Form SI-1

Annual Plan of Snow/Ice Countermeasure Cost

Administration Bureau (unit: thousand T.L)

Month / Items	November	December	January	February	March	April	Total
	Contract expenditure	Contract expenditure	Contract expenditure	Contract expenditure	Contract expenditure	Contract expenditure	Contract expenditure
Snow/ice countermeasure work							
Frost preventing chemicals							
Snow/ice countermeasure facilities							
Contracting the meteorological observation							
Traffic control (guard man)							
Total							

Form SI-2

Report of Snow/Ice Countermeasure Contract

Name of main maintenance center	Name of road	Snow/ice countermeasure work			Chemicals and solutions				Meteorological observation	Others
		Job title	Contract sum	Contractor	Name of chemical	Unit contract sum	Estimated quantity	Estimated sum		
									1. Name of contracting office 2. Contract sum 3. Contractor	Name of chemical/ solution contractor

Form SI-3

Snow/Ice Countermeasure Condition Table (Monthly Report)

Name of road	Name of maintenance office	Outline of the weather *1					Traffic regulation	Outline of the work *2		Consumption of chemicals		No. of workers		
		Max. snow depth	Max. snowfall/ day	No. of snow days	Min. temper- ature	No. of frost days		No. of frost work days	No. of snow removal work days	Chemicals (t) *3	Solution (m^3)	Contracted		KGM
												Binding A	Binding B	

*1 Enter the observed values at a location of the administration office.

*2 Enter the number of overlap days in parentheses when frost and snow removal works are conducted in the same day.

*3 When the chemical is purchased and sprays in a form of solution, convert the sprayed quantity into the quantity of chemical and enter the converted value.

Form SI-4

Application of Snow/Ice Countermeasure Cost (Monthly Report)

Year/month (unit: thousand yen)

Items	Planned sum	Up to the previous month	This month	Aggregate	Balance	Remarks
		Contract expenditure	Contract expenditure	Contract expenditure	Contract expenditure	
Snow/ice countermeasure work						
Frost preventing chemicals						
Snow/ice countermeasure facilities						
Contracted the meteorological observation						
Traffic control (guard man)						
Total						

Form SI-5

Reporting of Snow/Ice Countermeasure Condition by Phone
(Administration Bureau - Head Office) - Regular Report -

Name of Road	Section	Closing time	Cause of closing	Remarks												
				Outline of weather *				Outline of accident			Advisory under official announcement					
				Location	Snow-fall	Location	Min. temper-ature	Date	Location	Content	Gale advisory	Gale and wave advisory	Wind and snow advisory	Heavy snow advisory	Heavy snow warning	Avalanche advisory

* Outline around a bottleneck point

Form SI-6

Reporting of Snow/Ice Countermeasure Condition by Phone
(Administration Bureau - Head Office) - Emergency Report -

Name of road	Section	Closing time	Cause of closing	Remarks													
				Outline of weather				Outline of accident			Advisory under official announcement						
				Location	Snow-fall	Location	Min. temper-ature	Date	Location	Content	Gale advisory	Gale and wave advisory	Wind and snow advisory	Heavy snow advisory	Heavy snow warning	Avalanche advisory	

	Progress of work				Current work condition	Problems
Work condition	Alert system	(from	to	)		
	Chemical spray stage	(from	to	)		
	Snow removal stage	(from	to	)		
	Regulation for chain	(from	to	)		
	Door closing stage	(from	to	)		
	Emergency stage	(from	to	)		
	Traffic regulation condition				Others	
Traffic regulation conditions	Speed regulation	(from	to	)		
		(from	to	)		
	Regulation for chain	(from	to	)		
	Closing	(from	to	)		

4.12 Motorway Maintenance Manual for Pavement

4.12.1 General

1) Scope of Application

This guideline is applied to the motorway managed by KGM. The guideline is general and regional characteristics must be considered for specific items of inspections, planning, and maintenance.

2) Purpose of Pavement Maintenance and Repairs plus other Conditions

(1) The purposes of pavement maintenance and repairs are the following:

- To sustain pavement durability and the integrity of the pavement structure
- To sustain driver's comfort and maintain traffic safety
- To avoid environmental deterioration

(2) Inspection and maintenance activities are often conducted while open to public traffic. Therefore the following aspects shall be considered while inspections and maintenance are conducted:

- Identify surface condition changes in the early stages of deterioration
- Damages which need emergency repairs shall be repaired temporarily
- Surface conditions shall be monitored to predict future surface changes
- Maintenance schedules shall have long term plans
- Make effective use of surface condition information and construction records
- Enforcement of automobile laws and traffic safety education

3) Definitions for Pavement Deficiencies and Maintenance Methodologies.

(1) Deficiencies

Definitions of pavement deficiencies are as follows:

Name	Definition
Rutting	Rutting describes the formation of depressions or tracks in the pavement surface caused by wheel load.
Cracking	Cracking is separation of the pavement surface. It is classified according to the levels of deficiencies. They are called hair, linear, and alligator cracks.
Skid	The pavement surface is polished by traffic and high temperature. It will cause losses of skid resistance
Faulting	Level differences are caused by differences of whole pavement areas or materials structure.
Longitudinal roughness	Longitudinal unevenness is caused by corrugation, uneven subsidence or periodic waves.
Local surface condition	Local damages to the pavement.

(2) Definitions of Major Repair Methods

Name	Repair Method
Overlay	Addition of more than 3 centimeters of bituminous materials (overlay) on existing surface.
Replacement	Remove existing pavement and pave to the former surface height
Scraping	Removal of existing surface by machines.
Scraping and Repaving	Repave to the thickness scraped, or to the thickness of deficiency.
Patching	Filling depressions with mixture.
Faulting	Filling mixtures to even out an unleveled surface.
Sealing	Applying bituminous materials to cracks on surface.
Surface Repair	Chemicals, bituminous materials, sand, and other materials are applied to the surface.
Grooving	Groove on the surface of pavement (safety traction).

4) Administration Structure

(1) Maintenance offices shall have an administration structure allowing it to take prompt action for pavement deficiencies like cracks, potholes, traverse unevenness, longitudinal unevenness, by daily monitoring.

(2) Management should monitor the existing conditions of roads in its jurisdiction quantitatively and should evaluate them objectively.

4.12.2 Investigation for Pavement Surface Conditions

1) Method

Investigation for the pavement surface is the measurements and evaluation of existing deficiencies of the pavement surface. It is the fundamental process for rational and systematic repair/maintenance of the pavement surface. The methods of attesting the pavement surface conditions are broken down into inspections and investigations.

2) Main Inspections Items

Inspections will be made based on the Inspection Manual 4.7.

The following are the main inspections items of the pavement surface to be checked by maintenance patrols:

Items	Inspection
Rutting	(1) Observe the wheel behavior while driving. (2) When raining, surface water should be observed. At night, reflections of water from rutting areas are easy to detect.
Cracking	(1) Observe while driving slowly along the shoulder, or stopping occasionally. (2) Observe after rains, when the surface is drying. (3) Sound from the normal surface may be different from the cracked surface while driving. (4) When records from simple sketching and photographing are made, the width of lanes, width of lane markings (15 cm, 20 cm), or length of lane marksings (6m, 9 m) or other scaled objects shall be recorded with the crack information.
Skid Resistance	(1) Check to see if there is bleeding or flushing. (2) Check to see if there is textures and reflections. (3) Check to see if there are sand, dirt, ice, snow, and other foreign substances. Pay attention to the sound from the surface while driving.

Faulting	(1) Pay attention to the driving comfortability and the sound. (2) Observe vibrations and passing sounds of other vehicles when stationed at the shoulders. (3) Observe the movement of loads on heavy trucks.
Local Deformation	Potholes, surface detachment, rises, depressions, flushing, and foreign objects on the pavement surface shall be observed.

3) Measurements

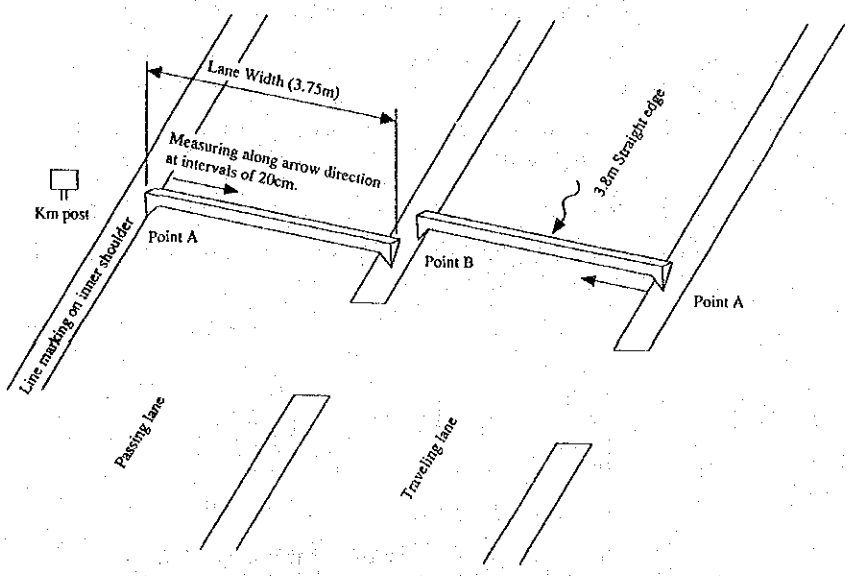
(1) Rutting

a) Method

A 3.8 m straight edge shall be utilized for deficiencies found locally for small scale measurements. On routes where large scale rutting is recognized, a rutting measuring vehicle will be employed, if possible. In areas where causes of rutting are from friction, studded tires, etc., periodic inspections shall be conducted after the winter season.

b) Measurement by a 3.8 m Straight Edge

On traveling lanes (climbing lanes included), a 3.8 m straight edge is set at the inside shoulder lane marking. On the passing (inner) lane, it is set at the inside lane marking on the side of the median. The following Figure, is referred to the measurement.



Mesuring Method for Rutting by Straight Edge

c) Measurement by a Rutting Measuring Vehicle

This measurement is conducted by a manual or vehicle with photographing device based on the km posts set along the shoulder.

d) Organizing the results

The results of measurements shall be organized in tables and annual changes shall be illustrated on graphs.

(2) Crack

a) Methods of Measurement

The initial stage of damage, crack density rate of about 15 %, shall be recorded by sketching, and intermediate stage of damage, crack density rate of about 20 % shall be recorded and measured by the crack recording method. The periodical recording shall be conducted after winter program.

Section of repair methods and design of overlay thickness requires data on deflection depth, therefore, survey for deflection depth should also be done in the same period with the crack survey.

b) Sketching

The pavement surface survey method in the initial research shall be selected from the following methods.

(i) If the traffic volume (one direction) per day is less than 10,000 vehicle (equivalent to peak hour volume of 1,000 vehicle/hour), the crack area shall be recorded by photographing on the ground or by the scale and sketching. The cracks on surface shall be chalked white for clearer record on photographing.

(ii) If daily traffic volume is more than 10,000, the cracks will be sketched and evaluated by ocular survey by reading a tape measure placed on the motorway shoulder.

(iii) Three to five technician shall calculate the crack density rate of crack areas segment by segment directly. Photographs of cracks which represent typically the areas shall be taken.

(iv) Crack density rate is calculated from photographs taken from the shoulders. The photographs shall include lanes and shall be taken from one direction.

c) Method by Crack Measuring Vehicles

Lanes that have crack areas spotted visually are photographed by employing the vehicle which is equipped with photographing devices, batteries, and lighting devices.

d) *Organization of Results*

The results of crack survey are organized by using Form of Pavement Record. The crack rate is organized by 100 meter segment, and further, the data shall be organized by 1,000 meter segment also.

(3) Deflection Measurement Method

The purpose of deflection measurement is to determine pavement strengths in order to assess the pavements residual life, as well as to design overlays/strengthening wearing courses.

Deflection measuring methods are available for use in pavement evaluation work. The following are typical equipment for surveying:

- Benkelman Beam
- Falling Weight Deflectometer (FWD)

a) Deflection Measurement by Benkelman Beam

(i) Multiple wheel load of rear wheels is 5 ± 0.25 ton and air pressure is 7 ± 1.0 kg/cm^2

(ii) When deflection is measured, surface temperature and atmospheric temperature shall be recorded when deflection is adjusted to the impact of temperature, an adjustment shall be made to overlay design.

b) Deflection Measurement by FWD

Bearing capacity evaluation by the Falling Weight Deflectometer (FWD) is an analytically based method. The advantage compared with more empirical methods is that FWD analyses may be used on any type of materials and structures and under all

climatic conditions, whereas the empirical methods may only be used under those conditions for which the empirical relationship were developed.

One of the great advantages of this fully automatic and remote controlled test equipment is the measuring speed, which is at least five time as fast as a Benkelman Beam team. This advantage may be used to obtain more precise information of the bearing capacity by reducing the distance between the measuring points only 50 meter, and still have a higher operating speed compared with the Benkelman Beam.

(4) Skid Resistance

Skid resistance between the pavement and a tire is measured by a locked wheel skid test vehicle. A test vehicle travels at a constant speed with rolling the test wheel. When it is desired to measure the skid resistance, the test wheel is completely locked and the generated braking force, F, and the wheel load, P, are simultaneously measured. Then skid number, SN, is determined by as follows;

$$SN = \frac{F}{P} \times 100$$

Measuring conditions are follows.

a) measuring speed : 80 km/h.
b) measuring interval : 200 m
c) water film : 0.5 - 1.0 mm

(5) Faulting

Faulting between embankments and structures can cause a bump at the approach to a structure. The faulting is measured by routine inspection. If it is necessary to express the faulting depth, faulting at the backfill of the structure is measured by a string and rule. A string 15 m long is stretched along the outer wheel path from the expansion joint of the abutment. The depth to the pavement surface from the base line string is measured and the maximum depth is the amount of faulting.

(6) Longitudinal Roughness

Roughness and corrugation in the longitudinal direction of the road are measured using a longitudinal profilometer.

The longitudinal profilometer is manually drawn over the road to record the roughness of the road surface.

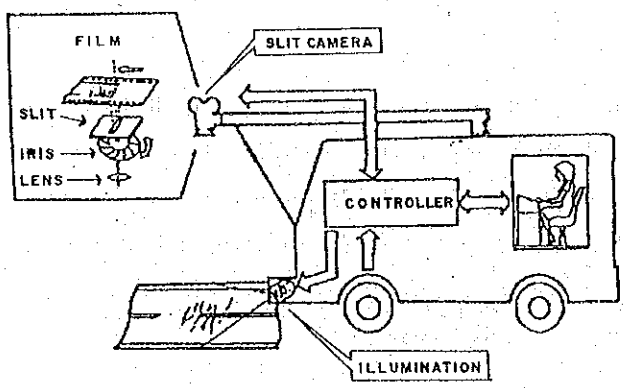
The measurement is conducted along the rutting line in the lane, with the results of the measurement being read every 1.5 m. The standard deviation of these values is taken as the value of the longitudinal roughness.

