10) Damages at the anchorage of prestressing tendons

(a) Inspection area

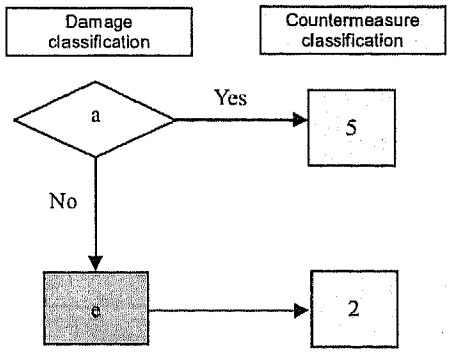
The existence of damages at all the anchorage of prestressing tendon within visually perceptible area shall be inspected.

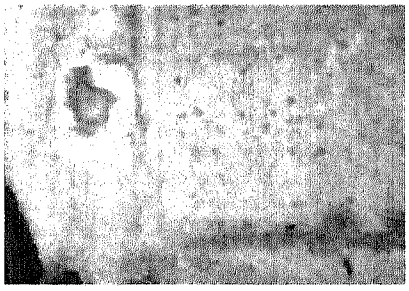
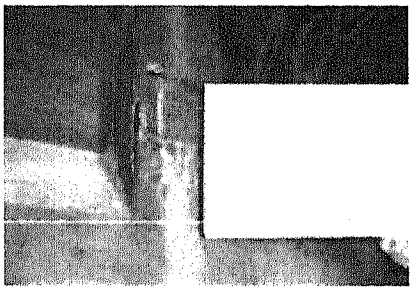
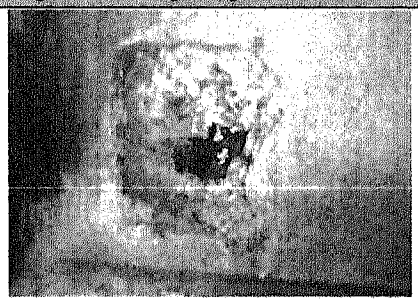
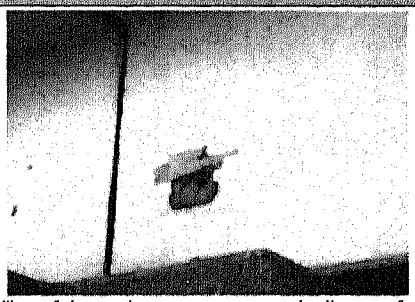
(b) Classification of damages

The inspected results shall be evaluated with the following classification:

Evaluation criteria	Classification
No damage	a
Damages at the anchorages of prestressing tendons Damages in the prestressing tendons	e

(c) Judgment of CC



Damage level e -> [CC 2]	**Damage level e -> [CC 2]**
	
Rust stain on the concrete surface at the anchorage	Rust stain on the concrete surface at the anchorage
Damage level e -> [CC 2]	**Damage level e -> [CC 2]**
	
Spalling of the anchorage concrete and steel corrosion	Spalling of the anchorage concrete and slip out of the PC tendon

11) Unevenness of road surface

(a) Inspection area

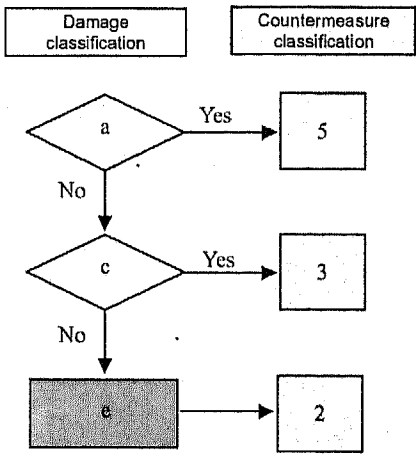
The existence of unevenness and level difference all over the road surface shall be inspected approaching closely.

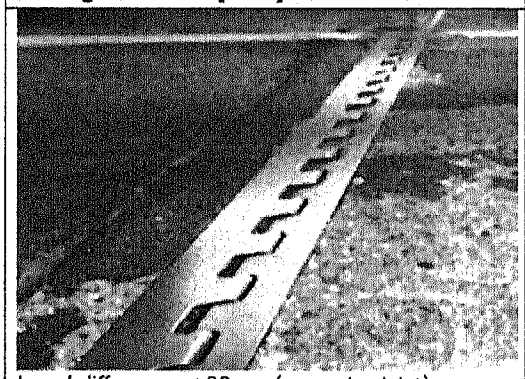
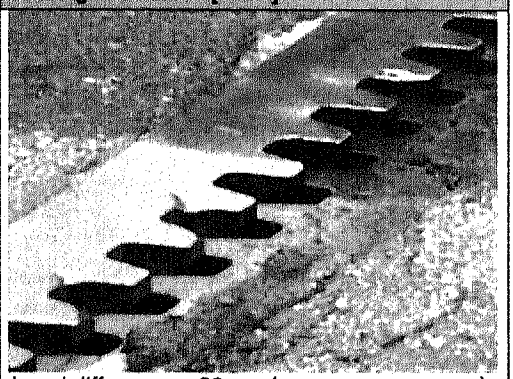
(b) Classification of damages

The inspected results shall be evaluated with the following classification:

Evaluation criteria	Classification
No damage	a
Level difference < approx. 20mm (No difficulty in driving)	c
Level difference = approx. 20mm (Difficulty in driving)	e

(c) Judgment of CC



Damage level c -> [CC 4]	Damage level e -> [CC 2]
	
