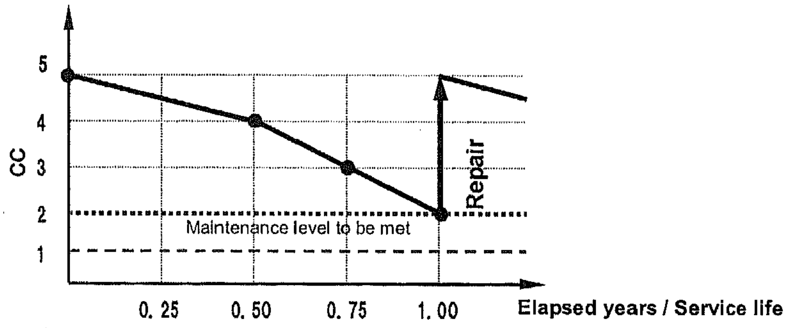


- The number of years it takes a member to go down from CC 5 to CC 2 should be set as the service life of the member.
- The number of years it takes a member to go down from CC 5 to CC 4 should be set as [service life x 0.5].
- The number of years it takes a member to go down from CC 4 to CC 3 should 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 4.4.6: 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 4.4.2).

(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 4.4.6, 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 4.4.2).

Figure 4.4.6 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 4.4.2: Repair methods for the damages detected in inspection

Bridge type	Member category			Damage	Repair method	Unit	Approximate repair cost Unit price(B)	Estimation of repair quantity: Calculation		Estimation of repair quantity: Remarks	Remaining years up to countermeasure cl. 2: countermeasure cl. 5	countermeasure cl. 4	countermeasure cl. 3
Concrete bridge (RC) (PC)	Main member	Deck	Concrete (RC)	Rebar exposure	Patching	B/m²	17,500	A[illegible]	0.120	assumed to be 20% of cracking (a) 20%	30	15	7
				Deck cracking	CFR	B/m²	22,500	A[illegible]	0.620	from experience (a)	30	15	7
			Concrete (PC)	Rebar exposure	Patching	B/m²	17,500	A[illegible]	0.100	assumed to be 20% of cracking (a) 20%	30	15	7
				Deck cracking	CFR	B/m²	22,500	A[illegible]	0.500	assumed to be 80% of RC deck (a) 80% (b)	50	25	12
				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 repaired every 2 pos	-	-	-
		Girder Crossbeam	Concrete (RC)	Cracking/Water leakage/Free lime	Resin injection	B/m	5,000	A[illegible]	0.050	from experience (c)	30	15	7
				Rebar exposure	Patching	B/m²	17,500	A[illegible]	0.010	from experience (d)	30	15	7
			Concrete (PC)	Cracking/Water leakage/Free lime	Resin injection	B/m	5,000	A[illegible]	0.040	assumed to be 80% of RC deck (c) 80%	30	15	7
				Rebar exposure	Patching	B/m²	17,500	A[illegible]	0.008	assumed to be 80% of RC deck (d) 80%	30	15	7
				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	Number of substr.	5.540	from experience	30	15	7
				Rebar exposure	Patching	B/m²	17,500	Number of substr.	2.240	from experience	30	15	7
				Damages in substructures (Scour)	Foot protection	B/substr.	1,750,000	Number of substr.	1.000	from experience	-	-	-
	Secondary member	Bearing		Functional damage of bearings	Metal spraying	B/bearing	120,000	Number of bearings	1.000	from experience	30	15	7
Steel bridge	Main member	Deck	Concrete (RC)	Rebar exposure	Patching	B/m²	17,500	A[illegible]	0.120	assumed to be 20% of cracking (e) 20%	30	15	7
				Deck cracking	CFR	B/m²	22,500	A[illegible]	0.620	from experience (e)	30	15	7
				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 repaired every 2 pos	-	-	-
		Girder (Steel member)	Steel	Corrosion	Repaint with Re-I paint	B/m²	3,500	A_{paint}	1.000	Truss A[illegible] [illegible]	20	10	5
					Scaffolding	B/m²	3,000	A[illegible]	1.000	—	-	-	-
				Cracking	Reinf. with steel pl	B/pos.	166,700	Number of cracks	1.000	—	-	-	-
				Missing bolts	Bolt change for splice pl.	B/pos.	133,400	Number of repl.	1.000	—	-	-	-
				Fracture	Reinforcement of fractured parts	B/pos	166,700	Number of frac.	1.000	—	-	-	-
				Deformation & loss	Replacement of deformed parts	B/pos	166,700	Number of deform.	1.000	—	-	-	-
		Substructure	Concrete	Cracking/Water leakage/Free lime	Resin injection	B/m	5,000	Number of substr.	5.540	from experience	30	15	7
				Rebar exposure	Patching	B/m²	17,500	Number of substr.	2.240	from experience	30	15	7
				Damages in substructures (Scour)	Foot protection	B/substr.	1,750,000	Number of substr.	1.000	from experience	-	-	-
			Steel pier	Corrosion	Repaint with Re-I paint	B/m2	3,500	Number of substr.	5.000	assumed to be 5.0m² substr.	20	10	5
	Secondary member	Bearing		Functional damage of bearings (Corrosion)	Metal spraying	B/bearing	120,000	Number of bearings	1.000	from experience	30	15	7
Common members	Secondary member	Pavement		Level difference of road surface, Damages in pavements	Pavement replacement	B/m²	5,000	A[illegible]	1.000	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	L[illegible]	N[illegible]	—	30	15	7
			Concrete	Damages in barriers (Rebar exposure)	Patching	B/m²	17,500	A[illegible]	0.004	from experience	30	15	7
		Expansion joints	Rubber	Damages in expansion joints	Change of rubber exp	B/m	66,700	W[illegible]	1.000	—	15	7	3
			Steel	Damages in expansion joints	Change of steel exp	B/m	133,400	W[illegible]	1.000	—	30	15	7
			Filling material	Damages in expansion joints	Joint filling	B/m	10,000	W[illegible]	1.000	—	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 coloured repair methods are the countermeasures to the result of periodic inspection
- The assumption for the repair quantity is based on the experience in Japan

