration of water from elsewhere.

Main characteristics of the cover materials are shown in **Table 6.6-20**.

Table 6.6-20 Main characteristics of the cover materials

Types of cover materials	Characteristics
Silane	Is moisture permeability material which emit moisture inside the concrete outside
Epoxy	This material has high water resistance, but low weather resistance so it is used as middle coating materials. It cannot be hardened at low temperature, and should not be used at low temperatures. If flexibility is required, the flexible type should be used, but the thick film type to prevent severe corrosion.
Polymer Cement	Used as middle coating materials. Cheap, can keep alkalinity inside the concrete. Can be constructed even in wet environment.

Polyurethanes Fluorine	This material has good weather resistance and can be dry quickly so it is mainly used as final coating materials.
Gum	This material is good at flexibility and can prevent cracks well but not convenient at construction.

(2) The surface cover method aimed at preventing peeling off

In the paint cover method, if after repairing, cracking and peeling occur and it is unable to completely prevent peeling off, the treatments of pasting steel sheet, carbon fiber, aramid fiber, glass fiber on the repaired concrete surface can be applied to prevent peeling. This method is suitable to the places where must be caution to make damages or dangers to the 3rd part from peeling such as the floor undersurface, concrete barrier.

The steel sheet pasting is use of anchor bolts to paste on the concrete surface, and pour Epoxy resin to make the steel sheet stick closely to the concrete surface.

Parameters of steel sheet sticking method are as follows:

- Thickness of the steel sheet: 4.5mm
- The space to fill Epoxy resin : 5mm
- The space of anchor bolts: M10, under 50cm

FRP covering method is making Epoxy resin binding materials and fiber reinforcing materials impregnated to the concrete surface, to create laminating adhesion, to unify with the concrete fiber reinforcing materials are such as carbon fiber, aramid fiber, glass fiber.

In comparison with the steel sheet pasting method, lighter weight material is used makes this method is more preminent. Furthermore, it is unnecessary to worry about the corrosion as the steel sheet. The material which is most commonly used is carbon fiber, usually one layer sticking at the longitudinal direction, one layer at the cross direction, making a total of 2-storey construction.

Aramid fiber compared with carbon fiber has low elastic modulus so it is easy to use and does not need to take the corner.

Recently, the method widely used is cyber sheet (super strength polyethylene fiber) which has lighter weight than carbon fiber and aramid fiber, also high alkali resistance

The materials used in these surface cover methods have high ultimate tensile strength and give reinforcement efficiency.

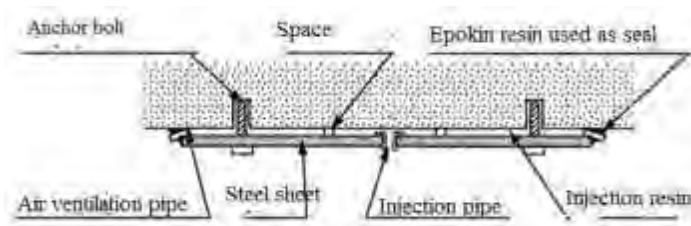


Figure 6.6-22 Example of sticking steel sheet

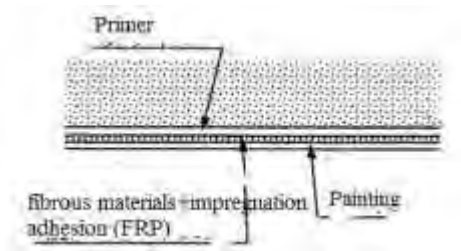


Figure 6.6-23 FRP sticking method

6.6.4.3.6 Anti-rust treatment method

If the cross section damage of reinforcing bar is small, the concrete surface is chipped to make the reinforcing bar exposed, then clean the rust of the reinforcing bar, and paint anti-rust materials on the reinforcing bar. This treatment procedure is called anti-rust treatment method. This method is also used as a temporary treatment in order to limit the spread of corrosion of the exposed reinforcing bar.

Painting materials are used such as Epoxy resin, polymer cement. It should be noted that if coating is not carried completely, means a part of the coating of the reinforcing bar is damaged, the electrical corrosion can be occurred focusing to the position which is not covered and increase the corrosion of the reinforcing bar.

The method in which anti-rust materials of high permeability (lithium nitrite) are used to make the dissipation of the anti-rust materials inside concrete can overcome the above shortcomings.

The anti-rust treatment of the reinforcing bar due to salt damage is painting the anti-rust paste mixed with salt adsorption materials on the exposed reinforcing bar in order to make adsorptive immobilization of chloride ion inside the concrete, and make lithium ion released and prevent the corrosion of the reinforcing bar.

If the cross section damage of reinforcing bar is large, it is necessary to add new reinforcing bar. Repairing the cross section of the concrete is conducted by the cross section repair method.

6.6.4.3.7 The method of making titanium metal anode to prevent the electric corrosion (the impressed current system)

Making titanium metal anode to prevent the electric corrosion is a method to keep the reinforcing bar inside the concrete structure as cathode and keep the titanium metal on the surface of the concrete as anode, then let a electric current run through directly and make the reinforcing bar become the inactive state and prevent the spread of the corrosion. This method is used when the reinforcing bar of the concrete is corroded by salt damage, neutralization.

This method is also used as a measure preventing corrosion of the reinforcing bar of the concrete structure in harsh environments which are expected in the area of corrosion in the future.

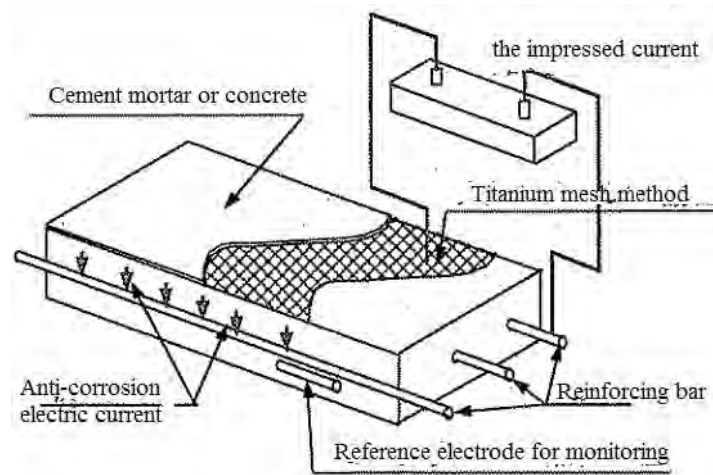


Figure 6.6-24 The impressed current system to prevent the electric corrosion

Due to the high cost and large scale construction, this method is only used in the special case of corrosion. In anti-corrosion methods by changing the titanium metal anode, depending on the maker, there are different methods as titanium mesh method, conductive coating material method, titanium grid method, In Internal closet anode method, it is necessary to choose the method suitable for the spot situation.

In the electric anti-corrosion method, it is necessary to conduct regular maintenance checks to confirm the system is operating in an effective manner or not.

- Normal check: every two months (confirm amperage, electrometry)
- Periodical check: one per year, with four times for the first year to confirm the integrity of the entire anti-corrosion network.
- Exact check: one in five years

6.6.4.3.8 The electric anti-corrosion methods by changing the zinc anode (the anode current system)

These are methods to keep the reinforcing bar inside the concrete structure as cathode and keep the zinc on the surface of the concrete as anode, then let electric current run through directly and make the reinforcing bar become the inactive state and prevent the spread of the corrosion.

The methods are used when the reinforcing bar of the concrete is corroded by salt damage, neutralization,

The methods are also used as a measure preventing corrosion of the reinforcing bar of the concrete structure in harsh environments which are expected in the area of corrosion in the future.

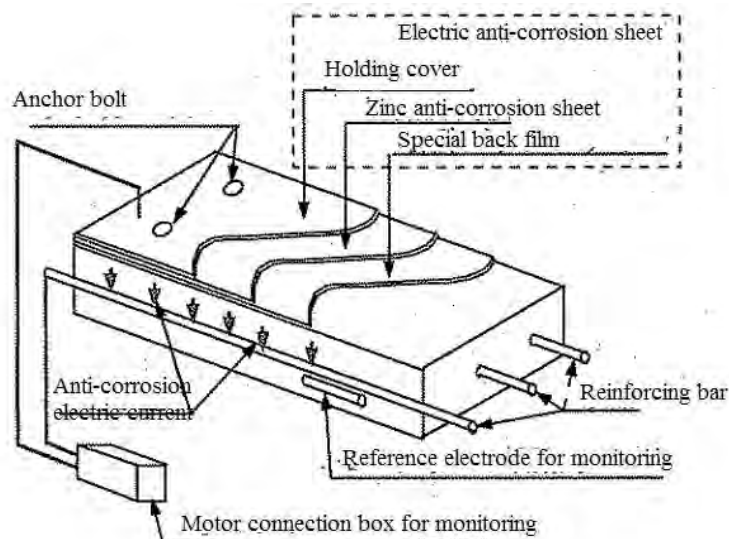


Figure 6.6-25 Conception of the anode current system

Due to the high cost and large scale construction, these methods are only used in the special case of corrosion.

The methods consist of:

(1) Zinc sheet method

Use anchor bolts to fix the zinc anti-corrosion sheet made from zinc sheet; special back fill and protective cover on the concrete surface and install monitoring equipment.

(2) Zinc injection method

Spray tiny zinc particles in molten state which is heated, accelerated by spraying gun on the concrete surface, form a zinc-spray film on the concrete surface and joint electrically with the reinforcing bar inside the concrete.

The electric anti-corrosion method by changing the zinc anode does not need a power source but because zinc will corrode by a potential difference, so if using zinc of thickness of 1mm, the effect period is about 15 years.

6.6.4.3.9 Electro chemic desalination method

This is the method of housing external electrode temporarily and let an electric current run directly through the reinforcing bars inside the concrete and extract salt out the concrete.

The desalination method is used when the salt concentration in the reinforcing bar reaches over the rusting limit ($1.2 \div 2.0 \text{ kg/m}^3$) or if does not interfere with, the salt concentration will predicted to increase. This method is effective in the case when the method of removing the concrete aging due to salt damage and covering the cross section does not match.

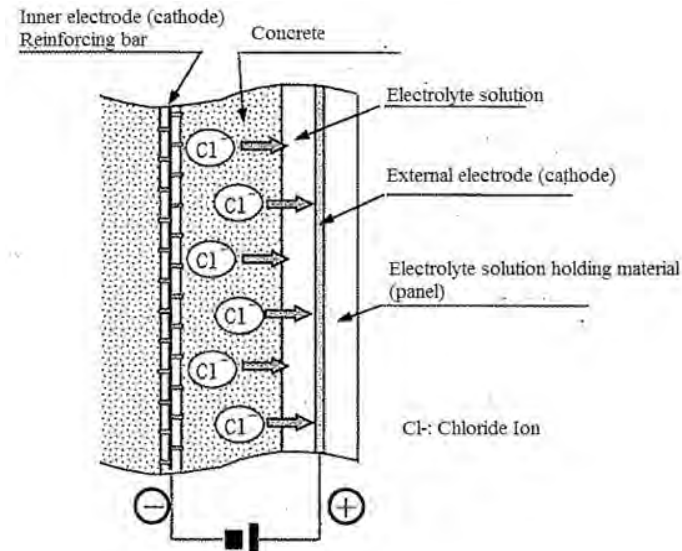


Figure 6.6-26 Conception of electro chemic desalination method

This method cannot be applied in the following environment:

- The places where cannot set up scaffolding
- In the case of on-going implementation of measures to protect the insulation surface on the concrete surface.
- In the case where the concrete surface is wet
- In the case where conductors such as bolts are being exposed.

In the desalting method, it is necessary to let an electric current with power density of 1A per 1m^2 of the concrete surface area run continuously about 8 weeks.

6.6.4.3.10 Electro chemic re-alkali method

This is the method of housing external electrode temporarily and let electric current run directly through the reinforcing bars inside the concrete and make alkaline solution in temporary materials penetrate compulsorily into the concrete and re-alkali. This method is used in cases which neutralization is spreading to the reinforcing bars position steel core, or if does not interfere with, the neutralization is predicted to spread and make corrosion of the reinforcing bars.

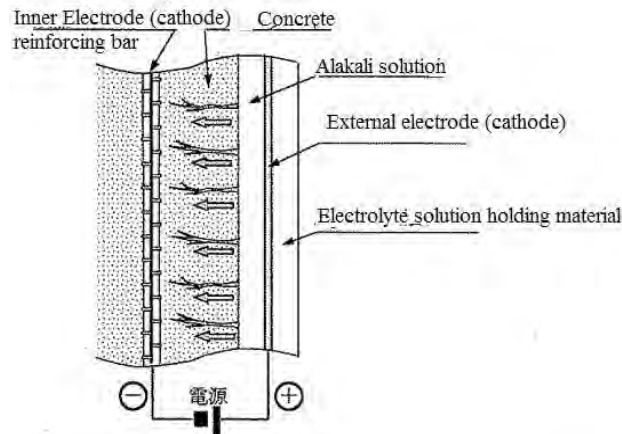


Figure 6.6-27 Conception of re-alkali method

This method is effective in the case which the method of removing the concrete aging due to neutralization and covering the cross section does not match.

This method cannot be applied in the following environment:

- The places where cannot set up scaffolding
- In the case of on-going implementation of measures to protect the insulation surface on the concrete surface.
- In the case where the concrete surface is wet
- In the case where conductors such as bolts are being exposed.

In the desalting method, it is necessary to let electric current with power density of 1A per 1m² of the concrete surface area run continuously about 8 weeks.

In the re-alkali method, if the depth of neutralization is less than 30mm, it is necessary to let an electric current with power density of 1A per 1m² of the concrete surface area run continuously about 1 week.

6.6.4.3.11 Water proofing method, water stopping method

Water proofing method is the method of painting water proof materials on the concrete surface, aims to prevent water and not let water to penetrate into the concrete.

Water stopping method is the method of filling water stop cement into the cracks which are in water drainage in order to stop water leakage.

(1) The waterproofing method on the concrete floor

Waterproofing sheet, waterproofing coating film are used. Bitumen materials are also used effectively.

When repairing under side of the concrete floor, if necessary, water proofing method must be conducted on the floor. Water proofing coating film method is used in the partial repair method.

(2) The stopping water method at water leaking places

In water stopping materials, there are cement system water stopping materials, cement system osmosis water proofing materials, urethane resin system water stopping materials.

6.6.4.3.12 The method to replacing the entire materials

This method is applied in cases such as damage on a large scale and the case in which concrete quality is poor so construction is particularly bad, and it is difficult to conduct repairing and reinforcing, and the case in which the result of repairing and reinforcing cannot be expected. Meanwhile, we will replace with the entire new concrete of the same shape with the present condition.

In the construction process, it is necessary to stop all the traffic or proceed with traffic lane regulation, only permit a part of vehicles go through. Until the casted concrete become harden, it is necessary to pay attention not to give excessive vibration and collision, transformation, and to consider the speed control of the traffic vehicle.

6.6.4.4 Bridge bearing repair

6.6.4.4.1 Introduction

Damage of the bridge bearing is caused by a lateral move and the subsidence of the substructure, and the influence of other parts (materials) including the slant. In these cases, in combination with repairing the bridge bearing, it is necessary to repair and reinforce the other parts (materials).

(1) Typical methods of bridge bearing repair

- The partial repair method
- The method of replacing the entire materials:
 - Replacing with the same shape,
 - Replacing with different shape
- The method of filling more materials
 - Anti-rust method: the painting repair method,
 - Method of injecting zinc

(2) When exchanging the bridge bearing, it is necessary to conduct the jack up. So it is necessary to consider the reinforcement of the main girder, the cross girder and the reinforcement of widening the abutment and the bridge pier.

(3) The criteria of cause of damage and repair method are shown in **Table 6.6-21**.

Table 6.6-21 Causes of Damages and Criteria for Repair Methods

Damage	Cause of damage		Repair methods				
			Partial repair	Replacing with the same shape	Replacing with the other shape	Filling mortar	Anti-rust
Corrosion	Due to environmental	Salt damage	○	◎			◎
		Chemical corrosion	◎	◎			◎
	Due to aging of materials	Quality defect	◎	○	○		○
	Produced by construction	Construction, production is not good	◎	◎	○		○
		Prevent water, good sewage	◎				◎
	Due to the structure	Construction, production is not good	○		◎		○
Crack	Due to external forces	Continuous heavy capacity	◎	○	◎		
		Due to earthquakes	◎	○	◎		
	Due to aging of materials	Quality damage	◎	○	○		
	Produced by construction	Construction, production is not good	◎	◎	○		
	Due to the structure	Construction, production is not good			◎		
Loose	Due to external forces	Continuous heavy capacity	○	○	◎		
		Due to earthquakes	◎	○	○		
	Due to aging of materials	Quality damage	◎	○	○		
	Produced by construction	Construction, production is not good	◎	○	○		
	Due to the structure	Construction, production is not good			◎		
Breaks	Due to external forces	Continuous heavy capacity	◎	○	◎		
		Due to earthquakes	◎	○	◎		
	Due to aging of materials	Quality damage	◎	○	○		
	Produced by construction	Construction, production is not good	◎	○	○		
	Due to the structure	Construction, production is not good			◎		
Paint aging	Due to external forces	Fires					◎
	Due to environmental	Corrosion salt					◎
	Due to aging of materials	Quality damage					◎
	Produced by construction	Construction, production is not good					◎
		Prevent water, good sewage					◎
	Due to the structure	Construction, production is not good	○		○		○
Cracked grout	Due to external forces	Continuous heavy capacity		○	◎	◎	
		Due to earthquakes				◎	
	Due to environmental	Dry and shrink, the temperature change				◎	
		Been damaged in salt				◎	
		Corrosion salt				◎	

Damage	Cause of damage		Repair methods				
			Partial repair	Replacing with the same shape	Replacing with the other shape	Filling mortar	Anti-rust
	Due to aging of materials	Be neutral				◎	
		Quality damage				◎	
	Produced by construction	Construction, production is not good				◎	
		Prevent water, good sewage				◎	
	Due to the structure	Construction, production is not good			◎	○	
There is a strange noise	Due to external forces	Continuous heavy capacity	◎	○	◎		
		Due to earthquakes	◎	○	◎		
		Due to land pressure, the subsidence	◎	◎	◎		
		Washing by digging, corrosion	◎	◎	◎		
	Due to environmental	Dry and shrink, the temperature change	◎		○		
	Due to aging of materials	Quality damage	◎	○			
	Produced by construction	Construction, production is not good	◎	○			
	Due to the structure	Construction, production is not good			◎		
Moving	Due to external forces	Continuous heavy capacity	◎	○	◎		
		Due to earthquakes	◎	○	◎		
		Due to land pressure, the subsidence	◎	◎	◎		
		Washing by digging, corrosion	◎	◎	◎		
	Due to environmental	Dry and shrink, the temperature change	◎		○		
	Produced by construction	Construction, production is not good	◎	○			
	Due to the structure	Construction, production is not good			◎		

◎: Extremely effective, ○: Effective

6.6.4.4.2 The partial repair method

The partial repair method is local damages repair by replacing the damaged parts of a bridge bearing.

Typical examples of the partial repair method as follows:

- 1) Replace roller for roller bearing
- 2) Widen the upper shoe and the under shoe
- 3) Replace the bearing and the upper shoe of the bearing
- 4) Tighten the anchor bolts which are loosened
- 5) Fix the cracks and the broken parts of the moving regulation equipment
- 6) Replace the upper shoe which are deformed or broken, or repair sole plate

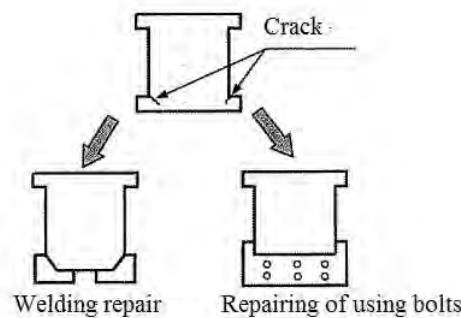


Figure 6.6-28 Repairing parts of sole plate

6.6.4.4.3 Bridge bearings replace

- (1) The method of replacing with the same type

Due to the damage of bridge bearings, they do not achieve supporting and moving function, while there is not any structural defect of the shape, the bearing will replace by the new one of the same shape. The precondition is that the cause of damage does not originate from the shape of the bearings.

This method is mostly used in case when moving function is not achieved by compression, crane of the bearings of the steel bridge and in case when some important parts are eroded at large scale and damage the cross section.

The bearings of steel bridge joint with the girders and the upper foot by bolts and nuts so changing the upper foot is easy. But if anchor bolts of the upper foot are buried in the concrete of the girders, removing the bridge bearings is not easy.

When replacing all bearings of a bridge, it is necessary to set main girder. If the girder is set in front of the bearings, it may need to widen of the abutment at the edge at the setting position.

Also the case of replacing all bearings of a bridge, established system of anchor bolts and snag can be used in order not to harm the reinforcing bars of substructure and joint old bearings with new bearing together during replacing process.

(2) The method of replacing with other type

Due to the damage of bridge bearings, they do not achieve supporting function and moving function, replacing new bearings with specific type can be proposed. A typical example is that the roller of a roller bearing is damaged; the roller bearing can be replaced by new bearing.

When replacing all bearings of bridge, it is necessary to set a main girder. If the girder is set in front of the bearing, it may need to widen the edge of the abutment at the setting position.

6.6.4.4.4 Methods of filling more materials

(1) The method of filling mortar

This method includes setting a girder and conducts a jack-up, snag the damaged mortar, and fill no shrinkage mortar upon.

Mortar damage can be caused from corrosion of steel material which is used to control height and shape of bearing. The corroded steel must be removed and replaced by new one, and then new mortar is filled back in.

(2) The painting repair method

After cleaning the rusted part, bearing surface is painted to prevent corrosion. The condition is that it must ensure the space to be able to carry out cleaning and painting. If the movable function is lost by corrosion, it is necessary to inject lubricant into.

(3) The method of injecting zinc

The bearings are cleaned completely by brush, and a spraying film of the alloy of zinc and zinc aluminum is applied on the surface of the bearings. If the spraying film of the alloy of zinc and zinc aluminum then can be coated by epoxy resin of permeability, the anti-rust effect will be higher than normal but cost is high.

This method is effective for corrosion caused by water leakage from flexible equipment and the accumulation of dust after years. If the movable function of bearings is lost by corrosion, it is necessary to inject lubricant into.

6.6.4.5 Repair expansion joints

6.6.4.5.1 Overview

Damage of expansion joints is caused by a lateral move and the subsidence of the substructure, and the influence of other parts (materials) including the sealant. In these cases, in combination with repairing the flexible equipment, it is necessary to repair and reinforce the other parts (materials).

The typical methods of expansion joints repair are as follow:

- The partial repair method

- The method of replacing the entire materials:
- Replacing with the same shape,
- Replacing with the other shape
- The method of filling more materials
- The non-drainage method

Expansion joint must work in harsh conditions, so if life expectancy is failed by damage, it must be replaced by material of the same shape.

If the equipment is damaged, an investigation should be carried carefully to define the cause, then consideration for repairing method in order damage not to be arisen after repairing should be made.

Causes of damage and repair methods of expansion joint are shown in **Table 6.6-22**

Table 6.6-22 Causes of damage and repair methods of expansion joint

Damage	Repair methods		The partial repair method	The method of replacing the entire materials with the same shape	The method of replacing the entire materials with the other shape	The method of filling more materials	The non-drainage method
	Causes of damage						
Corrosion	Due to environmental	Salt damage	◎	○	○	○	
		Chemical corrosion	◎	○	○	○	
	Due to aging of materials	Quality defect	◎	○	○	○	
	Due to production and construction	Bad production and construction	◎	○	○	○	
		Bad waterproofing and water draining	○				◎
	Due to the structure	Bad form and shape of the structure	○		◎	◎	
Crack	Due to external forces	Repeated load	◎	○	○	○	
		Earthquake	◎	◎	◎	◎	
	Due to aging of materials	Quality Defect	◎	○	○	○	
	Due to production and construction	Bad production and construction	◎	○	○	○	
	Due to the structure	Bad form and shape of the structure	○		◎	◎	
Loose	Due to external forces	Repeated load	○	○	◎	◎	
		Earthquake	○	○	◎	◎	
	Due to aging of materials	Quality Defect	◎	○	○	○	
	Due to production and construction	Bad production and construction	◎	○	○	○	
	Due to the structure	Bad form and shape of the structure			◎	◎	
Broken	Due to external forces	Repeated load	○	○	◎	◎	
		Earthquake	○	○	◎	◎	
	Due to aging of materials	Quality defect	◎	○	○	○	
	Due to production and construction	Bad production and construction	◎	○	○	○	
	Due to the structure	Form and shape of the structure is not good			◎	◎	
Abnormal expansion	Due to external forces	Repeated load		○	◎	◎	
		Earthquake		◎	◎	◎	
		Due to land pressure, the subsidence		◎	◎	◎	
		Due to land pressure, the subsidence		◎	◎	◎	
	Due to environmental	Dry and shrink, the temperature change		○	◎	◎	

Damage	Repair methods		The partial repair method	The method of replacing the entire materials with the same shape	The method of replacing the entire materials with the other shape	The method of filling more materials	The non-drainage method
	Causes of damage						
	Due to production and construction	Bad production and construction		◎	◎	◎	
	Due to the structure	Bad form and shape of the structure			◎	◎	
Different if level	Due to external forces	Repeated load		○	○	◎	
		Earthquake		◎	◎	◎	
		Due to land pressure, the subsidence		◎	◎	◎	
		Washing by digging, corrosion		◎	◎	◎	
	Due to environmental	Dry and shrink, the temperature change		◎	◎	◎	
	Due to aging of materials	Quality damage		○	○	◎	
	Due to production and construction	Bad production and construction		○	○	◎	
	Due to the structure	Bad form and shape of the structure			◎	◎	
Abnormal noise	Due to external forces	Repeated load		○	○	○	
	Due to environmental	Earthquake		○	○	○	
		Due to land pressure, the subsidence		○	○	○	
		Washing by digging, corrosion		○	○	○	
		Dry and shrink, the temperature change			○	○	
	Due to aging of materials	Quality damage		○	○	○	
	Due to production and construction	Bad production and construction		○	○	○	
Due to the structure	Bad form and shape of the structure			◎	◎		
Water leakage	Due to environmental	Dry and shrink, the temperature change	○				◎
		Salt being harmful	○				◎
		Corrosion chemicals	○				◎
	Due to aging of materials	Quality damage	◎				◎
	Due to production and construction	Bad production and construction	◎				◎
		Bad waterproofing and water draining					◎
	Due to the structure	Bad form and shape of the structure	◎		○	○	◎

(Note) ◎: Extremely effective

○: Effective

6.6.4.5.2 The partial repair method

If the expansion joint is damaged partially, the damaged part should be repaired and replaced.

Typical examples of this method are as follows:

- 1) Replace the damaged bolts
- 2) Pour materials into the detached bolt hole
- 3) Replace gum of the steel joint which are detached
- 4) Repair cracks of the steel finger joint

6.6.4.5.3 Replacing the entire materials

- (1) The method of replacing the entire materials with the same type

The damaged expansion joint when being unable to repair by the partial repair method, can be replaced by new one. If there is not any problem with the form of joint before repairing, the replacement of new joint is for the life of the joint, the damaged joint can be replaced by new joint with same form.

Before replacing the entire joint, it is necessary to check expansion gap and expansion quantity. If the expansion gap is in the appropriate range which required expansion joint, the damaged joint can be replaced by new one without any problems.

The expansion quantity should be calculated before repair considering to construction statement, drying and shrinking properties of sealant material.

It is necessary to combine the method of replacing the entire materials with the method of filling more materials.