Level difference < 20mm (expansion joint)	Level difference < 20mm (concrete – pavement)

12) Functional damages of bearings

(a) Inspection area

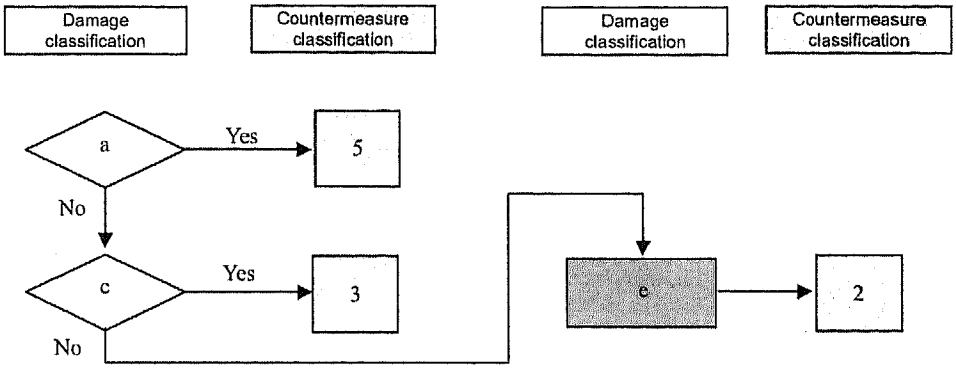
The existence of functional damages for all bearings shall be inspected approaching closely.

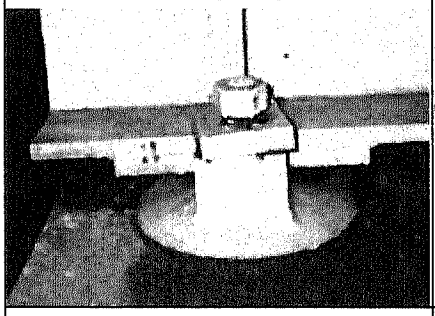
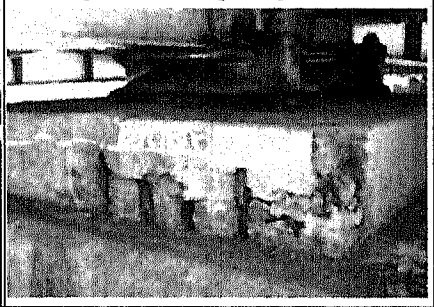
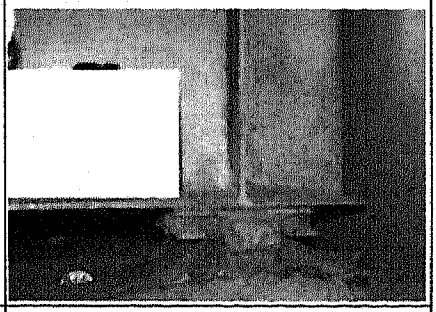
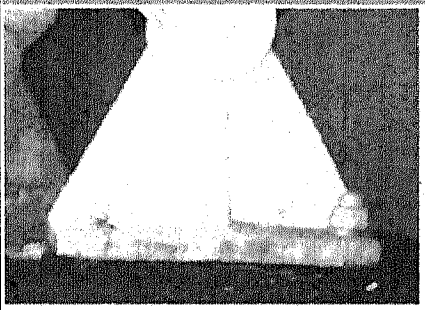
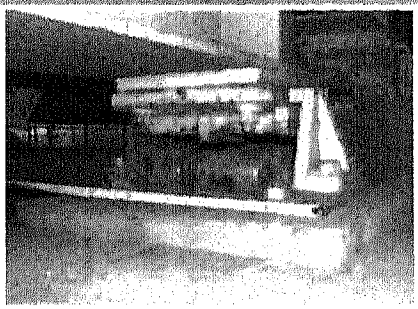
(b) Classification of damages

The inspected results shall be evaluated with the following classification:

Evaluation criteria	Classification
No damage	a
Functional damages of bearings	c
Remarkable functional damages of bearings	e

(c) Judgment of CC



Damage level c -> [CC 3]	**Damage level c -> [CC 3]**	**Damage level c -> [CC 3]**
		
Loosed anchor bolts of bearing	Limited damages in bearing seat only (evaluated in cracks, water leakage, free lime or rebar exposure)	Bearing corrosion without remarkable functional damage
Damage level e -> [CC 2]	**Damage level e -> [CC 2]**	**Damage level e -> [CC 2]**
		
Functional damage in movement due to the accumulation of soil and dirt	Raised bearing	Broken bearing

13) Damages in substructures

(a) Inspection area

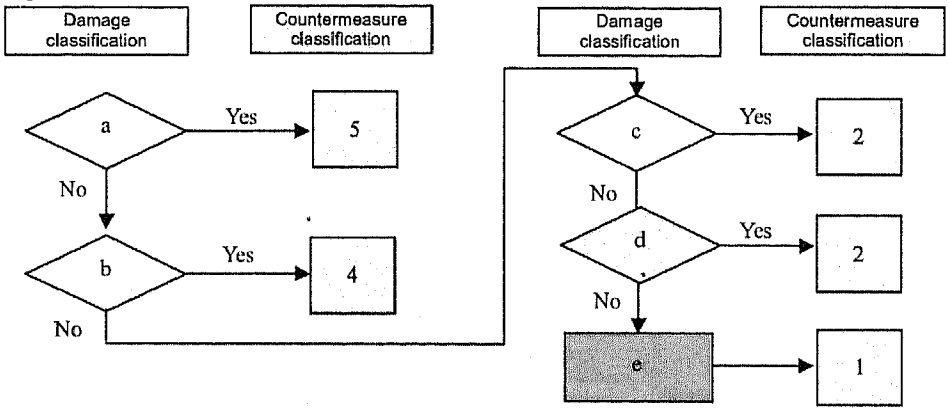
The existence of settlement, movement, inclination, scour and erosion within visually perceptible area shall be inspected for all substructures. Especially settlement, movement, inclination, scour and erosion of substructures on land can be detected easily through observing the condition change of the surrounding ground such as the ground surface, interlocking pavement, etc..