(7) Introduction of Automatic Survey and Recording System by Vehicle

An automatic survey and recording system for an evaluation of pavement surface is introduced herewith for cracking, rutting and longitudinal roughness surveys based on experience in Japan. The followings are the concept of each equipment.

a) Cracking Survey

Continuous Road Surface Photographic Recorder for Survey cracks.

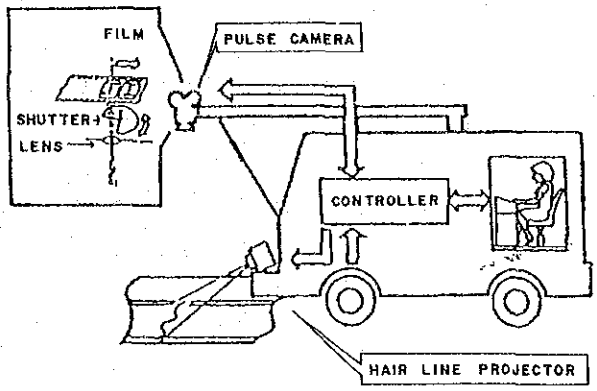


Cracking Survey

Cruising at speeds of 5 km/hr. to 80 km/hr. it records existing pavement conditions continuously on 35 mm strip film.

b) Rutting Survey

Rut Depth Photographic Record for rutting survey.

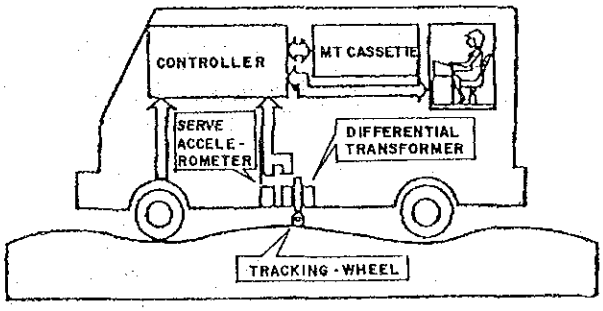


Rutting Survey

Cruising at speeds of 0 km/hr. to 80 km/hr. it records rutting conditions in paved road surfaces at specified intervals (minimum 0.1 m) on 35 mm film.

c) Longitudinal Roughness

High-speed Profilometer for surveying longitudinal roughness.



Longitudinal Roughness Survey

Cruising at a speed of 0 km/hr. to 40 km/hr. it records longitudinal roughness for measurement of roughness.

(8) Survey Methods by AASHTO

(a) Cracking Survey

Classification of Cracks

Cracks are classified in accordance with the AASHTO Road Test procedures, as follows:

Class 1: Fine cracks not visible under dry surface conditions by a person with good vision standing at a distance of 15 ft.

Class 2: Cracks that can be seen at a distance of 15 ft. but exhibit only minor spalling such that the opening at the surface is less than 1/4 inch.

Class 3: Any crack spalled at the surface with a width of 1/4 inch or more for at least one-half its length.

Class 4: Any crack which has been sealed.

Cracks in Class 1 and 2 are classified as fine cracks and Class 3 and 4 as wide cracks. Cracks are also categorized into four (4) types by their shape sharpness and location, e.g.:

- longitudinal crack
- transverse crack
- corner crack
- block/random crack

Cracking

Cracking is defined as the proportion of the pavement surface with cracks and is expressed in linear meters of cracks (class 3 and 4) per 1,000 sq. meters of surface area.

Cracking Index

The Cracking Index is the total length of all cracks (Class 1, 2, 3, and 4) per 1,000 sq. meters of surface area.

Survey Method

The length of cracks may be roughly estimated for each area by determining its proportion in relation to a longitudinal or transverse segment of the area. Although no

tape may be used for the measurement, it can be visually estimated accurately enough. For the first stage of the survey, the surveyors should be trained with different illustrations of cracking levels. Whenever accuracy in the surveying of cracks is required, the actual length of cracks should be measured by tape.

(b) Patching survey

Patching

The area of pavement surface patched with asphalt concrete is expressed in square meters of patching per 100 sq. meter of surface area.

Survey Method

The patch area may be estimated by using the judegment of surveyors trained in the knowledge of civil engineering. Actual measurements are recommended if accuracy is in question.

(c) Roughness Survey

The Roughness of the road Surface can be surveyed by a profile analyzer or a response type of roughness meter. In the first case, the indicator is expressed by one or more coefficients while in the second case, it is expressed by (mm/km) or cm/km.

4.12.3 Maintenance and Repair Standards and Evaluation of the Road Surface Condition

1) Determining the Maintenance and Repair Standards

Maintenance and Repair Standards are created to carry out maintenance and repairs in a rational and systematic way. The standards shall be determined to establish a long term maintenance and repair plan for the pavement surface. The standard consists of Repair Requiring Judgement Values and Maintenance and Repair Objective Values, as follows:

(1) Repair Requiring Judgement Values

These are the surface condition values for starting a repair plan preparation to determine the type of repair needed and the schedule for that repair.

(2) Repair Requiring Objective Values

These are based on surface condition values where maintenance and repair shall be completed before the surface condition value reaches the objective value .

2) Maintenance and Repair Standards

Maintenance and Repair Requirement Judgement Values and Maintenance Requirement Objective Values are listed in the following Table 4.12.1.

Table 4.12.1 Repair Requiring Judgement Values and Maintenance Requiring Objective Values

Evaluation	Rutting (mm)				Faulting (mm)						Skid Resistance		Cracking (%)	
	Lanes other than Climbing Lane		Climbing Lane		Connecting to Bridges		Connecting to Traverse Structures		Bridge Deck Expansion Joint Connecting parts					
Rating	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Value	15	25	20	40	-	20	-	30	-	15	30	25	20	40

note:

Rating	Description
A	Repairs may be necessary because of heavy damage
B	Repairs may not be necessary since damage is not heavy

3) Repair Standards and Planning

(1) Procedure for Establishing a Repair Plan

The following procedures should be followed to establish a long term repair plan, based on the repair evaluation measurements for rutting, skid resistance, and cracking. The measurement data location, comparison against the standards and timing of repairs will be determined.

- preparation of a surface condition management chart
- evaluation of the surface conditions
- prioritized programming of motorway sections
- programming of annual repair activities

(2) Preparation of Surface Conditions Management Chart

The measurement results per unit of distance (usually 1 km) for rutting, skid resistance and cracking should be calculated and organized on a "Surface Condition Management Chart".

(3) Evaluation of Surface Conditions

The surface condition survey results are ranked based on Table 4.12.1 to judge necessity of repair. (It is convenient to calculate accident rates per 1 km).

(4) Evaluation of Surface Conditions by PSI (AASHTO)

The serviceability of a pavement is expressed in terms of the present serviceability index (PSI). The PSI is obtained from measurements of roughness and distress, e.g., cracking, patching and rut depth (flexible) at a particular time during the service life of the pavement. Roughness is the dominant factor in estimating the PSI of pavement.

Equations to determine the level of serviceability of the pavement are as follows:

$$PSI = 5.03 - 1.91 \log (1 + SV) - 0.01 \sqrt{C + P} - 1.38RD^2$$

PSI = the present serviceability index

SV = the mean of the slope variance in the two wheel paths

C = cracking: the area in square meters per 1,000 sq. m. of pavement surface exhibiting class 2 or class 3 cracking

P = patching: the area of skin/deep patching in square meters per 1,000 sq. m. of pavement surface

RD = a measure of rutting in the wheel paths

In this equation, roughness is measured by a Road Roughness Meter.

Present serviceability is a subjective assessment by the road users using their own guidelines and judgement. It is understood that the basis for judgement may be affected by the sensitivity of the road users, national characteristics and national economic conditions since comfort or riding quality is a matter of subjective response or the opinion of the users. Each country, therefore, may have their own rating criteria.

However, a PSI value of 3.2 is recommended for pavement overlay, considering the following:

- Designed terminal serviceability is 3.0
- Safety factors is 0.2.

(5) Preparing Priority Chart

The result from an aggregation of the rankings by using the surface evaluation scale should be written on a "Priority Chart".

(6) Determination of Repair Segments and Timing

The major considerations when determining repair segments and timing by the Repair Priority Chart are the following:

(a) Repair of the segment ranked first in each category should be completed within the fiscal year unless otherwise stipulated.

(b) The segments which are ranked high by the combination of two category should be repaired preferably within the fiscal year. For those segments which cannot be repaired within the fiscal year, repair shall be planned for the following fiscal year.

(c) Even when the total evaluation ranking is low, long term plans for the whole area of interest shall be prepared to avoid a concentration of repair work in any one year.

(d) Generally the repair requirements are segmented in 1 km units. However, when segments are determined, the relationships of the degree of damages in the adjacent segments, traffic control, structures, and operations budget shall be considered.

4.12.4 Selecting and Designing Maintenance and Repair Methods for Asphalt Pavement

1) Fundamentals of Selection

To maintain and repair pavement, it is important to select an appropriate and rational method of repair. For this purpose, it is necessary to evaluate comprehensively the conventional methods of construction experienced to date, after completely clarifying the cause of the damage to the pavement according to the type of road.

The road should normally be open to traffic while it is being paved. Under these conditions, the methods used for maintenance and repair are selected from a relatively small number of alternatives. Nevertheless, it is important to select a safe, fast, and maneuverable method of construction, with high consideration given to the durability of the treatment and the cost of application. The maintenance and repair method chosen is not primarily dependent upon a particular type of damage to the pavement. Various treatment methods have been used according to the behavior of a specific road surface. These can range from a band-aid type of treatment to a long-term type of repair. Consideration should be given to various methods of construction, so that the optimum treatment suited to the particular region can be used.

Maintenance and repair methods can be classified as follows:

(1) Maintenance Method of Construction

Work to be accomplished immediately
Patching, filling potholes, correcting differences in levels, etc.

Work to be executed in due course
Treating the road surface, cutting the road surface, taking corrective measures for a decrease in slip resistance or for localized cracks, etc.

(2) Repair Method

Work to be accomplished for a long-term improvement
Overlaying, re-casting, etc.

The following are methods for the selection and design of construction for breakage based on the findings and investigations of road behavior and detailed research to help determine the causes of damage.

2) Rutting road

To repair a road where rutting has developed, select one of the methods specified below according to the causes and degree of such rutting:

Rutting attributable to consolidation and flow

- Cut convex portions on the road and use it without further repair
- Overlay
  - Direct overlay
  - Overlay after cutting convex portions of the road
  - Entirely cut the surface course and reconstruct

Rutting attributable to abrasion

- Patch worn portions
- Overlay
- Entirely cut the surface course and reconstruct

(1) Cut convex portions and use the road without further repairs

In this method, convex portions in a section not affecting the road drainage (mainly curves and straight portions, etc.) are cut off as shown in Figure 4.12.1, while the road is used without further repair. It involves, however, some problems in flatness and noise control. On an expressway, therefore, it is desirable to limit the use of this method to local maintenance and repair as a temporary method.

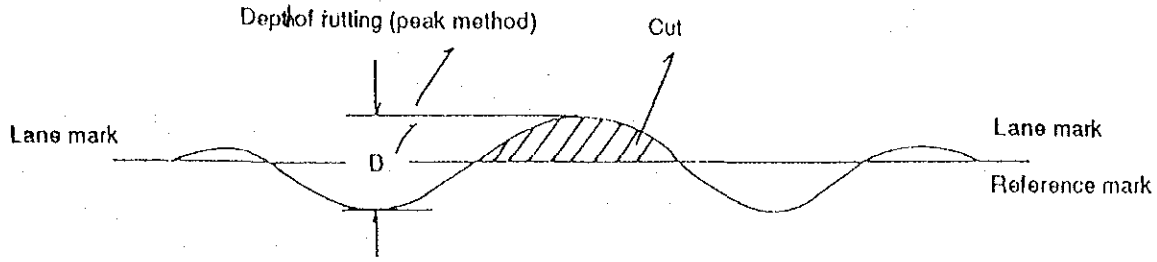


Figure 4.12.1 Cutting Convex Portions on the Road

(2) Overlay

As a maintenance/repair method to be used after putting the road into service, it is desirable to select the overlay method for the following reasons:

- An increase in asphalt course thickness will lead to an improvement in the entire pavement construction.
- It is unnecessary to correct or modify the drainage and traffic safety facilities in the first overlay.

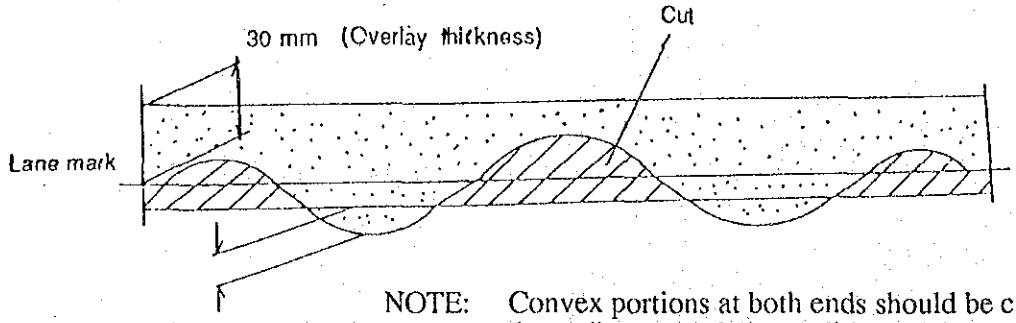
In this method of construction, it is the general rule to overlay all lanes of the road. From an economic point of view, the overlay method should be applied to a four-lane section of the road. For a six-lane section and an entrance lane section, it is necessary to fully study whether the overlay method or some other method of construction should be used, while considering the rutted road condition. The road may have a changed quality due to an improper preparation of the surface course mixture, a breakage of a surface course, insufficient compaction, superelevation, etc. In such cases, it is desirable to cut and remove the defective portion or portions and the overlay method should not be used. The following methods of construction are available as corrective measures for rutting:

a) Direct overlay

This method is used in the early stages (with rutting of less than 20 mm) within a range of maintenance and repair target values, with a thickness of 40 mm per course as the standard. In the overlay method, a road is overlaid without any pretreatment, such as cutting.

b) Cut convex portions and overlay

In this method, convex portions are cut and overlaid at a rutting level of over 20 mm, as shown in Figure 4.12.2. The overlay is normally 30 mm thick.



NOTE: Convex portions at both ends should be cut, depending upon their conditions. The gate portion should be within a maximum of 10 = deep below the level so cut.