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

For a bridge that recovered its original soundness as a result of the repair measures taken for the damage identified by the periodic inspection, periodic inspection should be conducted and planned repair and member renewal corresponding to the service life should be appropriately conducted from the viewpoint of preventive maintenance, thereby efficiently maintaining the soundness of the bridge. Planned repair and member renewal should consider the items shown in Table 4.4.3.

Table 4.4.3: 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	22,500	$A_{bridge\ surface}$ · 0.620
			Concrete (PC)	Deck cracking	50	CFR	B/m²	22,500	$A_{bridge\ surface}$ · 0.500
		Girder Crossbeam	Concrete (RC)	Rebar exposure	30	Patching	B/m²	17,500	$A_{bridge\ surface}$ · 0.010
			Concrete (PC)	Rebar exposure	30	Patching	B/m²	17,500	$A_{bridge\ surface}$ · 0.008
		Substructure	Concrete	Rebar exposure	30	Patching	B/m²	17,500	Number of substr. · 2.240
	Steel Bridge	Deck	Concrete (RC)	Deck cracking	30	CFR	B/m²	22,500	$A_{bridge\ surface}$ · 0.620
		Girder	Steel	Corrosion	20	Repaint with Rc-1 paint	B/m²	3,500	A_{paint} · 1.000
						Scaffolding	B/m²	3,000	$A_{bridge\ surface}$ · 1.000
		Substructure	Concrete	Rebar exposure	30	Patching	B/m²	17,500	Number of substr. · 2.240
			Steel pier	Corrosion	20	Repaint with Rc-1 paint	B/m²	3,500	Number of substr. · 5.000
Planned renewal	Common members	Bearing		Functional damage of bearings (Corrosion)	30	Metal spraying	B/bearings	120,000	Numeber of bearings · 1.000
		Pavement	incl. water proofing	Level difference of road surface.	20	Pavement replacement	B/m²	5,000	$A_{bridge\ surface}$ · 1.000
		Barriers Railings	Steel	Damages in barriers (Corrosion)	30	Change of steel railings	B/m	20,000	L_{span} number of barriers
			Concrete	Damages in barriers (Rebar exposure)	30	Patching	B/m²	17,500	L_{span} × 2.0m number of barriers
		Expansion joints	Rubber	Damages in expansion joints	15	Change of rubber	B/m	66,700	$W_{total\ road}$ · 1.000
			Steel	Damages in expansion joints	30	Change of steel	B/m	133,400	$W_{total\ road}$ · 1.000
periodic inspection + reserve					2	---	B/bridge	233,400	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.