- (2) The method of replacing new materials with a new shape

If it is unable to repair by the partial repair method and keeping the shape as before repairing is not suitable, method of replace the entire expansion joint with a new shape is recommended.

When replacing the entire equipment, it is necessary to check expansion gap and expansion quantity before, and replace with new equipment of different shape which is suitable to the range of expansion gap. The expansion quantity should be calculated before repair considering to construction statement, drying and shrinking properties of sealant material.

When replacing with other shape, the matching gum joints will drop out easily so it is necessary to replace with the gum joints of the underground laying system or the load bearing system.

If the expansion gap is too large in comparison with expansion quantity, we should consider for repairing the edge of the floor. In addition, if expansion quantity is small, it is necessary to consider changing to the underground laying system.

It is necessary to combine the method of replacing the entire materials with the method of filling more materials.

6.6.4.5.4 The method of filling more materials

For the method of filling more materials, it is necessary to fix expansion joint before pouring more materials into them on two sides of expansion gap. In case of cracks and peeling of the filled materials are visible, loose materials should be removed for clean joint then replaced by new materials.

The damage of expansion joint needs to be repaired soon in any case. The damage of filled part if being ignored will result to damage of fixing position of the expansion joint and widespread of damage to the entire expansion joint.

The later filling materials are used can be resin concrete, resin mortar, concrete, mortar, etc. However, super quick hardening concrete should be used for traffic opened early.

6.6.4.5.5 The non-drainage method

The steel finger joint of the old type have the form as a drainage gutter established under the joint but due to the accumulation of earth and sand, water drainage is not completely and causes damage of the substructure and the surrounding of the bearing.

The non-drainage method includes filling back up materials and elastic seal materials into the expansion gap. The structure of this method has stainless gutter type and web type.

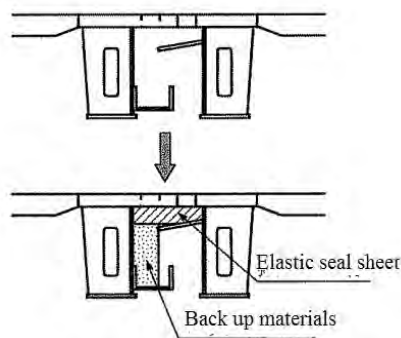


Figure 6.6-29 Non-drainage method

The backup materials are used as polyurethane and polyethylene, but recently urethane material of high elasticity is mostly used. In addition, foaming gum can be set on top of elastic seal materials to prevent the materials flying out. In the method of injecting elastic seal materials, it is necessary to control traffic until the sealing material is compressed to 85% of completion.

6.6.4.6 Bridge cleaning

Except for special cases, the bridge itself virtually rarely cleaned but at the points where are next to the truss bridge, in terms of structure, in the places of waste accumulation, they are easy to make the

bridge rusty so periodical inspection and cleaning is necessary. Also, in expanded or narrow places, near the supporting places, soil and sand can easily accumulate to affect the function of the bridge and it is considered as the cause of bridge damage so it is necessary to have bridge cleaned while periodic inspection.

Besides, if the sewage system blocked, in case of high suspension bridges then at the places where are under a girder bridge, it will easily arise problems. If the road is flooded, it would obstruct the traffic. To avoid this situation, it is necessary to check the sewage system (if any) and to carry out cleaning.

6.6.5 Data Registration of Maintenance and Repair History

Record of repairing in principle is keeping the checking time, the detailed investigation, and the operation time of the structure.

The record should present how repairing works have been conducted according result of checking, surveying, etc. for the bridge. It also includes details of repairing work, such as repairing parts, repairing method and the person in charge of repairing, etc.

The standard contents should be recorded during repair implementation are shown in **Table 6.6-23**.

Table 6.6-23 Typical contents to be recorded during repair implementation

Person in charge of repairing	Name of the repairing company, name of the person in charge of the repair (repair work manager)
Date of repairing	Repairing time, starting and completing date
Repair purposes	Type of damage, the detailed investigation
Repairing location	Repairing locations, name of the used materials, the scope of repair work
Repair methods	Repair methods, the used main material
Repairing results	Report of the repairing results
Evaluation results after repairing	Number of years that the repairing is effective (the warranty period of repairing that the manager required)* Evaluation results on the necessity of repairing

Note: If the repair technology is new technology used in recent years, however, it should be clear in record whether it is able to verify the durability of the repair methods or not.

Record of repairing works in addition should include information of repaired parts condition by time. It is because of the repaired parts will be aging and need to be repaired again, so it is necessary to check the repaired parts regularly and record durability and the problem of the repair methods in order to store information and data.

6.7 Road Tunnel Maintenance Management

6.7.1 Introduction

It is necessary to evaluate the abnormal states of tunnels by the investigation and estimation of the causes. Depending on the state of change, it is needed to discuss the most appropriate method to be

able to restore the functionality and endurance of the tunnel's structures that were weakened. According to actual tunnel condition based on the inspection and investigation results, considering to maintenance policy, the economic decisions of the scope and scale of the project that must meet the requirements of the policy.

There can have two types of project scale for tunnel maintenance. The first is repairing that can promote the normal function and parts of the tunnel after arising abnormal status. The second is extreme large scale which can affect to components of the tunnel and be applied in the case of abnormal state of the tunnel has been going on.

6.7.2 Typical Damages Observed

6.7.2.1 Tunnel damage types

The most significant problem in constructed tunnels is groundwater intrusion. The presence of water in a tunnel, especially if uncontrolled and excessive, accelerates corrosion and deterioration of the tunnel liner. Other popular defects of tunnel are cracks, damages of segmental liners, corrosion of steels or cast iron components, concrete or masonry elements movements or degradation which create gaps at backfill. All these defects relates directly to problem of groundwater intrusion.

Groundwater intrusion is phenomenon of water appearance on roof or ceiling of the tunnel through cracks. Each site of groundwater intrusion has its own particular environmental and physical properties which impact to treatment selection. They are pH, hardness, chemical composition, turbidity of the groundwater entering the tunnel, which contribute to the ability of the chemical or particle grouts to effectively seal the leaking defect, and physical conditions that created the defect, movement of the crack or joint, the potential for freezing and the amount of water inflow all are site specific constraints for the selection of the repair material.

The selection of the proper grout to seal a tunnel liner is dependent on the degree of leakage into the tunnel from the defect. Typically the tunnel defects that cause leakage are construction joints liner gaskets, and cracks that are the full depth of the liner. Standardized terms have been developed to describe the inflow of water. The degree of water inflow is in **Table 6.7-1**.

Table 6.7-1 Descriptions of tunnel leakage

Item	Symbol	Description
Moist	M	Discoloration of the surface of the lining, moist to touch
Past Moisture	PM	Area showing indications of previous wetness, calcification
Glistening Surface	GS	Visible movement of a film of water across a surface
Flowing	F	Continuous flow of water from a defect; requires volume measurement
Dry	D	Structural defect illustrates no signs of moisture

6.7.2.2 Monitoring and causes of damage

Monitoring means observing carefully main points discovered through the investigation process of standards, the process of thorough investigation and policy construction positions for unusual points.

For the contents of observation, in case of following the causes of abnormal changes we have to make daily checks. Confirming effectiveness of changes and policy, construction method must have the same content and level of investigation.

Treatment for tunnel damages should be made after knowing exactly the cause of the abnormality and based on assessment of the effectiveness, feasibility, safety, and economic as well as construction time considering maintenance policy.

These measures are not merely adding materials, reinforcing and improving the degradation positions of the tunnel, but it also includes items and measures to strengthen the control and supervision of tunnel's degradation as well as controlling and supervising traffic under tunnel's condition.

One of the focal points of these policies is that if it removes the management of emergency when there is unusual state, it must understand the causes of these abnormal states. If in terms of research, depending on each cause of those unusual states that we can see phenomenon of the different change of state. Therefore, for guessing reasons of degradation, together with reading the special causes, we also need to conduct generally based on materials related to the design and construction of the tunnel, cadastral status to verify latitude longitude location of the situation that arises abnormal changes. The causes for state change of the tunnel will be classified as following:

- Soft soil foundation (including collapse due to cracks)
- Pressure of rocks and earth deviating on one side
- Land-slip
- Soil pressure with expansion
- Lack of capacity to support
- Water pressure
- Pressure of frozen soil
- Degraded arterial and material
- Water leak
- Back type face to be empty
- Not enough thickness
- No invert arch

6.7.2.3 Treatment selection

Above is the list of the causes, however, the causes occur only by a reason is very few, almost it usually happens by a few overlap reasons and cases such as the nature of the construction materials at each time, the design is error and empty at back type face or improper construction also is the cause. So to choose a method of the policy, we need to calculate carefully the items as specified in the Table **5.13.1**, and even independent and combination construction method, we also need to study carefully. In addition, when constructing, we also need to focus on the calculation to the regulations on traffic, safety measures as well as the time when carrying out the project.

6.7.3 Inspection of Road Tunnel

6.7.3.1 Focus Point of Inspection

- (1) The inner lining concrete is deteriorated by chemical reaction working between lining concrete and chemical components in the water. Damages appear on the concrete in the forms of cracks, peeling, creeping, carbonation, water leakage and free lime.
- (2) Concrete cracks on the inner lining concrete are caused by tensile stress working on the Tunnel Lining, which is a deviated pressure generated by land slide occurring nearby Tunnel or changes in pressure of natural ground behind the Tunnel Lining. This deviated pressure is a main cause of tunnel damage, so that it is necessary to check carefully and conduct detailed inspection when it is found.
- (3) The water leakage from concrete lining is often caused by the voids in the lining concrete, causing deviated pressure on the Tunnel Lining. The water leakage leads to the damages not only to the Tunnel body, but to the pavement, creating slippery driving conditions in the tunnel.
- (4) Poor construction quality, including improper repair works on the concrete lining, insufficient concrete pouring into arch crown and improper concrete joint construction, often leads to cracks, peeling, corner dropping, and water leakage due to aging and earthquakes.
- (5) Tunnel Portals are in general constructed on the ground which has sufficient bearing capacity. However, if they are constructed on the steep slope in the mountainous area, uneven settlement of portal facility often occur due to insufficient bearing capacity of the ground, thereby causes transverse cracks on the portals and gaps at the construction joints. With this, it is necessary to inspect surrounding areas of the Tunnel Portal.
- (6) The damages of Tunnel Interior Decoration Board are often caused by water leakage or the material deformation given by vehicle accident often appears in the form of corrosion on the fixing bolts.
- (7) Damages on the Drainage Systems in the Tunnel including deformation or break of the Drainage System are often caused by the deviated stresses working on the concrete lining.
- (8) Damages on the pavement in the Tunnel including cracks, depressions or swelling are often caused by external stresses originated from the deformation of Tunnel Portal and lining concrete.

6.7.3.2 Inspection Points

Road facility inspection for Tunnel facilities shall be implemented on the inspection points shown in **Table 6.7-2** for Tunnel Concrete Lining, **Table 6.7-3** for Tunnel Portal and **Table 6.7-4** for Tunnel Interior Decoration Board. Also, **Figure 6.7-1** illustrates inspection points on the Tunnel Lining and **Figure 6.7-2** inspection points on the interior facilities.

Table 6.7-2 Inspection Points (Concrete Lining)

Structure	Position	Member	Sort of damage	Initial Inspection	Daily Inspection	Periodic Inspection	Detailed Inspection
Tunnel	Concrete lining		Cracks/ corner drop	X	X	X	As required by Routine or Periodic Inspection
			Peel	X	X	X	
			Joint gap	X	X	X	
			Leakage/ free lime	X	X	X	
			Spalling, Void	X	X	X	

(Note) X15: To inspect 15~20 years after from opening to traffic.

Table 6.7-3 Inspection Points (Portal)

Structure	Position	Member	Sort of Damage	Initial Inspection	Routine Inspection	Periodic Inspection	Detailed Inspection
Tunnel	Portal /entrance		Cracks/ corner drop	X	X	X	As required by Routine or Periodic Inspection
			Peeling	X	X	X	
			Rebar exposure	X	X	X	
			Settlement/ movement / tilt	X	X	X	
			Joint gap	X	X	X	
			Scouring	X	X	X	
			Drain/ spring water	X	X	X	

(Note) X: Inspection items, but not limited.

Table 6.7-4 Inspection Points (Interior Decoration Board and Others)

Structure	Position	Member	Sort of Damage	Initial Inspection	Routine Inspection	Periodic Inspection	Detailed Inspection
Tunnel	Inner decoration board		Body damage (plate type)	-----	X	X	As required by Routine or Periodic Inspection
			Body damage (tile type)	-----	X	X	
			Accessory damage	-----	X	X	
	Drain system		Facility damage	-----	X	X	
	Debris and soil piling		-----	X	X		

(Note) X: Inspection items, but not limited.

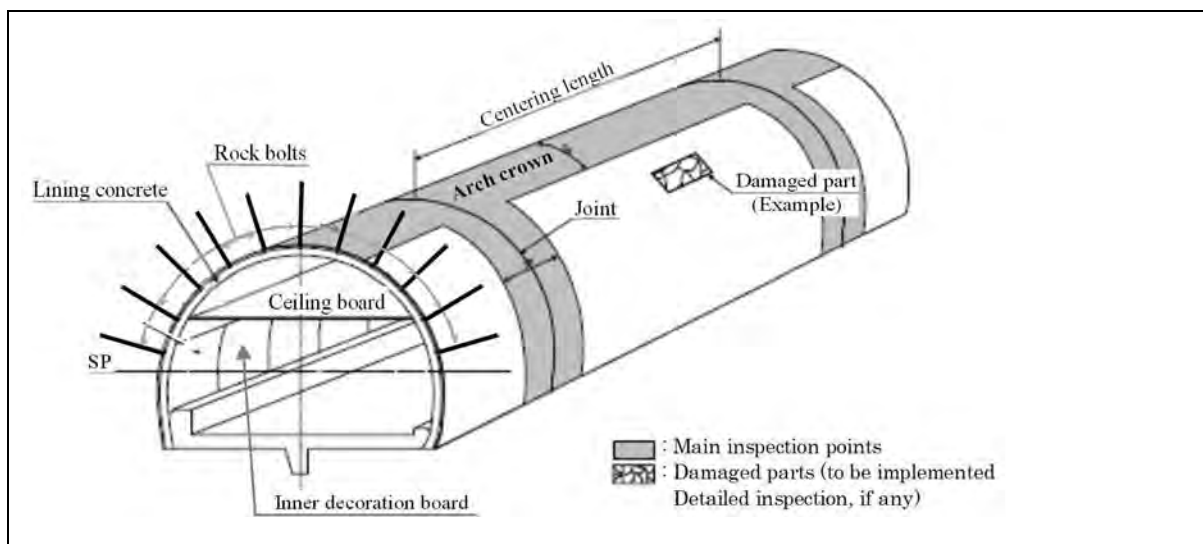


Figure 6.7-1 Inspection Points on Tunnel Lining

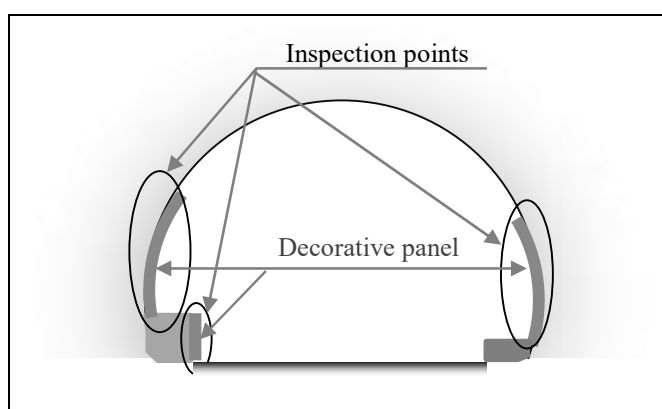


Figure 6.7-2 Inspection Points on Interior Facilities

6.7.3.3 Inspection Methods and Frequencies

Inspection methods and inspection frequencies in principle follow the Standard Inspection Methods and Standard Inspection Frequencies in this Guideline. However, inspection methods specialized for periodic inspection of Tunnel facility shall follow the methods prescribed in **Table 6.7-5**.

Table 6.7-5 Inspection Methods and Frequencies

Inspection Method		Inspection Frequency
Periodic inspection	The following inspection methods are applied to the points where abnormalities are found. ● Short-distance visual inspection ● Hammering by test hammer	Follow the Standard Inspection Frequencies in the Guideline

(Note) **Figure 6.7-3** shows the figure of test hammer.



Figure 6.7-3 Test Hammer

6.7.3.4 Evaluation of Inspection Results

- (1) Evaluation of the results of routine inspection, periodic inspection and emergency inspection shall be conducted, following relevant articles in this Guideline. Sample evaluation criteria for Tunnel Lining are shown in ANNEX-F. Also, particular notes for the evaluation of some major damages are described below;
- (2) When cracks in high density are progressing rapidly or tensile cracks in wide gaps or shear cracks appear on the concrete lining, the damage is rated as “D” in this Guideline.
- (3) When large-scale concrete peeling or corner drops is found on the concrete lining, it leads to the fatal damages given to the lining, so that the damage is rated as “D” in this Guideline.
- (4) When above damages are expected to be caused by deviated pressure working on the Tunnel Lining, detailed inspection shall be conducted immediately.
- (5) When large-scale water leakage occurs from the Tunnel Lining, it may cause voids behind the concrete lining, thereby causing harmful pressure on the Tunnel body. Rating “D” is applied to this damage in this Guideline.
- (6) When concrete cracks caused by uneven settlement or movement of Tunnel Portal is found in the inspection, they will lead to fatal damages to the Tunnel Portal, the damage is rated as “D” in this Guideline.
- (7) When large scale damages including concrete cracks and gaps are found on the pavement and drainage facilities inside Tunnel, which are caused by lateral or uplifting pressure, massive pressure may be working on the Tunnel Lining. Rating “D” is applied to these damages in this Guideline.

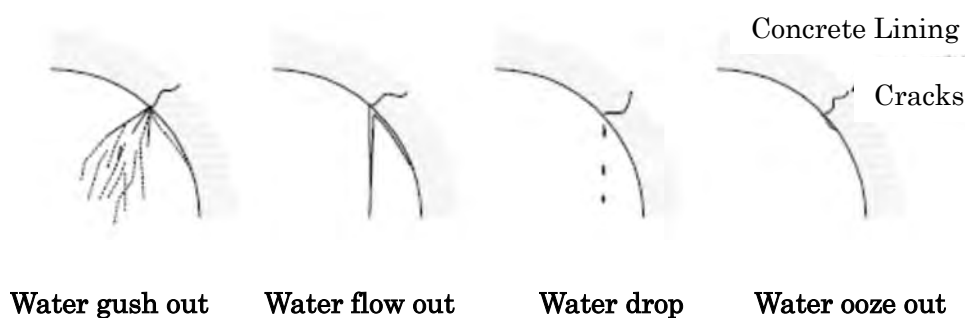


Figure 6.7-4 Water Leakage from Tunnel Lining

6.7.3.5 Registration and Reporting of Inspection Data

Registration of inspection data and reporting shall be conducted, following relevant articles in this Guideline.

6.7.4 Planning and Implementation of Maintenance and Repair Work

6.7.4.1 Cement atomization

(1) Concepts

Cement is atomized on back space of repaired area and inside tunnel, after that this material will be frozen and considerably improve coherence between repaired area and earth. Aim of this method is to fulfill back space of construction because of followings reasons.

- The material is fulfilled in back space of work to reduce reaction for external force decrease of the tunnel.
- Pressure decentralization on earth is based for making its weight to be the same form. (Prevent contact point and differential pressure).
- Making back space stable.
- Preventing downgrade of construction due to water penetration.
- Controlling water leakage, assume responsibility for safe of transport vehicle.

And it is basic method to improve safe and assume responsibility for safe of construction as well. Furthermore, it also helps stabilize old parts, gain initiative in prevention of external force such as earthquake and effect of neighboring construction.

(2) Key issues of design and construction

Due to different atomized material, equipment and machines used in construction process and atomization pressure, it should choose suitable method depending on actual conditions such as back space, status of earth, leakage, construction condition.

Basically, material used for back atomizing is cement milk, cement mortar, air-cement milk or air-cement sand grout. However, the method does not need so hard material such as concrete. So cement mill or cement mortar can be replace with fly ash or bentonite, which helps reduce volume of cement usage, its connection with AE active ingredient brings higher mobility.

Table 6.7-6 Causes of change and criteria to select measurements

Cause of change Method		Cause of change											
		Change by action of external force							By degraded materials	By water leak	Other causes		
		Loose, soft earth pressure by conflict	Earth pressure deflecting at one side	Land-slip	Earth pressure with expansion	Lack of support	Water pressure	Pressure of frozen soil			Gaps at backfill	Lack of thickness	Not having dilatation joint
Methods	Focus on treating back side	⊙	⊙	⊙	⊙	⊙	⊙	⊙		△	⊙		
	Protecting net made by parachute cord								⊙				
	Guniting	△	○	○	○		△	△	○			○	
	Bolt	○	⊙	○	⊙	○	△	○	△			○	⊙
	Anti-water seepage treatment	△	△	○	△	○	⊙	⊙		⊙			
	Pour arc concrete inside	△	○	○	○		△	△	○			⊙	
	Heat insulation							⊙					
	Stable construction of bevel (policy from outside the tunnel)		○	⊙									
	Blowing construction in mountain earth	△	△			○		△		△	○	○	○
	Construct grout anchor type	○	⊙	⊙	⊙	△							△
	Construct invert type		⊙	○	⊙	⊙		△	○				
	Construct again each part	○	○	○	○	○		△	△	⊙	○	○	⊙

(Note) ◎: Policies that are considered the most effective to causes of change, ○ : Policies that are considered the most effective to causes of change, △ : Policies that are considered the provisional effectiveness to causes of change

For choosing atomization material, pay attention to following points.

- Should use insulating material, freeze composite which have less shrinkage volume after atomized.
- In case of water inside atomizing space, the material has heavy density will be chosen as material with light density will be washed away easily.
- Need balance between used material and earth pressure. Normally, material has pressure intensity from 10 to 15kg/cm³ will be used.

For method preventing displacement of atomized material, followings steps are implemented.

- The leakages on weak points of concrete will be stop with mortar or wiper. If this method is not successful, atomization will not be continued provisionally until dry of the leakage.
- Prevent the deflecting flow without expecting

Firstly it is blown around the area to be treated a material with its quick frozen to form the rags to over flood. Position of the rags is approximately 200 m, for places that has much penetration, only should create rags about 100m. The width of these rags according to a way that previously were often made is 5m. However, setting this rag along with its width must depend on the reality of improvement blowing construction on the back side.

(3) Coordinate the design

Material used should have a high mobility ensures it has to fill in the gaps that need to blow. In case of using the mortar and milk grout, its mobility is closely related to separated materials, and if its mobility increases too high, it will become the cause affecting the separated material, it should be note. Normally people will manage the use of mortar grout by the process.

- The process of air mortar (P lot): 25 ± 5 sec
- Process of air milk (Cylinder method): $200 \div 20$ sec

Table 6.7-7 Example of coordinate air mortar

No	Design standards intension $\delta 28$ (kgf/cm ³)	Scope of process (s)	Scope of air volume (%)	Rate of grout W/C (%)	Unit weight (kg/m ³)				C:S ratio
					Cement	Sand	Water	Foaming materials	
1	10	25 $\pm$ 5	35 $\pm$ 5	110	195	975	215	Appropriate quantity	1:5
2	10	25 $\pm$ 5	40 $\pm$ 5	100	210	840	210	Appropriate quantity	1:4
3	10	25 $\pm$ 5	45 $\pm$ 5	80	240	720	192	Appropriate quantity	1:3

- (Note)
- a. Scope of the air volume in the table must ensure coordination is $\delta 28 = 10\text{kgf/cm}^3$
 - b. Rate of FM combination of sand is 2.2
 - c. The table of above process is by Plot method
 - d. Foaming materials must be calculated according to a rate to match the air flow.

Table 6.7-8 An example of the combination of air milk

Design standards intension $\delta 28$ (kgf/cm ³)	Scope of process (mm)	Scope of air volume	Rate of grout W/C (%)	Genetic density	Unit weight (kg/m ³)		
					Cement	water	Foaming materials
10	200±20	65±5	66	0.58±0.05	350	231	17

(Note) a. Scope of the air volume in the table must ensure coordination is $\delta 28 = 10\text{kgf/cm}^3$

b. Schedule process is by cylinder method

Table 6.7-9 Example of coordinating grout stopper

Liquid A (5001) kg			Liquid B (5001)kg	
Quick frozen substance	Substance makes slow	Water	Normal cement	Water
100	0.3	465	300	403

Characteristics of blowing material are quick frozen substance according to a kind of cement are:

- The soft soils locate between the clay and sand, clay, and can be blown in as the circuit format.
- There is feature of gallate gel in a short time
- When combined with grout will have the high-strength.

Especially when blowing combination into renovation construction at the backside, where has the high water permeability, after confirming result of test generally expect the following items.

- Dissociated materials (separated) in low construction process.
- After blowing, the stability in the treated region is enhanced.
- Volume changes a little.

(4) The construction procedure

The blowing procedure on backside will be sequential as following steps

Hole drill ↓	Hole drill in concrete part of construction (of tunnel) on mark of central hole drill
Install blowing equipment ↓	After drilling, install blowing pipe into drilling hole
Grout ↓	Blowing grout into hole by pump using pressure blowing forms
Change to another blowing point	Confirm blew volume through access hole, after blowing necessary material volume, change to another point

- Hole drill and install the blowing equipment

Because of the blowing volume and level of effectiveness are different by blowing pipes are arranged at positions separated according to line, so when constructing must grasp the state of spaces that need to the construct of work. Normally the spaces of the building are near the arched

roof of the tunnel, so when want to blow in an amount such that the left and right side are the same, it will design blowing hole in the middle of the arches concrete. It is the most optimal method. However, when calculating to traffic vehicle in the tunnel, if a tunnel is used for many lanes, it often encounters problems such as the difficulty of the hole drill, connecting, the dismantling of the tube used in the blowing process, the distribution of materials during construction, access to the main routes so it is also divided into two above and below lines to make construction. The blowing holes, after calculating and considering the amount of space and materials to blow, they will set up the tunnel into two above and below lines about from 0.5 to 1 m as shown in **Figure 6.7-5** and **Figure 6.7-6**. The designed holes are according to the actual damage conditions and should be stated before construction. They have the same distance as the blowing hole drilled on the arched roof of the tunnel.