Figure 4.12.2 Cutting and Overlaying Convex Portions on Road (an instance of work execution in the case of 20 mm and above in rutting)

(3) Entirely Cut and Replace the Pavement

This method of construction is used normally to overlay those roads that have been overlaid twice or more. If rutting should exceed the maintenance and repair standards due to a consolidation, flow or abrasion on the surface course, cut the road entirely. In this case, the formation level should be shaped as shown in Figure 4.12.3, by cutting or otherwise.

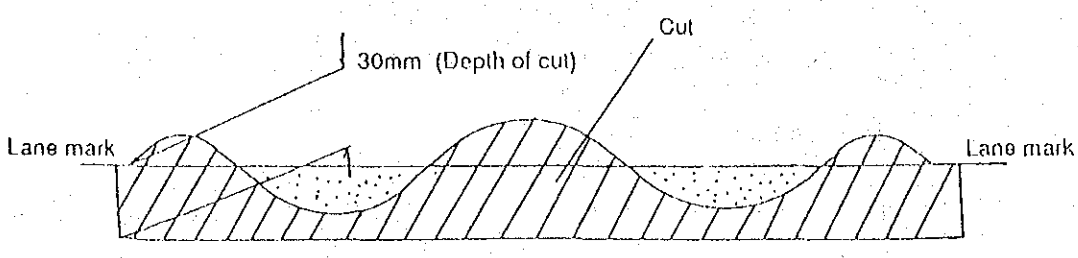


Figure 4.12.3 Cutting and Replacing Pavement

A minimum paving thickness is generally determined at 2.5 times the minimum aggregate particle diameter (D) (or 2.5 D) of a ply of paving materials. Although dependent upon the condition of rutting, the depth of cut is generally determined as described below.

A standard minimum depth of cut is approximately 30 mm. For a single rut with a cutting depth of 30 mm (e.g., in a section like an entrance lane, where rutting is remarkably advanced) or if a section of pavement has a maximum aggregate particle diameter of 20 mm, the depth of cut may be within 50 mm.

(4) Patching

In this method, a ply of paving materials is directly placed in a concave area. With the concave portion cut at the ends as shown in Figure 4.12.4, it is patched as a strip.

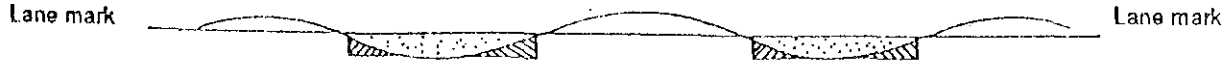


Figure 4.12.4 Patching

3) Cracking Road

(1) Cracking on earthwork.

Irrespective of the cracking rate, the maintenance/repair method discussed below should be used. The rate at which cracking has developed and the sequential changes with which a crack has been extending on a plane should be recorded and used as data to determine a method of repair.

- A line crack should be sealed with an emulsifier, straight asphalt, mortar, etc., according to the width of the aperture.

- For a crack which has occurred through a plane, the road should be overlaid to a required minimum thickness on the surface and corrective measures for rutting should also be taken.

- Where alligator cracks are clustered locally while cracking is found elsewhere on the road surface and if the cause can be attributed, as follows:
  - to a structural problem, the road should be locally reconstructed.
  - to a material problem, the surface course should be reconstructed locally.

- Where alligator cracks are clustered locally and there is considerable cracking elsewhere.

  - after locally reconstructing the defective portion, the cracked portion should be overlaid to a required thickness to reinforce the pavement as a whole, as required, if such cracks are attributable to a structural problem.

  - after cutting and reconstructing the defective portion locally on the surface course, the cracked portion should be overlaid to a required minimum thickness to seal the surface entirely, as required, if such cracks can be attributed to a material problem.

- Where alligator cracks are found continuously over a wide range.

  - after reconstructing the pavement entirely, an overlay should be applied to a required thickness to reinforce the pavement as a whole, if such cracks can be attributed to a structural problem.

  - the road should be entirely cut and reconstructed, if such cracks can be attributed to a material problem.

(2) Cracking on a bridge

To repair cracking on a bridge, sections within bridge joints should be independently evaluated, and an overlay-free method of construction should be selected from the methods heretofore presented.

The overlay should be limited to one course. Two or more courses of overlay involve drainage improvements, an increase in height of safety fences, signs, etc. Therefore, a final decision should be made after an economic evaluation.

Such roads as a toll roads or the like, which can be used by low-speed vehicles, may be subjected to a surface treatment method of construction aimed at the prevention of penetration by rainwater, etc.

4) Slippery Road Surface

For a road which has had a decrease in sliding resistance, one of the following methods should be selected, depending on the cause and extent of the decreased sliding resistance:

(1) Where the road has been worn by traffic (mainly pavement mixtures):

- Apply a coat of hot asphalt mixture or an overlay
- Add a sealant to which a highly adhesive binder is applied or apply a resin coat
- Cut the road thinly on the surface and putting it into use without further treatment
- Grooving (asphalt concrete is not durable enough)

(2) Where the excess asphalt in surface course mixtures has frozen (or flashed):

- After cutting the surface of the road, apply a hot asphalt mixture or an overlay
- Apply a hot asphalt mixture or overlay
- Add a sealant to which a highly adhesive binder is applied or an overlay
- Treat the surface by spreading aggregates (this method should not be used for an expressway)

5) Faulting

For a road with differences in levels, one of the methods mentioned below should be selected.

(1) Correcting Faulting

As illustrated below, patching should be performed after grinding to a required depth at the end. An applied length of 10 to 15 meters is generally used. The patch should be applied so as to attain a gradient difference of 0.5 % or less from front to back.

(2) Before and After an Expansion Joint on a Bridge

According to the extent of breakage, selection of one of the following methods is recommended:

- Replacement ----------where an extreme difference in levels or alligator cracking has taken place
- Strip patching----------most appropriate method of construction
- Resin surface treatment------a method appropriate within a difference between levels range of about 10 mm

(3) Explanation of Maintenance/Repair Methods

a) Faulting

The method of correcting a faulting has been nearly standardized. Figure 4.12.5, shows the general form of this method.

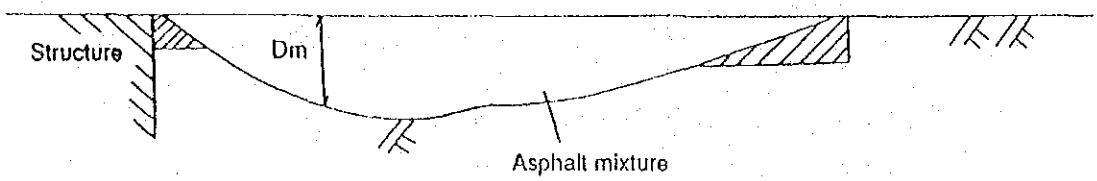


Figure 4.12.5 Correcting Differences in Levels where a Structure Exists

As illustrated in Figure 4.12.5, the portion to be patched is cut off at the end to a level equal to the spread thickness and the patch is applied so as to attain a cross sectional gradient difference of 0.5 % or less.

The applied length, although dependent upon the depth and/or shape of the difference in levels, is generally 10 to 15 meters. Patching is to have a maximum depth of 20 to 30 mm above the reference value.

Two types of patching materials (maximum particle diameter 5 mm or 13 mm, with asphalt volumes around 7.0 % and 6.5 %, respectively) are to be properly used according to the maximum depth.

b) Correcting a difference in Levels before and after an Expansion Joint

The correction of a difference in levels before and after an expansion joint has a correction depth range of from 5 to 15 mm depending on the purpose of the correction such as repairs for damages to the floor plate, noise reduction, etc.

The methods of construction currently employed may be enumerated as follows:

Replacement

To replace pavement, approximately two meters before and after an expansion joint are excavated and a hot asphalt patch is applied. This method has disadvantages in that the excavation process takes time and that the ability to execute the patch requires more planning. Some other method of construction should be used except when the road has extreme differences in levels or has alligator cracking.

Strip Patching Method

This method is removing the minimum thickness of asphalt which would permit patching.

Resin Surface Treatment

In the resin surface treatment method, a resin material may be applied for a level difference of less than 10 mm. It is necessary to use a flexible resin, which offers good adhesion and has the property of following the surface of asphalt concrete. This method, although highly flexible, is costly because the material is expensive. It also has the disadvantage that flatness is not easily attained if the road is deeply rutted.

6) Longitudinal Roughness

According to the type of longitudinal roughness, one of the following corrective methods should be selected:

(1) Differential settlement

A hot mixture should be applied to a patch or to an overlay.

(2) Corrugation

Generally, the method of cutting and reconstructing the pavement is used to repair corrugation. Those pavements which are slightly corrugated, however, may be repaired with an overlay.

7) Localized Changes on the Road Surface

Localized changes on a road surface have a wide variety of causes. Generally, these phenomena require immediate action. Depending on the local situation, the road should be repaired promptly for maintenance purposes.

(1) Pot Holes

A pot hole should be repaired immediately by an appropriate maintenance method after determining the cause. Before patching, the surrounding loose portions should be stripped and tack-coated. It should then be filled with road patch materials at the ambient temperature. It should then be fully compacted by a tamper or similar equipment. It is important to bring the patching materials flush with the existing roadway.

(2) Leakage Oil

A road covered by leakage oil will create a reduction in asphalt allowing the aggregate to scatter. As a result, a pot hole will develop. The leakage oil should therefore be covered with lime, sand, etc., and then cleared off as soon as possible.

Form PV-1

Basic Pavement Register

Name of road _____ Classification of road _____ Classification of administration _____ From _____ K.P. ~ To _____ K.P

Name of maintenance office (breakdown of the length)			
Date of commencement of service			
Component of cross section and width			
Quantity necessary for administration			
Name of intersection and important bridge and tunnel, and kilometer post Tunnel, Viaduct bridge Through line bridge Crossing bridge			
Name and boundary of pavement structural mixture, and kilometer post			
Sectional view of pavement structure			
	Asphalt concrete surface course		
	Asphalt concrete binder course		
	Asphalt stabilized base course		
	Cement stabilized base course		
	Subbase		
	Appear Subgrade		
	Lower Subgrade		
Earth Work Contractor			
Name of Earth Work			
Name of Pavement Contractor			
Name of Pavement Work			
Name of Pavement (Earth Work) Work Office			
Name of Construction Bureau			

Form PV-2

List of Survey Periods

Name of road ______ Name of main maintenance ______ Period From / Period To ______

No.	Type of survey				Date of Survey	Survey items									Survey KP	Classification of lane				Measurement method				Ordering authority	Name of survey Contractor	Content of survey			Cost	Storing authority		Relationship with other documents			Remarks
	Periodic	Special	Follow-up	Detail	Y/M/D	R D	C R	S H	Faulting	Corrugation	Pr I	Others	Up route	Down route	Start point (upper) ~ End point (lower) or name of location	Climbing lane	First through lane	Second through lane	Passing lane	High-speed photo	Leveling cord rule	Sketch	Others			Length	Area	No. of Location		Authority to store original data and report	Authority to store analytical result	B2	B3	B4	

Form PV-3

List of Work Period

Period From

To

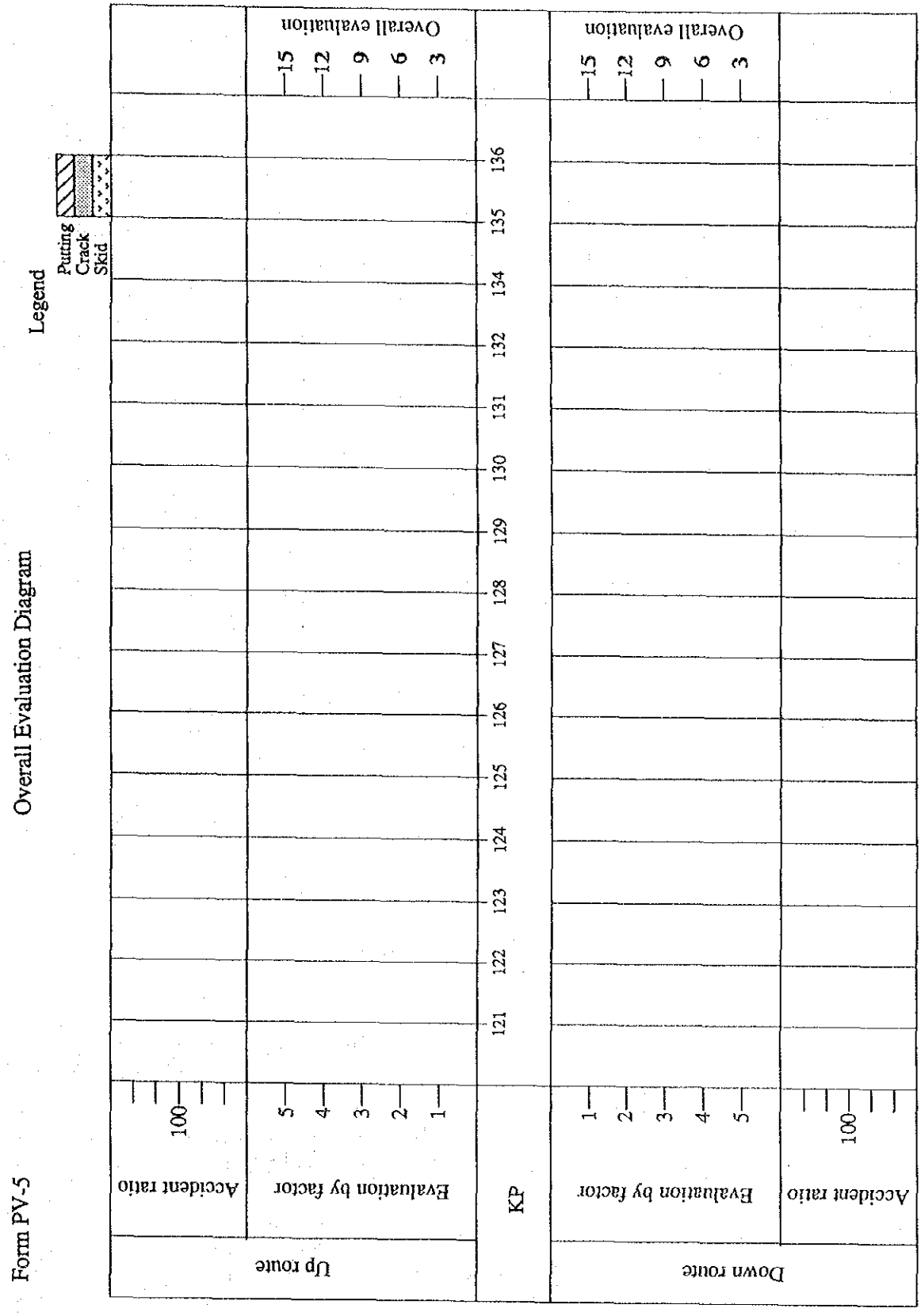
Name of road Name of main maintenance center