4.4.3 Long-term maintenance plans for individual bridges

(1) Long-term maintenance plan

In this section, a maintenance cost for each individual bridge for 100 years hereafter is estimated according to the following flow chart based on the countermeasure classification determined by the bridge long-term maintenance manual and the inspection results.

The approximate repair cost here is based on the standard prices in Japan, which leads the cost is relatively higher.
See Report 4 for LCC for each bridge.

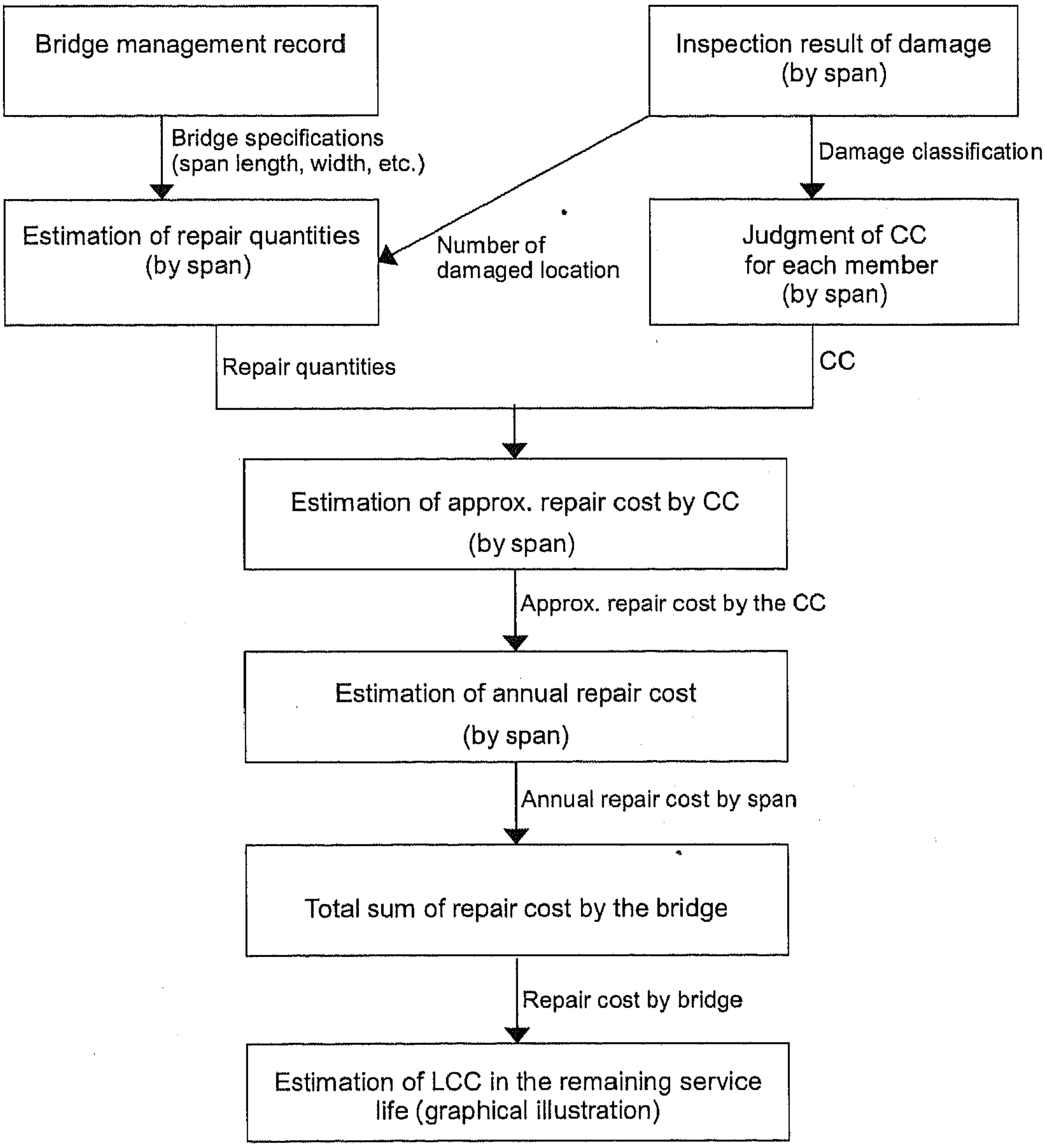


Figure 4.4.7: Flow chart for long-term maintenance planning

1) Judgment of countermeasure classification (by span)

For each member countermeasure classification is judged according to the damage level. Depending on the damage type further detail information is required to judge the countermeasure classification.

2) Estimation of repair quantity (by span)

Repair quantity of each member is estimated based on the bridge management records and the damage inspection results according to the assumption of repair quantity in Table 4.4.2.

3) Estimation of approximate repair cost by countermeasure classification