(b) Classification of damages

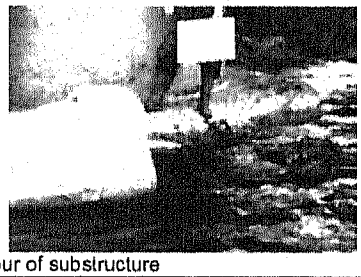
The inspected results shall be evaluated with the following classification:

Evaluation criteria		Classification
Settlement, movement, inclination	Scour, erosion	
No settlement, movement and inclination	No scour, erosion	a
	Slight scour, erosion	b
	Remarkable scour, erosion	c
Settlement, movement or inclination	No scour, erosion	c
	Slight scour, erosion	d
	Remarkable scour, erosion	e

(c) Judgment of CC

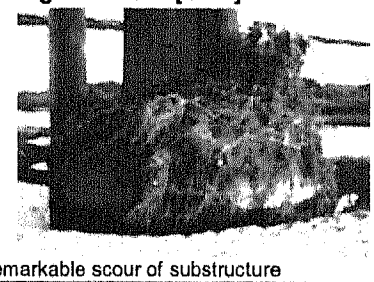


Damage level b -> [CC 4]



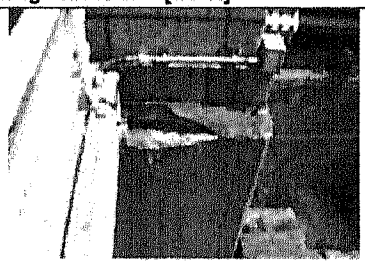
Scour of substructure

Damage level c -> [CC 2]



Remarkable scour of substructure

Damage level c -> [CC 2]



Movement and Inclination of substructure

Damage level e -> [CC 1]

Settlement and Inclination of substructure and remarkable scour

14) Damages in pavements

(a) Inspection area

The existence of cracks, layer separation, and pot holes shall be inspected for all pavements.

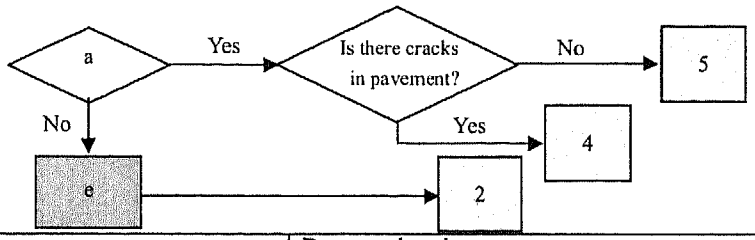
(b) Classification of damages

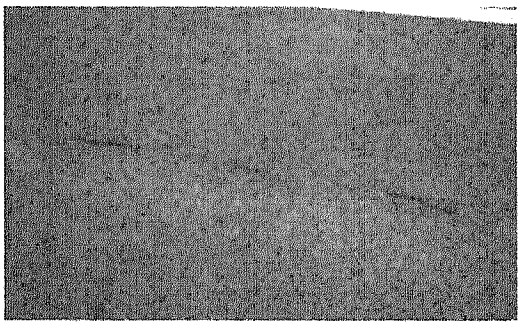
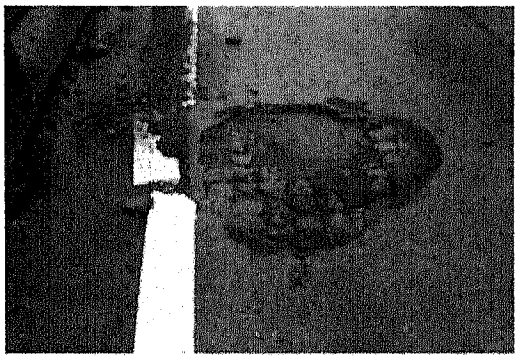
The inspected results shall be evaluated with the following classification:

- Asphalt pavement

Evaluation criteria	Classification
No damage / - Cracks with the width w = 5mm - Deck concrete not broken to small pieces nor no potentially remarkable deflection due to the fatigue cracks of a steel plate deck	a
- Cracks with the width w = 5mm - Deck concrete broken to small pieces or potentially remarkable deflection due to the fatigue cracks of a steel plate deck	e

(c) Judgment of CC



Damage level a	Damage level a
	
Crack with the width = 5mm, but not latticed	Crack with the width = 5mm, but not latticed
Damage level e	**Damage level e**
	
Remarkable unevenness. Bicycle or motorcycle can turn over.	Spalling or cave-in of the deck potentially. Dangerous traffic condition.