No.	Name of design docu-ment	Work period	*Cause(s)* for repair	Bounds	Repair point (name of bridge if applicable)		Classification of lane				Name of contractor	Work quantity No. of location Length (m) Area (m^2)	Repair method Principal materials used	Repair method (Thousand)	Completion drawings		Work report (present/ not present)	Relationship with other documents			Remarks
					Start point KP	End point KP	Climbing lane	1st through lane	2nd through lane	Passing lane					Yes/No	Storing authority		C2	C3	C4	

Form PV-4

Road Surface Characteristics Control Diagram

Bound	Repair factors	Skid (µ)	06 05 04 03	
		Rutting (mm)	20 15 10 5	
		Crack ratio (%)	25 20 15 10 5	
		Actual repair condition		
		Through lane / Passing lane		
Horizontal alignment				
Crossfall				
K.P.				9 1 3 5 7 9 1 3 5 7 9 1 3 5 7 9 1 3 5 7 9 1 3 5 7 9 1 3 5 128. 129. 130. 131. 132. 133.
The slopes of vertical alignment				


Form PV-5
Overall Evaluation Diagram
Legend
Patching
Crack
Skid
Up route
Accident ratio
100
Evaluation by factor
5 4 3 2 1
KP
121 122 123 124 125 126 127 128 129 130 131 132 134 135 136
Overall evaluation
15 12 9 6 3
Down route
Evaluation by factor
1 2 3 4 5
Accident ratio
100
Overall evaluation
15 12 9 6 3

Form PV-6

Pavement Maintenance Repair Record

(1) Name of road

From:
To:

Legend
Radius R
Gradient

Purpose of repair
(1) Rutting
(2) Crack
(3) Skid
(4) Faulting
(5) Cross-sectional roughness
(6) Insufficient pavement length and thickness
(7) Others

Repairwork
a. Overlay
b. Cutting and replacing
c. Cutting of convex
d. Leveling
e. Grooving
f. Surface treatment

Pavement condition and location diagram		
	3rd	
	2nd	
	Up route 1st	
	Intersection and kilometer post	
	Bridge Down route 1st	
	2nd	
	3rd	

Form PV-7

Pavement Maintenance and Repair Method

Name of road   Place   from   to

Year	Work period (From to)	Bounds	Work place (From to)	Thickness (cm)	Work area (m^2)	Purpose of repair	Repair method	Design method	Name and feature of mixture	Design document (sum)	Name of contractor

Form PV-8

Report of Survey on Faulting of Structure in Pavement Repair
- Report of Repair Work to be prepared When the Repair Work has been executed-

Name of main maintenance center: Name of maintenance office:

Name of object structure: Name of road:

Rough location map of bridge and earth work sections, and joint in the bridge section	Bounds	Cause of faulting at joint		Document at a time of construction	Survey contractor			Max. faulting position	
		Type of joint	No.		Date of survey	Lane surveyed	Max. faulting	Length from outside lane mark to joint	Length along lane from joint
K.P. ↕ To K.P. To									

Name of structure

Form PV-9

Report of Survey on Faulting around Structures and Maintenance and Repair Work

Causes for repair
- A. Faulting repair method
- B. Corrugation
- C. Pot hole
- D. Concave
- E. Others

- a. Patching
- b. Thin resin surfacing
- c. Overlay
- d. Cutting and overlay
- e. Replacing
- f. Others

Name of main maintenance center　　Name of maintenance office　　Name of road

Record of survey immediately before repair　　Name of object structure　　Record of repair work

With/ without survey on faulting	Up or Down route	Cause of faulting (joint, etc.)		Kilometer post	Contractor of survey			Position of max. faulting		Repair position No.	Date (year/ month/day) of repair	Principal cause for repair (m^2)	Area	Repair method	Name of mixture used for repair	Cumulative sum	Design drawing	Name of contractor	Remarks
		Type of joint, etc.	No.		Date of survey	Lane investigated	Max. faulting (mm)	Length of the lane from the joint (m)	Distance from the outside lane to the joint (m)										

4.13 Motorway Maintenance Manual for Bridges

4.13.1 General

1) Definition and Purpose

Experience shows that the need for maintenance and repairs to bridges is due to the following reasons:

- Deterioration will start immediately after completion of most civil works structures;
- Live loads of vehicles and loading frequency will increase with time;
- Structures will be constructed in general with unexpected defects which create in efficiencies and eventually will affect the safety of the structure.

In addition the reliability of technical products decreases with time. It is necessary to emphasize that a bridge is a technical product.

The purpose of maintenance and repairs are classified in two categories as follows:

- To retain load bearing capacity and to sustain bridge durability;
- To prevent failure of the bridge structure and to maintain traffic safety.

It is necessary to keep design data, in particular the detailed engineering specifications and drawings of bridges and viaducts since these are essential reference materials for planning and engineering of the maintenance and repairs.

Maintenance and repairs of Bridges is closely related to the inspection of bridges. In order to maintain bridges in good condition, the deck surface, superstructure and substructure of bridges shall be inspected by routine, periodic and special inspections. When deficiencies are found, maintenance and repairs must be carried out.

2) Terminology

Terminology used for deterioration is the following:

Cracks ---------- Cracking occurs when tensile stresses exceed the tensile strength of the concrete mainly due to traffic load and impacts to slabs. When concrete contraction is inhibited by slab and girder bindings, or when tensile strength of reinforcing bar is small, cracks tend to be deep.

Corner Failure ----- The corner of cracks are spalled by crack's widening and narrowing movement caused by vibration from the traffic.

Abrasion---------- Powdery substance, created by vibration of slab and abrasion by traffic, fills and widen the cracks from the edges of cracks.

Free Lime ---------- Rain water percolates from the slab surface, and the lime in concrete ooze out from the bottom of slab as white residue. When free lime mixed with dirty water is observed on the bottom of the slab, the cracks are penetrated through the slab.

Peeling---------- Adhesive bonding between reinforcing steel bars and concrete is destroyed. Bottom part concrete falls from the reinforcing steel bars.

Failure---------- Adhesive bonding between reinforcing steel bars and concrete is destroyed. A part of concrete separated by the polygon shaped cracks falls from the reinforcing steel bars.

Typical operations performed on a bridge can be listed in two groups

4.13.2 Investigation

1) Purpose of Investigation

The structures which is judged as the degree of damage A or B during the periodic or special inspections shall be investigated. The density of cracks shall be quantified, and including the conditions of damages other than cracks and the cracks shall be measured according to the degrees of damages.

2) Investigations on Cracks

(1) Method of Creak Measurement

Temporary structure for paths, and magnifying glasses shall be used for observing and measuring crack widths and lengths.

(2) Selection of Measurement Location

The location of measurement shall be the part where cracks are observed based on the inspection results of cracks.

(3) Density of Cracks

Cracks shall be taken by color photograph to identify the locations and lengths. The photographs shall be examined, and the density is calculated by grid density method on cracks which density is wider than 0.1 mm.

3) Investigation of Damages other than Cracks

Deficiencies other than cracks shall be observed on the following elements, and the results of detailed investigation shall be confirmed; and organized as additional documents for judging the degree of damage.

- Water leak, and free lime condition
- Exposure and rust of main reinforcing steel bar
- Spalling or corner failure and abrasion condition
- Crack condition

4) Judgment Standard on Degree of Damage when Investigated

From the crack density measured in the investigation, the degree of damage is scaled. The judgment standard shall be established.

5) Record of Research

The results of investigation shall be summarized to the following investigation information formation format:

(1) Inspection Record
(2) Crack Condition Investigation Table
(3) Record Photographs
(4) Others

4.13.3 Maintenance and Repairs to Slabs

1) Objective

Slabs are the member that carry the wheel load directly and when damaged, tends to extend rapidly. In the case of slabs, repairs become more difficult, with increasing cost and time as the damage extends. Accordingly, it is essential to achieve early detection of damage and make early corrective measures through periodic inspection of the slab.

2) Types of Maintenance and Repairs

(1) Action of excessive wheel loads

- Reinforcement of slabs and restriction of wheel loadings

(2) Action of excessive impact

- Maintenance and repair of bridge deck pavement and expansion joint

(3) Action of excessively large moments due to passage locus of wheel load

- Adjustment to lanes (designating the passage position of large vehicles),
- reinforcement of slabs

(4) Insufficient load carrying capacity

- Reinforcement, replacement, or exchange of slabs
- Poor quality and placement of concrete
- Replacement or exchange of slabs

(5) Insufficient distribution reinforcement

- Reinforcement of slabs

(6) Insufficient stiffness of slabs

- Reinforcement of slabs (increase stiffness of slabs or reduction of span)

(7) Action of negative moment or tensile force due to action of main girder

- Reinforcement of slabs

(8) Action of excessively large moment at free end

- Installation of floor beam, reinforcement or partial replacement of slabs

(9) Action of additional moment due to differential settlement of bearing beam

- Installation of load distribution cross beam, reinforcement of slabs

3) Maintenance and Repairs

Prior to start repair of the reinforced concrete slab, the cause of damage must be identified through inspection. It is also necessary to understand the degree of progress of damage and to judge whether or not the function can be recovered by repair. If crack in the slab has not grown much and the reinforced concrete retains functions to a satisfactory extent, repair by adding a stringer or by bonding steel plates can be made. If the repair method cannot be applied because of excessive crack and other damage or poor concrete quality or placement state or if the repair is expected to be ineffective, measures such as replacement with new concrete slabs, etc. must be taken.

Maintenance and repair methods described below are suitable for reinforced concrete slabs.

(1) Maintenance and Repair by filling resin

Filling cracks in concrete with resin will help enhance water-tightness and prevent weathering of concrete and reinforcement.

As direct increase in the durability of slabs cannot be expected by resin filling only, this method is mostly employed along with the reinforcement method.

(2) Maintenance and Repair by adding stringer

This method is intended to support the slabs by adding new stringers between existing main girders or stringers and to reduce the active bending moment by reducing the span of slabs. A clearance in provided between the upper flange of stringers to be added and the slabs, into which the resin is filled to achieve tighter contact and the improved supporting performance.

(3) Reinforcement through adhesion of steel plate

Steel plates 4.5 - 6 mm in thickness are bonded to the tensile surface of slab concrete by means of resin, to be integrated with the existing slabs. This method is expected to achieve the section strength by allowing the steel plates to bear the deficiency of the live load.

(4) Replacement of slabs

This method is to replace damaged slabs with new reinforced concrete slabs or with other kinds of slabs (steel slabs, precast concrete slabs, etc.). This is expected to the most effective method, but requires total closing of the road while the work is under way.

(5) Other methods

There are an FRP adhesion method in which the glass roving cloths coated and impregnated with epoxy resin are tightly adhered in an overlapped manner and united after placing steel sheets onto slabs motor is sprayed to be integrated with existing slabs. But the reinforcement effect thus achieved is not as great as the addition of stringers and adhesion of steel plates. The location to employ such repair needs thorough review.

4.13.4 Maintenance and Repairs to Expansion Joints

1) Objective

These devices are necessary for two main reasons:

- to permit traffic to pass over the breaks in the continuity of the structure with least disturbance;
- to protect the underlying structural parts from aggressive materials and dirt which can infiltrate at these beaks.

Of course, these devices must not in any way prevent the normal movements of the structure envisaged at these points.

Damage to the expansion joint is mostly caused by multiple factors. The probable causes are listed below:

- Improper use manner of the expansion joint
- Factors related to design, such as insufficient stiffness of the slab end, insufficient stiffness of the expansion joint proper
- Factors related to construction, such as error in the expansion spacing of slabs, faulty installation of the expansion joint
- Factors related to maintenance, such as deterioration of slabs, roughness of road surface before and after the expansion joint

The repair work must be executed while taking the following matters into account.

2) Maintenance and Repairs

When replacement work becomes necessary because damage has grown to a considerable extent, it is first necessary to investigate thoroughly the probable causes of damage, expansion

spacing of joint, beam structure and slab/beam end structure, bridge deck pavement, support, necessity of water leakage prevention, etc.

Repair work is directly associated with demolition of the pavement and slabs around the expansion joint and that the scope of demolition and the members to be exposed differ depending on the type of the expansion joint. Utmost care is also needed not to damage reinforcement of the slabs during demolition work. Particular care is essential in the case of a prestressed concrete bridge because there are anchorage elements for prestressed concrete wires at the end of the beam.

The replacement work of the expansion joint must be planned in a series of short work periods so as to minimize the negative influence on traffic. In addition, the work should be planned for each half of the width while regulating the traffic or planned to be executed at night.

It should be mentioned that from the maintenance and repair viewpoint the operations to ensure the functioning of a continuity joint are always given urgent priority, whereas those connected with the waterproofing are likely to be postponed, insofar as the deterioration due to waterproofing defects is a rather slow process, depending on environmental conditions. In the first instance, the breakdown of a joint component, or the differences in level which develop between the pavement and the joint, are either a danger to traffic or at least will result in damage to the joint device given the continuous impacts to which it is subjected, especially under heavy traffic.

It is necessary to distinguish between the two main types of expansion joints. First of all, there are the "large joints", i.e. where the prevailing movement is due to thermal expansion, and "small joints" present on structures where the thermal expansion does not exceed 1-2 cm, and where the more important movements are those generated by traffic.

(1) Large Joints

These are generally of the metal type, either the more traditional comb or cover-plate types, or the steel and rubber profiles inserted in varying number according to the amount of the expansion, or the vulcanized steel in neoprene type.

Maintenance operations for continuity joints consist of dismantling and re-assembly, cleaning and greasing, generally carried out by specialized personnel; sometimes it is also necessary to substitute certain elements such as moulded rubber elements, etc. With the more modern types these operations are facilitated by the use of modular devices which can easily be broken down into similar elements and, generally, waterproofing is ensured

by strips of elastomer, fastened below the metal sections either fixed to these, or, better still, to the edges of the adjacent structures of the bridge. The maintenance to this part of the joint consists generally in cleaning operations (with jets of water sprayed from the sides or from the top of the structure), or periodic substitution of the whole rubber sheath which can easily be inserted from below (i.e. without having to dismantle the continuity joint), even in devices which were not originally designed with this in mind. It is very important that these devices should consist of materials resistant to ultraviolet decay, especially in large joints where the sunlight can more easily penetrate. Finally, it should be mentioned that such operations also fall into the class of preventive maintenance.

(2) Small Joints

The range of smaller joints is much more diversified; these may be similar to the large ones but constructed on a smaller scale, or, as is more frequently the case, they may simply be nosing of epoxy resin or, far less frequently, cement mortar. Finally, there are buried joints on bridges having a span not exceeding thirty metres where movements due to traffic are limited, either because of the massive nature of the structure, or the type of traffic it normally carries.