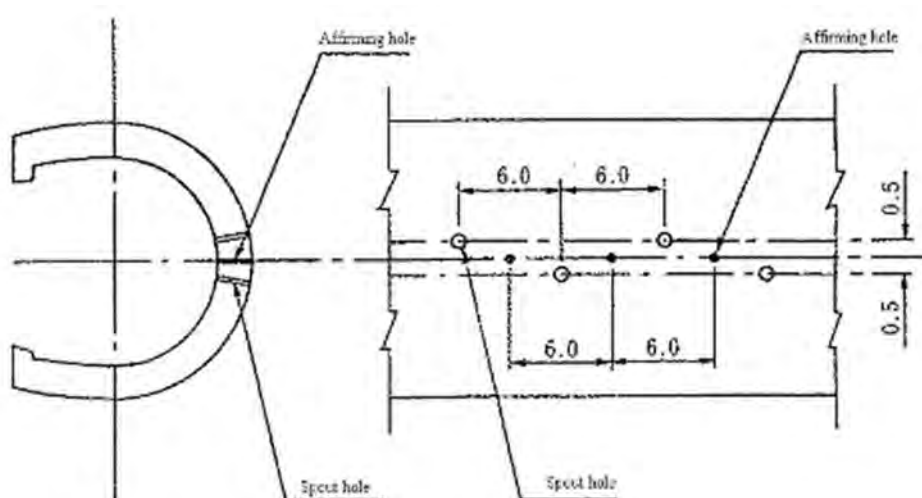


Figure 6.7-5 Illustration of blowing pipes arrangement

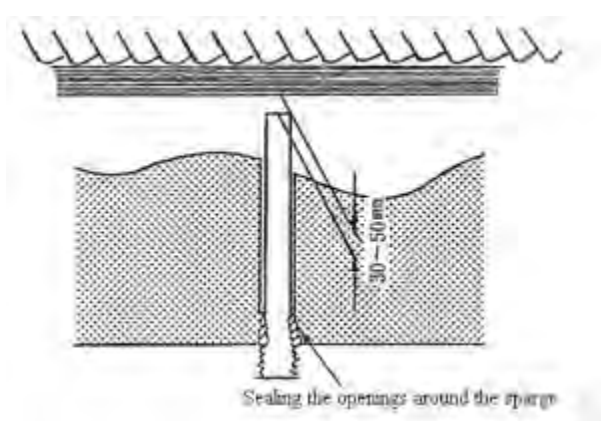
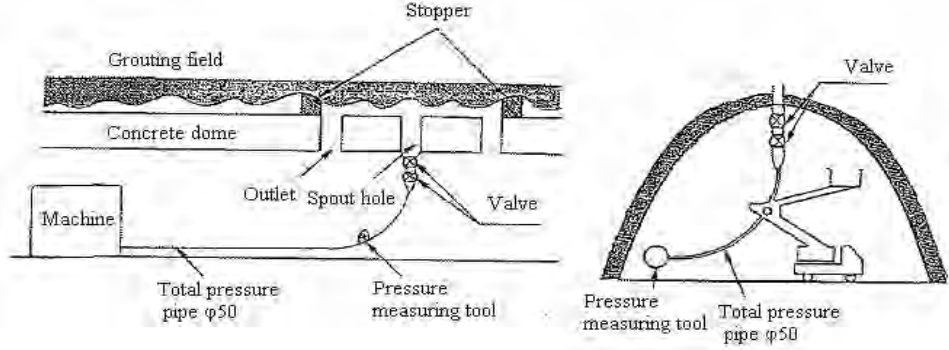


Figure 6.7-6 Illustration of blowing pipe installation

Table 6.7-10 Table distinguish and compare the types of materials used in construction

Items	Method of construction GROUT STOPPER	Method of construction AIR MILK	Method of construction AIR MORTAR	Method of construction BENTONITE cement
Drawing				
Typical features	This prevents the spreading of the material injected into the construction work to other places. It shall be poured into specified locations only. Freezing time (gel time), the type of material based on cement groups, and the LW group are adjustable.	The dorsal side of the tunnel is atomized a mixture of a foaming agent and airmilk at a low pressure (1 to 2kgf/cm ³). This method offers higher mobility, wide-scale spraying yet a great leakage. Distance of total pressure pump is over 500m.	Sand is poured in. Mobility is lower than that offered by airmilk. Bearing strength, whereas, is far better. Its compressive strength is about 10kgf/cm ³ . Effective distance of total pressure pump is less than 300m.	Cement without a foaming agent is mixed with bentonite. Its mobility is far lower than that of airmilk and airmortar. Bearing strength is expected to reach over 10kgf/cm ³ and effective distance of total pressure pump is less than 300m.
Registered items	The materials included in the cement group are cheaper than others, but it is more costly using them to make a stopper in comparison with the construction methods of airmilk, airmortar, or bentonite cement; so, they are used limitedly at some points. Grout stopper + airmilk Grout stopper + airmortar Grout stopper + bentonite cement	Easy to freeze and unseen points become visible under strength. When the foaming agent works, its volume is doubled, but its proportion is smaller than that of water $\gamma = 0.6$. Machines can be installed outside the tunnel. Able to withstand pressure when the foaming agent takes effect.	The ability to freeze is slower than that of airmilk, bearing strength is secure at 10kgf/cm ³ level. The distance of total pressure pump is not advantageous, so machines must be installed inside the tunnel. However, mobile machines are expected to be manufactured. Able to withstand pressure when the foaming agent takes effect.	Combinations are different but able to withstand a pressure of up to 20kgf/cm ³ . The distance of total pressure pump is not advantageous, so machines must be installed inside the tunnel. However, mobile machines are expected to be manufactured. Able to withstand pressure when the foaming agent takes effect.

- Grout

Press operation must be carried out based on the quality control of materials, recording the regime of construction, coherent construction management (e.g. certifying state of the pour)

Compressor, as shown in **Figure 6.7-7**, the majority is formed by gout mixer and grout pump.

Press pressure for the new tunnel that is constructed, usually 3kgf/cm^2 , but in the case of cracking, due to the risk of distortion, so besides confirmation before seeing lining can withstand the pressure or not, need to manage the press pressure from $1.5 \div 2.0\text{ kgf/cm}^2$. In addition, have to prevent leak of beam materials by caulking.

Therefore, it must set up pressure gauges having accuracy from 0.1kgf/cm^2 or more to measure the press force. In particular, in part of the grout pump, the speed and pressure of the material in the pipe when concreting can affect the productivity and efficiency of press that should pay attention in determining the amount of mixing, pumping capacity and diameter of pipe, it must try not to lose the balance between those factors.

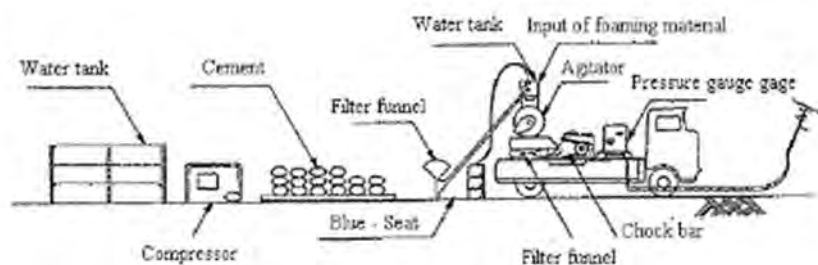


Figure 6.7-7 Diagram of equipment

6.7.4.2 Breaking base, projecting net

(1) Overview

For danger of falling lining material due to aging factionary material such as crack, breaks in the surface of lining backing in the relatively narrow scope, this method of construction is a solution to fix protecting net in surface of covered backing by bolt anchor, against falling. Illustrations presentation is in **Figure 6.7-8**. For example, there are many cases of construction which simultaneously use two measures: rescue and policy

(2) Key issues of design and construction

- Like a treatment method before constructing, the aging parts seem to fall off need to be considered as falling parts.
- Installing hinge bolt over $2\text{ pieces} / \text{m}^2$ that make protecting grid not be fallen out by wind force of passing cars.
- For protecting grid, select the type with small mesh, small weight, not cause load for lining backing. In addition, it needs to select material of protecting grid having fire resistance.

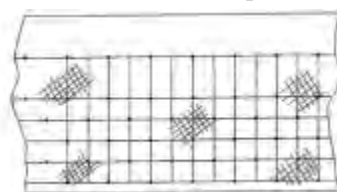


Figure 6.7-8 Protecting grid

6.7.4.3 Concrete blowing

(1) Overview

This is a construction method by blowing grout and reinforced concrete at 100 ÷ 150mm of thickness in surface of lining at a relatively wide range, is complete repair-assisted solution or repair a part of the lining's surface for trouble of peeling the lining's surface of the tunnel. If there is not a reliable guarantee of adhesion between gunite concrete and lining concrete, it may cause peeling of the blowing material. So, in the blowing construction method, treat lining surface is conducted, as splinter proof, to have integration of materials by metal grid attached consistent anchor with the lining works were done before.

However, this method of construction has many different types of materials, depending on the degree of deformation and condition of construction; therefore, it must choose the appropriate type responding to the situation.

- Grout + metal grid
- Concrete + metal grid
- SFRC (Servo-assisted concrete with steel wire)
- GFRC (Servo-assisted concrete with glass wire)

(2) Key issues of design and construction

It should stipulate structure of concrete and blowing grout to gain grout type with good strength, adhesion and construction. In particular, in the case of mixing glass and steel wire, it needs to calculate carefully effectiveness and construction.

In order to support in bending and anti-peeling by integration, adding metal grid that is coherent with disfigurement. However, if metal grid is escaped after blowing will cause corrosion, cracking, peeling, need to set up the covering appropriately.

Gunite concrete often arises rebounding, so in the case of constructing by passing a side, must pay attention to the exchange of gas and dust, precaution not to affect the rebounding for vehicles passing through.

When constructing base floor, drying occurs too quickly will generate cracks, is the cause of subsidence, therefore, it needs to pay attention to concrete maintenance in the first time and avoid constructing with low temperature

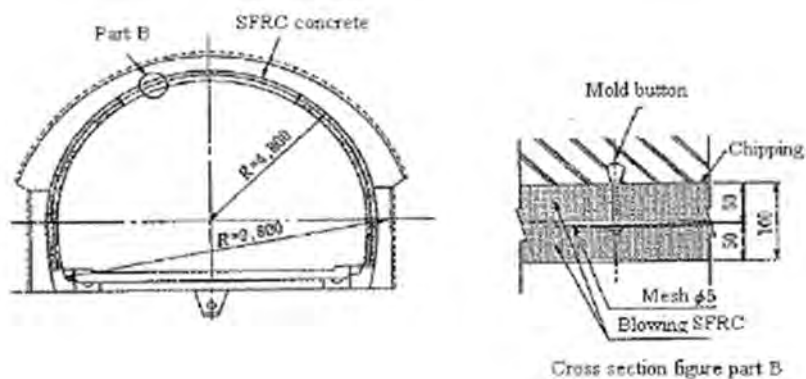
To have integration with lining backing that was constructed before, need to establish breech button 1 piece/m².

After constructing gunite concrete, there is a case appearing the phenomenon of moving rock on outside wall. Main cause is due to limitation with low background and lack of quickly stable admixture. It should be noted during the construction process.

Construction method of gunite concrete having dry type and wet type, each one has its own advantages and disadvantages. Note to the condition of the construction site to choose the method of construction.

Table 6.7-11 Comparison between the method of dry and wet construction.

	Dry construction	Wet construction
Quality of concrete	Because of mixing water with dry substance by nozzle, quality depends on heat miscibility and capacity of operator.	Because it calculated types of materials before (including water) exactly, it is easy to manage quality.
Limitation of action	Dry material was availably mixed at certain level, so there is no limitation in action of material delivery.	Having crossed limitation in action of material delivery
Distance of displacement	Can displace at a relatively long distance	Not be suitable to displace at a long distance
Generated dust	Relatively much	Relatively little
Rebounding	Relatively much	Relatively little
Space of action	Small-size action machine	Large-size action machine

**Figure 6.7-9 Illustration of gunite concrete maintenance by SFRC (unit: mm)**

6.7.4.4 Locking bolt

(1) Overview

For the deformation caused by external forces such as the elastic pressure, unsymmetrical pressure, this method of construction will close the locking bolt into the base, forming the assumed structure in a part of the base around the available structure, in order to achieve effectiveness of internal pressure, raising moving pressure of base.

Locking bolt is classified according to adhesive form is the comprehensive and dead end cohesive types, in addition, classified according to the hole drilling method, there are grout and the type of hole drilling (**Figure 6.7-10**). However, it should use locking bolt having dead end exposure will be limited by hard rock or average hard rock, hereinafter present a comprehensive cohesive is major (**Figure 6.7-11**).

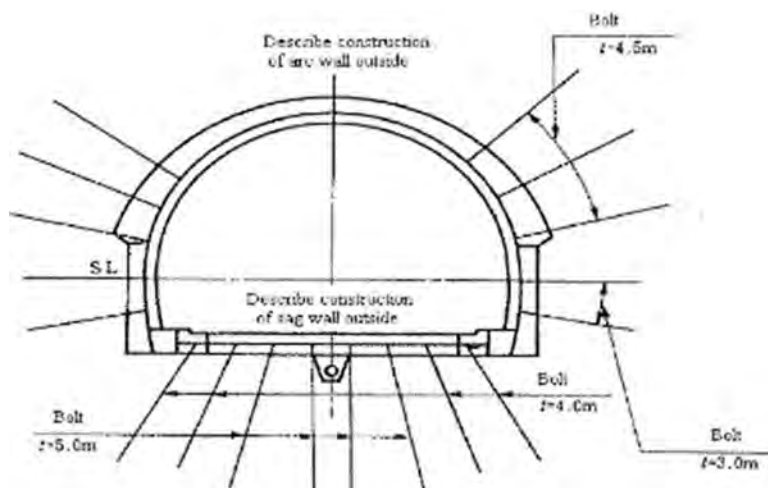


Figure 6.7-10 Illustrates construction of locking bolt

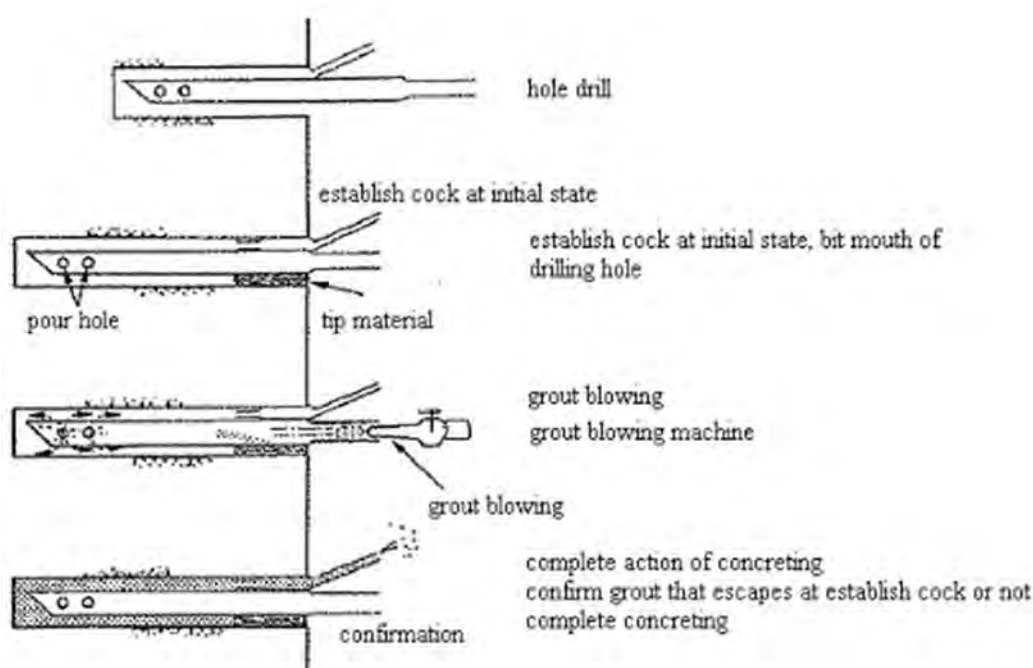


Figure 6.7-11 Construction sequence of bolt to drill hole

(2) Key issues of design, construction

When designing, grasp accurately condition of soil substance, pitch, the length of the bolt should be based on standard form of formwork, at the same time, needing to confirm resistant capacity to stretching force by experiment.

The important thing is along with the design of bolt's length, must try on constructing in the original position, measure the force of locking bolt axis, measure displacement in the soil.

Land foundation through the annual change, capability of aging is high, so it will arise rough holes and large holes in drilling, causing difficulty to construct. In this case, use the locking bolt to drill hole, for the type of cement and in the urgent case, it needs to consider renovating the ground by using

concrete materials such as urethane, silicon glue. However, in the cracked tunnels, pressure may increase the risk of breakage, so it needs to construct at pressure does not affect the lining.

Depending on the condition specifying the route should select construction machine and length of bolts.

Depending on the state of deformation, there is a case to create pressure

Table 6.7-12 Characteristics to select comprehensive adhesive- type locking bolt

Types of bolt	Cement	Field of application (level of spring water)	Function	Drill jig
Backfill type by grout	Grout	Much ↑ Little	Hole, grout backfill, bolt with type of comprehensive adhesive when plugging bolt	Drill jumbo
Type of compression	Cement passage having quick toughness, dry grout	Much ↑ Little	Pour adhesion at level 1.3 shot	Drill jumbo Leg drill
Self-drill hole type	Grout, urethane	Much ↑ Little	Pour adhesion material from the central hole Using screw should be optional on selecting the length of bolt Can select auger according to ground base Good adhesion by deformed steel bar	Drill jumbo Leg drill
Casing type	Grout, urethane	Much ↑ Little	Be easy to construct in ground having subsidence Can pour at high pressure Can use equipment, construction machines that have ever had	Drill jumbo

6.7.4.5 Anti-seepage construction

(1) Overview

This is the most common method of construction, regarded as a policy for the watermark by cracking of lining and long-term used concrete.

However, this method is suitable for the case of water leak is not agglomerated, for case of anti-setting water in cold places.

To select the effective water leakage protection technology, we need to rely on status of water leakage and environmental conditions. The methods can be combined in proper way. Typical water leakage protection technology and selection table of water leakage protection methods are shown in **Figure 6.7-12** and **Table 6.7-13**.

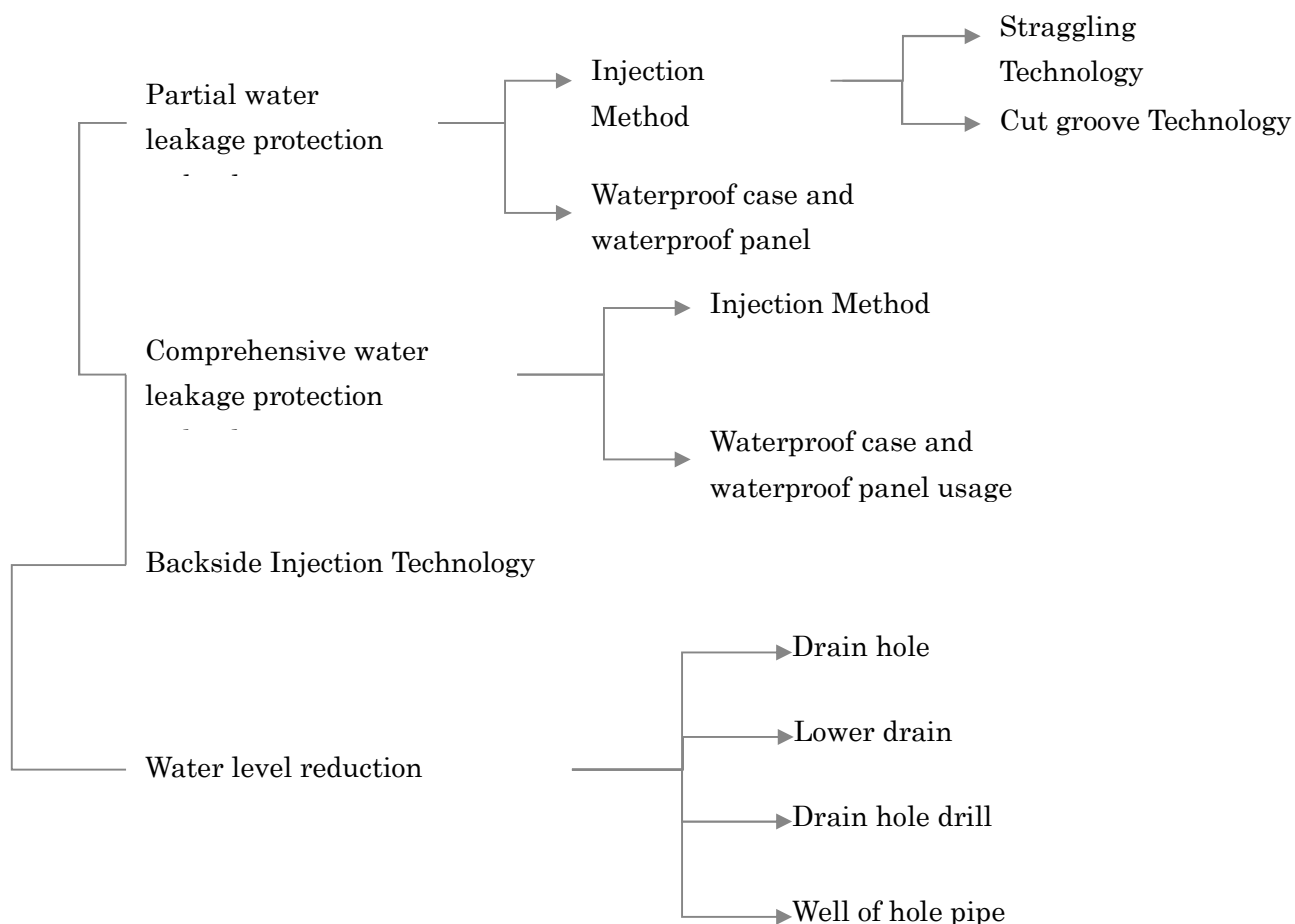


Figure 6.7-12 Typical water leakage protection technology

Table 6.7-13 Water leakage protection methods

Reason Solution		Input Water Amount (Small)		Input Water Amount (Large)	
		Excessive section in tunnel (With)	Excessive section in tunnel (Without)	Excessive section in tunnel (With)	Excessive section in tunnel (Without)
Partial water leakage protection technology	Water gutter Technology		○		○
	Straggling Technology		○		
Comprehensive water leakage protection technology	Injection Technology	○		○	
	Cover Technology		○		
	Waterproof case and panel	○		○	
Backside Injection Technology					○
Water level reduction					○

6.7.4.5.1 Irrigation method

(1) Overview

Irrigation Method is a way that we make water along the leaking location so that the water line is not blocked, mainly for maintaining the spatial landscape in the tunnel. It also helps us adjust the cross section of water output depending on the more or less amount of drainage water.

As shown in **Figure 6.7-13**, this is vertical water gutter technology that is designed as a water pipe outside the tunnel, and the tunnel surface makes up U or V-shaped. The vertical water gutter method is one of irrigation methods through the installation of plastic or synthetic rubber pipe.

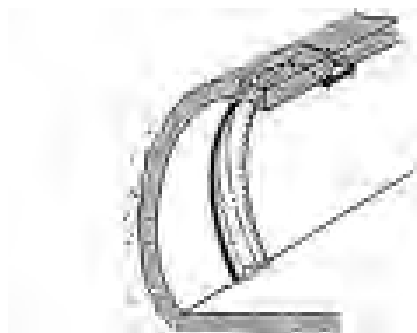
In vertical water gutter technology, the material on the surface of the concrete tray is fixed by rivets. Although it is not beautiful, it is easy to clean up in case of congestion by cement.

Straggling Technology is the one that grooves are made in the concrete surface for irrigation, in which U-cutting method, which is cut from rectangular, can ensure cross section is larger than the V-cut ones and build broken lines, curves, ... In addition, because the surface is protected by synthetic rubber which is elasticity, highly insulated, it is useful for the solid surface.

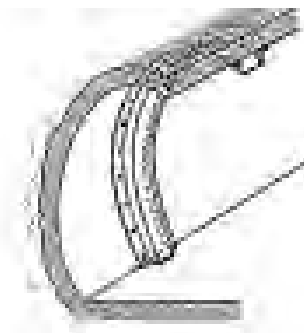
The two methods as mentioned above are selected depending on the location and amount of water leakage.

(2) Key issues of design and construction

- Select materials for long-term use (durability)
- Understand the status of water input, and ensure cross-sectional area of the drain pipe in accordance with the amount of water flowing into it.
- Based on the relationship between the location of machine and the quality of slice surface in the mine, it is necessary to look at the water-spout installation's location carefully.



Straggling Technology



Vertical water gutter technology

Figure 6.7-13 Irrigation Method

6.7.4.5.2 Technical measures to block water

(1) Introduction

The technical measures to block water is the measures which reduces the amount water released by blocking water flow in small gaps because water flows along the joints or cracks-connectors where water leakage generates.

As described in **Figure 6.7-14** and **Figure 6.7-15**, these measures include blocking the streams and cover crack without groove.

(2) Key issues of design and execution

It is necessary to choose reasonable materials and methods, where is setting time is the most important.

In the case of water leakage condition, it is necessary to choose hydrophobic material.

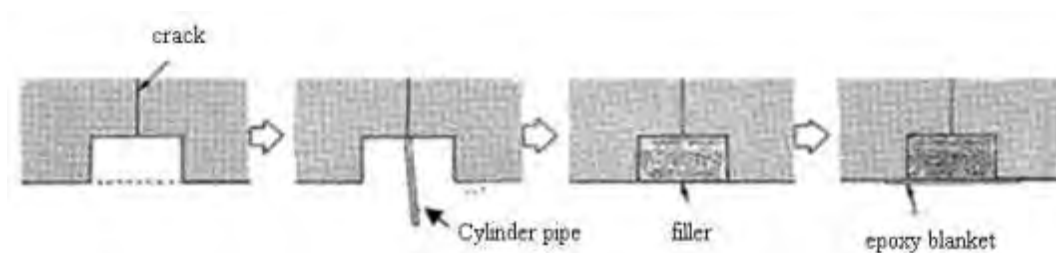


Figure 6.7-14 Water anti-seepage method according to U cross section

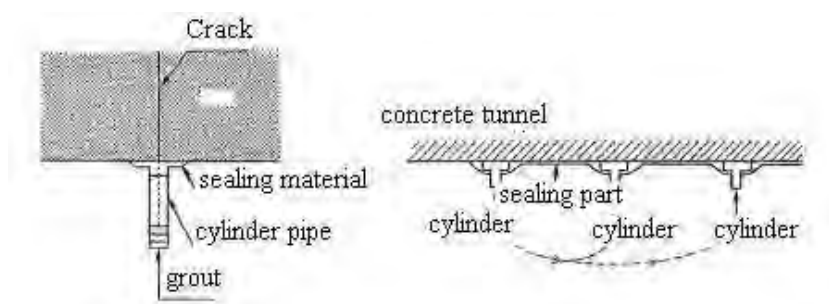


Figure 6.7-15 Water anti-seepage method by spraying crack

6.7.4.5.3 Method waterproof, waterproof coated panels

(1) Overview

This is the method of surface water, used in the case of water leakage on the surface a little or simultaneously with measures of other reliable water leak.

FPR, polymer (vinyl-chloride, etc.) is essentially used waterproof coated panels, waterproof coated plate uses polyethylene on its surface to drain water.

(2) Key issues of design and execution

- Material selection

Waterproof-coated panels: strong, fireproof

Waterproof coated plates: including 3 types such as vinyl- chloride (PVC), polyethylene (PE), Ethylene Vinyl Acetate (EVA) fireproof and, thick over 0.8mm.

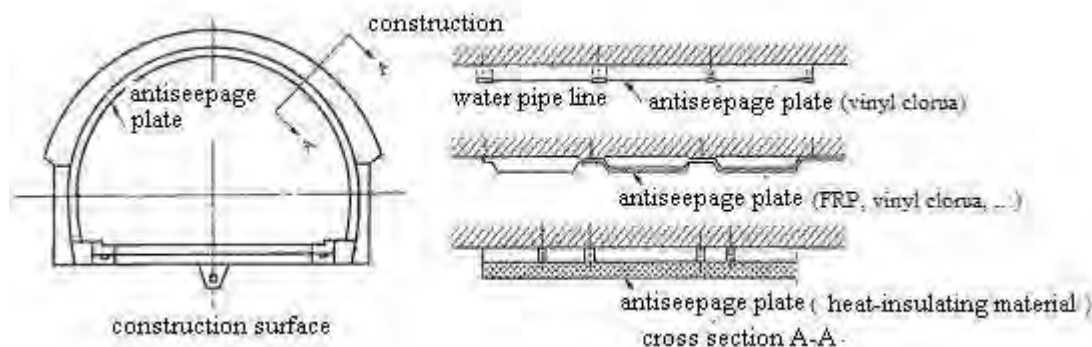


Figure 6.7-15 Illustrate using anti-seepage

- Considering the suitable position of cross-sectional shape, make sure the cross-sectional area of the tunnel arch.
- Before proceeding, it is required to perform cables protection and sanity, cleaning the dirt, preparing for construction can proceed smoothly.
- Both waterproof covers and panels must be carried out treatments at the edges and margins correctly, take caution not to let water leak for a long time.
- With crack rails, it is necessary to create specialized window design for supervision and inspection.