15) Damages in barriers

(a) Inspection area

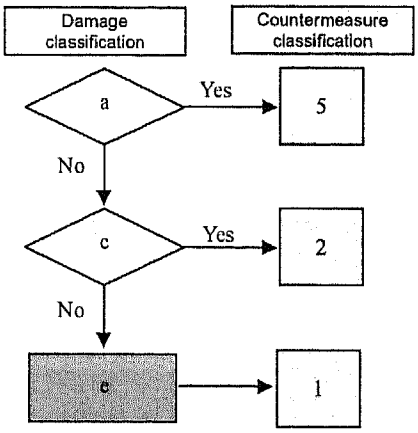
The existence of deformation and loss of materials shall be inspected for all barriers.

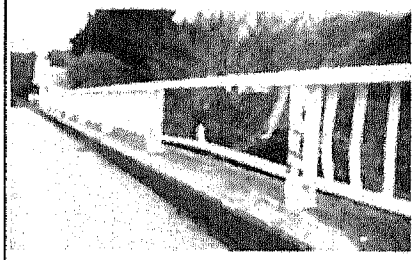
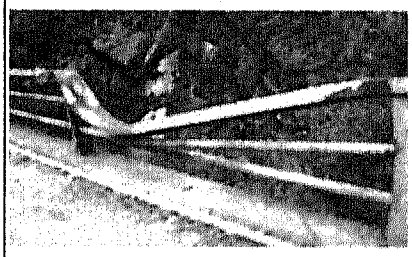
(b) Classification of damages

The inspected results shall be evaluated with the following classification:

Evaluation criteria	Classification
No damage	a
Local deformation and partial loss of steel or concrete	c
Remarkable local deformation and remarkable partial loss of steel or concrete	e

(c) Judgment of CC



Damage level c -> [CC 2]	**Damage level c -> [CC 2]**	**Damage level e -> [CC 1]**
		
Local deformation	Rebar exposure with remarkable area of damage	Remarkable reduction in strength by the sectional reduction due to pitting corrosion
Damage level e -> [CC 1]	**Damage level e -> [CC 1]**	**Damage level e -> [CC 1]**
		
Breakage in large area. Dangerous traffic condition	Large deformation. Dangerous traffic condition.	Remarkable local loss of concrete

16) Damages in expansion joints

(a) Inspection area

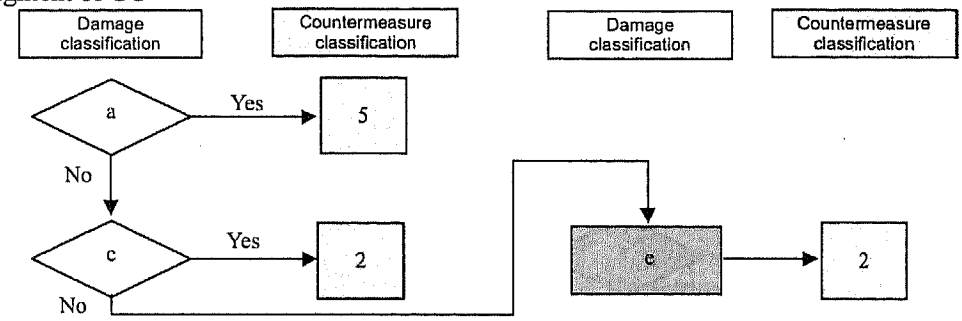
The existence of damages, unusual gap and water leakage downward shall be inspected for all expansions.

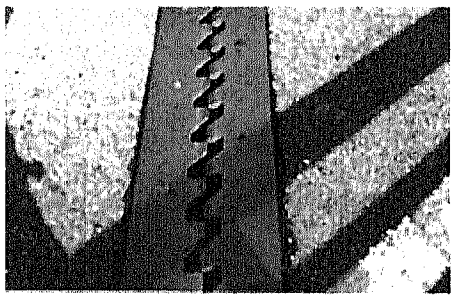
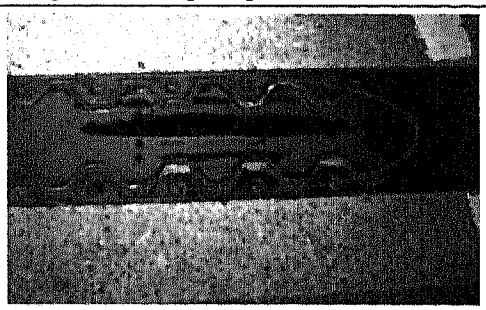
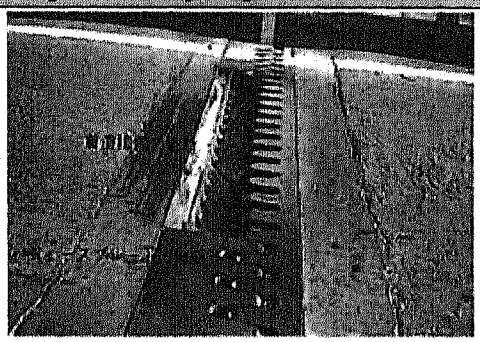
(b) Classification of damages

The inspected results shall be evaluated with the following classification:

Evaluation criteria	Classification
No damage	a
Local deformation or partial loss of steel or rubber etc / Excessive gap to the design value leads to the difficult traffic condition to the pedestrians and bicycles	c
Remarkable local deformation or remarkable partial loss of steel etc. / Corrosion in girders or bearings due to water leakage	e