The maintenance techniques naturally vary in accordance with the type of joint.

(a) For metal types the same techniques are used as in the case of the larger ones described above.

(b) In the case of resin mortar joints, maintenance will often consist in reconstituting the nosings, or parts of them, damaged by the traffic. The results in the formation of transverse cracks in the nosings and renders them easily detachable. Repairs to these are facilitated if the waterproofing is ensured by a profile of neoprene or other material bonded to the vertical edges of the concrete slab.

In fact, the rubber profile, besides serving to drain off the water which may infiltrate between the deck and the nosing (through cracks or limited detached areas, even if the nosings are solidly attached), permits repairs to be made to the damaged parts of the nosings without having to touch the waterproof joint. The upper rubber profile can be removed and replaced in such cases without difficulty. In replacing the nosings, or a part of them, the connection with the deck can be improved by inserting a number of steel studs into the latter (in holes made by drill or small core borers), sealing them with pure epoxy resins. There are various types of nosing joints which permit maintenance

operations of this type with greater facility than is possible with modular metal joints; these consist of prefabricated nosing joints in lengths of around 1 metre. These elements are constructed in cement mortar or (rarely) in resin mortars which are simply glued to the deck. In several versions the rubber profile in contact with the traffic is also modular, which makes replacement easier.

(c) Buried joints are generally the least costly to construct and, when laid on structures for which they are suited, cost less to maintain.

The maintenance operations consist in periodic re-sealing covering in addition any possible cracks which might form. The types of special surfacing most easy to maintain are those in which the paving over the joint crack consists of poured asphalt or plug-type joints.

The maintenance operations in the case of plug-type joint are limited to periodic resealing of the borders. Because of its low cost, the plug-type joint can also be used for preventive maintenance operations on bridges which, because of the limited span, were not originally equipped with waterproofing devices (e.g. overpasses, underpasses, etc.).

4.13.5 *Maintenance and Repairs to Substructure*

1) Objective

Substructures comprise the foundations, piers and abutments to bridge structures. Defects to piers and abutments include those of the structure and those of the foundation. These defects may be attributable to the causes in the pier or abutment structure itself, but mostly to the defective condition of the foundation.

The foundation located in such a configuration of the ground as a slope, alluvial fan, alluvial plain, or marshy hinterland of a river requires particular attention because it is susceptible to sudden change in ground conditions.

Defective foundations are roughly classified into these affected by: settlement and differential settlement; inclination; movement; joint offset; abnormal stress of a structure; and cracking. These are attributable to settlement of the ground, movement of the ground, improper design and construction, loss of bearing strength of the foundation, decrease in the ground bearing capacity, degradation and scouring of the riverbed, and increase load acting on the foundation.

Though a defect in the foundation is often difficult to confirm directly, it exerts critical influence on a bridge. A fundamental measure must be taken therefore if the defect worsens. In this context, early detection and an analytical estimate of its rate of distress are essential for adequate measures to be taken.

2) Types of Defects

(1) Footing foundation

- Susceptible to scoring due to small embedment depth
- Displacement tends to occur readily when the ground is unstable (slope, etc.) and the consolidation layer exists in the bearing layer.

(2) Rock foundation

- Cracking tends to occur readily due to shearing during earthquake.

(3) Floating foundation

- This foundation is constructed on the soft ground and tends to develop displacement due to environmental change (consolidation settlement) caused by lowering of the groundwater level and is also sensitive highly to geological effects such as liquefaction.

(4) Caisson foundation

- When the cushion layer is a weak clay layer, pit excavation or filling of the nearby work will cause displacement of the cushion layer, resulting in displacement of the foundation.
- Settlement of the ground may cause more or less settlement of the foundation.

(5) Timber pile

- Rotting may occur when the groundwater level lowers, and air can attack the piles

(6) Precast RC and PC piles

- Piles integrity may be impaired when the head is broken.
- Piles may be damaged when they are driven in an out of vertical manner.

(7) Bored RC and PC piles

- These piles are not expected to offer a ground compaction effect, but suffer a decrease in bearing capacity or differential settlement depending on the geology or excavation method.
- These piles may develop settlement when slime or slurry remain in the pile end or the pile end is open.

(8) Steel pile

- These are mostly long piles, penetrating through the soft layers and penetrating into the bearing layer. They are therefore sensitive to negative friction due to consolidation caused by lowering of the groundwater level.
- If the electrolytic protection is employed, unsatisfactory corrosion prevention may accelerate corrosion.

(9) Cast-in-place concrete pile

- These piles may suffer reduction in the pile diameter or material degradation owing to wrong selection of the method, faulty construction control resulting in differential settlement or horizontal displacement due to insufficient bearing capacity.
- The pile may develop settlement when bentonite treatment is not satisfactory.

(10) Liquefaction

- The foundation may develop settlement due to bursting of the bearing layer and decrease in the bearing capacity caused by boiling and heaving under certain ground conditions.

3) Maintenance and Repairs to Foundation

Generally, the foundation can be repaired as follows:

(1) Insufficient embedment

- Reinforcement of the area around the foundation by means of sheet pile, cast-in-site diaphragm wall
- Reinforcement of the area around the foundation by means of steel pipe pile, cast-in-site concrete pile, and cast-in-site diaphragm wall, and augmentation of bearing capacity.

(2) Insufficient bearing capacity

- Increase in the bearing capacity by expanding the footing or increasing the number of piles
- Alleviation of the load acting on the structure
- Tentative methods, including a chemical grouting method, lime pile method, sand compaction method

(3) Degradation and scouring of the riverbed

- Foot protection
- Prevention of degradation

4) Maintenance and Repairs to Piers and Abutments

The pier and abutment structures are located between the superstructure and foundation, transmitting the load from the superstructure to the foundation. These structures are in a position to be affect by increased loads on the superstructure and defects the foundation. In particular, they are likely to develop critical cracks under the influence of foundation defects, such as settlement, lateral movement, inclination, etc.

These structures are generally reinforced concrete which suffer crack or spalling because they are exposed to effects of the weather, sea water, acid, and alkaline over an extended period of time. Weathering and damage as well as deterioration of concrete structures occurs with time.

Defects occurring in these structures are cracks, spalling, exposure of reinforcement, deterioration, etc. The best telltale is a crack, which often becomes a clue to the early detection of defects in the structure.

When the repair method of these structures is to be considered, the structure drawing, reinforcement arrangement drawing, stress calculation sheet, and geological data must be examined to understand the construction and to take the design stresses into account.

The repair work may require replacement of the abutment parapet wall, repair of the bearings and traffic regulation. Besides, the repair method to be selected must be the one which ensures the operational stability and reliability and is appropriate to the construction environment.

This is essential because the operations frequently occur under the girders where the space is likely to be restricted.

Crack are conventionally repaired by grouting cement milk or spraying with mortar. Recently, the epoxy resin grout has come to be used. On the other hand, if stressed steel rods are to be used to repair a crack, and grant quantity must be determined while considering the concrete strength, active stress, etc., so that the concrete compressive stress may be controlled below the allowable stress.

The repair method for concrete spalling consists of patching of the concrete section where reinforcement is not exposed or when it is exposed, but not rusty. Spalled concrete and loose concrete are to be removed, with the section patched using cement mortar, concrete, or resin mortar.

Where the spalling portion is sensitive to the effect of plant effluent, the use of water-and chemicals-resistant paint will prove effective.

4.13.6 Maintenance and Repairs to Superstructure

1) Objective

The superstructure bears the full load carried by the bridge and transmits the loads through bearings on to priers and abutments.

Two types of construction are considered, concrete and steel. The significant effect of bridge maintenance is carrying out the repair work, frequently many metres above ground. Scaffolding is not discussed in this manual.

Bridge superstructures deteriorate and usually the distress shows visibly in cracks, corrosion or spalled concrete. Usually there is supporting evidence of the cause. Maintenance work can occur at many points on the superstructure, and the difficulties and durability of the maintenance work can vary considerably depending on size and location.

2) Maintenance and Repairs to Concrete Bridges

The common maintenance and repair requirements for bridges are to patch spalled concrete or to scale cracks.

(1) Spalled Concrete

A condition common to all spall repair operations is that proper preparation of the surface is essential if the maintenance is to be a success. The operations are generally as follows:

- removal of the deficient concrete down to the level of the sound material;
- complete removal of all oil or grease on the concrete which could impair surface adhesion;
- removal of surface mortar and possible curing projects;
- removal of rust from any exposed steel reinforcing bars, and the possible passivation of the latter (by means of anti-oxidizing products).

The spalled concrete can be removed by manual or mechanical chipping with small drills or by high-pressure blasting with water, or better, grit-blasting. This procedure also permits dressing the reinforcing steel at the same time.

The prepared surfaces are given different treatments depending on the type of materials to be used. In general, it is necessary to apply a primer which serves to increase the adhesion between the concrete and the patch; in the majority of cases this consists of a suitably formulated epoxy resin (or, less frequently, a polyurethane or polyester resin), consisting of a base plus a hardener.

Cement mortars or even synthetic binder mortars are then applied over the latter. These mortars should have the optimum combination of the following characteristics:

- high strength;
- good bond;
- rapid hardening;
- limited or nil shrinkage (in some circumstances a slight expanding effect is desirable);
- limited porosity.

The products which appear to be in most widespread use today are mortars with epoxy binders, combined with siliceous fillers.

Other products in common use are "special" cement mortars which are applied by means of traditional techniques. These are generally marketed in pre-mixed form (aggregates plus binder) so as to avoid mistakes in mix designation.

The ones in most common use are those containing super-plasticisers (rheo-plastic mortars) which are workable (fluid) with very low water-cement ratios. It is necessary, therefore, to avoid the use of wooden forms (too porous) and to apply curing agents after laying.

Sprayed concrete made of these products has been found to be more waterproof and durable. In many countries it is the practice to paint or protect the concrete after the above-described repair has been made. This procedure is useful in many cases if the damage occurs in concrete that is easily prone to attack by environmental agents and because it is probable that the concrete will continue to deteriorate in the unprepared zones.

Another factor is the quality and make-up of the concrete to be protected. A porous Portland cement concrete, for example, is more prone to deterioration than a compact structure of pozzolan cement. For these reasons, then there are generally two classes of concrete protection:

(a) Maximum protection for: ends of the bridge deck and beams, end-diaphragm beams, tops of cross-heads of piers and of abutments, toppings in parapet zones (including drip stones, support zones at hinges: thin structures in general.)

(b) Relatively minor protection of the body of the beams and intermediate diaphragms, piers and abutments of light-weight structures.

The first category may also include overpass piers and abutments. Naturally, it can happen that under particular climatic conditions or with a greater or lesser degree of atmospheric pollution certain structures belonging to the second category will have to be given maximum protection.

(2) Cracks in Concrete

Among concrete defects, cracks require investigation with particular care. Though the factors considered responsible for cracks are: insufficient area of reinforcement; insufficient strength of concrete; insufficient design section; corrosion and expansion of reinforcement; increase in the vehicle load; etc., an in-depth investigation is necessary because the cracking direction, etc. differs depending on the stress conditions causing the crack.

Repairs to a concrete bridge must be planned with consideration on the material characteristics of reinforcement concrete, stresses in the existing reinforcement concrete, etc.

Repairs to cracks in no way serve to reinforce the structure, but only to prevent corrosion of the steel which could result from the free circulation of water through the cracks.

Here, too, the products most commonly used in the repair of both passive (dead) cracks or active ones are epoxy resins. As in all their other uses, good performance depends on the formulation of the resin and the application techniques.

With these operations it is often impossible to provide a preventive treatment. In cracks of a certain age it is impossible to eliminate the calcite or other impurities which may form. When carrying out the injection the general practice is to insert injector tubes into the two extremities of the crack and at intermediate points (30 ~ 40 cm intervals), then to seal the crack (in cases of active cracks, the sealing is preceded by the chipping of a V-shaped channel along the length of the crack, in such a way as to provide for a greater thickness of sealing material at the most exposed point).

The product injected has generally hardener compatible with the moisture level and containing re-agent additives which form a structural bond between the resin and the concrete. The viscosity of the formulation should be compatible with the size of the crack; as the latter increases, the additives are also increased up to a point where use of mineral additives can be permitted (generally cracks exceeding 2-3 mm).

In the case of prestressed tendon sheaths, the technique is much the same, whether the operation is performed during the maintenance stage or at the time of construction. In recent years good results have been obtained with vacuum injection systems following prior evaluation of the cavities present. This technique requires a good air-tight sealing of the structure, by applying an external sealing coat to the zone involved. In using epoxy resins as filler material, either they should be used in combination with cement so as to obtain a mixture pH sufficient to protect the steel (and in such cases the viscosity in quite high), or care should be taken to ensure the perfect adherence to the prestressed tendon or wire, as otherwise there would be a break in the continuity of the adherence allowing water to circulate and corrode the steel elements. In all cases maintenance of a concrete bridge is best achieved by preventing the entry of water in the first place, by perfectly waterproofing the bridge deck and painting the side parts.

3) Maintenance and Repairs to Steel Bridges

In the case of a defect in a major member, such as main girder, cross beam, sway bracing, and flow system, early investigation is essential. Otherwise, such defect may lead to the collapses of the bridge. Since a defect in these members is difficult to detect during regular inspection, it is recommended to plan priority inspections on points which are likely to suffer damage. Serious defects include: deformation; buckling; cracks; corrosion; collision damage; loose fasteners; abnormal vibration; and deflection.

- Corrosion

  This tends occur readily in a member where complete painting is difficult, or is exposed to rainwater and splash, or in a bridge located in a seaside area.

- Deformation and buckling

  These kinds of defects occur when a member is exposed to a sudden large force caused from the collision of a vehicle or driftwood. Note in particular that deformation of a compression member causes a large drop in the load carrying capacity.

- Loose Fasteners

  Looseness or loss of rivets and bolts in a joint is attributable to faulty manufacture or erection, design calculation error, and failure of the rivet or bolt material. In particular, bolts and rivets in the sway bracing or cross beam are likely to become loose because of repeated stresses.

- Cracks

  A member may develop deformation due to a substantial stress concentration or due to a collision which, results in the development of a crack.

- Vibration, deflection, or unusual sound

  These are considered to occur due to changes in the stiffness or bearing conditions of a bridge or a change in the structural system.

Preliminary investigation is necessary before the start of repairs to a steel bridge member. If a record of the mechanical and chemical properties of steel material used has not been maintained, then specimens need to be taken from the bridge.

It is also essential to examine design drawings and calculation sheets to review design assumptions and as-built conditions.

Maintenance methods includes replacement, reinforcement, and repair.

(1) Replacement: made when a member has been deformed excessively. In this case, investigation should also be made on other members because they may have possibly been deformed.