6.7.4.5.4 Method of backside covers spraying

(1) Overview

This is the method in which a liquid like cement or molten glass is plastered from the inner surface of the tunnel or from the ground surface, to the back of the tunnel or to the land in the middle of the mountains in order to prevent water leakage.

In addition, generally, counter-tactics for soil pressure would normally be carried out, so this method is also used in the case of binding tunnel to the mountain land through filling the gap in the dorsal surface of the tunnel, to balance the pressure that the land impacts on the tunnel.

(2) Key issues of design and construction

In the selection of wedging agents and methods of wedging, it is necessary to fully explain the principles of effective filling-up and osmotic properties of the wedging agents, then consider soil conditions and the other conditions. In addition, the molten glass is not considered as the only effective waterproof material, but the method of wedging spray with ash powder burnt at high temperature... also needs to be developed.

The conditions required in the wedging spray are stated in the following categories:

- To be able to penetrate deeply into the interstices of the soil and cracks of the rocks, it is necessary to reduce the viscosity in the first period (viscosity before solidification and gelatinization) as much as possible.
- After solidification and gelatinization, the spray material should be observed as highly durable, not to be divided, shrink... but show stable waterproof property.
- Stabilize all the environmental factors in the long term.

- The mixing and using of wedging agent are quite simple, moreover, it is also easy to adjust its solidification and gelatinization time.
- Solidification and gelatinization reactions are hardly affected by the diversity of chemical and physical properties of the mountain ground.
- Does not include matters polluting the mountain area and the groundwater.

Because the crack can expand as a result of spraying pressure, so before implementation, along with analyzing whether the tunnel can withstand wedging pressure, it is also necessary to maintain the spraying pressure at about $1.5 \div 2 \text{ kgf/cm}^2$.

After spraying, to prevent the rise of the groundwater, it should be designed to create drainage holes on the wall.

(3) Common measures to assess injection efficiency

Test drill holes and collecting documents, along with the condition assessment through observation and phenolphthalein reaction, the soil strength also needs to be good for the air compression test.

Check the efficiency in blocking water for the test of water soaking into the field test.

Suitability between environmental conditions and the wedging spray method is presented in **Table 6.7-14**.

Table 6.7-14 Suitability between environmental conditions and the wedging spray method

Spraying Method/ Ground condition		PP Double Tube Packer	Single Tube – PP Road	Double Tube - PP neighboring coalescence	Double Tube – PP Road resultant	Grouting- PP Blow grout
Rock sheet	Normal crack		○			
	Multiple crack	○	○			
	Break each particle	○	○			
	Sand surplus	○				△
	Clay	○				△
Binding formation	Array lava stone	○	△		△	△
	Semi-frozen sandstone	○			△	○
	Flexible stone with mud state	○			△	
Normal soil horizon	Even and steady sand	○	○	△	○	
	Medium sand ~ crude	○	△	○	○	○
	Grained sand	○		○	○	○
	General sand	○			○	△
	Clay	○	○	○	○	△

○: accommodated

△: unsure accommodation

6.7.4.5.5 Lowering the water table

(1) Overview

This construction method is lowering the water table in the back of the tunnel liner or groundwater levels near the construction of the tunnel, to prevent water leakage with interstitial sand drift into crevices.

The common method is the construction of lowering the water table of the behind tunnel's lining, to arrange installation of the drainage holes, deep down drains response; but in special situations is

lowering the water table near the construction of the tunnel, it must consider the construction to the case of horizontal drains in the direction of the tunnel axis.

(2) Key issues of design and construction

- To prevent incidents such as drainage holes rules, it is necessary to use materials with filtering.
- In the case of lower drainage system, should be noted carefully, grasp the disfigurement occurs.
- When applied to the drain, in addition to the usual investigation, need to understand the status of groundwater and geological conditions of the peripheral area of the tunnel.
- Need to handle the end of the flow from the end of the drainage holes to drain

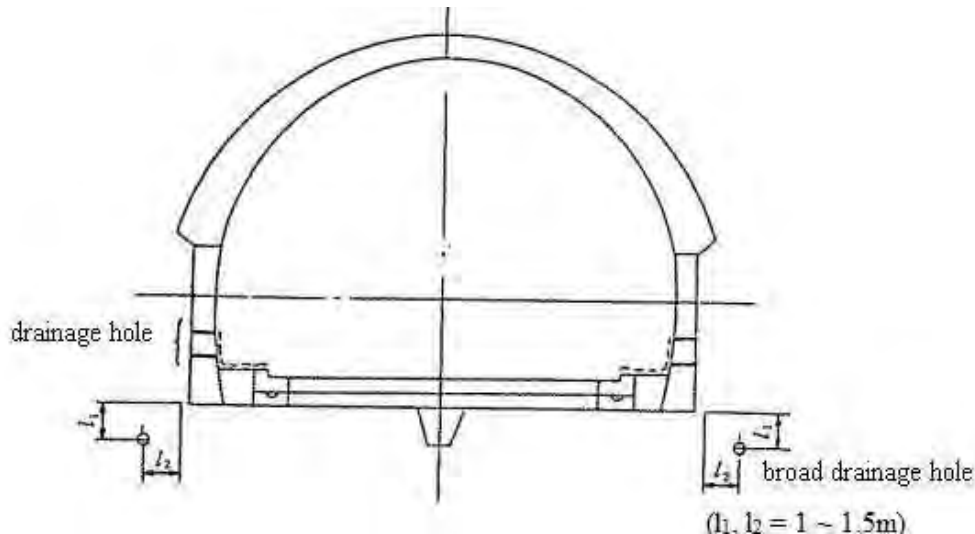


Figure 6.7-16 Drainage hole

6.7.4.6 Internal rolled concrete

(1) Overview

This implementation method is applied to the phenomenon of deformation caused by damage to the material as well as the impact of external forces such as pressure, in the case, it can be easily seen that the coil thickness which is still spacious enough inside in the cross section of the tunnel, can reinforce more concretes into available lining coat (180kgf/cm² design strength), increasing surface area in order to strengthen the overall endurance capacity of works.

This method is not very suitable in case of continuous traffic, so it is recommended to apply construction methods called PCL (the method of using armored concrete arch bars with highly mechanical strength in light red color which have been shed available at the assembly construction site inside the tunnel), thereby reducing the traffic problem.

(2) Key issues of design and construction

- Decision on coil thickness must be considered carefully based on the inner damaged state, external forces such as pressure, excessive space inside the cross-sectional area ... as well as considering similar cases in the past. Besides, it is feasible for rolled thickness of 12.5 cm or more. In the case of about 12.5 to 15 cm, it is necessary to discuss to maintenance contractor for the feasibility and the economy.
- On the disposal prior to the construction, to ensure adhesion of the concrete tunnel, the cross-

sectional tunnel must have a depth of 1 cm to 2 cm, as shown in **Figure 6.7-17**.

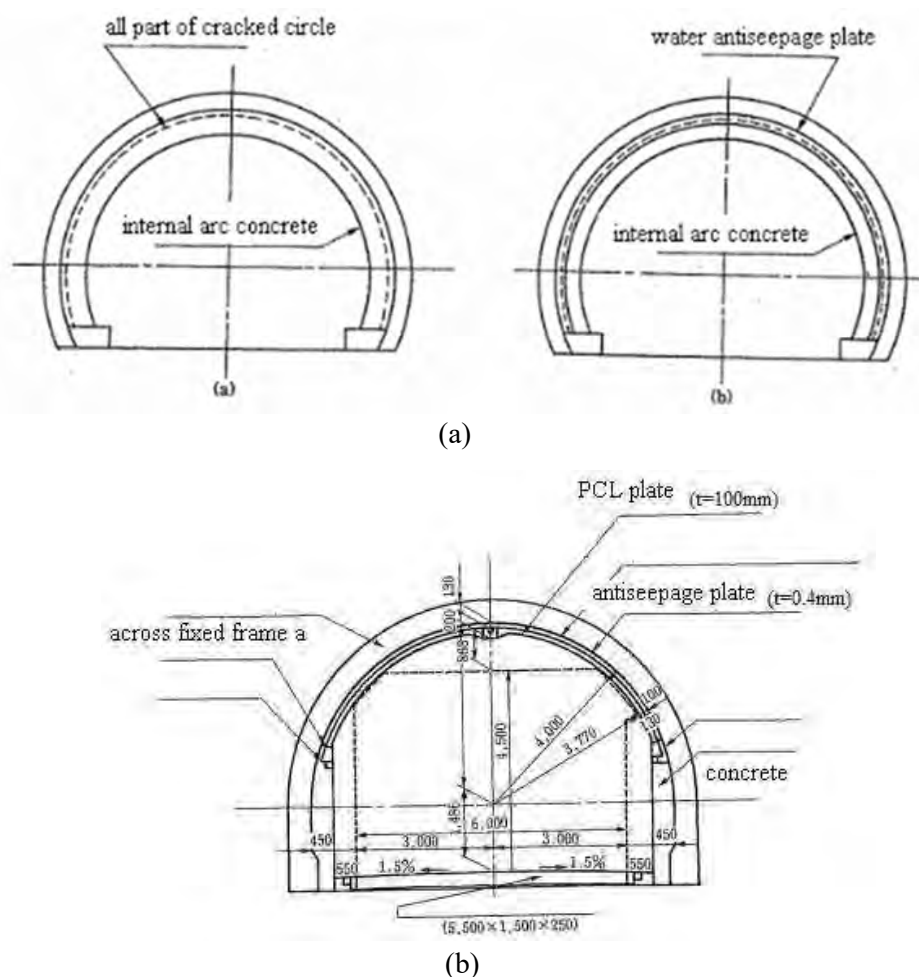


Figure 6.7-17 (a) - Construction method of internal arc concrete; (b) - Illustrate PCL construction method (unit:mm)

- In case of being designed in the unified purposes the previous construction, depending on the construction, after applying adhesive glue to joints, installed on 2 sheets/m². The thickness of the inner layer is made thicker while not using the same previous methods, it requires to use the tempered glass construction and waterproofing, as shown in **Figure 6.7-17 (b)**.
- In case of inner section not having the extra space, reinforce the tempered glass capacity, and use anti-fall caused by cracks, using efficient construction method as sticking fiberglass or carbon fiber.

6.7.4.7 Cleaning the road at tunnel

(1) Introduction

Road tunnel is often dirty because of rain and there are no places to flow, so the best way is to regularly clean the road, however in fact the cleaning of the road tunnel is usually carried out at the same time as the normal road surface.

When cleaning the road tunnel, it is necessary to consider the status of dirt and traffic planning. Tunnel cleaning can be considered as periodic maintenance.

(2) Cleaning the tunnel's walls and furniture

Wall and the interior materials in the basement can obstruct the view when soiled; reduce lighting efficiency so it needs to be maintained in a good condition.

The wall of road tunnel is blackened by automobile's smoky emission, which cannot be washed by water. In order to increase effective of cleanness, it should be cleaned by water with detergents. When using detergent, do not select the type of corrosive equipment in the road tunnel but select the neutral type, because it can be dangerous for the vehicles and for the cleaners.

In addition, it will be more effective by using sprayed detergent together with machine brush. Waste wash water should be considered as it can affect the environment.

In addition, when cleaning, it should be careful not to break down the equipment used in an emergency and should not let them watered, so as not to degrade the functionality of these devices.

(3) Cleaning lighting devices

The lighting devices in the road tunnel can be contaminated by smoke and dust to impair lighting function. It should be considered for maintaining and cleaning periodically.

It is noted that should use soft cloth or cotton tip to clean lighting devices in order not to affect the glass of the lamps and reflector plates. At the same time while cleaning, it should be careful not to splash the lights or the wiring.

(4) Cleaning sewage system.

Wastewater system at the mouth of the road tunnel often impaired in terms of function as sand, dust settle and harden. In addition, in case the drainage in road tunnel is not good it will lead to damage the tunnel pavement, to dust and to ruin the coating walls and furniture in the road tunnel. So it is necessary to carry out cleaning sewage system periodically.

Water mostly used when cleaning the road tunnels, so before cleaning, it is necessary to check the status of drainage and culverts, and to keep them in a good condition.

2) Cleaning other devices

When the warning device is abnormal, other display devices located in the road tunnels contaminated, it will make visual observation decreased so together with checking the functions of those devices, it also needs to clean the surface of them.

3) Frequency of cleaning

Frequency of cleaning should be based on actual conditions, such as type of road, traffic volume, the character of the surrounding area, and in general, in case of being more and more traffic, the frequency of cleaning should be increased.

6.8 Culvert Box and Pipe Culvert Maintenance Management

6.8.1 Introduction

6.8.2 Typical Damages Observed

(1) Damages on the Reinforced Box Culvert

- Cracks/ corner drop
- Peeling
- Rebar exposure
- Void
- Water leakage from joints/Free lime
- Settlement
- Joint Damage

(2) Damages on the Reinforced Concrete Pipe Culvert

- Cracks/ corner drop
- Peeling
- Rebar exposure
- Settlement
- Connection joint damage
- Drain function

(3) Damages on the Corrugated Metal Pipe Culvert

- Structure damage
- Corrosion
- Settlement
- Connection joint damage
- Drain function

6.8.3 Inspection of Culvert Box and Pipe Culvert

6.8.3.1 Focus Points of Inspection

- (1) The Box Culvert does not have pile support, settlement or uneven settlement of the Box Culvert facility is caused by insufficient bearing capacity of foundation under Box Culvert facilities.
- (2) Damages often comes out in the form of concrete cracks and peering on the body, damages on the joints between Box Culvert segments and on the connection joints with neighbour Drainage Systems.
- (3) In particular, uneven settlement causes transverse concrete cracks on the Box Culvert.
- (4) Insufficient height clearance caused by the settlement of Box Culvert often becomes a cause of vehicle collision, so that some traffic control measures including installation of traffic signs are needed.
- (5) In the case of the water way Box Culvert, water leakage and scouring at the joint between Box Culvert and waterway often cause the degradation of bearing capacity under Box Culvert and provide damages to neighbouring facilities such as Retaining Wall, concrete block masonry, waterway, etc.

6.8.3.2 Inspection Points

Road facility inspection for culvert facilities shall be implemented on the inspection points shown in **Table 6.8-1** for Box Culverts and in **Table 6.8-2** for Pipe culverts

Table 6.8-1 Inspection Points (Box Culverts)

Facility	Member	Damage	Initial inspection	Routine inspection	Periodic inspection	Emergency inspection	Detailed Inspection
Box Culvert	Reinforced Concrete Box Culvert	Cracks/ corner drop	X	-----	X	X	As required by Routine or Periodic Inspection
		Peeling	X	-----	X	X	
		Rebar exposure	X	-----	X	X	
		Void / Honey comb	X	-----	X	X	
		Water leakage from joints/Free lime	X	-----	X	X	
		Settlement / Scoring	X	X	X	X	
		Joint Damage	X	-----	X	X	

Table 6.8-2 Inspection Points (Pipe Culverts)

Facility	Member	Damage	Initial inspection	Routine inspection	Periodic inspection	Emergency inspection	Detailed Inspection
Pipe Culvert	Reinforced concrete pipe culvert	Cracks/ corner drop	-----	-----	X	X	As required by Routine or Periodic Inspection
		Peeling	-----	-----	X	X	
		Rebar exposure	-----	-----	X	X	
		Settlement	-----	X	X	X	
		Connection joint damage	-----	-----	X	X	
		Drain function	-----	-----	X	X	
	Corrugated metal pipe culvert	Structure damage	-----	-----	X	X	As required by Routine or Periodic Inspection
		Corrosion	-----	-----	X	X	
		Settlement	-----	X	X	X	
		Connection joint damage	-----	-----	X	X	
		Drain function	-----	-----	X	X	

6.8.3.3 Inspection Methods and Frequencies

Inspection methods and inspection frequencies in principle shall follow the relevant articles of this Guideline.

6.8.3.4 Evaluation of Inspection Results

- (1) Evaluation of the results of routine inspection, periodic inspection and emergency inspection shall be conducted, following relevant articles in this Guideline. Sample evaluation criteria for Concrete

Box Culverts and Pipe Culverts are shown in **ANNEX-G**. Also, particular notes for the evaluation of some major damages are described below;

- (2) The Box Culvert does not have pile support, so that culver box is in general set higher than the design height, assuming some settlement caused by consolidation of bearing layer. However, if settlement occurs larger than expected, gaps in height between approach road and the culvert becomes wider. The damage is rated as “C” in this Guideline.
- (3) When water leakage occurs at the end joint of culver box and infiltrates into the bearing layer of the culver box, it may degrade the bearing capacity of the culver box or scour the foundation of neighbour facilities. The damage is rated as “C” in this Guideline.
- (4) When damages include the opening of gaps and difference in height on the joints of pipe culver box facilities progress, it may break water-stop plate, cause water leakage and falling of water-stop plate. The damage is rated as “C” in this Guideline.
- (5) When drain function is degraded due to the damages at the joints of Drainage Systems or due to the piling of debris in the drain systems, thereby causing water leakage from the joints, the damage is rated as “C” in this Guideline.

6.8.3.5 Data Registration and Reporting

Registration of inspection data shall be conducted, following relevant articles in this Guideline.

6.8.4 Planning and Implementation of Maintenance and Repair

Planning and implementation of maintenance repair work for culvert box and pipe culvert facilities shall follow that for road tunnels, “0

Road Tunnel Maintenance Management”.

6.9 Retaining Wall Maintenance Management

6.9.1 Introduction

Retaining walls are structural support to prevent slope failures or landslides where natural or structurally protected slopes cannot ensure the stability of slopes due to topographic reasons or limited availability of land. Retaining walls shall have damages such as cracking, swelling, falling down due to the change of load working behind wall or the tope of wall, or may be leaned or broken due to subsidence of wall foundation.

This manual regulates

To renovate and upgrade the retaining walls, embankments system, the topography of the area, geological features, biological condition of the carpet slope, materials, land use status, meteorological characteristics.... should be fully aware of and understood properly.

6.9.2 Classification of Retaining Walls

Retaining walls can be classified by used materials and the shape of walls, but in general fall into the following walls;

- a. Stone or concrete block masonry

- b. Gravity-type retaining wall
- c. Cantilever-type retaining wall
- d. Counterfort retaining wall.

6.9.3 Typical Damages Observed

Table 6.9-1 Damages by the Type of Retaining Wall

Retaining wall	Damages
Stone or concrete block masonry	- Cracks, swelling
Gravity-type retaining wall	- Concrete peeling
Cantilever-type retaining wall	- Steel bar exposure
Counterfort retaining wall.	- Settlement or movement
	- Abnormal joint gap
	- Scouring

6.9.4 Inspection of Retaining Walls

6.9.4.1 Focus point of inspection

- (1) Damages of retaining walls shall often appear in unusual weather conditions such as heavy rain, storm, flooding, earthquakes etc., so that emergency inspection shall be implemented immediately after such disasters.
- (2) In case big damages are detected, detailed investigation shall be implemented to evaluate potential hazard and to find out countermeasures. In order to facilitate the designing of repair works, road inventory data including retaining wall initial design data should be preserved.
- (3) Focus points of inspection are shown below;
 - Any concrete cracks, joint cracks, swelling and deterioration of wall surface
 - Leaning, sliding and subsiding of retaining wall
 - Damages on the drain holes, water reserve on the back fill and water seepage
 - Gaps and voids between wall body and backfill soil
 - Damages on wall foundation

In particular, much attention shall be paid on the damages on the drainage systems. The damages often cause imbalanced load working on the back of retaining wall, thereby give serious damages on the wall body.

6.9.4.2 Inspection points

Inspection points of retaining walls are summarized in **Figure 6.9-1** However, the table regulates the minimum requirement of inspection points, so that users can supplement some inspection points whenever needed.

Figure 6.9-1 Inspection Points for Retaining Walls

Facility	Member	Damage	Initial inspection	Daily inspection	Periodic inspection	Emergency inspection	Detailed Inspection
Retaining walls	Reinforced concrete retaining walls and	Cracks	X	X	X	X	As required by Routine or Periodic Inspection
		Peeling	X	X	X	X	
		Steel bar exposure	X	X	X	X	

Facility	Member	Damage	Initial inspection	Daily inspection	Periodic inspection	Emergency inspection	Detailed Inspection
	Stone Masonry	Settlement or movement	X	X	X	X	
		Abnormal joint gap	X	X	X	X	
		Scouring	X	X	X	X	
		Poor drainage or spring water	X	X	X	X	

(Note) X: Inspection items.

6.9.4.3 Inspection methods and Frequencies

Inspection methods and inspection frequencies in principle shall follow the relevant articles of this guideline.

6.9.4.4 Evaluation of Inspection Results

Evaluation of the inspection results obtained in routine inspection, periodic inspection and emergency inspection shall be conducted, following relevant articles in this Manual. Sample evaluation criteria for the inspection results of retaining walls are shown in ANNEX-C.

6.9.4.5 Registration of Inspection Data and Reporting

Registration of inspection data and reporting shall be conducted, following relevant articles in this guideline.

6.9.4.6 Planning and Implementation of Maintenance and Repair Work for Retaining Wall

Maintenance and repair methods for retaining walls shall basically follow those for concrete and reinforcing concrete facilities. Some particular issues to be considered in maintaining and repairing retaining walls are shown below:

(1) Improper water treatment

Drainage system plays an important role in the maintenance and the repair of retaining walls. If it does not function well, ground water or rain water shall accumulates in the backfill soil and causes increase in soil pressure, thereby causes significant negative effects to the wall body. It is therefore necessary to conduct appropriate water treatment and prevent water infiltration into the backfill soil. It is also necessary to lead water to downstream drainage systems.

Some typical measures to treat these water are shown as follows;

a. Prevention of surface water infiltration

- To implement the coverage of slopes by mortar or concrete spraying, concrete blocks, etc. as shown in **Figure 6.9-2**.
- To install a U-shaped drainage system on the slope berm as shown in the figure.

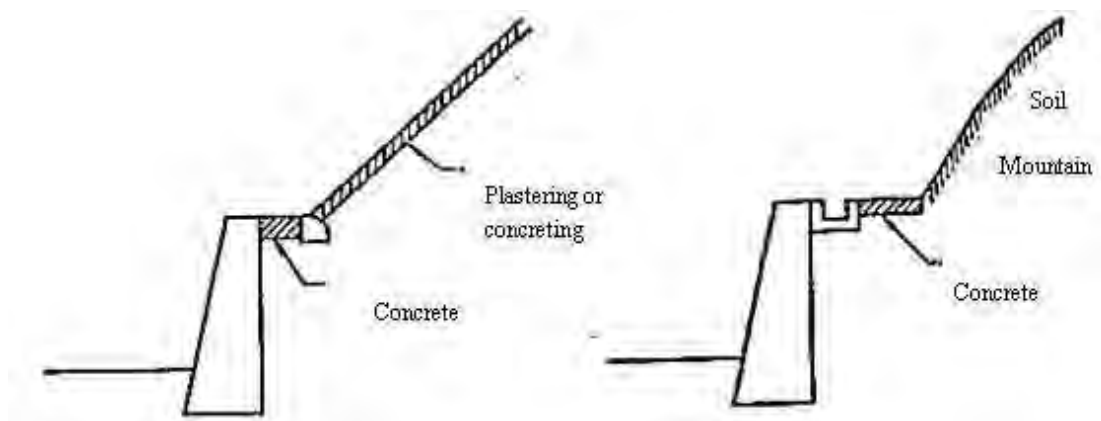


Figure 6.9-2 Sample Water Treatment

b. Release of water pressure

A drainage hole shall be installed to release water pressure out of the wall which is installed once every 2-3m² in water accumulation area on the back. Drainage holes are in general made of PVC plastic pipe with a diameter of 5 to 10 cm. Care should be paid not to fill the pipes with concrete spills or debris during construction.

(2) Gaps or voids arising between retaining walls and backfill soil

It is necessary to fill gaps and voids between retaining walls and backfill soils by using appropriate materials including cobbles, crashed stones and sand. The following shows the implementation methods for small damages.

- Clean and scratch out damaged joint mortar, soil and plants using air compressor, water sprayer, hammer or chisel,
- At the points where the joint needs to be completely renewed, the stone or brick should be removed temporarily until a new mortar bed is placed,
- Water the joint surfaces where fresh mortar has to be applied,
- Mix a mortar of cement and sand as required (1 cement: 3 sand) and add only enough water to permit mortar to be applied,
- Apply fresh mortar to joint, filling all space available, compacting with a suitable wooden hammer. Do not use mortar which has fallen on the ground,
- Smooth joints with a suitable tool (a piece of rubber or plastic water hose, or bent reinforcing steel),
- The final mortar surface should be placed slightly from the stone/brick surface to achieve a tidy finish,
- In the dry season, mortar can dry out quickly. Prevent this by sprinkling water on joints after the mortar has set and until mortar has completely hardened. Alternatively cover the work area with wet jute sacks or similar,
- Clean visible stone or brick surfaces which have been stained by mortar or cement-water in the process of the work so that the finished work will present a neat appearance,
- Remove surplus materials and leave the site in a clean and tidy condition.

(3) Swelling of wall body

The most prevailing method of repair work for this damage is to remove swelled wall bodies and reconstruct wall body again in case swelling is expected to grow. If cracks appear on the stone masonry, cement mortar has been used to fill the crack gaps.

(4) Instability of wall bodies (Leaning)

For cracks on the concrete or reinforced concrete walls, epoxy resin material shall be applied to repair cracks. However, if cracks are expected to grow wider and cause the leaning of walls, repair works shall be carefully selected based on detailed investigation. Some countermeasures are shown below;

a. Anchor works

This method is to distribute tensile force by inserting steel anchors, which are steel materials with high hardness such as PC steel wire and PC bars, into bore holes set in the ground as shown in **Figure 6.9-3**. There are many variations in materials and in design methods, so that further study shall be conducted.

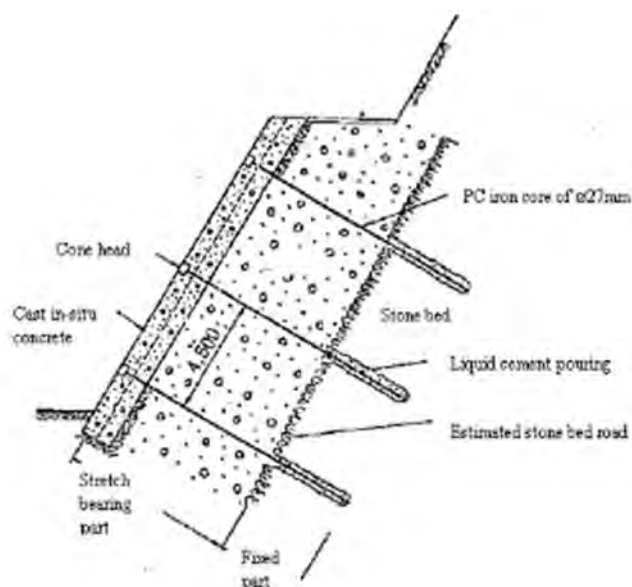


Figure 6.9-3 Example of anchor work

b. Reinforcement of masonry by concrete retaining wall

When the gabion or masonry wall is swelled, sprouted and cracked, which may impede wall body stability, so that it is necessary to reinforce wall body by constructing a new concrete wall on the damaged stone masonry. Care shall be paid to the stability of the overall wall system in designing.