(c) Judgment of CC



Damage level c -> [CC 2]	**Damage level c -> [CC 2]**
	
Large gap. Problem to pedestrian or vehicles	Local cracks in the rubber
Damage level e -> [CC 1]	**Damage level e -> [CC 1]**
	
Water leakage. Potential corrosion in the bearings	Breakage of expansion joint Potential turning over of bicycles or motorcycles

17) Damages in cable

(a) Inspection area

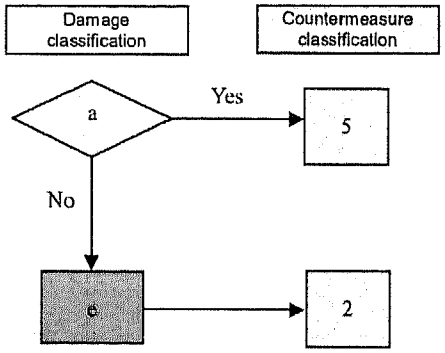
The damages in the cables such as deterioration of cable sheathing, deflection, twist, fracture, etc. and those in the cable anchorages such as deterioration of waterstop cover, missing bolts, corrosion, deterioration and missing of sealing material, etc. are inspected approaching closely or using binocular.

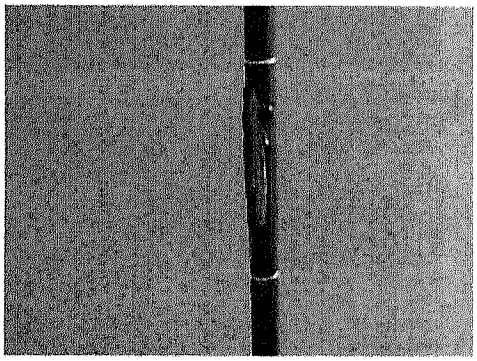
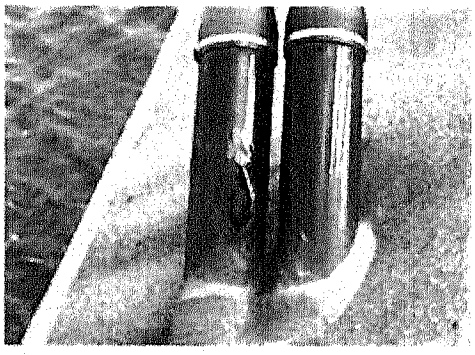
(b) Classification of damages

The inspected results shall be evaluated with the following classification:

Evaluation criteria	Classification
No damage	a
Damaged	e

(c) Judgment of CC



Damage level e -> [CC 2]	Damage level e -> [CC 2]
	
Damage of cable	Damage of anchorage

3.3.3 Estimation method of LCC

(1) Repair measures against the damage detected by periodic inspection

[Basic policy for repair measures]

(a) Timing for repair measures

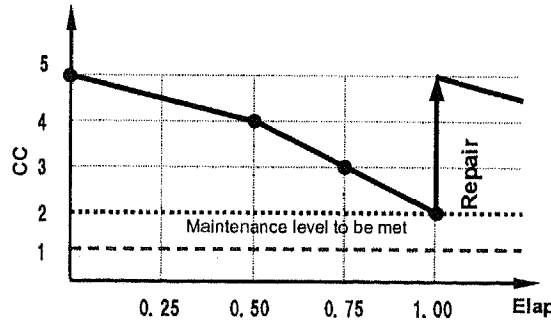
To cope with the damage identified by periodic inspection result, it is necessary to take appropriate measures in the stage where the corresponding maintenance level can be maintained. The Manual specifies, as the basic policy, implementation of appropriate repair measures depending on the member type when a member is evaluated to be in "CC 2" upon inspection or has reached the stage of "CC 2" after inspection as a result of deterioration over time so as to maintain the maintenance level of the 12 Chao Phraya bridges.

(b) Prediction method of deterioration

In order to follow post-inspection changes over time of damage, it is necessary to conduct deterioration prediction by the damage. Because of the following reasons, however, the manual specifies estimation of LCC by setting the action timing based on the consideration of the service life of members and the general modes of deterioration, therefore it is decided that deterioration prediction using theoretical methods or methods based on data analysis will not be applied.

[Reasons why the service life of the member is used for setting of the action timing for countermeasure]

- The 12 bridges over the Chao Phraya are daily maintained with a relatively advanced level by the maintenance offices in vicinity of them. Considering the ongoing periodic repair service including re-painting and replacement of members, as a first stage, it is judged that the setting of action timing based on the service life of member types, not the deterioration prediction based on inspection results or test results, well agrees with the actual maintenance condition.
- If the action timing were determined based on deterioration prediction, the inspection results in the past years should be available as the basic data that allow such deterioration prediction. However, since no such data are available in the first place, it is difficult to attain a sufficient level of prediction accuracy.
- The method of deterioration prediction using a theoretical methods based on the past facts requires implementation of various tests such as laboratory test with field samples or non-destructive test, and such prediction is highly likely to suffer degradation of prediction accuracy depending on the quality of construction or the environmental conditions. Considering these facts, this method is considered inappropriate for the 12 bridges.
- It is a general trend that the soundness of a member decreases at an accelerated pace as the years of use increase and the member nears to the limit of service life. This notion is illustrated based on the relationship between service life and CC as in Figure 3.3.4.