(2) Reinforcement: made using formed steel or by plate reinforcement. What is of importance here is selection of the connections. Most reliable is to connect using high-strength bolt. Riveted connections should be avoided as much as possible.

(3) Repair: mostly done by welding and heating work, which in turn requires an appropriate procedures to be followed to prevent hardening and embrittlement during heating.

(4) Cracks: Fatigue cracks can occur in various parts of steel bridges, especially the deck elements of orthotropic decks. A number of methods of crack repair are being used, ranging form the interception of the tip of the crack by the drilling of holes, the blunting of the crack tip by hammering or peering, or even the remitting of a cracked area by welding techniques. Great care must be exercised in the evaluation of the crack repair methods used on the main structural members of bridges, since this involves the safety of the structure.

4) Maintenance to Painting

There are three factors to be considered

- Type of Paint
- Preparation
- Application

(1) Type of Paint

Traditional and more modern types of anti-corrosion paints are used. Base coat passivators include both traditional coatings such as minimum (red-lead) or zinc, and mixtures of complex salts such as zine chromates and phosphates and lead silicochromates, which provide more effective protection. These passivators are combined with different types of binders such as alkyds, oleoresinous/phenolic, chlorinated rubber, chlorinated rubber/alkyd and epoxy resins.

Use of the various types of binders often depends upon economic considerations, which are not only related to the costs of the painting cycle operations, but also to the varying thicknesses necessary to obtain comparable corrosion protection (number of coats). More recent formulations such as epoxy resins require a more careful preparation, but provide good protection with thinner layers.

All layers over the base coat will generally have the same composition as the latter, but with certain variations in the passivating salts content, inasmuch as they are normally covered with a finishing coat.

The finishing coat, when this is employed, is generally of a different composition than the undercoats, since it must be resistant to external agents (infra-red and ultra-violet rays, thermal shock, etc.), and must prevent as long as possible the penetration of degenerative agents into the underlying layer(s). The best finishing coats (and also the most costly) are polyurethane-resin-based paints which are often used to cover epoxy-resin-based undercoats. Chlorinated rubber-acrylic resin finishes are also used over non-modified chlorinated rubber coats.

(2) Preparation

The methods applied for cleaning surfaces depend upon the age of the structure and the degree of degradation, and may consist of the following: washing and sanding to varying degree (generally on more recent structures), burning with special oxyacetylene torches with a high percentage of oxygen, followed by mechanical or manual brushing or sanding. There are also standards for determining the degree of degradation reached in relation to the types of protection which should be applied to the surfaces. The length of the time interval between these operations and the application of the first paint coat depends on the following factors:

- climate;
- relative humidity;
- presence of aggressive agents.

The time interval chosen is in the range of hours, inasmuch as the surfaces treated can oxidize very quickly.

(3) Application

Given the function required of the base coat and its high passivating salts content, it is better applied by brush or roller, so as to obtain better impregnation of the substrate.

Airless spray application is also permitted, however, for the subsequent layers.

4.13.7 Maintenance and Repairs to Bearings

1) Objective

Proper functioning of the bearing is of basic importance in the preservation of modern bridge structures. These devices, if correctly dimensioned, must ensure the distribution of loads as calculated by the designer. If maintenance of bearings and their supporting structure is neglected, the functional behavior of the bridge may be affected and damage of variable severity may be caused including, in extreme instances, collapse of the structure. There are cases where this has occurred, even newly-built bridges have failed in this way.

In the majority of cases the location of the bearings coincides with that of the joints and, hence, the maintenance operations on the latter can also be considered as a protection of the bearing.

As can be noted, the majority of maintenance operations for bearings consist in their substitution; for this reason it is necessary to design or subsequently modify bridge structures so that the deck head-pieces are of a shape and size to facilitate their lifting for maintenance purposes.

2) Maintenance and Repairs of Metal Bearings

For traditional steel types (roller bearings, rocker bearings, etc.) the purpose is mainly to protect against corrosion and to maintain the required mobility; hence it is necessary to repaint them completely, i.e. first stripping and then repainting.

After the painting, or independently of it, the greasing and graphitising operations are carried out.

Very often, however, this type of bearing presents rather inconvenient maintenance problems; for example, there may be a defective alignment between the various elements (in the case of rocker) or an excessive shifting of the rollers. In these cases it is necessary, in order to restore proper functioning, to jack up the decks in order to put the elements back in place.

In the case of metal bearings, more serious difficulties often arise from an unbalanced stress distribution in the supporting concrete. To remedy these, it is possible to inject synthetic resins or cement mortars into the damaged support, to band it, or, in the most severe cases, to reconstruct it.

3) Maintenance and Repairs to Metal Bearing

In recent years a major development has occurred in the use of steel or aluminum bearings with large cylindrical or spherical sliding surfaces which take advantage of the low friction properties of steel-PTFE Polyterafluorethylene contact.

These bearings, which can be built and assembled in such a way as to better ensure the mobility conditions required in the original design, also appear to be more reliable from the maintenance standpoint. This is due to both their form and the materials in contact, as well a to the protective devices with which they are generally equipped.

These types of bearings have not been in use of very long periods of time, but it is expected that the maintenance operations, when and if necessary, will consist in the dismantling of the bearing and the replacement of the wearing sections, i.e. probably the PTFE layers.

These operations require that the PTFE by detached from the steel backing to which it is usually bonded or mechanically fitted, while, on the other hand, rebounding, lubrication and fitting together is a job requiring clean factory conditions and new or temporary bearings will probably be used while the old ones are being repaired elsewhere.

4) Maintenance and Repairs to Elastometric Bearing

In general, this work is carried out when inspections show that the materials have lost their functional characteristics. In the case of the old-type elastomeric bearings, i.e. consisting of simple overlays of steel and neoprene, without vulcanisation and protection at the outside borders, it has been notes that the functional life of the materials has sometimes been short. However, durability is increased with anti-ozone treatment of the rubber and by fully encasing the steel plates.

Form BR-1

Inspection Record

Bridge side view

Slab plan

Slab plan

Name of bridge	
Type	

Type inspetion	Ordinary inspection	Detail inspection	Survey
Date of inspection			

1. Inspection record

Necessity of detail inspection	yes no
(Remarks)	

2. Degree of damage judged from detail inspection

Degree of damage	Slab panel No.	No. of panels
A		
B		
C		

3. Degree of damage judged from survey

Degree of damage	Slab panel No.	No. of panels
IV		
III		
II		
I		
0		

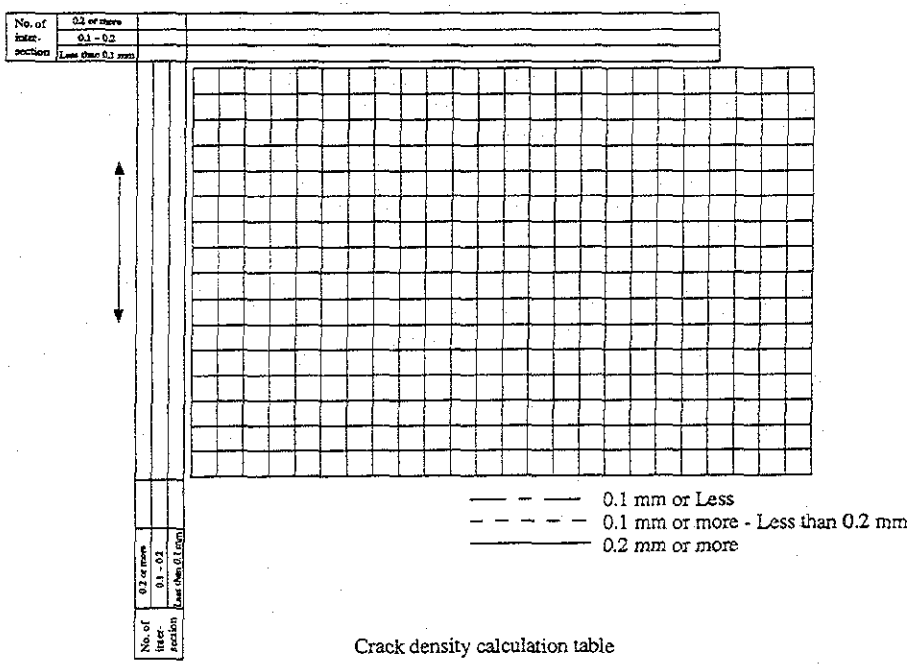
Form BR-2

Bridge Crack Condition Investigation Table

Survey location map

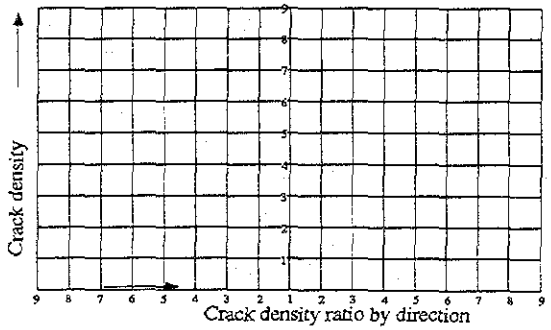
Crack condition diagram

Direction normal to bridge axis scale



Crack density diagram

(Crack width of 0.1mm or more)



Aggregate survey result table (m/m²)

Date of survey						
Crack width	Crack	Density				
(1) 0.2 mm or more						
(2) 0.1 mm ~ 0.2 mm						
(3) Less than 0.1 mm						
(1) + (2)						
Rank of degree of damage						
Rank at inspection						

Crack density calculation table

		No. of Intersections ΣN①	Length ②(m)	No. of Lattices ③	② x ③ = ④	Crack density ①÷④(m/m²)	$\frac{A}{B}$ or $\frac{B}{A}$	Remarks
0.2mm or more	A							
	B							
	Total							
0.1 mm ~ 0.2 mm	A							
	B							
	Total							
0.1 mm or more	A							
	B							
	Total							
Less than 0.1 mm	A							
	B							
	Total							

Form BR-3

Daily Work Report

Co., Ltd.

Field representative

Job title: Repainting work of ____ bridge

Supervisor	Chief assistant supervisor	Assistant supervisor	Weather	Max. temperature/ humidity during painting work period	Min. temperature/ humidity during painting work period

Outline of the work	Location	Description
Others		
Work scheduled for the next day		
Note by supervisor		

Form BR-4

Repainting and Paint Film Thickness Measurement Record

Job title											
Time of measurement	Repainting (with brush)		After base treatment		After prime painting (intermediate painting)		After finish painting (standard film thickness gauge)				
Object members											
Date of measurement				Measured by							
	Measured values										
Measuring point	1	2	3	4	5	Total	Average	Average film thickness after base treatment	(3)=(1)-(2) Average of film thickness	X-Xi	$(X-Xi)^2$
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
21											
22											
23											
24											
25											
Total											

Average and standard deviation

Average $\frac{1}{N} \sum_{i=1}^{X} Xi = \quad \mu$

Standard deviation $\sqrt{\frac{1}{N-1} \sum_{i=1}^{X} (X-Xi)^2} \quad \mu$

Judgement

Standard deviation	Standard x 0.2
Average	Standard x 0.9
Min. value of average of five points	Thickness x 0.6

Frequency distribution

Class of film	Medium	Check	Frequency

Histogram

Frequency

Thickness

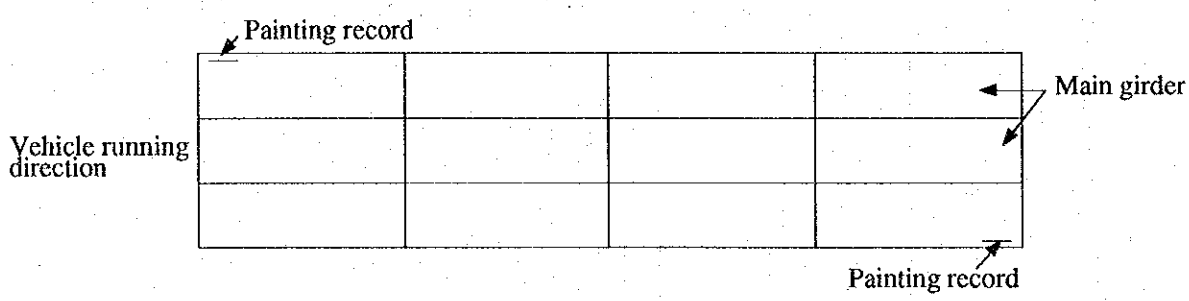
Form BR-5

Painting record

Completion of painting	
Base treatment	
Prime paint Intermediate paint Finish paint	For each brand name of paint, standard, and layer
Manufacturer	
Contractor	

40 cm

The paint record is marked in a position shown below.



Painting record

4.14 MOTORWAY MAINTENANCE MANUAL FOR TUNNELS

4.14.1 General

Most tunnels are generally located in an area of steep ground slopes and, in most cases, there are no alternative routes when these tunnels become blocked. Moreover, an accident occurring in a tunnel is most likely to develop into a serious disaster like a fire, etc. with an extremely heavy influence being exerted at the same time on other general traffic.

A tunnel is a special and complicated construction equipped with ventilation, lighting, and emergency facilities. Accordingly, the maintenance and repairs of a tunnel must be more complete and comprehensive requiring careful attention, than the case with other general sections.

Maintenance and repairs of tunnels are roughly categorized by the work content into operation and control of various appurtenances (ventilation, lighting, and emergency facilities), into inspection and maintenance and repair of the main body structures (road surface, drainage facilities, tunnel of interior, tunnel lining) and the various appurtenances.

Repair work must involve employing planned traffic regulation to ensure the safety of both workers and traffic. It is also recommended to keep an accurate record of the tunnel condition by arranging in sequence and keeping in custody the reference materials (geological materials, work record, and past maintenance and repair records) in addition to basic materials (design drawings and manufacturing specifications). The inspection, investigation and maintenance procedure must also be established to maintain various tunnel facilities in a satisfactory condition, thereby ensuring safe and rational operation of those facilities.

4.14.2 Investigation

The following are types of investigations for defects:

- Deformation of tunnel
- Weathering of concrete
- Earth pressure against the back face of lining

The following is a description of investigation on deformation of tunnel.

1) Outline

Investigation on deformation of tunnel is made on the entire tunnel to know in detail the damage, displacement, and water leakage in the tunnel.

The tunnel lining and portal develops crack, joint breakage, missing, water leakage and lining deformation due to material nature, defective workmanship, or earth pressure.

The lining is mostly made from plain concrete and will develop crack when the lining suffers deformation and displacement. In this context, the best index for deformation is to know the crack condition.

2) Investigation Items

Investigation items on tunnel damage are indicated in Table 4.14.1.