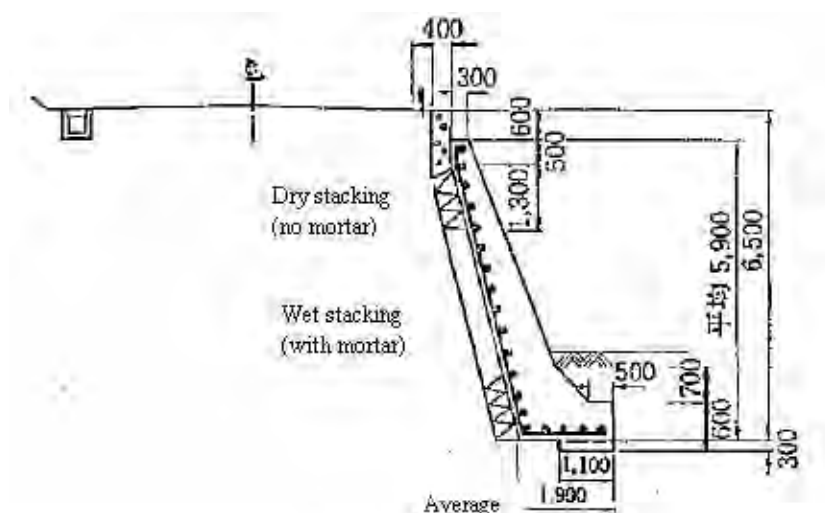


Figure 6.9-4 Stone Masonry reinforcement

c. Reinforcement of foundation

Reinforcement of foundation against damaged foundation shall be made by installing sheet piles, concrete piles and underground wall to reinforce foundation and surrounding area. Also, foundation reinforcement can be made by applying liquid chemicals to strengthen bearing capacity of foundation. However, these repair works in general are very costly, so that a comparative study shall be made on the construction cost needed for foundation reinforcement and reconstruction of retaining wall.

6.9.5 Planning of Implementation of Maintenance and Repair Work for Revetment

6.9.5.1 Introduction

Revetment sometimes shall become a part of road facilities when road is running parallel to river or crossing over the river. Revetment may receive damages such as erosion and scouring by water, so it is necessary to keep watching especially at the foundation of revetment. Expected damages on revetments may include damages to the foundation, erosion of river bank and coastal area, and landslides. In case some damages are detected, it is necessary to study the causes of the damages and to evaluate whether the damages grow bigger.

Inspection of revetment shall follow the inspection methods of retaining walls. In addition, it is necessary to conduct an emergency inspection immediately after storm, heavy rain and to inspect the revetment.

6.9.5.2 Maintenance and repair Works

- (1) Maintenance and repair works for revetment are similar to those for road slope maintenance. The following are the particular notes for the maintenance and repair of revetments,
- (2) In case erosion or scouring is detected, it is necessary to refill additional materials such as stones and to protect revetment by installing concrete frame works, piles etc. to prevent further progress of the damages.

- (3) Revetment slopes shall become vulnerable to scouring and landslides caused by water flow and wave. The problem in general shall initiate from unseen slopes or foundation under water level. It is therefore necessary to conduct emergency inspection to the facilities under water level in particular after unusual weather conditions. When detecting any abnormalities of erosion or sliding, it is necessary to immediately take actions to prevent further progress of these damages.
- (4) When gabion is applied, it is necessary inspect wire corrosion and drop-out of rocks. When damage is detected, it is necessary to repair and reinforce the facility by replacing with a new one or applying concrete brock to the damages.
- (5) In case there is a corrosion of foundation, it is necessary to reinforce foundations by applying piles, wire cylinders, concrete frames to the damaged portions in order to prevent the further progress of these damages.

6.10 Traffic Safety Facility Maintenance Management

6.10.1 Introduction

Traffic safety facilities in the road are mostly the products of the second industry and the forms and types of these products are very diverse. Therefore, when carrying out maintenance, it should understand not only functions but also types and forms of these facilities.

Most of these facilities have specified technical standards when installed. These technical standards should be referred when checking their functions.

Where these facilities are broken, they need to be immediately restored to ensure their functionality. Thus, from the beginning, there must be reserved spare parts or a complete purchasing system.

6.10.2 Classification of Traffic Safety Facilities

Traffic safety facility to be covered in this Guideline includes guard rail, guard cable and delineator/ road reflector

6.10.3 Typical Defects Observed

.Expected damages to be inspected for these facilities are as follows;

- (1) Damages on the Guard Rail
 - Main member damages; Breakage, dropout or tilting of beams, pipes, posts etc.
 - Accessory damages; Breakage or dropout of mounting brackets, dropout or looseness of connection bolts, etc.
 - Foundation damages; Cutting or dropout of anchor materials, or scouring around foundation which leads to the breakdown of guard facilities.
- (2) Damages on the Guard Cable
 - Main member damages; Breakage, dropout or tilting of pipes or guard posts etc.
 - Accessory damages; Breakage or dropout of mounting brackets, dropout or looseness of connection bolts, etc.
 - Foundation damages; Cutting or dropout of anchor materials, or scouring around foundation which leads to the breakdown of guard facilities.
- (3) Damages on the delineator/ road reflector

- Main member damages; Dropout or breakage of reflector, tilting of pipes etc.
- Accessory damages; Breakage or dropout of mounting brackets, dropout or looseness of connection bolts, etc.
- Foundation damages; Breakdown of anchor or scouring around foundation which leads to the breakdown of guard facilities.

(4) Damages on the Concrete Wall-type Guard Facilities

- Concrete cracks or corner dropout

6.10.4 Inspection of Traffic Safety Facilities

6.10.4.1 Focus Points of Inspection

- (1) Guardrail facility damages are mostly the deformation caused by the force of vehicle accident. However, damages are sometimes given to the neighbouring guardrail poles or brackets, so that inspection is to be conducted on the neighbouring facilities.
- (2) Corrosion often degrades the strength of the guardrail facility. When serious corrosion is found on the guard posts or on the brackets during inspection, it is better to examine the thickness of the member with ultrasonic thickness meter if necessary. A past study has clarified that design strength of guard posts driven in the ground is maintained even 20 years after the installation if ground condition is good. However, care should be paid to the facilities installed where ground water level is high.
- (3) Regarding the guard cables, when an upper cable sinks and touches to the lower cable by the weight of inspection staff, the cable tension is deemed insufficient which needs restressing urgently.

6.10.4.2 Inspection Points

Road facility inspection for traffic safety facilities shall be implemented on the inspection points shown in **Table 6.10-1**.

Table 6.10-1 Inspection Points for Traffic Safety Facilities

Structure	Position	Member	Sort of damage	Initial inspection	Routine Inspection	Periodic inspection	Detailed Inspection
Traffic safety	Guard rail	Guard rail/Cable	Main member damages	-----	X	X	As required by Routine or Periodic Inspection
			Accessory damages	-----	-----	X	
			Corrosion	-----	-----	X	
			Foundation damages	-----	-----	X	
			Main member damages	-----	X	X	
			Accessory damages	-----	-----	X	
			Corrosion	-----	-----	X	
			Foundation damages	-----	-----	X	
		Concrete Wall-type guard facility	Cracks/ /corner drop	-----	X	X	

(Note) X: Inspection items.

6.10.4.3 Inspection Methods and Frequencies

Inspection methods and inspection frequencies in principle follow the relevant articles stipulated in this Guideline.

6.10.4.4 Evaluation of Inspection Results

- (1) Evaluation of the results of routine inspection, periodic inspection and emergency inspection shall be conducted, following relevant articles in this Guideline. Sample evaluation criteria for traffic safety facilities are shown in **ANNEX-H**. Also, particular notes for the evaluation of some major damages are described below;
- (2) When deformation or severe damage to beams, pipes or cables or tilting of the support pole is identified, it can no longer fulfil functions of protecting vehicles and drivers on board, so that the damages are rated as “D” in this Guideline.
- (3) When damages are identified, such as deformation, bending and or tilting of the beams, pipes, cables and/or supporting poles, guard function is deemed slightly degraded, so that the damages are rated as “C” in this Guideline,
- (4) When damages are detected on the accessories of guard facilities, such as parts loss, loosening of bolts which lead the main structure damage and so forth, the damages are rated as “C” in this Guideline.
- (5) When severe corrosion is observed on the beam, pipe, cable and/or support pole, degradation of structural strength may occur. If the corrosion spreads wide area, it is rated as “C” in this Guideline, requesting a detailed inspection by applying detailed evaluation of the corrosion including examination of thickness measuring of main members. However, a past study has reported that guard rail facility will work together with those located in the affected area to absorb shocks given by vehicle collision. The affected area of vehicle collision is said about 20 meters, so that diagnosis needs to be made on the facilities located in the affected area, rather than focusing on some specific facilities.

6.10.4.5 Data Registration and Reporting

Registration of inspection data shall be conducted, following relevant articles in this Guideline.

6.10.5 Planning and Implementation of Maintenance and Repair Work

6.10.5.1 Safety Fence

(1) Introduction

Barriers are intended primarily to prevent cars from running out of control and crashing out of the lanes or to the opposite direction, hitting pedestrians. Besides, they also have the following sub functions:

- Keeping the car crash right in the current lanes
- Ensuring the safety of people in the cars.
- Ensuring the safety of pedestrians.
- Reducing damage significantly.
- Navigating the driver's view.

In addition, it can also restrict the pedestrians from going outside the permitted areas and prevent pedestrians or bicycles from going / riding out of the lanes

(2) Restoration

In case barriers are broken due to accidents or natural disasters, malfunction barriers are detected, it needs to record the broken distance, parts, road's condition and damage cause... and then process immediately to promote full protection function of barriers

For the facilities damaged by traffic accidents, barriers account for an especially large proportion and need to be done immediately at the site. When immediate recovery is not possible, for normal traffic accidents, especially at the areas that are considered dangerous, there should be a temporary recovery using available materials in emergency.

The principle of barrier recovery is conducting in accordance with forms, types that have already been installed. In addition, depending on the damage, barriers must be replaced in accordance with installation standard for a certain distance while reused barriers should be reserved for emergency.

In addition, due to the new surface coating (overlay), the distance between barriers and the road surface is greatly reduced. Therefore, it is necessary to adjust height and replace barriers which are too rusty.

(3) Painting

If the barriers' paint is peeled due to scratches or rust, it is necessary to conduct quick repaint. Paint not only provides protection, but also has vision-navigating function. It also enhances the landscape. Paint is vulnerable in traffic areas or in seaside areas where it is susceptible to salt. Therefore, the number times for painting should be more than usual. Before painting, the rusty layer should be scraped off and phosphate lining treatment should be conducted.

(4) Cleaning the fence

With regard to dirty fence and the emissions of the cars involved in not only affect the function of observability and the external beauty but also causes rust, wear and tear, so depending on the dirty level, road situation, the amount of traffic that needs washing, cleaning accordingly.

Cleaning methods can vary depending on the degree of dirt but as per the case of contamination by dust, mud, etc., you can use a cloth or soft brush and wash with water. Also, as per the cases contaminated by car exhaust, black smoke, it is should be used by brushes, steel tufts to clean with neutral detergent. And after using detergents, it should be used clean water to rinse several times to avoid rust.

The cleaning of the long barriers cannot be done by human power, so it should be carried out by machinery. When making use of the machine, it is necessary to use the vehicle equipped with attachment.

6.10.5.2 Delineator/ road reflector

(1) Introduction

It is very important to maintain the common reflectiveness of delineators and road reflectors

Driving in the night to use reflected light rays emitted from the headlamp for the column-view, and because of this delineators function driver should need to keep these columns reflect the brightness with light evenly, not to the phenomenon of a distance, glistening, almost suddenly bright.

(2) Maintenance and Repair

Because they are placed in the road, in regular patrols, we need to pay attention to the state of roadside grass, or grow-out trees. If they affect the functions of delineators and road reflectors, they need cutting and pruning.

Delineators and road reflectors work well in normal conditions. Thus, if they are tilted or damaged, they will look very ugly and this affects landscape badly. In this case, they need be fixed quickly right after inspection.

6.11 Traffic Management Facility Maintenance and Management

6.11.1 Introduction

Traffic management facilities are mostly the products of the second industry and the forms and types of these products are very diverse. Therefore, when carrying out maintenance, it should understand not only functions but also types and forms of these facilities.

Most of this auxiliary equipment has specified technical standards when installed. These technical standards should be referred when checking their functions.

Where traffic management facility is broken, they need to be immediately restored to ensure their functionality. Thus, from the beginning, there must be reserved spare parts or a complete purchasing system.

6.11.2 Classification of Traffic Management Facility

Traffic management facility to be covered in this Guideline is Road Lighting and Traffic Signs.

6.11.3 Typical Defects Observed

(1) Damages on the Main Body of Traffic Sign

- Deformation or breakage of sign boards
- Deformation, instability and breakage of sign poles
- Deterioration and stain of sign boards
- Low luminance of sign boards

(2) Damages on the Accessories of Traffic Signs

- Loosening or dropout of bolts or nuts on the mounting brackets

6.11.4 Inspection of Traffic Management Facilities

6.11.4.1 Focus Point of Inspection

- (1) Inspection of the street lighting equipment is different from that of tunnel lighting equipment because the locations to set up the equipment are scattered largely. Main items for normal inspection are as followed:

- Lightning status
- Checking whether the protection caps are damaged or not
- Status of attached lights
- Checking whether the lights are shifted and curved

The common tests can be done by visual inspection, and can also be conducted in conjunction with the daily afternoon patrols, but also depending on the situation of the relevant managed area, in some cases, the object of patrols is only lighting equipment.

- (2) For road signs, in regular patrolling, patrolling staffs should observe from patrol cars whether trees and billboards alongside the streets obscure them or not, whether the signs and columns are damaged or not. In addition, the items below should also be periodically tested. In case unusual weather conditions such as strong winds and storms can be predicted, and as soon as they occur, the items below should be temporary inspected

- Whether signs and columns are broken, stained or corroded.
- Whether paint and reflective substances are peeled.
- Whether signs are deviated or left out
- Status of lighting equipment
- Basic status
- Reflecting features (only in periodical inspection)

6.11.4.2 Inspection Points

Road facility inspection for traffic management facilities shall be implemented on the inspection points shown in **Table 6.11-1** also illustrates inspection points for traffic sign.

Table 6.11-1 Inspection Points for Traffic Management Facilities

Structure	Position	Member	Sort of damage	Initial inspection	Daily inspection	Periodic inspection	Detailed Inspection
Traffic Management Facility	Traffic Signs	Traffic signs	Main member damages	-----	X	X	As required by Routine or Periodic Inspection
			Accessory damages	-----	-----	X	
			Corrosion	-----	-----	X	
			Foundation damages	-----	-----	X	

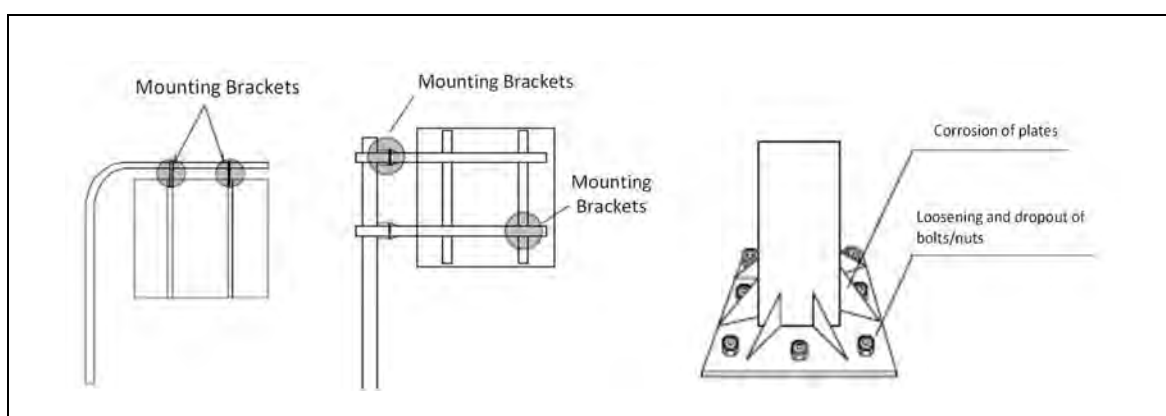


Figure 6.11-1 Inspection Points for Traffic Sign

6.11.4.3 Inspection Methods and Frequencies

Inspection methods and inspection frequencies in principle follow the relevant articles stipulated in this Guideline.

6.11.4.4 Evaluation of Inspection Results

- (1) Evaluation of the results of routine inspection, periodic inspection and emergency inspection shall be conducted, following relevant articles in this Guideline. Sample evaluation criteria for traffic signs are shown in **ANNEX-I**. Also, particular notes for the evaluation of some major damages are described below;
- (2) For the serious damages on the traffic signs including dropout, deformation or tilting of materials, evaluation criteria for traffic safety facilities shall be applied.
- (3) When traffic sign is not readable due to deterioration of paints, stains of sign boards or the peering of reflection sheet, rating of “C” is applied in this Guideline.
- (4) For corrosion on the foundation or on the accessories of traffic signs, evaluation criteria for traffic safety facilities shall be applied.

6.11.4.5 Data Registration and Reporting

Registration of inspection data shall be conducted, following relevant articles in this Guideline.

6.11.5 Planning and Implementation of Maintenance and Repair

Where traffic management facilities are broken, they need to be immediately restored to ensure their functionality. Thus, from the beginning, there must be reserved spare parts or a complete purchasing system. In general, inspection for the failure situation of the facility based on the practices from previous years should be carried to calculate the necessary amount and make ready for urgent situation.

6.11.5.1 Road Lighting

(1) Introduction

Street lighting purpose is to ensure traffic safety during the night. However, the cost of installation and maintenance of the lights is certainly high. Therefore, places where installation of the lightning equipment has general great investment efficiency will take priority.

(2) Maintenance and Repair

The certification of the status of lamp is done much based on patrols at night or when there are announcements from management organizations. Broken lights will be handled depending on whether they are continuously or locally lit lamp. However, inspections must be taken quickly.

If the lights are damaged by traffic accidents, they must be immediately treated depending on the situation.

The bulb replacement is carried for unusable bulbs or replaced periodically. However, it is the best to check, clean and paint at the same time.

In cases of natural disasters such as heavy rain, storms, earthquakes, the inspection should be taken combined with periodic inspection for the items below:

- Status of wastewater in a septic tank or sewer
- Status of panel (Switchboard), the status of the wire (wire hanging on the air)
- Painting status

The periodic inspection in general normally is carried once per year checking lightning tool condition, with or without bulbs, whether there is damage due to corrosion or not.

The inspection also needs to examine causes such as road shocks, emissions and rain water leading to lose assembly or screw places and corrosion. During inspection, special attention should be paid to the bolt in the base plate.

- Status of manholes or hand holes

For lighting of common highways, there are few examples of common use. However, in some cases, they can be installed in large bridges or in high suspension bridges.

It should be noted that if all of the things in the hand holes or manholes are not waste water, the electric wire will damage quickly.

Besides, depending on installation position, after the rains, we should immediately check and make waste water treatment...

- The type of central switchboards

For central switchboards, we should check the status those with waterproof covers, opening and closing equipment, electric field exposure equipment and automatically disconnected systems.

- Painting status

In case bulb paint is peeled or scratched, for safety, it should be repainted immediately

- Brightness measurement

In continuously lighting areas, some represented places should be chosen for brightness measurement.

- Cleaning the lighting devices in road

Degree of making dirt of the lighting equipment in the normal road is different from the degree in the tunnel, however dust, gas emission from the automobile reduce lighting effect of devices so depending on the level of contamination, the situation where devices placed that need cleaning to keep the lighting efficiency.

It should be carried out cleaning one time per year.

While cleaning, in some cases, it is also necessary to limit the traffic, so, the plan should be considered in advance, full time as well as implementation methodology.

6.11.5.2 Traffic Signs

(1) Introduction

Street signs are important to ensure traffic safety and vehicles circulating smoothly, each has mutual link with others, leading to consistent traffic. Therefore, even after signs were installed, maintenance is necessary to not affect that function; and we have to always keep them in good condition.

(2) Maintenance and Repair

All of unusual road signs discovered by inspection should be immediately restored to the normal conditions. The scope of work for restoring are as followed:

- Repair

The peeled paint stains caused by scratches on the signs and support columns or rust should be repainted before these stains spread. In special cases when these stuffs are too old, it should be replaced rather than repainted.

If the signs or support columns are bent, which worsen the landscape, they should be quickly fixed. For the support columns, they should be tightened depending on where they are placed.

Attention should be paid to installing the signs. If they are loose, they should be tightened immediately, avoiding accidents due to their falling. Especially, when being checked before or after bad weather, they have to be tighten immediately if found to be abnormal.

- Replacing signs

The rusted and damaged signs that are difficult to recognize should be replaced.

Furthermore, it needs to often check the ability to recognize the signs at night. The signs that lose reflective functions also need to be replaced quickly.

- Changing the placing positions

In case there are similar signs nearby or traffic obstruction, placing positions or display content is not appropriate in terms of communication and observation, it needs to review completely and make necessary adjustments.

- Cleaning the road signs

At the places where the road sign are dirty, making it difficult to observe so it is necessary to clean those road signs periodically.

The detergent commonly used is liquid, but if you use the kind of over strong detergents, it will lead to rust, so at places where are often dirty, you should increase the frequency of cleaning and by using water.

6.12 Road Cleaning

6.12.1 Introduction

Road cleaning work aims at maintaining the function of the road, ensuring the aesthetics of the road and protecting the roadside environment.

The pavement cleaning work can include:

- Cleaning the surface of highways, pedestrian ways, pedestrian bridge, median strip area on the road
- Cleaning the waste water system
- Cleaning the tunnels
- Cleaning auxiliary equipment of the street such as other bridge expansion devices, lighting system, barriers, road signs, direction signs...

The frequency of road cleaning like this depends on the condition of the road, traffic and environmental conditions. In addition, with each cleaning methods, the productivity is also different. For example, in the cases that the traffic is limited, it is the best to carry out all cleaning works at the same time. If there is a concern that road sanitation may affect or contaminate the road surface, it is

necessary to develop a master sanitation plan, for example, we can choose to clean the roadside just before cleaning the road surface.

It is also necessary to pay attention to safety measures when performing road cleaning to ensure the safety for the cleaner at the same time handle the traffic. The time for cleaning must be determined basing on the actual condition in each area. For example, in the downtown or in the street of big traffic volume or in the area having difficulties for cleaning in daytime, it is necessary to conduct quick cleaning or clean at night.

Furthermore, when carrying out the cleaning, it is not recommended to leave the soil and sand at roadsides in a long time but quickly clean up.

6.12.2 Road Surface Cleaning

6.12.2.1 Implementation and execution plan

Pavement surface should be clear from trees, debris, by labor or by sweeping machine. Depending on actual cleanness of pavement and the requirement of specific urban region, this type of work can be carried daily or normally around 1÷2 times per week.

Cleaning of the road surface varies depending on the situation of the street and of both roadsides. Therefore, it is necessary to investigate and analyze the structure of the road, the auxiliary equipment of the road, special used buildings, the actual condition of cleaning area which can be based on to develop the plan for cleaning.

The points need to be considered when develop the plan for cleaning

6.12.2.1.1 Determine the operating environment and the space for road cleaning.

- When developing the plan for cleaning, it is necessary to pay attention to traffic safety so that a plan for cleaning in good condition can be developed.
- The cleaning work must not affect traffic and houses on roadsides.
- When reviewing the implementation method and traffic conditions, road conditions, safety of the cleaner and the necessity of the cleaning, it may require to place the sign posts and barricade.
- When establishing the cleaning area, it is necessary to investigate the cleaning distance, cleaning time, the time required to complete the cleaning, the number of clean, the place to be clean, place of disposing to develop and determine the cleaning schedule both effectively and economically.

6.12.2.1.2 Set up cleaning teams

The road cleaning is conducted primarily by machines, people only do auxiliary operations. However, the two key teams of road cleaning including machine-based cleaning team and human-supported cleaning team.

Machine-based cleaning team is established including:

- The foreman, supervisor
- The driver of cleaning machine (including those with combination between machine and driver)
- Worker who clean up material refuse and/or soil.

The human team is to support the cleaning works which a machine can not do, such as the collection of huge rubbish

6.12.2.1.3 Operation capacity

Cleaning distance in a day may vary depending on the quality of machine, road conditions, amount of rubbish, cleaning clearance, time of cleaning. However, normal cleaning distance is from 20 to 40 km. In big cities where the traffic condition is not good, this standard may be less or more than 20km.

Cleaning capacity is determined by the features of the cleaning machine. The relationship between the standard operating speed and the operating capacity depends on the cleaning condition. However, the time required for the cleaning work t (in hour) could be calculated using the following formula:

$$T = \frac{L}{V \cdot E} + n * t_1 + Q * t_2 + \frac{l}{v}$$

Where :

V: standard cleaning speed (km/h)

L: Actual cleaning distance (km)

E: Operating efficiency

n: Number of waste disposal (time)

t_1 : Waste disposal (h/time)

t_2 : Water intake time (h/l)

Q: Water intake quantity (l)

l: cleaning clearance (km)

v: Speed of recovery (km/h)

6.12.2.1.4 Determine the operation speed

Operation speed is determined basing on the standard operation speed of the machine which are already defined in terms of features and the efficiency of the operation in terms of actual conditions. The operation efficiency normally falls in the range of 0.75÷0.95

In addition, the factors affecting the speed of operation are also the amount and type of waste, the wetness of the road, the condition of the road, the traffic situation, the weather conditions, there is or not the obstacles or damaged things on the road....

6.12.2.1.5 Garbage disposal

Collected garbage is mostly handled as below. However, it is necessary to determine the garbage disposal site which can accommodate the collected garbage volume

- Carrying garbage to public garbage disposal site or waste disposal areas.
- Carrying garbage to garbage disposal site which is specified by the Road management Board.
- Assign a cleaning contractor to handle the garbage disposal

6.12.2.1.6 Cleaning work by machine

The road structure has great influence on the productivity of the cleaning work using machines. The car parking on the roadsides is also a big obstacle. Therefore, the road surface condition, the pavement condition, gutters, sewage works, and the removable manholes are expected to be good. At the same time, widely notice before cleaning is also necessary. For example, it must have prior notice at the parking lot on the day and time of cleaning.

6.12.2.1.7 Water spraying and supplying

(1) Water spraying

To avoid dust and increase the productivity of cleaning machine during cleaning works, we can spray the water and the method is as follows:

- Spraying water by cleaning truck: The water amount is small and there is water supplying line along the road which can be easy for water feeding.
- Spraying water using sprinkler vehicles: This method is used in the cases that the cleaning distance in a day is long or the cleaning place is in urban areas or at place having sandy dust. In addition, this washing method will require a large amount of water and should only be used if we cannot make sure about the water supplying point along the road.

(2) Water supply

Water supply can be done by specialized water feeding tap, vehicles sprinkler, water in rivers or lakes or water for industrial use. However, we should use the specialized nozzles for road surface cleaning in order to ensure the good efficiency of water supplying. Arrange water tank along the road is also another option. In this case, there must be parking lots for sprinkler vehicles to intake water.

6.12.2.1.8 Road cleaning with manpower

If there is the plan for cleaning using machine in combination with manpower, the efficiency and effectiveness of cleaning work can be improved much. The major tasks in cleaning work having manpower support can be named as below:

- Before cleaning by machine, collect and dispose large rubbish
- Carry out cleaning in narrow road section or in section with obstacles which cannot be done by machine
- Cleaning works at intersections or the loop of extended road section
- Cleaning the dust on the pavement
- Cleaning the auxiliary equipment of the road.