- The number of years it takes a member to go down from CC 5 to CC 2 should be set as the service life of the member.
- The number of years it takes a member to go down from CC 5 to CC 4 should be set as [service life x 0.5].
- The number of years it takes a member to go down from CC 4 to CC 3 should be set as [service life x 0.25].
- The number of years it takes a member to go down from CC 3 to CC 2 should be set as [service life x 0.25].
- The repair cost for each member should be estimated based on the relationship between service life and CC after clarifying the action timing related to the determined CC upon inspection.

Figure 3.3.4: Concept of action timing using the relationship between service life and CC

[Repair measure according to countermeasure classification]

(a) Repair measure for "CC 2"

For members judged to fall under "CC 2" based on the periodic inspection result, select the repair method corresponding to the type of members and damages and estimate the repair cost by [approximate unit price x assumed repair quantities] (see Table 3.3.3).

(b) Repair measure for "CC 3", "CC 4 "and "CC 5"

Members judged to fall under "CC 3", "CC 4 "and "CC 5" based on the periodic inspection result deteriorate and are damaged over time. Therefore, based on the action timing determined in Figure 3.3.4, when those members reach "CC 2", select the repair method corresponding to members and damages and estimate the repair cost by [approximate unit price x estimated repair quantities] (see Table 3.3.3).

Figure 3.3.4 shows the member repaired or renewed at the stage of "CC 2" recover to "CC 5" and the ratio of the remaining years until "CC 2" (elapsed years / service life) equals 1.00. It should be noted that the service life is different in repair and renewal.

It is important to improve the accuracy of the long-term maintenance plan by accumulating the repair data and making timely renewal of the settings, such as the unit price for the approximate maintenance cost and service life, in the future.

Table 3.3.3: Repair methods for the damages detected in inspection

Bridge type	Member category			Damage	Repair method	Unit	Approximate repair cost Unit price(¥)	Estimation of repair quantity		Remaining years up to countermeasure el. 2		
								Calculation	Remarks	① assessment	② assessment	③ assessment
Concrete bridge (RC) (PC)	Main member	Deck	Concrete (RC)	Rebar exposure	Patching	B/m²	17,500	[illegible]	assumed to be 20% of cracking (at 20%)	30	15	-
				Deck cracking	CFR	B/m²	22,500	[illegible]	from experience (at)	30	15	-
			Concrete (PC)	Rebar exposure	Patching	B/m²	17,500	[illegible]	assumed to be 20% of cracking (at 20%)	30	15	-
				Deck cracking	CFR	B/m²	22,500	[illegible]	assumed to be 80% of RC deck (at 80% - 0)	60	25	12
		Girder Crossbeam	Concrete (RC)	Damages at anchorage of PC tendon	CFR (upper & bottom)	B/pos.	45,000	Number of damaged positions	assumed to be 1 0m 1 0m pos. and repeated every 2 pos.	-	-	-
				Cracking/Water leakage/Free lime	Resin injection	B/m	5,000	[illegible]	from experience (at)	30	15	-
				Rebar exposure	Patching	B/m²	17,500	[illegible]	from experience (at)	30	15	-
			Concrete (PC)	Cracking/Water leakage/Free lime	Resin injection	B/m	5,000	[illegible]	assumed to be 80% of RC deck (at 80%	30	15	-
				Rebar exposure	Patching	B/m²	17,500	[illegible]	assumed to be 80% of RC deck (at 80%	30	15	-
				Damages at anchorage of PC tendon	Reinforcement with external PC tendon	B/pos.	1,000,000	Number of damaged positions	assumed to be the repair for 5m 4 cracks pos.	-	-	-
		Substructure	Concrete	Cracking/Water leakage/Free lime	Resin injection	B/m	5,000	[illegible]	from experience	30	15	-
				Rebar exposure	Patching	B/m²	17,500	[illegible]	from experience	30	15	-
				Damages in substructures (Scour)	Foot protection	B/substr	1,750,000	Number of substr.	from experience	-	-	-
	Secondary member	Bearing		Functional damage of bearings	Metal spraying	B/bearing	120,000	[illegible]	from experience	30	15	-
Steel bridge	Main member	Deck	Concrete (RC)	Rebar exposure	Patching	B/m²	17,500	[illegible]	assumed to be 20% of cracking (at 20%	30	15	-
				Deck cracking	CFR	B/m²	22,500	[illegible]	from experience (at)	30	15	-
				Damages at anchorage of PC tendon	CFR (upper & bottom)	B/pos.	45,000	Number of damaged positions	assumed to be 1 0m 1 0m pos. and repeated every 2 pos.	-	-	-
		Girder (Steel member)	Steel	Corrosion	Repaint with Rc-I paint	B/m	5,000	[illegible]	Trace [illegible]	20	10	5
					Scaffolding	B/m²	5,000	[illegible]	—	-	-	-
				Cracking	Reinf. with steel pl.	B/pos.	166,700	Number of cracks	—	-	-	-
				Missing bolts	Bolt change for splice pl.	B/pos.	133,400	Number of repl.	—	-	-	-
				Fracture	Reinforcement of fractured parts	B/pos.	166,700	Number of frac.	—	-	-	-
				Deformation & loss	Replacement of deformed parts	B/pos.	166,700	Number of deform.	—	-	-	-
		Substructure	Concrete	Cracking/Water leakage/Free lime	Resin injection	B/m	5,000	[illegible]	from experience	30	15	-
				Rebar exposure	Patching	B/m²	17,500	[illegible]	from experience	30	15	-
				Damages in substructures (Scour)	Foot protection	B/substr	1,750,000	Number of substr.	from experience	-	-	-
			Steel pier	Corrosion	Repaint with Rc-I paint	B/m2	5,000	[illegible]	assumed to be 5 (m²/ substr.	20	10	5
	Secondary member	Bearing		Functional damage of bearings (Corrosion)	Metal spraying	B/bearing	120,000	[illegible]	from experience	30	15	-
Common members	Secondary member	Pavement		Level difference of road surface Damages in pavements	Pavement replacement	B/m	5,000	[illegible]	incl. surface- & base course and water proof	20	10	5
		Barriers Railings	Steel	Damages in barriers (Corrosion)	Change of steel railings	B/m	20,000	[illegible]	—	30	15	-
			Concrete	Damages in barriers (Rebar exposure)	Patching	B/m²	17,500	[illegible]	from experience	30	15	-
		Expansion joints	Rubber	Damages in expansion joints	Change of rubber exp.	B/m	166,700	[illegible]	—	15	-	5
			Steel	Damages in expansion joints	Change of steel exp.	B/m	133,400	[illegible]	—	30	15	-
			Filling material	Damages in expansion joints	Joint filling	B/m	10,000	[illegible]	—	10	5	2