Table 4.14.1 Investigation Items on Tunnel Damage

	Lining	Portal	Ceiling Slab
Crack	○	○	○
Crack Spalling	○	○	
Joint Spalling	○		
Displacement, Deformation	○	○	
Corrosion			○
Difference from Correct Position	○		
Inner Cross Section	○		
Water Leakage, Free Line	○		

3) Investigation Method

The investigation method on deformation of tunnels is as follows:

(1) Investigation on the inner cross section

Secular change is made on the separate distance in terms of level, vertical, and oblique directions with reference to the lining.

(2) Investigation on Water Leakage

The position, amount, turgidity and temperature of water leakage should be investigated.

4) Judgment Standard

From the investigation, the degree of damage is identified. The judgment standard on degree of damage shall be established.

5) Record of Research

The results of investigation shall be summarized to the following investigation information format:

(1) Inspection Record
(2) Damage Condition Investigation Table
(3) Record Photographs
(4) Others

4.14.3 Maintenance and Repairs of Defects

Table 4.14.2 shows the cause and remedies against defects in the lining. Causes are competitive and aggravating mutually in not a few cases, and combining methods must be considered when the countermeasure is to be planned.

Each countermeasure method is outlined below.

1) Reinforcing by Centering

This method is used when deformation of the lining is small and limited reinforcement is adequate to maintain a balance of force and tunnel safety. I and H beams are used for the centering. To install the centering, the foundation should be of concrete construction (to an adequate depth) and the centering joint should be of a press type.

2) Reinforcing by an Inner Lining

Reinforcement can also be provided by a concrete lining to the inside of the lining where deformation is excessive and there is an allowable space in the inner section of the tunnel.

Table 4.14.2 Causes and Remedies Against Defects in the Lining

Cause	Remedy
(i) Deterioration	① Reinforcement with centering ② Reinforcement with inner or outer lining ③ Reinforcement by grouting at the back of lining
(ii) Water leakage	① Application or spray of water-proofing mortar to the inside of lining ② Grouting of mortar, cement milk, or chemicals ③ Installation of drainage in the rear of lining or to the inside of lining
(iii) Uneven pressure	① Reinforcement with inner or outer lining ② Reinforcement by grouting in the rear of lining ③ Reinforcement by installation of an invert ④ Counter-weight fill or cutting for balance of ground
(iv) Weakened members due to harmful materials	① Guided drainage of leaking water ② Placement of water tight concrete with acid resistant cement ③ Application or bonding of acid resistant materials

The minimum thickness of inner concrete lining is 20 - 30 cm, and reinforcing concrete is generally used.

3) Reinforcement with Outer Lining

This method is intended to reinforce a tunnel by placing new concrete in the rear of the existing lining without removing the lining. This method includes reinforcement by an enlarged side wall. Reinforcement with an outer lining is suitable in the case where there is not much allowance in the inner sector.

4) Reinforcement with Invert

When earth pressure increases or an uneven pressure occurs because of changes in the geology or topography, construction of the invert only at an early stage of the work will make the tunnel resist deformation forces.

5) Reinforcement by Grouting at the Rear of Lining

The purpose of grouting at the rear of the lining is to reinforce the lining by strengthening the rock mass and by filling the gap in the rear of the lining. In addition, the grouting agent penetrates into cracks or joints, reinforcing the lining proper directly, blocking a seep channels and preventing water leakage.

6) Counter-weight Fill or Cutting for Balance of Ground

When uneven pressures attributable to the topography is expected to act on a tunnel, the ground on the higher pressure side is cut off (if the rock mass allows cutting) and filling made on the lower pressure side. Otherwise, filling only is made to keep the balance of ground.

7) Relining

The lining must be removed for partial or entire relining when deterioration is serious or when the lining has lost its capacity because of excessive cracking.

4.14.4 Remedies against Water Leakage

Water leakage presents substantial trouble to traffic by degrading the durability of lining, lowering the safety of the traffic on the road, and moreover in the cold areas by freezing on the road surface, causing icicles, and wall icing, etc.

As a remedy for water leakage, drainage and cut-off's need to be used in combination as required. The drainage method includes the following processes:

1) Drainage in the Rear of the Lining

A part of the lining concrete is broken in a form of groove up at the rear surface of the tunnel and also part of the rock mass is excavated to provide space for a stone filled drain or perforated pipe through which water is collected and directed to the drains. Fig. 4.3 shows the stone filled drain type drainage and Fig. 4.4 the culvert type drainage.

2) Drainage in the Front of the Lining

In the case of concentrated water leakage through the lining surface, a V-shaped groove is excavated in the lining surface to direct leaking water to the gutter.

3) Boring, etc.

When the water inflow into a tunnel is much a boring for drainage is made into the rock mass.

4) Waterproofing Method

Waterproofing after completion of a tunnel is made by providing the lining surface with a waterproof layer. Various waterproofing materials, such as cement and resin are used. A method which proves itself as a more complete method requires the pasting of a waterproofing sheet over the lining surface.

4.15 Motorway Maintenance for Cut and Fill Slopes

4.15.1 General

1) Purpose of Slope Maintenance

The purposes of slope maintenance are as follows:

- To maintain the durability of the slopes
- To prevent slope failures and to maintain traffic safety
- To provide drivers with pleasant visual surroundings

2) Objectives for Slope Maintenance

The objectives for slope maintenance are as follows:

Slope protection will gradually change due to external forces which can be predicted at the time of construction and eventually will result in failures. Maintenance and repairs are required to keep the slopes in good conditions.

Investigation is required to measure abnormal slope situations and protections. If there are signs of deformation, then measurements should be taken so that the degree of danger can be determined.

Maintenance and repair is needed to insure the function of the slope protection such as the application of fertilizer to vegetation, the periodic removal of sediment deposited in and so forth.

Taking appropriate measures include the construction of structures for preventing failures on the slopes, slope cutting and earth removal after failures, and the implementation of emergency measures to prevent subsequent failures.

4.15.2 Investigation

Investigations will be required to evaluate defective slopes and to design a countermeasure work in case routine, periodic and special inspections can not furnish sufficient data for the evaluation and design.

The following are types of investigations for slopes:

- Soundness of Slopes
- Rock Fall

- Mud and Stone Flow
- Void of Concrete Spraying
- Land Sliding

1) Investigation on Soundness of Slopes

The soundness of slopes is investigated as follows:

(1) The existing stability condition of individual slopes against rainfall should be assured from aspects of earth work, topography, and geology. From analysis of slope failures in the past, an evaluation is made on major causes which triggered the slope failures, considering rainfall.

(2) The existing protection work should be checked for any changes, such as damage, sealling, crack, and weathering.

(3) As a result of (1) and (2), the deformation phenomena (failure pattern, etc.) expected on the slope during unusual weather is predicted.

(4) As regards (3), the effect of the existing protection work is judged empirically to see how much effectively the existing one can achieve protection.

(5) The critical level of individual slopes against rainfall is judged from the comprehensive evaluation of (1) through (4).

2) Investigation on Rock Fall

The investigation method to be employed is as follows:

(1) Selection and investigation of critical slopes

The field condition concerning falling rocks should be known and critical slopes should be detected.

(2) Investigation and design of the countermeasure work

Investigation should be made on any critical point where falling racks is expected, concerning the source of falling rock, expected falling pattern and damage state, and possibility. Investigation is also made to establish the measures against falling stone.

3) Investigation on Landslide and Failure

If occurrence or possibility of landslide is observed, investigation should be made on following items:

(1) Collection and review of existing reference materials
(2) Apprehending of the topographical map and aerial photos
(3) Field survey
(4) Investigation by measurement
(5) Geological and soil investigation
(6) Investigation on groundwater

4) Judgment Standard

From the investigation, the degree of damage is identified. The judgment standard on degree of damage shall be established.

5) Record of Research

The results of investigation shall be summarized to the following investigation information format:

(1) Inspection Record
(2) Damage Condition Investigation Table
(3) Record Photographs
(4) Others

4.15.3 Maintenance and Repairs of Vegetation Slopes

Maintenance and repairs are divided into those activities completed up to the time of full sodding, and those activities taking place up to the stabilization of the sod. The points of maintenance activity by methods and soil types are indicated in Table 4.15.1.

Table 4.15.1 Summary of Maintenance after Sodding

(Maintenance classified by method)

Method	Time need to complete the covering (standard)	Maintenance up to the completion of covering		Maintenance up to the stabilization of sods	
Whole-surface seeding such as seed-mud spraying	2 to 3 months	Water spraying during sunny summer season		Additional fertilizer once a year for 2 to 3 years	
		Additional fertilization in next spring if constructed in autumn	Additional fertilizer, if needed.		Growth of sod is to be carefully watched. Additional fertilizer if bare patches are found.
Other methods	3 to 6 months				

(Maintenance classified by soil type)

Fills and cuts of soft soil	Sandy soil	Be cautions of poor germination. Surface be covered as soon as possible. Erosion prevention agent is to be used if sod is not ready to meet the heavy rainy season.	Any broken cover is dangerous. Additional fertilizer is needed quickly if any bare patches are found.
	Clay soil	Slow growth. It is desirable to cover before frost heaving occurs.	Maintenance is almost unnecessary. Additional fertilizer is required according to the conditions of growth.
Cuts of hard soil		Shortage of water immediately after work or lack of fertilizer. Sufficient water spraying and additional fertilizer are needed.	A long time is needed for he stabilization of sod. Additional fertilizer needed for several years.

For maintenance problems caused by soil conditions, sandy soils are generally more suited to the growth of plants than clay soils. Sandy soils tend to cause defective germination due to a shortage of water and delay in the formation of cover, resulting in considerable damage by erosion after heavy rains. It is therefore required to spray effective curing materials to cover the plants with a material like asphalt emulsion, to perform water spraying and curing in summer, and to give additional fertilizer as soon as possible in order to accelerate the covering of the whole surface (if the growth is very slow).

In the case of clay soils, the growth of plants is generally slow and plants are less damaged by the erosion. Therefore, it is not necessary to increase the speed of coverage.

The types of vegetation should correspond to the site conditions. Additional fertilizer should be applied once a year until the humus layer develops fully and is able to supply nourishment by itself. In the case of seed spraying and seed-mud spraying, additional fertilizer is necessary for 2 to 3 years after spraying, and additional fertilizer may be necessary for more years on steep slopes.

4.15.4 Maintenance and Repairs of Slope Protection with Structures

Slope protection using structures is used to slopes not suited for vegetation. Slope stability cannot be maintained by sodding alone, or large-scale slopes which could cause failures, rock fall or frost heaves.

1) Maintenance and Repairs of Slope Protection Structures

Slope protection structures fail primarily due to the following two reasons:

(1) Aging and deterioration

(2) Deformation due to external earth pressure

The failed or performed part of the structures should be repaired in case (1). Since structures may have failed in case (2), full scale investigations are required to determine the following deformations:

- deformation of the structures, worsening or not
- deformation of the structures, local slope protection area or all areas
- location of sliding face of deformation, elevation of water table and distance to natural ground surface and slope protection structures

Based on the results from the investigation and studies, structures should be repaired.

4.15.5 Emergency Measures for Slope Failures

Even though slopes are fully inspected and maintained, some slope failures may occur during abnormal weather, requiring emergency measures. Measures are taken in advance to prevent failures based upon the results of inspections and subsequent studies. It is important to determine whether traffic is to be restricted or not. If a traffic restriction is needed, the traffic control during the traffic restriction period should be reviewed.

When planning emergency measures, it is necessary to consider methods of preventation of secondary disasters, and securing the safety of traffic and workers and to examine the possibility of additional troubles at the time of restoration.

1) Emergency Measures for Vegetation Slopes

(1) Cut slopes

If any sign of failures is found or if a failure occurs, the scale of the failure should be carefully examined. The failure has occurred only locally and there is no immediate danger of other occurrences, then it is simplest to take emergency measures by using wicker works. If the scale of the failure is large, it requires to secure the long-term stability by re-shaping the slope and providing a gentler grade.

At failure of slopes, the cracked portion of the slope should be covered with sheets to prevent the infiltration of rainwater and to prevent progression of damages.

An example of measures taken against cracks and failures at the top of a slope is indicated in Figure 4.15.1.

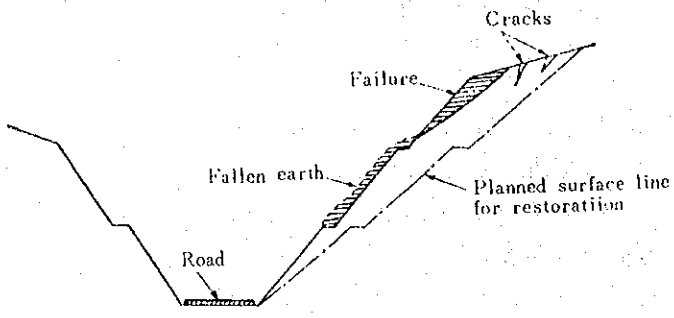


Figure 4.15.1 An Example of Restoration after Cracks and Failure

(2) Fill slopes

A slope failure will occur when ditches are filled with rainwater due to improper maintenance or a heavy local rain. In this case, the failure should be inspected and restored by placing and fully compacting good soil. Wicker work is shown in Figure 4.15.2 (a). Drains filled with crushed stone or the installation of gabions at the toe of the slope are shown in Figure 4.15.2 (b).

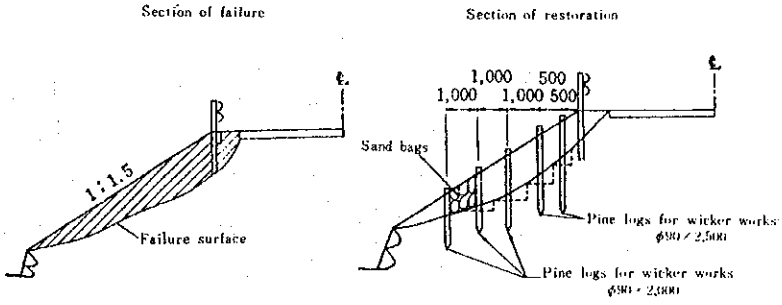


Figure 4.15.2 (a) An Example of Restoration of Slope Failure due to Surface Water From Road Site

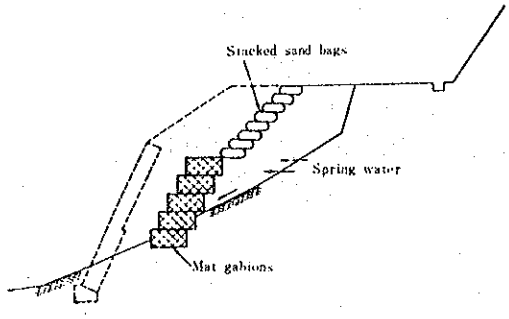


Figure 4.15.2 (b) An example of Emergency Restoration by Mat Gabins and Stacked Sand Bags

2) Emergency Measures for Slope Protection Works Using Structures

Typical examples of emergency measures for slopes protected by concrete or mortar spraying, block masonry and cribwork are described below.