6.12.2.1.9 Points need to be noted for the safety

When applying the cleaning work on road surfaces, it is necessary to pay attention to following points:

- Use of the spinning yellow light of the sanitary truck, use of road traffic signs
- Assign the monitoring car to go ahead for confirmation of the status of auxiliary equipment then carry out necessary handling measure.
- At the separation line on the middle of the road, if possible, the sanitary vehicle can perform the cleaning work at the same direction with other vehicles in circulation. Where it is impossible, the vehicle can use the opposite direction and such case requires road signs as well as guider arrangement to give instructions for means of transports passing through.
- When the sanitary module truck moves or stops, it is necessary to pay attention to vehicles and pedestrians. Instructions for transport vehicles should be given if needed.
- The loading of rubbish into another vehicle for transporting to dumping site must be conducted at a safe place.

Notices for operation and management of sanitary module truck

When operating, managing the sanitary module truck, the following points should be noted in order to perform the inspections and to direct the cleaning works.

- The driver must be proficient in operating the vehicle and must understand the road condition.
- Strictly observe the inspection works.
- Check the sanitary vehicle associated devices
- Follow the manipulation instruction
- After finish cleaning work, it is necessary to check the completion of the work and follow the repairing preparation procedure.
- Record accurately of work performed

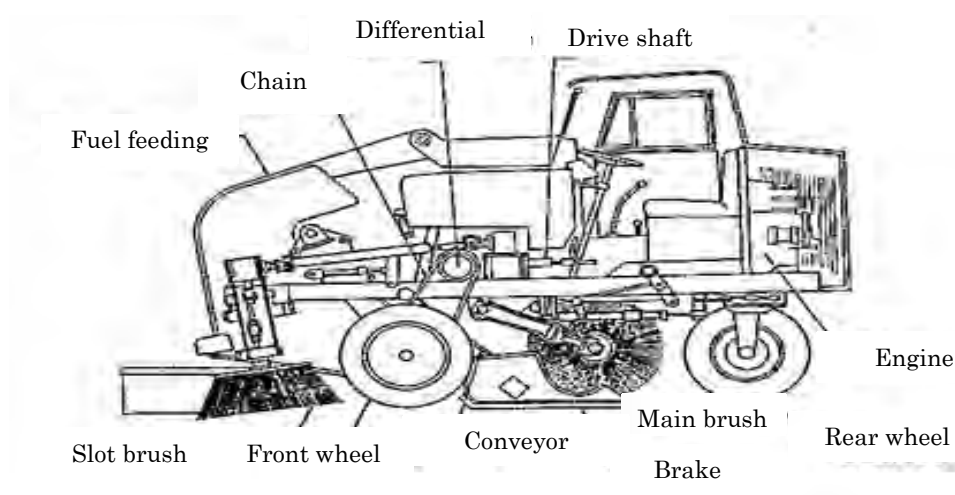
6.12.2.2 Mode of cleaning by machine and mode of combination

6.12.2.2.1 Selection of sanitary vehicle

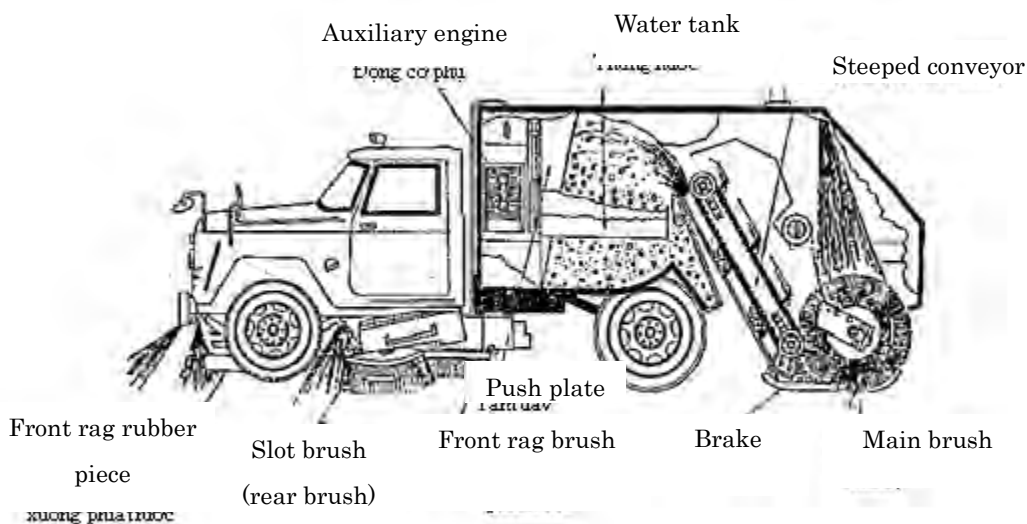
Table 6.12-1 shows the applications based on the types of cleaning machine and the sanitary condition. The selection can base on this Table. In addition, **Figure 6.12-1** shows the structure of the sanitary truck on the standard roads.

6.12.2.2.2 Combination machine

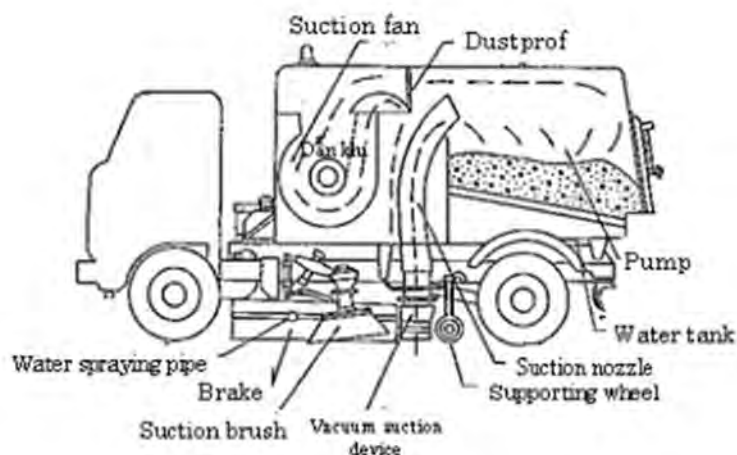
In order to carry out effectively the road surface cleaning by using the cleaning machine, it is also necessary to combine with other additional works when using the machine for cleaning. Combination means that before and after the cleaning machine performs the cleaning works, other auxiliary machine may be used. For example, before using cleaning machine, we can use the large rubbish collection truck, sprinkler, dump truck, etc. However, the common modes of combination are shown in **Figure 6.12-1**.



(1) Three-wheels brush truck (front lift dump)



(2) Four-wheels brush truck (front lift dump)



(3) Four-wheels vacuum truck (rear dump)

Figure 6.12-1 Structure of sanitary module truck

Table 6.12-1 Features comparison of different sanitary module trucks

Types of sanitary truck Performance conditions	Three-wheels brush truck (front lift dump)	Four-wheels brush truck (bottom dump)	Four-wheels vacuum truck (rear dump)
Soil and sand accumulation	⊙	⊙	○
Large rubbish and huge accumulation	⊙	⊙	○
Small size rubbish and small accumulation	○	○	⊙
Prolong the daytime performance	⊙	○	○
The cleaning is not done regularly in this area	○	⊙	⊙
Narrow and winding road	⊙	○	○
There are many obstacles on the road	⊙	○	○
Especially avoid dust	○	○	⊙
Reduce the influence of rain, slippery roads	○	○	⊙
The moving distance to another place is very far	△	⊙	⊙

Types of sanitary truck Performance conditions	Three-wheels brush truck (front lift dump)	Four-wheels brush truck (bottom dump)	Four-wheels vacuum truck (rear dump)
Only sanitary module truck performs the road cleaning	○	●	●
Avoid making noise when working	○	○	△
Expect to clean up the water tank and slot apart from cleaning the road	---	---	●
Expect to transfer the rubbish into another truck on the road	●	△	△
Can observe the side brush	●	○	○
Comfortable driving position	○	○	●
Driving license	Special huge truck	Normal huge truck	Normal huge truck

Note: ● good, ○ fair, △ Not suitable

Table 6.12-2 Example of combination between types of machine for road cleaning works

Type of machine	Three-wheels brush truck (front lift dump)	Four-wheels brush truck (bottom dump)	Four-wheels vacuum truck (rear dump)
Combination machine and quantity	01 large rubbish collection truck	01 large rubbish collection truck	01 large rubbish collection truck
	01 sprinkler	01 sprinkler	01 sprinkler
	01 sanitary module truck	01 sanitary module truck	01 sanitary module truck
	01 Dump struck	01 Dump struck	

Note: *: to be used if needed

6.12.2.2.3 Cleaning frequency

As reviewing the road cleaning frequency, it is necessary to consider following factors:

- Road types and road functions
- Traffic amount of passing vehicles
- Generated waste amount
- Situation of the area and the road side but it is important, that we have to make a decision basing on the level of aesthetics which is considered to appropriate in each area.

Therefore, it is difficult to define a specific uniform frequency, but according to survey results, the following is example data for reference. The ratio of cleaning the whole roads once per year is 93% in cities of over 500 thousand people, 82% in medium and small cities, 70% in other cities and the cleaning frequency in turn in above cities is 50 ÷ 150 times / year, 15 ÷ 50 times / year, 5 ÷ 15 times / year

6.12.2.3 Oil Contamination Clearing

The handling of oil, dirt and sand on the road, in principle, has to be done by people who cause this. But in most of cases, we do not know who did it before. When road management authorities realize of its bad influence on traffic safety, the road should be rapidly cleaned.

6.12.2.3.1 In case of oil spilling

If oil is spilled due to accidents, and be spread on a wide level, sand should be spread to avoid vehicle accidents due to slippery. Then, select the time when the traffic volume is low, use road-cleaning truck installed with water sprayer, or uses a specialized car to spray water to clean the oil and sand.

6.12.2.3.2 In case of dirt, sand was poured into the street

In case the road is heavily contaminated by big amount of unidentified cars day by day with a small amount of dirt, or sand, or garbage arising in nature, a road-cleaning truck installed with water sprayer, or a specialized car to spray water to clean can be used.

6.12.2.3.3 The other cases

If chemical drugs spread over the road and have to use neutralized chemicals to handle, contact the fire department to ask for treatment. Then, use a road-cleaning truck which is installed with water sprayer, or a specialized car to spray water to clean pavement.

In the square, in front of the station or sidewalks paved colorful tile, appropriate cleaners should be used.

6.12.2.3.4 Notes on washing the street

- Select the low traffic time to carry out cleaning the road, and always pay attention on vehicles or structures. However, spilled oil due to accidents has to be handled immediately regardless of the time.
- The collection of garbage in the region near gutter can be done easily. The gutters can be cleaned just after washing road surface.
- Consider carefully in terms of execution speed, spray pressure and water spray.

6.13 Traffic Control

6.13.1 Objectives

Objectives of traffic control is to ensure vehicle safety and worker's safety during maintenance and repair work by controlling traffic flow near road maintenance and repair sections.

6.13.2 Application of this Guideline

Traffic Control Guideline shall be applied to all works conducted on the expressways which need traffic control for the purposes of road facility inspection, detailed survey, road routine maintenance, disaster restoration, periodic maintenance and road investment project. The guideline stipulates the standard methods of traffic control. However, road and traffic conditions may vary from location to location, so that road operator is requested to flexibly apply this guideline and develop traffic control plan in conformity with road and traffic conditions under consideration.

6.13.3 Law Observation

Maintenance and repair works conducted on the expressway in operation is danger not only to road users but to maintenance staff in the field, so that Traffic control shall be implemented in conformity with relevant regulations including laws, decrees, circulars and decisions associated with road and traffic.

6.13.4 Planning of Traffic Control

The following are the key elements in planning traffic control methods, so that road operator is requested to take them into consideration in the planning;

- (1) To reduce the number of traffic control, by assembling multiple numbers of maintenance and repair works into a group of works and to implement them under the same traffic control, thereby it is possible to reduce the number of traffic control.
- (2) To shorten traffic control period by enhancing maintenance and repair work efficiency.
- (3) To select the timing and the time of traffic control best suited to the daily or the seasonal fluctuation of vehicle traffic.
- (4) To select appropriate traffic control methods best suited to the road maintenance and repair works in planning

6.13.5 Particular Note of Traffic Control

- (1) In this Manual, traffic lanes are defined as a cruising lane, a central lane and a passing lane, which are shown in the figures illustrated in the following paragraphs.
- (2) Traffic control staff shall keep monitoring traffic condition while maintenance staff places traffic control devices or removes them from expressway site.
- (3) Installation of the traffic control devices shall be commenced from upstream to downstream of the maintenance and repair sections. Likewise, removal shall be from downstream to upstream of maintenance and repair sections.
- (4) Maintenance and repair works shall be commenced after the installation of traffic control equipment or materials is fully completed.
- (5) Traffic control devices shall be in principle installed on the shoulder of expressways.
- (6) In case maintenance, repair and emergency works shall be conducted during night time, it is important to use traffic control devices with good visibility for approaching vehicles.
- (7) When traffic control is applied to the tunnel sections, traffic control shall start at upstream of the tunnel entrance.

6.13.6 Classification of Traffic Control

Traffic control falls in the following classifications. Processes for each traffic control method shall be explained with illustrations in the following paragraph.

- (1) Shoulder traffic control

Shoulder traffic control is to control vehicle flow for the maintenance, repair and emergency works conducted on the road shoulder.

- (2) Cruising lane traffic control

Cruising lane traffic control is to control vehicle flow for maintenance, repair and emergency works conducted on the vehicle lane. In case there are more than two lanes, the rightmost lane is defined as a cruising lane in this Manual.

- (3) Passing lane traffic control

Passing lane traffic control is to control vehicle flow for maintenance, repair and emergency works conducted on the leftmost lane (Passing lane) of the road, when there are more than two lanes in one direction.

(4) Central lane traffic control

Central lane traffic control is to control vehicle flow for maintenance, repair and emergency works conducted on the central lane of the road, when there are three lanes in one direction.

(5) Road closure on the site

Road closure is to block vehicle flow for emergency works conducted on the road.

The following are the symbols shown in the illustrations.

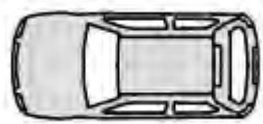
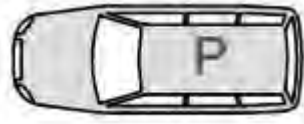
	Color cone		Arrow sign
	Maintenance Staff		Traffic Control Staff
	Obstacle		Patrol Vehicle

Figure 6.13-1 Symbols in the Illustrations

6.13.6.1 Shoulder Traffic Control

Processes of shoulder traffic control are shown below with figure.

- (1) Positioning of patrol vehicle, maintenance vehicle, traffic control staff, maintenance staff and traffic control signs to the obstacles to be handled are all shown in **Figure 6.13-2**.
- (2) To begin with, a traffic control staff shall install a safety arrow sign at the most upstream sections. Then, he shall move to the starting point of traffic control and keep monitoring vehicle flow and provide warning to approaching vehicles while traffic control devices are placed in the right position by maintenance staff.
- (3) Traffic control devices shall be positioned from upstream to downstream of the road, when installing the devices. On the other hand, removal of the devices shall be done from downstream to upstream of the road.
- (4) Maintenance, repair and emergency works shall be commenced after the installation of traffic control devices is completed.

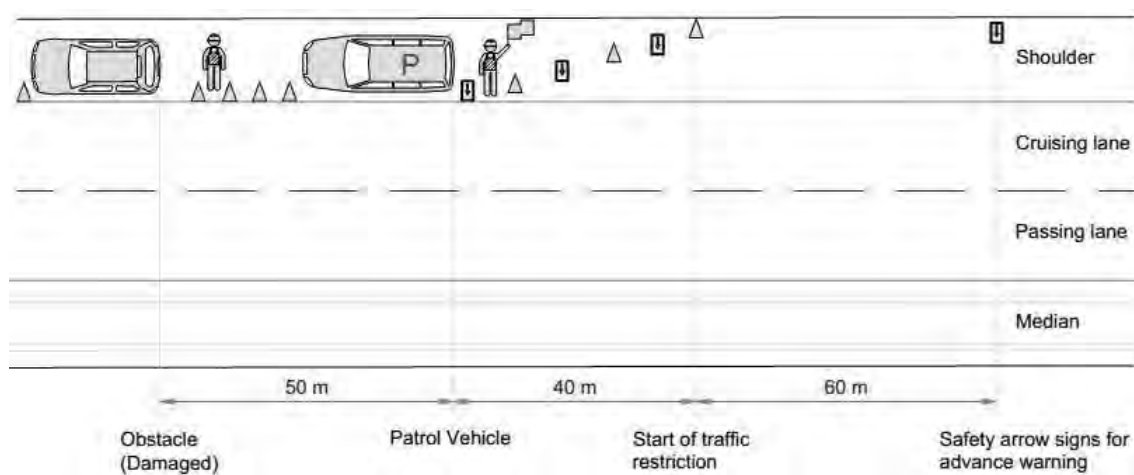


Figure 6.13-2 Shoulder Traffic Control

6.13.6.2 Cruising Lane Traffic Control

Processes of cruising lane traffic control are basically the same as those for the above shoulder lane traffic control.

- (1) Positioning of patrol vehicle, maintenance vehicle, traffic control staff, maintenance staff and traffic control signs to the obstacles to be handled are all shown in **Figure 6.13-3**.
- (2) Patrol vehicle shall move from road shoulder to the position in the figure upon installation of traffic control devices to protect maintenance staff involved in the obstacle treatment.

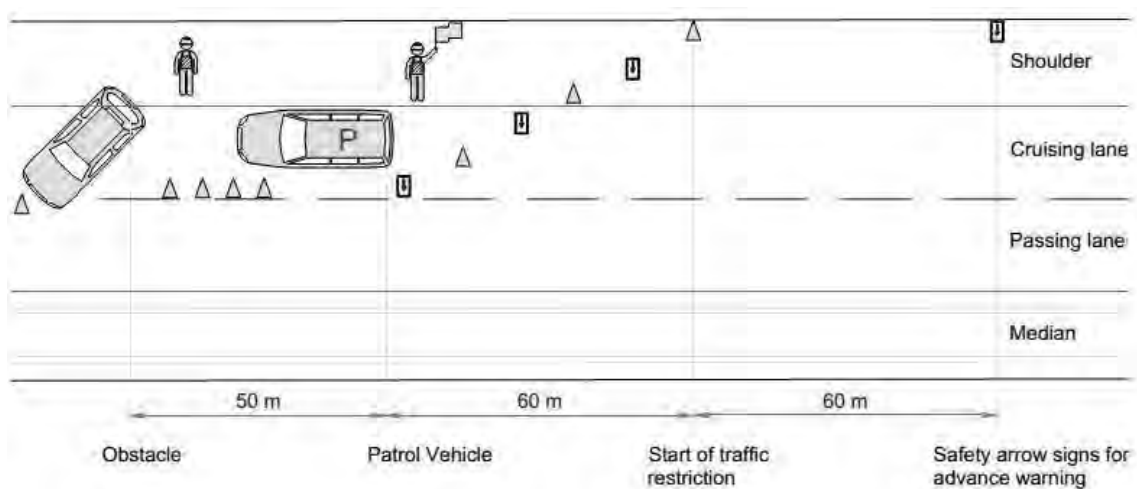


Figure 6.13-3 Cruising Lane Traffic Control

6.13.6.3 Passing Lane Traffic Control

Processes of passing lane traffic control are shown below with figure.

- (1) Positioning of patrol vehicle, maintenance vehicle, traffic control staff, maintenance staff and traffic control signs to the obstacles to be handled are all shown in **Figure 6.13-4**.
- (2) A patrol vehicle shall first stay approximately 50m upstream of the obstacles.

- (3) Traffic control staff shall move to the point 120 m upstream of the patrol vehicle and install arrow signs near the median strip in order to warn approaching vehicles.
- (4) Then, maintenance staff shall install traffic control devices as shown in the figure while traffic control staff keeps controlling traffic during the work.
- (5) Removal of the devices shall be done from downstream to upstream of the road.

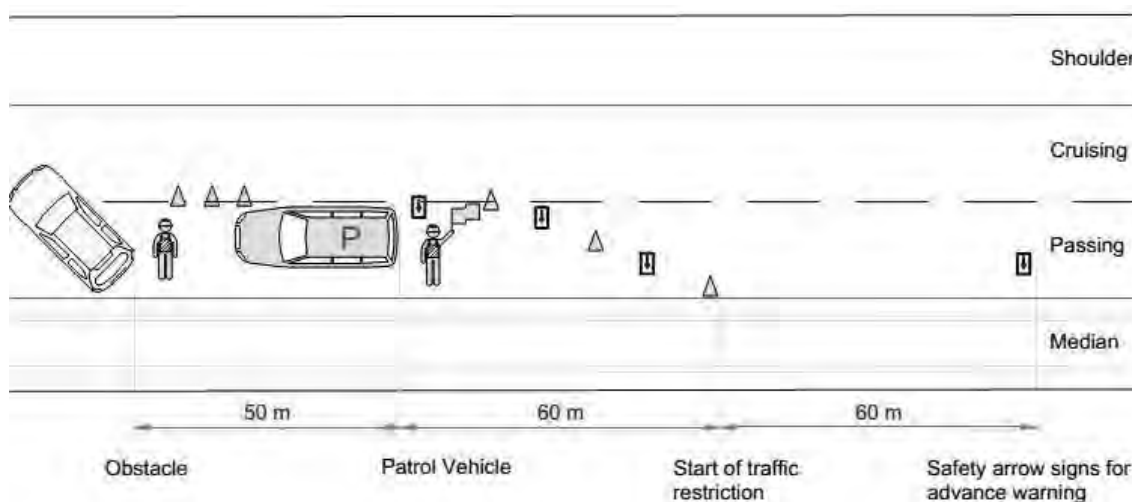


Figure 6.13-4 Passing Lane Traffic Control

6.13.6.4 Central Lane Traffic Control

Processes of central lane traffic control are shown below with figure.

- (1) Positioning of patrol vehicle, maintenance vehicle, traffic control staff, maintenance staff and traffic control signs to the obstacles to be handled are all shown in **Figure 6.13-5**.
- (2) In case of controlling central lane, it is very dangerous to control center lane alone from traffic safety view point. With this, it is important to control two lanes simultaneously including central lane. Two lane traffic controls shall be done coupled with cruising lane and central lane or coupled with passing lane and central lane, depending upon the position and the condition of obstacles.

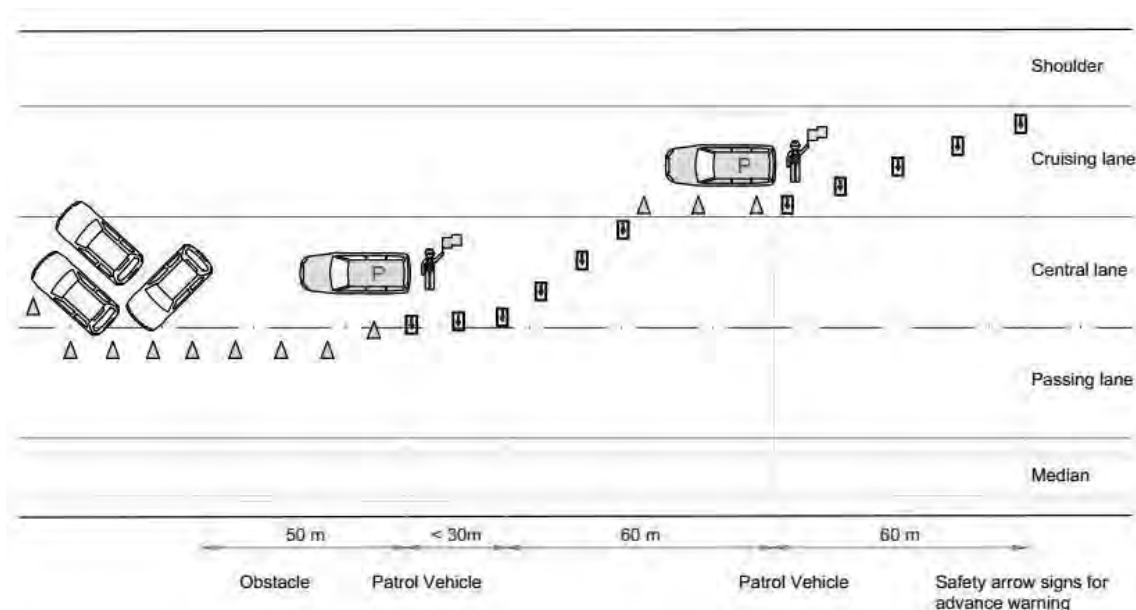


Figure 6.13-5 Central Lane Traffic Control

6.13.6.5 Road Closure on Site

Processes of road closure on site are shown below with figure.

- (1) Positioning of patrol vehicle, maintenance vehicle, traffic control staff, maintenance staff and traffic control signs to the obstacles to be handled are all shown in **Figure 6.13-6**.
- (2) Patrol vehicle shall first stop on the shoulder approximately 150m upstream of the obstacle.
- (3) The traffic control staff and maintenance staff shall stand behind the patrol vehicle, with red flags in hand to direct approaching vehicles to slow down and stop their cars. The traffic control staff and maintenance staff shall confirm that vehicles on the road are slowing down and safety is secured.
- (4) Upon confirmation, maintenance staff shall install traffic control devices in perpendicular to the lanes from shoulder to median as shown in the figure.
- (5) After installing the traffic control devices, the traffic control staff shall make the necessary announcements to the stopped vehicles and conduct monitoring while staying inside the control area.
- (6) The worker shall move patrol vehicle to the position behind the obstacles, then start taking care of the obstacles.

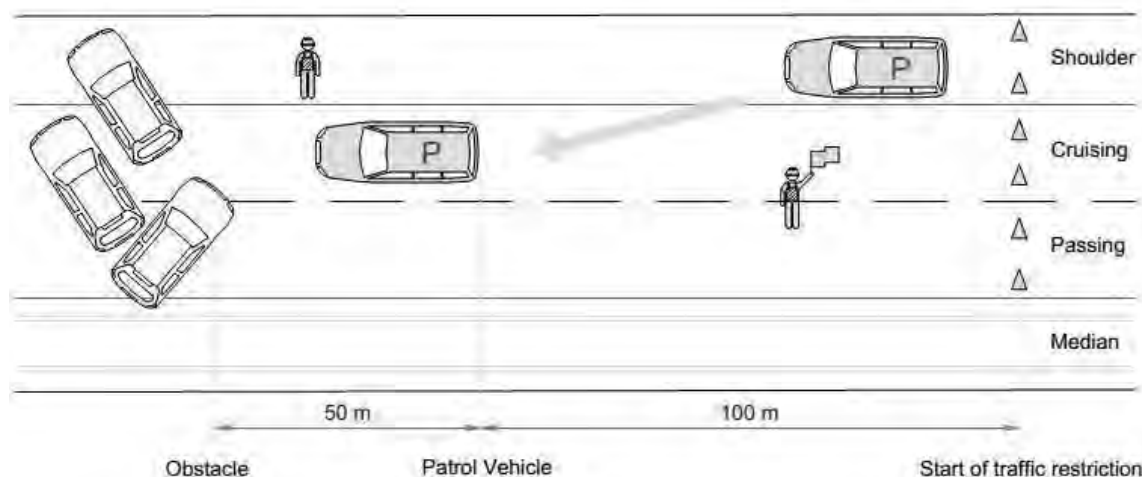


Figure 6.13-6 Road Closure on Site

6.13.6.6 Road Closure between Interchanges

Processes of road closure between interchanges are shown below with figure.