Note: - Approx. unit price includes overhead (Approx. direct constr. cost ×1.5)
- Numbers in countermeasure 5 indicate general service life
- The green colored repair methods are the countermeasures for the result of periodic inspection
- The assumption for the repair quantity refused on the experience in Japan

(2) Planned repair measures and member renewal after implementation of measures against damage

All the bridges has enough soundness after first repair work. We should continuously perform periodical inspection and scheduled member replacement from preventive maintenance point of view so that we can maintain the bridge soundness efficiently. We should refer to the items in Table 3.3.4 when considering systematic repair work and scheduled member replacement.

Table 3.3.4: List of planned repair and member renewal

	Bridge type	Member category		Damage	Repair cycle (Year)	Repair method	Unit	Approx. Repair cost unit price(B)	Assumption of repair quantity Formula
Planned repair	Concrete Bridge (RC, PC)	Deck	Concrete (RC)	Deck cracking	30	CFR	B m²	22.5千円	$A_{member\ surface}$ ×0.20
			Concrete (PC)	Deck cracking	60	CFR	B m²	22.5千円	$A_{member\ surface}$ ×0.50
		Girder Crossbeam	Concrete (RC)	Rebar exposure	30	Patching	B m²	17.5千円	$A_{member\ surface}$ ×0.10
			Concrete (PC)	Rebar exposure	30	Patching	B m²	17.5千円	$A_{member\ surface}$ ×0.08
		Substructure	Concrete	Rebar exposure	30	Patching	B m²	17.5千円	Number of substr 2.240
	Steel Bridge	Deck	Concrete (RC)	Deck cracking	30	CFR	B m²	22.5千円	$A_{member\ surface}$ ×0.20
		Girder	Steel	Corrosion	20	Repaint with Rc-I paint	B m²	3.5千円	A_{paint} 1.000
						Scaffolding	B m²	3.000千円	$A_{member\ surface}$ 1.000
		Substructure	Concrete	Rebar exposure	30	Patching	B m²	17.5千円	Number of substr 2.240
			Steel pier	Corrosion	20	Repaint with Rc-I paint	B m²	3.5千円	Number of substr 6.000
Planned Retrofit	Common members	Bearing	incl. water proofing	Functional damage of bearings (Corrosion)	30	Metal spraying	B bearings	120.000千円	Number of bearings 1.000
		Pavement		Level difference of road surface.	20	Pavement replacement	B m²	5.000千円	$A_{member\ surface}$ 1.000
		Barriers Railings	Steel	Damages in barriers (Corrosion)	30	Change of steel railings	B m	200.000千円	L_{span} number of barriers
			Concrete	Damages in barriers (Rebar exposure)	30	Patching	B m²	17.5千円	L_{span}×2.0m number of barriers
		Expansion joints	Rubber	Damages in expansion joints	15	Change of rubber	B m	66.7千円	$W_{road\ out}$ 1.000
			Steel	Damages in expansion joints	30	Change of steel	B m	133.400千円	$W_{road\ out}$ 1.000
periodic inspection + reserve					2	---	B bridge	233.400千円	per bridge

Note: Approx. unit price includes overhead (Approx. direct constr. cost ×1.5)

• For the damage that may occur after the measures for damage conducted in (1), sustainable periodic inspection and revision of the maintenance plan based on the results of periodic inspection should be conducted to cope with the damage.

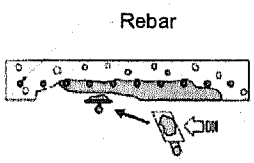
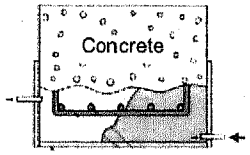
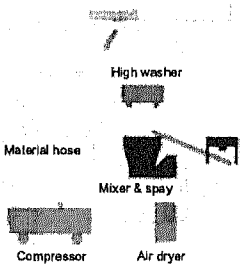
• It is important to improve the accuracy of the long-term maintenance plan by accumulating the repair data and renewing the relevant settings such as the approximate unit price and service year.

(3) The example of repair methods

1) Section repair

This is the repair method mainly applied for the damages such as rebar exposure, etc. in concrete members and divide into 3 types. In most cases patching is applied.