(1) If previously sprayed concrete or mortar is partially chipped off or separated from a slope due to weathering of the sprayed mortar or concrete, then emergency measures using the rockfall preventation net should be taken as shown in Figure 4.15.3 (a). Spraying should be reperformed if damage progresses further. If the ground itself has been weathered and is ready to fall or if the stability of the ground is gone and earth pressure acts to dislodge the concrete or mortar, it may be necessary to perform concrete patching or concrete cribwork.

(2) Block masonry

Abnormal conditions which occur in concrete block masonry are observed as cracks or warping resulting from the settlement of the foundation or from high earth pressure. For these cases measures such as a combination of cribwork and anchor work or cast-in-place concrete cribwork as shown in Figure 4.15.3 (b) will be normally used.

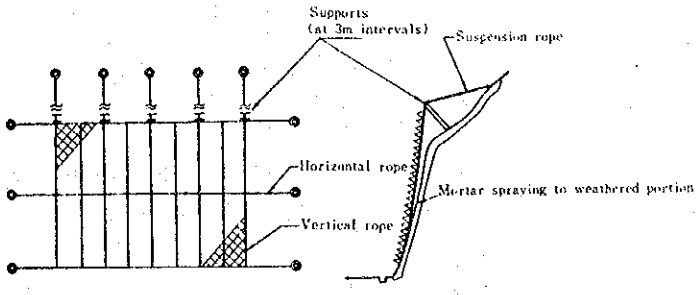


Figure 4.15.3 (a) An Example of Emergency Measures by Pocket Type Rock Fall Prevention Nets

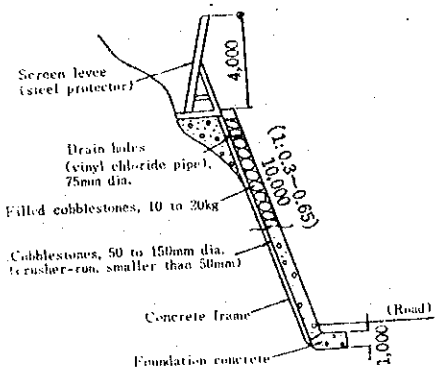


Figure 4.15.3 (b) An Example of Restoration by Cast-in-place Concrete Cribworks

(3) Slope cribwork

Abnormal conditions for cribwork are typically floated and fallen cobblestones which were originally a part of the fill used in the cribwork after properly disposing of spring water.

If there is sandy soil behind the cribwork and spring water is present, the rear of cribs may have scoured, resulting in the sinking of the cribs and an outflow of the sediment fill. In this case, the spring water should be properly disposed of, and re-installation of the cribs or a consolidation by concrete may be necessary.

(4) Measures for untreated slopes

Dangerous spalls or loose soil on a slope should be removed first. When the removal is difficult, the following measures also should be taken:

First, spalls or loose soil which can lead to fallen rocks are stacked at a safe place on the slope, or they are fixed to the slope by concrete or anchors.

Secondly, rockfall preventation fences or nets are installed to prevent damage to ordinary traffic in the event of rockfalls.

Thirdly, if necessary, rockfall sheds are sometimes installed.

Finally, though the two latter measures stated above are effective against sediment failures, the re-excavation of slopes to obtain a stable gradient or slope protection using structures is often used in order to stabilize the main portion of slopes.

4.15.6 Maintenance and Repairs of Drainage on Slopes

Most slope failures are caused by water. Rainwater becomes surface water on the slope and flows down along the face of the slope thereby eroding the surface, or rainwater becomes seepage water and may cause a slope failure.

Therefore, ditches on berms of high fill slopes and ditches at the top of cut and fill slopes should be periodically inspected. Fallen earth, rocks and weeds should be removed, and water concentrated in ditches other than the vertical drainage facilities must be avoided.

Maintenance and Repairs

If concrete ditches are used for vertical drainage facilities, the occurrence of any differential settlement should be carefully inspected since such settlement may separate the joints. It causes run-off of soil due to scour, and destroy the face of the slope.

If any of these problems have been found, the separate U-shaped ditch should be removed, foundation material should be added and fully compacted, and a new ditch installed. Also, a joint between the vertical drainage facilities and the ditch for the top of the slope should be frequently inspected since it become defective. Any defect must be repaired immediately. Wet conditions and spring water on the face of cut and fill slopes will need extra precautions. If these are found, they should be treated by the slope gabions, horizontal weep holes or other appropriate methods. If slope protection methods such as concrete spraying have been employed, the conditions of face of slope should be inspected and, if necessary, water drainage repairs should be performed.

REFERENCE

REFERENCE 1

Related Laws and Regulations for the Republic of Turkey

Law No.	Title/Subject
1593	"Access Controlled Highway Law-1972"
2918-Item 5b	"Highways Traffic Law(1983)-Police Powers, Duties and Authority"
2918-Item 7	"Highways Traffic Law(1983)-Duties and Authority of KGM"
2918-Item 13	"Highways Traffic Law(1983)-Road Traffic Safety, Traffic Signs, Buildings and Facilities"
5539	"Legislation Covering the Establishment and Duties of the General Directorate of Highways -1950"
NA	Proposed Regulation for Motorways-"Project of Access Controlled Highway Regulation"
NA	"Principals of Motorway Projects"
NA	"The Regulation on the Operation of Istanbul Bogazici(First) Bridge of Highways General Directorate"

Law No. 1593

"Access Controlled Highway Law - 1972"

Summary: This law deals with the authority of the KGM to construct access controlled highways within the Republic of Turkey, including determining their alignments, expropriating necessary land, the setting up of commercial establishments, & inhibited activities, and penalties.

ACCESS CONTROLLED HIGHWAY LAW

Law No : 1593

Passed on June 6, 1972
Published on June 11, 1972

Access controlled highway:

Article 1 - An access controlled highway is defined as a highway, specified specially for transit traffic whose entry and exit are forbidden except for particular places and conditions, on which pedestrians, animals and vehicles without motor are not allowed; but on which only motor vehicles are allowed, and on which traffic is regulated under special control. An access controlled highway can be within the boundaries of a municipality.

Construction and destruction of access controlled highway:

Article 2 - On the highways, present or to be rebuilt, an access controlled highway can be constucted or destructed by a proposal of the General Directorate of highways and the approval of the Ministry of Public Affairs.

The opinion of the concerned municipality is asked for the access controlled highways to pass through the boundaries of the municipality.

Link to Access controlled highways:

Article 3 - The links to access controlled highways are made in places and ways as considered appropriate by the General Directorate of Highways. Linking the areas around the access controlled highway to the connecting points is provided through collector roads or other roads reaching these connecting points. The owners, renters or users of the land neighboring the access controlled highway do not have the right to enter or exit this highway from their land due to the fact that their land is neighboring the highway or some other cause.

Passing through the city:

Article 4 - Designating the route of the access controlled highway in the city and specifying the links and connections of the highway to the city are decided upon by the Ministry of Public Affairs and Settlement, the General Directorate of Highways and the concerned municipality.
Settlement in the areas neighboring the highway outside the city:

Article 5 - The layout of the settlement on important parts of the access controlled highway, outside the city, is carried out through regulations prepared by the Ministry of Public Works, and through the settlement plans made by the Ministry of Public Works.

Buildings nonconforming with the regulations and settlement plans cannot be built. Buildings fixed as out-of-place by the General Directorate of Highways are cleared by the General Directorate of Highways under the supervision of the police.

Expropriation:

Article 6 - Land of the required width for the construction and improvement of the access controlled highway, and for the protection and organization of its neighbouring area is expropriated, and Article 23 of Law numbered 2942 is not applicable to the expropriation made for this purpose.

Indemnity:

Article 7 - When access control is created on an existing highway, should the entry and exit of a neighbouring land owner be cancelled and should his / her access to the highway not be made possible through collector road or in some other way, the loss of value relating to the loss of access is paid as an indemnity due to cancelling his / her entry and exit.

The difference between the current values of the loss of access before and after the cancellation of access is specified as the amount of the indemnity.

Should the previous access of the neighbouring land owners to the highway be cancelled due to the construction of new access controlled highway, the owners' access is provided through constructing a collector road or in some other way. If this is impossible, the value of the loss of access is paid as an indemnity.

The owners of and others who have rights of access and whose link to the access controlled highway is provided do not have the rights to claim for any other indemnity.

Setting up commercial establishments and their activities:

Article 8 - Within the specified or expropriated area for access controlled highways it is prohibited, except for repairshops, petrol stations, restaurants and motels, relating to roads and trips, which are set up with the approval of the General Directorate of Highways, to set up or operate a commercial establishment and to do any kind of business and like.

Settling up underground and over-ground PTT (Post - Telephone - Telegram), electricity, water installations and the like:

Article 9 - Within the boundaries of a newly built access controlled highway every kind of PTT, electricity, water installations and the like can be set up with the approval of the General Directorate of Highways. The legal rights given to those concerned for the setting up of such foundations are not applicable within the boundaries of the access controlled highways.

Other inhibited actions:

Article 10 - Without the approval of the General Directorate of Highways it is prohibited to move any earth, set up any construction and installation within and on the boundaries of the access controlled highway. Any offence and harm done to the buildings and foundations of the General Directorate of Highways are the responsibility of the police and the offender is required to pay the expenses incurred for these damages.

Notice:

Article 11 - On the existing or rebuilt highways at the time of application of this Law's conditions, and the inhibitions and limitations brought by this Law are announced through the Official Gazette.

Penalties:

Article 12 - Those who do the works and actions limited and inhibited by this Law, and those who make others do so and the owners of animals stepping on to the roads are fined for TL 50 to TL 1. 000 and sentenced from 5 to 30 days in imprisonment.

The authority of the Criminal Courts is allowed in these cases which are considered urgent.

Regulations of Access Controlled Highways:

Article 13 - The regulations concerning the application of this Law are prepared by the Ministry of Public Works, the Ministry of Public Affairs and Settlement, the Ministry Transportation within 6 months after the publication date of this Law.

Article 14 - This Law comes into force as of its publication date.

Article 15 - This Law is executed by the Council of Ministers.

Appendix No. 6

"The Regulation on the Operation of Istanbul Bogazici (First) Bridge of Highways General Directorate"

Summary: This regulation deals with the authority of the Highways General Directorate to operate the Bogazici Bridge, personnel in charge of the collection of tolls and their responsibilities, and procedures to be followed during the toll collection process.

THE REGULATION ON THE OPERATION OF ISTANBUL BOGAZICI (FIRST) BRIDGE OF HIGHWAYS GENERAL DIRECTORATE

FIRST PART
General Provisions

ARTICLE 1: Scope of Regulation:

The procedure on the collection of the transition toll payments from the vehicles and their passengers crossing the Istanbul 17th Division Bosphorus Bridge and the operation of the maintenance elevators of the same bridge of the Highways General Directorate are carried out according to the provisions of this Regulation

ARTICLE 2: Implementation Organization:

The implementation organization of this Regulation is the Bogazici and Halic Bridges Directorate established in relation with the 17th Division of the Highways General Directorate.

ARTICLE 3: Personnel in Charge and Responsibilities:

The personnel in charge of collection procedures have the duties and responsibilities below.

a) The Director of Bogazici and Halic Bridges is the supervisor of implementation and is responsible to the Regional Directorate and General Directorate for implementation of this regulation and any necessary measures. He is called "Director" in the following regulation.
b) The Operations Chief is responsible for the collection of toll payments and operation of maintenance elevators and electronic control equipment used for registration and administration of the personnel in charge of collection of payments and he is responsible to carry out the work according to the provisions of this Regulation.

c) Operation Technical personnel are responsible for the duties given to him by the Operations Chief for work under his responsibility.

d) The Responsible Accountant is responsible for the accounting work in relation to evaluation and delivery to the Bank and collection of bridge crossing payments and elevator payments according to the provisions of this Regulation and laws in force.

e) The Calculations Chief and Technical Calculators are responsible for carrying out the procedures in relation to the collection of bridge crossing toll payments and elevator payments, including preparation of necessary documents, updating records (accounting books), doing the other work given to them by the responsible accountant and finishing the calculations and evaluations in time.

f) Head Controllers: are responsible of following up the work of personnel in charge of ticket windows, controllers, and personnel in charge of elevators, and controlling the recording procedures done according to the provisions of this Regulation and management of the electronic recording system. When the regular work hours are over they take over the administrative responsibilities.

g) Ticket window controllers are responsible for the followup of the work of personnel in charge of ticket windows, for carrying out the purchase of foreign currency according to the provisions of this Regulation, to control the turnover payments collected and bagged by personnel in charge of ticket windows and elevators, and to do the work described in other articles of this Regulation.

h) Personnel in charge of the ticket windows are personnel employed as laborer status according to Paragraph d, Article 4 of the State Employee Law No. 657. They are subject to the Guarantee Law No 2489, because they handle money, etc. They are responsible for collecting the bridge crossing payments at the ticket window they are in charge of, according to the provisions of this Regulation, to record information as necessary, to count the money collected, to bag the money collected, to prepare the necessary reports and memos, to deliver the money bags according to the cash law and to give documented accounts of their activities, based on the results obtained from the electronic recording system.

i) The personnel in charge of the elevators are personnel employed as laborers according to Paragraph d, Article 4 of the State Employee Law No. 657. They are subject to the Guarantee Law No. 2489, because they handle money, etc. They are responsible to operate the elevator they are in charge of, to collect the payments in return for a ticket, to bag the money they have collected and deliver them to the cash box and to give an accounting of the collections they have made according to the provisions of this Regulation.

ARTICLE 4: Presentation of Documents during inspection and providing information to official institutions:

Documents and books are shown to inspectors and controllers and those who are authorized to investigate by a court request at the time of demand. Certified copies of the documents demanded by the authorities will be provided. If the original copy has to be given, the certified copy is made and kept. Without the permission or acknowledgement of the Director, no information can be given to others, including documents and work under the authority of this Regulation.

ARTICLE 5: Confidentiality of Procedures and the Necessity to Give Notice of Irregularities:

Personnel on duty for the work described in this Regulation are required to keep the information secret they are aware of because of their work and they are required to inform their supervisor of any irregularity they observe.

ARTICLE 6: Other Subjects Not Covered in this Regulation:

For those subjects relating to accounting and not explained in this Regulation, the State According General and Commercial Transactions Regulations apply.

ARTICLE 7: Amendments and Supplements to the Regulation:

Amendments necessary for this Regulation can be accomplished with the approval of the Ministry of Public Works and Ministry of Finance.

ARTICLE 8: Banking Service:

Bank service in relation with the revenue obtained from the work under this Regulation will be conducted with the central Bank or through its approved correspondent bank according to Article 41 of "Turkish Republic Central Bank Law No. 1211" .