- (1) Positioning of patrol vehicle, maintenance vehicle, traffic control staff, maintenance staff and traffic control signs to the obstacles to be handled are all shown in **Figure 6.13-7**.
- (2) Patrol vehicle shall first stop on the passing lane approximately 150m upstream of the branch point to the exit ramp.
- (3) The traffic control staff shall move to the point approximately 60 m upstream of starting point of traffic control and install the warning arrow signs on the median. Then traffic control staff shall stand at the place between the advance warning point and the beginning point of restriction. Moreover, the traffic control staff shall move forward to the approaching vehicles and instruct them to slow down vehicle speeds and to exit from the interchange with red flags in hand.
- (4) After traffic control becomes operable, maintenance staff shall install traffic control devices from the starting point of traffic restriction to the branch point and then to the exit ramp in the distance of approximately 210 m (150 m + 60 m), staying in the traffic control area.
- (5) Maintenance staff shall move their vehicle to the right position in the figure.

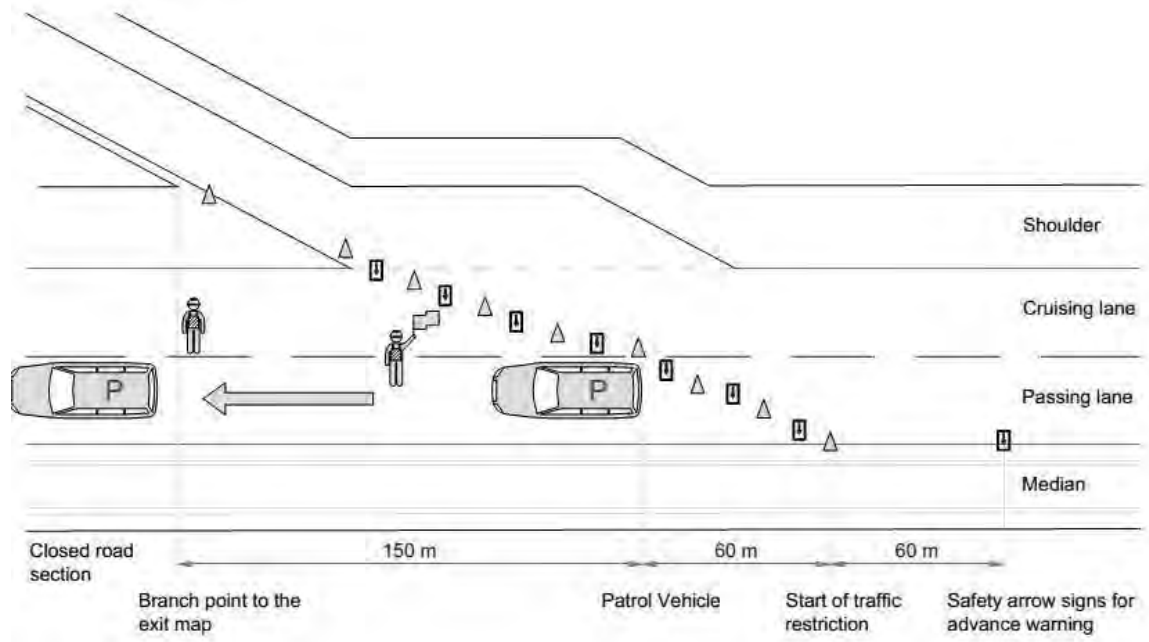


Figure 6.13-7 Road Closure between Interchanges

Table Sample Evaluation Criteria for Road Slope Inspection**a. General Slope (Cut Slope & Embankment)**

Facility	Member	Damage	Evaluation criteria		
			B	C	D
General slopes		Collapse		Small slope failure which has less potential of progressing	Slope failure which has high potential for expansion
		Cracks / swelling /settlement		Cracks, swelling or settlement which may not lead to slope failure	Cracks, swelling or settlement which may lead to slope failure
		surface erosion		Partial erosion which may not spread	Wide area surface erosion which has high potential of spread.
		Piling of Debris on slope steps	Small-scale pilings of debris which may not hinder the drain function on the steps.	Deposits of soil and stone which do not hinder the drainage installed on the slope steps	Deposits of soil and stone hinder the drainage installed on the slope steps.
		spring water	Spring water which is small potential for causing slope failures.	Spring water which increases in volume when rain falls, but does not have high potential of slope failures.	Spring water which increases in volume when raining and has high potential for causing slope failures.
		tree fall	Weeds which overran a wide area of slopes	Fallen or tilted trees, but do not lead to slope failures.	There are fallen or tilted trees, making holes around roots which can induce water infiltration into the slopes and cause slope failures.
		plant death	Lawn coverage more than 30% and less than 70%	Lawn coverage less than 30%	-----
		unstable stone/ rolling stone	-----	Unstable stones or rolling stones, but not so many.	Many unstable stones or rolling stones.
		Growing of hydrophilic plants and weakening of slope	-----	Slopes are weakened by spring water and covered with hydrophilic plants. Detail inspection is needed to identify underground water conditions.	Slopes weakened by spring water and covered with hydrophilic plants which have high potential of slope failures.

Table Sample Evaluation Criteria for Road Slope Inspection**b. Protected Slope**

Facility	Member	Damage	Evaluation criteria		
			B	C	D
Protected Slope Inspection	Concrete block frame in situ /concrete frame	cracks/ peeling	Cracks or concrete peeling which spread over part of the area.	Cracks or concrete peeling which widespread over the area.	Severe cracks or concrete peeling, which may cause falling of concrete or collapse
		Looseness/ swelling/ settlement	-----	Looseness, swelling or settlement is seen on the facilities, but they may not lead to failures.	Serious looseness, swelling or settlement seen on the facilities which may lead to failures.
		spring water/ drain water	Spring water from facility joints or drain pipes, but they do not lead to slope failures.	-----	A large amount of spring water from facility joints and drain malfunction by drain pipes filled with soil which has high potential of causing slope failures.
	Mortar spray/ Concrete spray	cracks/ peeling	Small cracks, swelling or settlement seen over part of the area which may not lead to slope failure	Cracks, swelling or settlement which may not lead to slope failures soon, but may lead to the failure in the long run.	Severe cracks, swelling or settlement which may lead to slope failure
		loosening / swelling/ settlement	Slope edge push-out, swelling and shear gaps at construction joints, but they may not lead to slope failures.	-----	Slope edge push-out, swelling and shear gaps at construction joints which may lead to slope failures.
		Voids	A trace of soil flow-out from drain pipes after rainfalls, and hammering inspection detects the existence of voids behind the surface concrete or mortar.	-----	-----
		spring water/ drain water	Spring water from facility joints or drain pipes, but they do not lead to slope failures.	-----	A large amount of spring water from facility joints and drain malfunction by drain pipes filled with soil which has high potential of causing slope failures.

Table Sample Evaluation Criteria for Road Drainage System

Facility	Member	Damage	Evaluation criteria		
			B	C	D
Slope drainage systems	- Slope shoulder drainage/ - Slope step drainage - Vertical drainage - Catch basins	Damages to drainage body	-----	Medium damages of drainage systems which hinder drain functions.	Heavy damage of drainage systems which cause water overflow and rain infiltration
		Improper drainage joints	Small water leakage which does not lead to slope failures.		Heavy damage of drainage joints which cause water leakage from joints and rain infiltration into slopes
		Debris/ soil accumulation	Limited or partial piling of soils and debris	Piling of soil and debris which hinder drain functions.	Large piling of soil and debris
		Hindrance of drain function by weeds	Small hindrance of drain functions		Heavy hindrance of drain function by weed

Table Sample Evaluation Criteria for Retaining Wall Inspection

Facility	Member	Damage	Evaluation criteria		
			B	C	D
Concrete retaining wall	RC retaining wall	Cracks/ corner failures	Small cracks running parallel with wide gaps which do not reach inner steel bars.	Small cracks running parallel with narrow gaps which reach inner steel bars.	Severe crocodile cracks which reach inner steel bars with free lime and rusty fluid.
		Concrete Peeling	Partial peeling or creep	Extensive concrete peeling or creep	
		Steel bar exposure and corrosion	Partial steel bar exposure	Severe steel bar exposure with the progress of corrosion.	
		Settlement/ movement/ tilting	Settlement, movement or tilting of facilities which does not lead to collapse.	Settlement, movement or tilting of facilities which does not need further survey	Settlement, movement or tilting of facilities which lead to collapse.
		Damages on structural joints	Joint gaps, but they do not lead to collapse.	Joint gaps which do not lead to collapse soon, but lead to collapse in the long run.	Large joint gaps which may lead to collapse.
		Scouring	Limited or partial scouring at foundations or around main bodies, but progress is not expected.	Scouring at foundations or around main bodies, which may need countermeasures in the long run.	Serious scouring at foundations or around main bodies which need urgent countermeasures.
		Drainage / spring water	Spring water from facility joints or drain malfunction by drain pipes filled with soil, but they do not lead to slope failures.	-----	A large amount of spring water from facility joints and drain malfunction by drain pipes filled with soil which has high potential of causing slope failures.

Table Sample Evaluation Criteria for Road Pavement Inspection**(i) Asphalt Concrete Pavement**

Structure	Member	Sort of damage	Evaluation Criteria		
			B	C	D
Road Pavement	Asphalt pavement	Pot holes/ Peeling/ Depressions	-----	20 cm–40cm in diameter or 30 mm-40 mm in depth	Over 40 cm in diameter or Over 40 mm in depth.
		Crack ratio	10% - 30%	30% - 40%	Over 40 %.
		Rutting Depth	10mm - 30 mm	30mm - 40mm	Over 40 mm
		IRI	2 – 4 mm/m	4 – 6 mm/m	Over 6 mm/m
		Edge Break	-----	Surface level difference 10 mm – 30 mm	Pavement width less than design lane width or Surface level difference over 30mm.
		Bump in pavement surface	-----	10 mm - 20 mm in depth at the connection with bridges	Over 20mm at the connections with bridges
				10mm - 30mm in depth at crossing structures or cut/fill transition points	Over 30 mm at crossing structures or cut/fill transition points.
		Skid Resistance	-----	0.25 i (V) - 0.3 i(V).	Over i (V) 0.25.

(ii) Bituminous Surface Treatment

Structure	Member	Sort of damage	Evaluation Criteria		
			B	C	D
Road Pavement	Bituminous surface treatment	Pot holes/ Peeling/ Depressions	Less than 20 cm in diameter or 30 mm in depth	20 cm–40cm in diameter or 30 mm-40 mm in depth	Over 40 cm in diameter or Over 40 mm in depth.
		Crack ratio	10% - 40%	40% - 50%	Over 50 %.
		Rutting Depth	10mm - 40 mm	40mm - 50mm	Over 50 mm
		IRI	4 – 6 mm/m	6 – 8 mm/m	Over 8 mm/m
		Edge Break		Surface level difference 10 mm – 30 mm	Pavement width less than design lane width or Surface level difference over 30mm.
		Bump in pavement surface	-----	10 mm - 20 mm in depth at the connection with bridges and at joints between slabs	Over 20mm at the connections with bridges and at joints between slabs.
				10mm - 30mm in depth at crossing structures or cut/fill transition points	Over 30 mm at crossing structures or cut/fill transition points.
		Skid Resistance	-----	0.25 i (V) - 0.3 i(V).	Over i (V) 0.25.

Table Sample Evaluation Criteria for Road Pavement Inspection**(iii) Cement Concrete Pavement**

Structure	Member	Sort of damage	Evaluation Criteria		
			B	C	D
Road Pavement	Concrete pavement	Crack ratio	-----	30% - 40%	Over 40 %.
		IRI	-----	-----	Over 4 mm/m
		Bump in pavement surface	-----	10 mm - 20 mm in depth at the connection with bridges 10mm - 30mm in depth at crossing structures or cut/fill transition points	Over 20mm at the connections with bridges Over 30 mm at crossing structures or cut/fill transition points.
		Slab joint seal	-----	Damaged but water infiltration is not observed	Damaged and water infiltration observed
		Skid Resistance	-----	0.25 i (V) - 0.3 i(V).	Over i (V) 0.25.

Table Sample Evaluation Criteria for Bridge Inspection Results-1/8

	Structural Part / Kind of Damage	Estimated volume based on damage level		
		B	C	D
1	All type of bridge			
1.1	Entire bridge condition			
	Abnormal deflection	Deflection of the superstructure is observed slightly by visual inspection	Deflection of the superstructure is observed obviously by visual inspection	More than L/500 where the bridge length is over 40 meters
	Abnormal Noise	-----	Noise arises when vehicles pass by	-----
	Abnormal vibration	-----	Vibration is identified by physical inspection or body feeling.	Serious vibration is identified by physical inspection or body feeling.
	Abnormal expansion gap	-----	Expansion gap is seen closed or open wide. Parapet & girder contacted each other.	End girder support length is not long enough. Parapet & girder contacted each other and are broken
	Settlement, Movement	-----	Superstructure or substructure moved a little.	Superstructure or substructure moved extraordinary.
	Scouring	Tendency of scouring is observed	Foundation/pile cap surface appeared due to scouring	Scouring depth reach below the bottom of foundation/pile cap
2	Concrete bridge			
2.1	Concrete girder (I or T section, Box girder)			
	Deformation, Deflection, Sag	-----	Deflection is observed slightly by visual inspection	Deflection is observed obviously by visual inspection
	Crack			
	i. Near end girder support	Small cracks extending vertically or diagonally near bearings	Large cracks extending vertically or diagonally near bearings.	Large vertical or diagonal cracks are observed near bearings with free lime or rusty fluid.
	ii. Near middle support	Small cracks are observed on upper flange or main girder web.	Large cracks are observed on upper flange or main girder web.	Large vertical cracks are observed on the upper flange of a main girder with free lime and rusty fluid.
	iii. Centre between supports	Small cracks are observed on the lower flange or the web of a main girder.	Large cracks are observed on the lower flange or the web of a main girder.	Large vertical or horizontal cracks are observed on the lower flange of a main girder with free lime and rusty fluid.
	iv. A quarter point between supports	Small vertical cracks are observed on the lower flange of a main girder.	Large vertical cracks are observed on the lower flange of a main girder.	Large vertical cracks are observed on the lower flange of a main girder with free lime and rusty fluid.
	v. Construction joints	Small cracks are observed near the construction joints.	Large cracks are observed near the construction joints.	Large cracks are observed near the construction joints with free lime or rusty fluid.
	vi. Segment junctions	-----	-----	Cracks or trace of free lime are observed near the segment joints.
	vii. Near anchors	-----	Crocodile cracks are observed near the anchorage.	Cracks are observed near the anchorage in shear direction

Table Sample Evaluation Criteria for Bridge Inspection Results-2/8

	Structural Part / Kind of Damage	Estimated volume based on damage level		
		B	C	D
	viii. Notch of a girder	-----	-----	Diagonal cracks are observed near the notch of a girder.
	Peeling, Spalling, Creep	Partial peeling is observed.	Wide concrete peeling is observed or peeling spreads.	Wide concrete peeling, spalling or creep with serious corroded rebar is observed
	Rebars exposure, Corrosion	Rebar exposure is observed partially	Rebar exposure is observed and rusting of rebars is progressing	-----
	Water leakage, Puddling	Water leakage or puddles is observed in rainy days.	Water leakage or puddles is observed regardless of weather.	-----
	Free lime	Free lime is observed, but no serious	Serious free lime is detected which seemingly from corroded steel members	-----
	Rusty fluid	Some rusty fluid is observed	Serious rusty fluid is observed, in particular, from rebars or PC cables.	-----
	Deterioration, Discoloration	Partial change in color is observed	Concrete changes its color on the surface near cracks	-----
	Honey comb, Void	Some of honey-combs and voids are observed, but not many	Many large honey-combs and voids are observed	-----
	Chemical attacks	Tendency of chemical attack effects is observed	Chemical attacks and serious rebars corrosion are observed	-----
2.2	Concrete cross beam, Diaphragm			
	Crack	Cracks at long intervals do not reached to rebar depth	Small cracks at small intervals reached to rebar depth	-----
	Peeling, Spalling, Creep	Partial peeling, spalling or creep is observed.	Wide concrete peeling, spalling or creep is observed	-----
	Rebars exposure, Corrosion	Rebar exposure is observed partially	Rebar exposure is observed and rusting of rebars progresses	-----
	Water leakage, Puddling	Water leakage or puddles is observed in rainy days.	Water leakage or puddles is observed regardless of weather.	-----
	Free lime	Free lime is observed, but not serious	Serious free lime is observed which seemingly from corroded steel members.	-----
	Rusty fluid	Some rusty fluid is observed	Serious rusty fluid is observed, in particular, from anchors of steel members or PC cables.	-----
	Deterioration, Discoloration	Partial change in concrete color is observed	Concrete changes its color on the surface near cracks	-----
	Honey comb, Void	Some of honey-combs and voids are observed, but not many	Many large honey-combs and voids are observed	-----
	Chemical attacks	Tendency of chemical attack effects is observed	Chemical attacks and serious rebars corrosion are observed	-----

Table Sample Evaluation Criteria for Bridge Inspection Results-3/8

	Structural Part / Kind of Damage	Estimated volume based on damage level		
		B	C	D
2.3	Concrete deck slab			
	Crack	Longitudinal and transverse cracks are observed	Cracks develops to crocodile cracks	Crocodile cracks cause spalling
	Peeling, Spalling, Creep	Small scale concrete peeling, spalling or creep is observed.	Wide concrete peeling, spalling or creep is observed	-----
	Rebars exposure, Corrosion	Partial rebars exposure is observed.	Rebar exposure is observed with progress of corrosion	-----
	Water leakage, Puddling	Water leakage or puddles is observed in rainy days.	Water leakage or puddles is observed regardless of weather.	-----
	Free lime	Free lime running in one direction is detected with color change	Free lime running in two directions is observed with color change.	Large extent of free lime running in two directions with color change is observed.
	Rusty fluid	Some rusty fluid is observed	Severe rusty fluid is observed.	-----
	Deterioration, Discoloration	Concrete surface has changed its color in limited areas.	Concrete surface has changed its color near cracks	-----
	Honey comb, Void	Some honey combs, voids are observed.	Large honey combs, voids are observed	Voids or holes due to crocodile crack are observed
	Chemical attacks	Tendency of chemical attack effects is observed	Chemical attacks and serious rebars corrosion are observed	-----
3	Steel bridge			
3.1	Steel girder, Truss member, Arch member and Steel pier			
	Deterioration of paint	Cracks, peeling, swollen or rust are observed in limited area.	Cracks, peeling, swelling or rust are observed over a wide area	-----
	Corrosion	There is one missing or loosen rivets or bolt-nuts observed on one connection plate	Reduction in steel plate thickness is observed due to corrosion	Corrosion on the main members develops significantly and gives significant negative impacts on strength of the structure
	Loosen and fallen of rivets, bolt-nuts, and HTBs	There is one missing or loosen rivets or bolt-nuts observed on one connection plate	More than 2 rivets or bolt-nuts are missing or loosen on one connection plate	-----
	Crack			
	i. Welding portions on sole plates	-----	Cracks appear	Cracks reached web plates
	ii. Girder end where cross section of web plate changes	-----	Cracks appear	Cracks reached web plates
	iii. Welding portions with vertical stiffeners	-----	Cracks appear	-----
	iv. Welding portions with gusset plates	-----	Paint cracks appear	Cracks progress onto web plates
	v. Butt welding portions on lower flanges	-----	Paint cracks appear	Cracks appear
	vi. Welding portions with steel deck plates	-----	Cracks appear	Cracks extend over two thirds of welding length

Table Sample Evaluation Criteria for Bridge Inspection Results-4/8

	Structural Part / Kind of Damage	Estimated volume based on damage level		
		B	C	D
	vii. Welding portions between vertical stiffeners and steel deck plates	-----	Cracks appear	Cracks appear on steel deck plates
	viii. End of stringers where cross section of the girder changes	-----	Cracks appear	Cracks progress on the stringer web extending in the direction that could break the stringer
	ix. Base of vertical members on the arch ribs	-----	There is potential of breaking vertical members	Cracks extend to arch chord or to the stiffeners of the girder
	x. Welding portions on shoe base plates	-----	Cracks appear	-----
	xi. Corners of steel piers	-----	Cracks appear	Cracks appear and may progress
	xii. Others	-----	Cracks appear	Other locations where large cracks are found
	Deformation and buckling	Slight deformation or buckling arises	Deformation or buckling arises and brings a negative impact on strength of the structure.	Significant deformation or buckling arises and brings significant negative impacts on strength of the structure.
	Water leakage, Puddling	Water leakage or puddles is sometimes seen on rainy days	Water leakage or puddle is seen anytime regardless of weather conditions	-----
3.2	Steel Cross beam, Stringer, Diaphragm			
	Deterioration of paint	Cracks, peeling, swollen or rust are observed in limited area.	Cracks, peeling, swelling or rust are observed over a wide area	-----
	Corrosion	Reduction in steel plate thickness is found due to corrosion	Corrosion on the members develops significantly and causes significant negative impacts on the strength of the structure	Severe rust on over 50% of length of the member
	Loosen and fallen of rivets, bolt-nuts, and HTBs	There is one missing or loosen rivets or bolt-nuts observed on one connection plate	More than 2 rivets or bolt-nuts are missing or loosen on one connection plate	
	Crack	-----	Some cracking	Severe cracking
	Deformation and buckling	-----	Slight deformation or buckling arises	Significant deformation or buckling arises and to be a significant negative impact on strength of the structure.
	Water leakage, Puddling	Water leakage or puddles is sometimes seen on rainy days	Water leakage or puddle is seen anytime regardless of weather conditions	-----

Table Sample Evaluation Criteria for Bridge Inspection Results-5/8

	Structural Part / Kind of Damage	Estimated volume based on damage level		
		B	C	D
4	Substructure			
4.1	Abutment and wing wall			
	Tilting, Settlement, Movement	Partially damaged by settlement, movement or wash out	Severe damage by settlement, movement or wash out	-----
	Scouring	-----	Footing or caisson or abutment base is scoured to exposure	Footing or caisson or abutment base is scoured deeper than design
	Collision of ship / floating object		Some impact damage	Major impact damage
	Crack	Crack at long intervals do not reached to rebar depth	Small cracks at small intervals reached to rebar depth	Large crack at support end or cantilevered base is observed
	Peeling, Spalling, Creep	Small scale concrete peeling, spalling or creep is observed	Peeling, spalling or large creeping is observed	-----
	Rebars exposure, Corrosion	Partial rebar exposure is observed.	Sever exposed and corroded rebars are observed	-----
	Water leakage, Puddling	Water leakage or puddles is observed in rainy days.	Water leakage or puddles is observed regardless of weather.	-----
	Free lime	Free lime running in one direction is observed with color change	Free lime running in two directions is observed with color change.	Large extent of free lime running in two directions with color change is observed.
	Rusty fluid	Some water leakage and rusty fluid are observed	Severe rusty fluid is observed	-----
	Deterioration, Discoloration	Concrete surface has changed its color in limited areas	Concrete surface has changed its color near cracks	-----
	Honey comb, Void	Some honey combs, voids are observed	Large honey combs, voids are observed.	Large honey comb, voids with heavy corroded rebars are observed
	Chemical attacks	Tendency of chemical attack effects is observed	Chemical attacks and serious rebars corrosion are observed	-----
4.2	Pier and pier head			
	Tilting, Settlement, Movement	Partially damaged by settlement, movement or wash out	Severe damage by settlement, movement or wash out is observed	Damage due to settlement, movement or wash out effects on bridge stability
	Scouring	Tendency of scouring is observed	Footing or caisson or abutment base is scoured to exposure	Footing or caisson or abutment base is scoured deeper than design
	Collision of ship / floating object		Some impact damage	Major impact damage
	Crack	Crack at long intervals do not reached to rebar depth	Small cracks at small intervals reached to rebar depth	Large crack at support end or cantilevered base is observed
	Peeling, Spalling, Creep	Small scale concrete peeling, spalling or creep is observed	Peeling, spalling or large creeping is observed	-----
	Rebars exposure, Corrosion	Partial rebar exposure is observed.	Sever exposed and corroded rebars are observed	-----
	Water leakage, Puddling	Water leakage or puddles is observed in rainy days.	Water leakage or puddles is observed regardless of weather.	-----

Table.. Sample Evaluation Criteria for Bridge Inspection Results-6/8

	Structural Part / Kind of Damage	Estimated volume based on damage level		
		B	C	D
	Free lime	Free lime running in one direction is observed with color change	Free lime running in two directions is observed with color change.	Large extent of free lime running in two directions with color change is observed.
	Rusty fluid	Some water leakage and rusty fluid are observed	Severe rusty fluid is observed	-----
	Deterioration, Discoloration	Concrete surface has changed its color in limited areas	Concrete surface has changed its color near cracks	-----
	Honey comb, Void	Some honey combs, voids are observed	Large honey combs, voids are observed.	Large honey comb, voids with heavy corroded rebars are observed
	Chemical attacks	Tendency of chemical attack effects is observed	Chemical attacks and serious rebars corrosion are observed	-----
4.3	Foundation (Footing, Pile cap, Pile)			
	Tilting, Settlement, Movement	Partially damaged by settlement, movement or wash out	Severe damage by settlement, movement or wash out	Damage due to settlement, movement or wash out effects on bridge stability
	Scouring	Tendency of scouring is observed	Footing or caisson or abutment base is scoured to exposure	Footing or caisson or abutment base is scoured deeper than design
	Collision of ship and floating object		Some impact damage	Major impact damage
	Crack	Crack at long intervals do not reached to rebar depth	Small cracks at small intervals reached to rebar depth	Large crack at support end or cantilevered base is observed
	Peeling, Spalling, Creep	Small scale concrete peeling, spalling or creep is observed	Peeling, spalling or large creeping is observed	-----
	Rebars exposure, Corrosion	Partial rebar exposure is observed.	Sever exposed and corroded rebars are observed	-----
	Water leakage, Puddling	Water leakage or puddles is observed in rainy days.	Water leakage or puddles is observed regardless of weather.	-----
	Free lime	Free lime running in one direction is observed with color change	Free lime running in two directions is observed with color change.	Large extent of free lime running in two directions with color change is observed.
	Rusty fluid	Some water leakage and rusty fluid are observed	Severe rusty fluid is observed	-----
	Deterioration, Discoloration	Concrete surface has changed its color in limited areas	Concrete surface has changed its color near cracks	-----
	Honey comb, Void	Some honey combs, voids are observed	Large honey combs, voids are observed.	Large honey comb, voids with heavy corroded rebars are observed
	Chemical attacks	Tendency of chemical attack effects is observed	Chemical attacks and serious rebars corrosion are observed	-----