Table 3.3.5 : Section repair methods

	Patching	Mortar injection	Mortar spray
Area	Relative small	Relative large	Relative large
Outline	Polymer cement or epoxy resin cement is filled by man power using board or pallet, etc..	Polymer cement mortar etc. are injected by compressor into formwork fitting with repaired section	Mortar etc. are sprayed on the repaired area.
Schema			

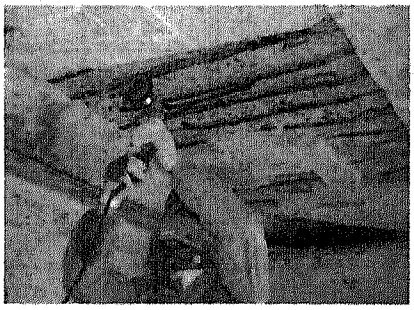
Working procedure of patching is shown in Figure 3.3.5.

Chipping

a) Cutter
The repaired area is cut in using disk sander.

b) Chipping
The concrete is chipped using hammer drills to the depth where the sound rebar can be confirmed.

Blasting



c) Rebar cleaning
Corroded rebars are cleaned to remove the rust.

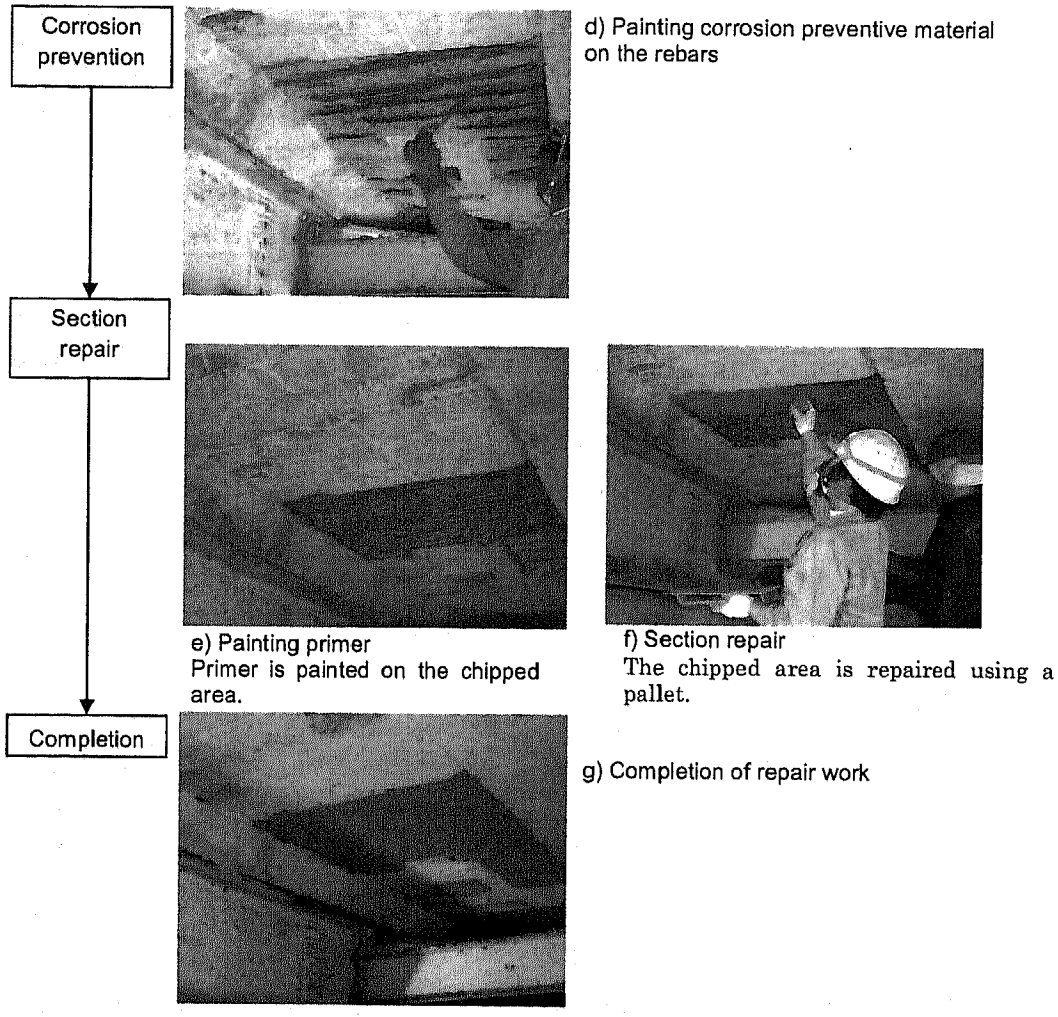


Figure 3.3.5: Work procedure of section repair (Patching)

Table 3.3.6 : Approximate repair cost of patching

Chipping, blasting & corrosion prevention	Unit	Quantity	Unit price(B)	Amount (B)	Remarks
General construction foreman	Man	1.5	5,400	8,100	
Special laborer	Man	4.5	4,700	21,150	
Laborer	Man	4.5	3,600	16,200	
Compressor operation 2.5 m³/min	Day	1.5	1,300	1,950	
Section repair					
General construction foreman	Man	1.5	5,400	8,100	
Special laborer	Man	4.5	4,700	21,150	
Laborer	Man	3.0	3,600	10,800	
Cement (Polymer cement mortar)	m^3	0.3	96,700	29,010	t=30mm
Overhead	%	50.0	116,460	58,230	
			Total (per $10m^2$)	174,690	
			per $1m^2$	17,500	