Table Sample Evaluation Criteria for Bridge Inspection Results-7/8

	Structural Part / Kind of Damage	Estimated volume based on damage level		
		B	C	D
5	Bridge accessory			
5.1	Bearing shoe			
	Breakage, Crack of bearing shoe body	Movement or rotation function slight malfunction	Shoe body moves up and down due to improper friction against horizontal movement. Cracks are detected on the members supporting a vertical load.	Vertical load support function does not function well due to breakdown of shoe materials by loading
	Deterioration of rubber (Loose of elastic, deformation, spalling, blister)	No cracking, some deformed	Cracked, deformed, sagged rubber bearing	Rubber bearing excessively deformed or with severe cracking. Severe rust on steel plates
	Corrosion	Moving and rolling functions are declining due to corrosion.	Vertical load support function declines due to corrosion.	Vertical load support function does not function well due to serious corrosion.
	Displacement	Movement sometimes reaches beyond design values.	Movement reaches beyond the allowable level, like collision with stopper.	Upper and lower shoe move significantly so that vertical load supporting function does not function well.
	Damages to attachments, anchor bolt-nuts	Looseness of set bolts, side block and anchor bolt nuts.	Breakdown of set bolts and anchor bolts. Damages on side block and pinch plates.	-----
	Damages to grout concrete or mortar	-----	Some breakdown of base concrete or mortar is detected.	Vertical load supporting function does not work well due to breakdown of base concrete or mortar.
	Abnormal sounds	Shoe generated sound.	Loud crashing sound is generated.	-----
	Piling of dust and sand	-----	Shoe is filled with soil or debris	Debris or soil is piled around shoe.
	Sweating, damping on bearing the pad	Some dampness	Standing water. Dampness. Dust. Vegetation	Dampness and spalling of concrete on bearing shelf
5.2	Expansion joint			
	Deterioration of rubber (Wearing, spalling, crack, breakage, ageing)	Torn around, no crack, not splitting	Torn cracks, splitting around	Deep torn or crack, splitting and ageing
	Breakage of steel (Corrosion, crack, deformation, breakage)	Deformation, no bent	Much deformation and bent	Serious deformation, bent over the limit
	Loosen or missing of anchor bolt-nuts	Some of anchor bolt-nuts are missing	Many anchor bolt-nuts are missing	-----
	Break off or breakage of drain gutter	Drain gutter is broken partially	Drain gutter broken widely	-----
	Out of level	Tilt appeared	Tilted out of position	Tilt caused danger to traffic
	Breakage of filling concrete	Some spalling, components intact and well anchored	Severe spalling, components damaged or torn loose anchor	Severe spalling, sections of Exp. J come loose and danger to traffic
5.3	Guardrail, Handrail			
	Breakage, missing due to vehicle collision	Some impact damage, no repairs required	Major impact damage - repairs required	Major impact damage - major repairs/ part replacement
	Crack, deformation	Some crack, deformation, no repairs required	Major crack, deformation, repairs required	-----
	Rebar exposure and corrosion	Some loose fixings	Many loose fixings	Loose fixings leading to local deformation
	Paint damage	Some deterioration of paint or rusting	Severe rusting	Guide post faded - not visible

Table ... Sample Evaluation Criteria for Bridge Inspection Results 8/8

	Structural Part / Kind of Damage	Estimated volume based on damage level		
		B	C	D
5.4	Approach road			
	Settlement of road	Settlement, movement - no signs of new movements	Major settlement, movement or deformation	Settlement and deformation with scour and slip
	Spalling/ Pothole on pavement	Some spalling, no potholes	Some spalling and potholes	Major spalling, many potholes
	Crack on pavement	Some cracking	Severe localized cracking	Severe cracking all over
	Settlement of foundation (Riprap, gabion)	—	Tension crack in approach embankment slope. Some scour but embankment slope stable	Fully developed slip failure. Major scour and unstable embankment slope
5.5	Traffic control sign board			
	Missing pole / breakage / deformation	User Information signs missing	Traffic prohibition sign missing	Load limit for weak bridge signs missing
	Affected by impact	Some impact damage but signs intact and visible	Major damage needing part replacement	Damage needing total replacement
	Unclear/ dirty	Dirty but visible	Only partially visible	Faded or barely visible fully blocked from view
	Obscured	—	Partially blocked by vegetation	Fully blocked from view
5.6	Lighting system			
	Warping of Lighting- post, reinforced leaking	Some rust on post	Severe rust on or slightly bent post	Rusted or bent post likely to fall on bridge deck
	Break/ Missing lighting- post	Functioning but not adequately	Many lights not working	Dangerously low lighting or electric shocks

Table Sample Evaluation Criteria for Tunnel Inspection

a. Concrete Lining

Facility	Member	Damage	Evaluation criteria		
			B	C	D
Tunnel	Concrete lining	Cracks/Corner Drop	Cracks (over 0.3 mm) or corner drops, which are not progressing	Cracks (over 0.3 mm) or corner drops which are progressing	Rapid progress of dense cracks or Tensile cracks and sheer cracks
		Concrete Peeling/ Creep	Thin concrete peeling or creeping	Thick concrete peeling or creeping	Large and wide scale Peeling or creeping
		Improper Construction joint	Gaps or opening of construction joints which are not progressing	Gaps or opening of construction joints which are progressing	‘-----
		Water leakage/ Free lime	Some leaks and free lime (Water ooze out)	Some leaks and free lime (Water drop)	Large-scale water leakage or free lime (Water gush out/flow out)

b. Tunnel Portal

Facility	Member	Damage	Evaluation criteria		
			B	C	D
Tunnel	Portal	Cracks/Corner Drop	Cracks (over 0.3 mm) or corner drops, which are not progressing	Cracks (over 0.3 mm) or corner drops which are progressing	Rapid progress of dense cracks or Tensile cracks and sheer cracks
		Concrete Peeling/ Creep	Partial concrete peeling	Wide concrete peeling or creeping	Large and wide scale Peeling or creeping
		Settlement/movement/ tilting	‘-----	Damage identifiable by visual inspection	Damage identifiable by visual inspection with cracks on the connection with tunnel body
		Improper Construction joint	Gaps or opening of construction joints which are not progressing	Gaps or opening of construction joints which are progressing.	‘-----
		Scouring	Small scouring	Large scouring	‘-----
		Water leakage/ Free lime	Some leaks and free lime	Large-scale water leakage or free lime	Large-scale water leakage or free lime

c. Inner Decoration Board & Tunnel Drainage System

Facility	Member	Damage	Evaluation criteria		
			B	C	D
Tunnel	Inner decoration board	Damage on the board	‘-----	Partial cracks and peeling	Large-scale cracks and peelings
		Damage on the accessories	‘-----	Damages on accessories, but do not lead to the falling of decoration board	Damages on accessories which lead to the falling of decoration board
	Drainage system	Damage on the drainage system	‘-----	Degradation of drain function	Heavy damage on the drain function
		Piling of debris	Small piling of debris, but no gradation of drain function	Degradation of drain function	Heavy damage on the drain function

Table Sample Evaluation Criteria for Culvert Facility Inspection**a. Box Culvert**

Facility	Member	Damage	Evaluation criteria		
			B	C	D
Box culvert	Reinforced concrete box culverts	Cracks	Cracks at long interval do not reach rebar depth	Cracks at short intervals reach rebar depth	Serious alligator cracks
		Concrete Peeling/ Creep	Some peeling or creeping	Large scale Peeling or creeping	‘-----
		Exposure of steel bars/ Corrosion	Partial rebar exposure	Severe rebar exposure and corrosion	‘-----
		Concrete Voids		Settlement/ movement / tilt can be seen	‘-----
		Water leakage/ Free lime	Some leaks and free lime	Severe leakage or free lime and corrosion	‘-----
		Settlement/ scouring	Settlement/ movement/ tilt to disturb drainage or scouring at wing or slope	Severe settlement/ movement / tilt to cause stagnant water or a gap between the culvert and the road Severe scouring at wing or slope	‘-----
		Abnormality at joints	Joint gap is not in progress	joint gap exudes seal	‘-----

b. Pipe Culvert

Facility	Member	Damage	Evaluation criteria		
			B	C	D
Reinforced concrete pipe culvert		Cracks	Cracks at long intervals do not reach rebar depth	Cracks at short intervals reaches rebar depth	Alligator cracks
		Concrete Peeling	Some peeling or creeping	Large scale Peeling or creeping	‘-----
		Exposure of steel bars/ Corrosion	Partial rebar exposure	Severe rebar exposure and corrosion	‘-----
		Settlement	Settlement that reduces drainage function	Severe settlement that disturbs drainage function	‘-----
		Joint defects	Leakage from connections	Severe leakage from connections	‘-----
		Water flow obstruction	Damage that reduces the drainage	Severely damaged with stagnant water inside pipe	‘-----
Colgate pipe culvert		Structural damage	Deformation or cracks in the structure	Large scale deformation or severe cracks in the structure	‘-----
		Corrosion	Some corrosion	Severely corroded	‘-----
		Settlement	Settlement that reduces drainage function	Severe settlement that disturbs drainage function	‘-----
		Connection joint damage	Leakage from connections	Severe leakage from connections	‘-----
		Drain damage	Damage to reduce the drainage	Severe damage and stagnant water inside pipe	‘-----

Table Sample Evaluation Criteria for Traffic Safety Facility Inspection

Guard Rail & Guard Cable

Structure	Position	Member	Damage	Evaluation Criteria		
				B	C	D
Traffic safety facility	Guard rail	Guard rail	Main member damages	Slight damage or tilting on the guard posts, beams or pipes.	Serious damages on the guard posts, beams and pipes, but do not lead to breakdown of main members.	Serious damages, dropout or tilting on the guard posts, beams and pipes.
			Accessory damages	Slight loosening or missing bolts on the mounting brackets, which do not lead to the drop out or breakdown of main members.	-	Loosening or missing bolts on the mounting brackets, which lead to the drop out or breakdown of main members.
			Corrosion	Some corrosion	Widespread corrosion	-
			Foundation damages	Slight damages of anchor materials or scouring around foundation, but do not lead to the breakdown of main members.	-	Serious damages of anchor materials or scouring around foundation which leads to the breakdown of main members.
		Guard cable	Main member damages	Limited damage, tilt or sagging at support pole or cable	Damage, tilt or sagging at support pole or cable	Serious damages on the posts or cables including sagging of cable and tilting of guard posts.
			Accessory damages	Slight loosening	-	Loosening or missing bolts, which lead to the drop out or breakdown of main members.
			Corrosion	Partial corrosion	Widespread corrosion	
			Foundation damages	Slight damages on the mounting brackets or partial scouring around foundation.	-	Serious damages on the mounting brackets or scouring around foundation which leads to the breakdown of main members.
		Concrete wall type guard facility	Cracks/ /corner drop	Partial cracks which has not reached steel bars.	Cracks, which is not large-scale, but has reached steel bars	Serious crocodile cracks which has reached steel bars

Table Sample Evaluation Criteria for Traffic Management Facility Inspection
Traffic Sign

Structure	Position	Member	Damage	Judge		
				B	C	D
Traffic management facility	Traffic signs	Main member, accessories, foundation	Main member damages	Slight damages including deformation and breakage of sign boards or sign poles. However, information on the sign boards is still readable.	Damages including deformation, tilting and breakage of traffic signs. Also, it is hard to read information on the sign boards.	Severe damages including dropout of poles or sign boards, or deformation or tilting of traffic signs.
			Accessory damages	Slight damages including loosening of bolts or deformation of sign boards. However, they may not lead to dropout of sign boards or mounting brackets.		Damages on the mounting brackets, loosening or dropout of bolts and nuts which may cause dropout of sign boards or sign poles.
			Corrosion	Partial corrosion	Widespread corrosion	
			Foundation	Slight damages to the anchors or partial scouring around foundation.		Dropout of bolts, breakage, deformation of anchor material or scouring around foundation. Also, they may lead to serious breakdown of traffic signs.

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Expressway Maintenance Manual

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General information

Road Management/ Department of Transportation (CC):			Bridge name:		
Company/ NH	Section:		Station of Bridge: National Highway:		
Inspector:			Main Obstacle Crossed:		
District:			Longitude: Latitude:		
Province/City:			Load Assessment:		
Starting time:			Inspector time: Date Month Year		
Finishing time:			Total of pages:		

Result of inspection, evaluation and works requirements are noted in tables of this Sheet

Map/ Pictures of Bridges, Parts of Bridges and damage locations (supplemented at the end of report, if any)

General Remarks:

.....

Engineer
 (Sign, name)

.....

Proposal of management unit:

.....

The report is checked and approved by:

.....

Reference: INSPECTION DATA FORMAT (BRIDGE FACILITY-1)

Guiding for note taking: Required to mark all the parts, the degree of damage. Where the structural parts that do not have the dash to confirm that no parts. Cases were not tested, clearly marked "Not inspection" and together with the reasons.

Total quantity / weight: recorded total volume or quantity of the whole kind of structural parts, units as described in the Manual Guide.

Volume estimates on the extent of damage: recording volume or the number of estimated damage for each level of damaged scales A, B, C, D as classified in the Manual Guide. Total estimated volume or quantity of the four levels of damage equal to the total volume / number as in the previous column.

Description of damage: Make sure the reader test results visualize the extent and scope of damage and location. For all the damage was assessed at level C or D must have graphics and photos, to indicate the level of damage (photos included with gauge) . For structural parts such as girders, piers of the multiple spans bridge as much description should indicate the exactly piers, spans which are deteriorated, damaged . Digitized, photos and detailed description of the damaged position is documents attached to the BIS.

Estimated maintenance method: including the normal maintenance with proposed volume (including cleaning, type rust, paint, and surface sealing, crack sealing patching, straightening warped tune, apply grease, wrapped reinforced concrete, clearance ...) or promote the repair damage at high levels. If not sure the proposed repair, write "discussion with the engineer" and make sure to provide enough information to help engineers can make decisions in office.

Priority: propose priority level at: **E** – Emergency; **H** – High

Reference: INSPECTION DATA FORMAT (BRIDGE FACILITY-1/2)

ANNEX-J_B-2-1/2

Code	Structural Part / Kind of Damage	Unit	Total Quantity	Estimated volume based on damage level				Damage description (Damage at level C and D must be noted)	Tentative repair works	Priority level
				A	B	C	D			
1	All type of bridge									
1.1	Entire bridge condition									
	Abnormal deflection	-								
	Abnormal Nosie	-								
	Abnormal vibration	-								
	Abnormal expansion gap	-								
	Settlement, Movement	-								
	Scouring	-								
2	Concrete bridge									
2.1	Concrete girder (I or T section, Box girder)									
	Deformation, Deflection, Sag	-								
	Crack	-								
	i. Near end girder support	m/m ²								
	ii. Near middle support	m/m ²								
	iii. Centre between supports	m/m ²								
	i. A quarter point between supports	m/m ²								
	v. Construction joints	m/m ²								
	vi. Segment junctions	m/m ²								
	vii. Near anchors	m/m ²								
	viii. Notch of a girder	m/m ²								
	Peeling, Spalling, Creep	m ²								
	Rebars exposure, Corrosion	m ²								
	Water leakage, Puddling	m ²								
	Free lime	m/m ²								
	Rusty fluid	m ²								
	Deterioration, Discoloration	m ²								
	Honey comb, Void	m ²								
	Chemical attacks	m ²								

Reference: INSPECTION DATA FORMAT (BRIDGE FACILITY-2/2)

ANNEX-J_B-2-2/2

Code	Structural Part / Kind of Damage	Unit	Total Quantity	Estimated volume based on damage level				Damage description (Damage at level C and D must be noted)	Tentative repair works	Priority level
				A	B	C	D			
2.2	Concrete Cross beam, Diaphragm									
	Deformation, Deflection, Sag	-								
	Crack	m/m ²								
	Peeling, Spalling, Creep	m ²								
	Rebars exposure, Corrosion	m ²								
	Water leakage, Puddling	m ²								
	Water leakage, Puddling	m2								
	Free lime	m/m ²								
	Rusty fluid	m ²								
	Deterioration, Discoloration	m ²								
	Honey comb, Void	m ²								
	Chemical attacks	m ²								
2.3	Concrete Deck slab									
	Crack	m2								
	Peeling, Spalling, Creep	m2								
	Rebars exposure, Corrosion	m2								

Reference: INSPECTION DATA FORMAT (BRIDGE FACILITY-3)

Code	Structural Part / Kind of Damage	Unit	Total Quantity	Estimated volume based on damage level				Damage description (Damage at level C and D must be noted)	Tentative repair works	Priority level
				A	B	C	D			
3	Steel bridge									
3.1	Steel girder, Truss member, Arch member and Steel pier									
	Deterioration of paint	m ²								
	Corrosion	m ²								
	Loosen and fallen of rivets, bolt-nuts	%								
	Crack	m								
	i. Welding portions on sole plates	m								
	ii. Girder end where cross section of web plate changes	m								
	ii. Welding portions with vertical stiffeners	m								
	iv. Welding portions with gusset plates	m								
	iii. Butt welding portions on lower flanges	m								
	vi. Welding portions with steel deck plates	m								
	vii. Welding portions between vertical stiffeners and steel deck plates	m								
	viii. End of stringers where cross section of the girder changes	m								
	ix. Base of vertical members on the arch ribs	m								
	x. Welding portions on shoe base plates	m								
	xi. Corners of steel piers	m								
	xii. Others	m								
	Deformation and buckling	m								
	Water leakage, Puddling	m ²								
3.2	i. Steel Cross beam, Stringer, Diaphragm									
	Deterioration of paint	m ²								
	Corrosion	m ²								
	Loosen and fallen of rivets, bolt-nuts, and HTBs	%								
	Crack	m								
	Deformation and buckling	m								
	Water leakage, Puddling	m ²								

Reference: INSPECTION DATA FORMAT (BRIDGE FACILITY-4)

Code	Structural Part / Kind of Damage	Unit	Total Quantity	Estimated volume based on damage level				Damage description (Damage at level C and D must be noted)	Tentative repair works	Priority level
				A	B	C	D			
4	Substructure	m ²								
4.1	Abutment and Wing wall									
	Tilting, Settlement, Movement	-								
	Scouring	-								
	Collision of ship and floating object	-								
	Crack	m/m ²								
	Peeling, Spalling, Creep	m ²								
	Rebars exposure, Corrosion	m ²								
	Water leakage, Puddling	m ²								
	Free lime	m ²								
	Rusty fluid	m ²								
	Deterioration, Discoloration	m ²								
	Honey comb, Void	m ²								
	Chemical attacks	m ²								
4.2	Pier and Pier head									
	Tilting, Settlement, Movement	-								
	Scouring	-								
	Collision of ship and floating object	-								
	Crack	m/m ²								
	Peeling, Spalling, Creep	m ²								
	Rebars exposure, Corrosion	m ²								
	Water leakage, Puddling	m ²								
	Free lime	m ²								
	Rusty fluid	m ²								
	Deterioration, Discoloration	m ²								
	Honey comb, Void	m ²								
	Chemical attacks	m ²								
4.3	Foundation (Footing, Pile cap, Pile)									
	Tilting, Settlement, Movement	-								
	Scouring	-								
	Collision of ship and floating object	-								
	Crack	m/m ²								
	Peeling, Spalling, Creep	m ²								
	Rebars exposure, Corrosion	m ²								
	Water leakage, Puddling	m ²								
	Free lime	m ²								
	Rusty fluid	m ²								
	Deterioration, Discoloration	m ²								
	Honey comb, Void	m ²								
	Chemical attacks	m ²								

Reference: INSPECTION DATA FORMAT (BRIDGE FACILITY-5)

Code	Structural Part / Kind of Damage	Unit	Total Quantity	Estimated volume based on damage level				Damage description (Damage at level C and D must be noted)	Tentative repair works	Priority level
				A	B	C	D			
5	Bridge accessory									
5.1	Bearing shoe									
	Breakage, Crack of bearing shoe body	Each								
	Deterioration of rubber (Loose of elastic, deformation, spalling, blister)	Each								
	Corrosion	Each								
	Displacement	Each								
	Damages to attachments, anchor bolt-nuts	Each								
	Damages to grout concrete or mortar	Each								
	Abnormal sounds	-								
	Piling of dust and sand	m ²								
	Sweating, damping on bearing the pad	m ²								
5.2	Expansion joint									
	Deterioration of rubber (Wearing, spalling, crack, breakage, ageing)	m								
	Breakage of steel (Corrosion, crack, deformation, breakage)	m								
	Loosen or missing of anchor bolt-nuts	Each								
	Break off or breakage of drain gutter	m								
	Out of level	m								
	Breakage of filling concrete	m ²								
5.3	Guardrail, Handrail									
	Breakage, missing due to vehicle collision	m								
	Crack, deformation	m								
	Rebar exposure and corrosion	m								
	Paint damage	m								
5.4	Approach road									
	Settlement of road	m ²								
	Spalling/ Pothole on pavement	m ²								
	Crack on pavement	m ²								
	Settlement of foundation (Riprap, gabion)	m								
5.5	Traffic control sign board									
	Missing pole/ breakage/ deformation	Each								
	Affected by impact	Each								
	Unclear/ dirty	Each								
	Obscured	Each								
5.6	Lighting system									
	Warping of Lighting- post, reinforced leaking	Each								
	Break/ Missing lighting- post	Each								

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INSPECTION DATA FORMAT (TRAFFIC SAFETY FACILITY)

[illegible]

INSPECTION DATA FORMAT (TRAFFIC MANAGEMENT FACILITY)

[illegible]

ANNEX-K

PICTURE RECORDS

PHOTO NUMBER:		PHOTO NUMBER:	
ROAD ID		ROAD ID	
STATION POST		STATION POST	

PHOTO NUMBER:		PHOTO NUMBER:	
ROAD ID		ROAD ID	
STATION POST		STATION POST	

ANNEX-L

Sample Intervention Levels of Bridge Inspection (Reference Material)

1. Introduction

Decision whether needed for repair or not is made along with consideration of priority order of maintenance activities based on the effects of damage to the road traffic safety, to the load bearing capacity and the durability of the bridge, the third one and costs needed for the repair.

The decision whether to repair steel and concrete structures is based on the results of inspection and divided into three categories is shown in **Table 1**. Category A is judgment which needs to repair soon, and B is no need to repair.

Table 1 Intervention level of steel and concrete structures of bridge

Classification			Items	Judgement content
A (Need to repair)		Serious or large damage, so need to be repaired urgently	To maintain the function of the road	Impact to the safety of road
			Improve bearing capacity and durability of the structure	If ignored, it will be extend to require reinforcement
			Repair to prevent damage to human	There is danger to human
B (No need to repair)	Conduct follow-up inspection	Depending on the develop of damage that consider the need to repair or not	To maintain the function of the road	May interfere with the safety of road
			For the load bearing capacity and durability of the structure	The load bearing capacity and durability of the bridge is reduced, likely to have to carry out repairs
			For prevention damage to human	May give danger to human
	No need to conduct follow-up inspection	Damaged but expansion is not expected	To maintain the function of the road	Can ensure road safety
			For the load bearing capacity and durability of the structure	No need to repair
			For prevention damage to human	There is no danger to human

- When damages as invested is class A which needs to repair, it is expected to consider priority order of repairing and managing works and decide the conducting time of works based on the priority order and available budget.
- If the damage is too large to be repair, or if the cause of the damage is harmful effects of salt, alkali, neutral reaction, repeating over loading and it requires specialized knowledge, it should be consulted for advice and guidance of knowledgeable and experienced specialists.

2. Criteria of intervention level of steel structures

From the results of detailed inspection, consider whether need to repair or not the main parts, spare parts, adjunct of the bridge corresponding to their functions. It should have judgement criteria supporting to damage evaluation to decide the necessity of treatment.

Table 2 Criteria of repair necessity for steel structure (Steel girder bridge, steel pier)

Evaluation		A (It is necessary to repair)	B (No need to repair, following inspection)
Type of damage			
Corrosion		Cross section damage is more than 10% of material thickness	Rust at large range and dotted corrosion
Cracked		Cracked	
Loose	The main material	More than 10% or more than 10 bars	At 5 ~ 10%, or from 5 ~ 10 bars
	Subsection	More than 35% or more than 10 bars	At 10 ~ 35%, or from 5 ~ 10 bars
Broken		Broken	
Painting aging		Painting is peeling off the entire surface	Painting is peeling off some places
Abnormal sound		Abnormal sound of metal	Squeal of metal
Abnormal shake		Abnormal shake	
Abnormal Flexure, transformation	The main material	Bent ≥ 125 the length of the material	Bent under 125
	Subsection	Bent ≥ 50 mm	Bent under 50mm
Cracked the welding		Cracked the welding	Painting film cracking near the welding

For the steel components except those shown in the above table such as shoes, expansion joint, bridge-fall preventing facility, it is necessary to inspect the condition of damage part, the cause of damage, the growth of the damage, and to judge whether repair is necessary or not.

3. Criteria of intervention level of concrete structures

There are many causes of damage of the concrete structure and the phenomenon of damage is also complicated, so it is necessary to capture the results of detailed inspection and aging prediction to decide whether need to repair or not.

For level A - need to repair, if there is a hazard to road traffic safety or human, based on survey results, it is necessary to repair quickly.

For those parts which are likely to cause harmful commander for the main part of the concrete structure and the third side, need to repair or not is represented by the values obtained after detailed inspection as shown in **Table 3**.

Table 3 Judgment of repair based on detailed inspection for concrete structure

Judgment Inspection Items	A (Need to repair)	B (Need to repair) (Note1)
(Note 2) Compressive strength	Compressive strength is less than 85% of standard design strength.	Compressive strength is greater than 85% of standard design strength.
Chloride ion content	≥ 2.5 kg/m ³	≤ 1.2 kg/m ³
Depth of carbonation	The carbonation spread is within 10 mm from reinforcing bar	The neutral spread is under 10 mm from reinforcing bar
Alkali-Aggregate Reaction (Note 3)	Has alkali-Aggregate Reaction	Has not alkali-Aggregate Reaction
Corrosion of reinforcing bar	Cross-sectional surface corrosion is remarkable	Corrosion is not visible

Judgment Inspection Items	A (Need to repair)				B (Need to repair) (Note1)			
Crack up (unit mm)		(Note 4) Corrosive environment				(Note 4) Corrosive environment		
		Serious	Normal	Light		Serious	Normal	Light
	Big	≥0.4	≥0.4	≥0.6	Big	≤0.1	≤0.2	≤0.2
	Medium	≥0.4	≥0.6	≥0.8	Medium	≤0.1	≤0.2	≤0.3
	Small	≥0.6	≥0.6	≥1.0	Small	≤0.2	≤0.3	≤0.3
	(Note) Big, Medium, Small level show level of harm to durability of concrete							

(Note)

- (1) If the value reached after detailed survey results exceeds the value and condition showed in section B-No need to repair in **Table 3** and do not repair, we must investigate more at least 1 time to confirm the spread of the damage.

If the damage is confirmed to be spreading strongly after further investigation, decide whether to repair or not according to the results of further investigation.

- (2) In the case except taking the core for other examination, it is possible to measure the compressive strength with a Schmitt hammer. However, if the decline of the compressive strength of concrete structure with high strength is not allowed or higher accuracy is needed, it is desirable to check the compression by taking the core.
- (3) To determine whether or not Alkali-Aggregate Reaction, it is necessary to consider synthetically items such as (1) Type of stone, minerals (2) Rate of the reaction components (3) Alkali in concrete (4) Width of crack (5) Gel is leaked or not.
- (4) Environment Corrosion is defined as below;

Serious: in heavy rain and frequently wet; in serious dew and freezing; be worn away by seawater or the water of rough field.

Normal: normal climatic conditions and normal structure; No heavy rain, no immersion in water, no freezing, for example, concrete in the ground and concrete in water continuously

Light: in normal climatic conditions, only a short time in the beginning nutrients and level of harm of damage to the durability of the concrete is shown in **Figure 6.6-20**.

Table 4. Judgement of Alkali-Aggregate Reaction

Alkali-Aggregate Reaction	No Alkali-Aggregate Reaction
Alkali-Aggregate Reaction is identified. Spread $\geq 1000\mu$, and crack width $\geq 0.2\text{mm}$ of PC structure, density per unit of $\geq 0.3\text{mm}$ crack width of RC structure $\geq 1\text{m}^2/\text{m}^2$	Beyond the value in the left column

Table 5 Level of harm of damage to the durability of the concrete

Items	Level of harm		
	Large	Medium	Small
Depth of cracks	Passing-through crack	Medium crack	Surface crack
Covering depth	$\leq 40\text{mm}$	40~70mm	$\geq 70\text{mm}$

Notes Causes affecting the level of damage, in addition to the reasons stated above, are whether of not concrete surface covering, materials, concrete mix proportion, concrete joints.

The allowance values of the crack by design are listed below:

- 1) Especially serious corrosion: 0.0035 C
- 2) Corrosion environment: 0.004 C
- 3) General environment: 0.005 C
- 4) C: Reinforcing bar covering depth (mm)