Approximate repair cost by countermeasure classification is estimated based on the repair quantity and the damage inspection results according to the unit price in Table 4.4.2.

4) Estimation of annual repair cost

While the repair cost is counted in the next year in case the damage inspection result is judged as "CC 2", it is counted in the year when the member reaches the stage of "CC 2" in case it is judged as "CC 3" or "CC 4" In case it is judged as "CC 5" or after the year when the above repair cost is counted, the approximate cost for the planned repair and renewal will be counted in a repair cycle. The sum of the above approximate repair cost is accumulated.

5) Total sum of repair cost by the bridge

The approximate repair cost estimated by span is accumulated for the whole bridge.

6) Estimation of LCC in the remaining service life

The repair cost estimated in 6) is illustrated graphically to grasp the LCC of the remaining service life

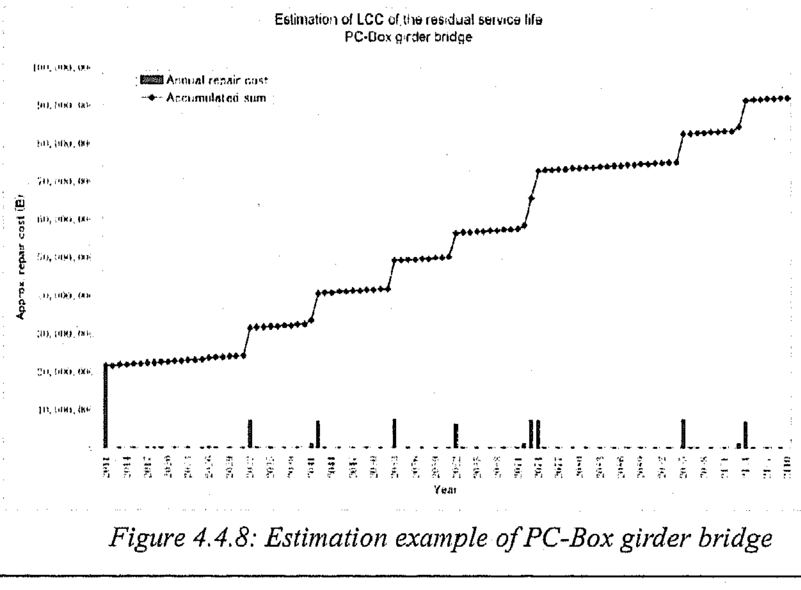


Figure 4.4.8: Estimation example of PC-Box girder bridge

(2) Long-term maintenance plan for PC bridges

1) Deck

In case of RC deck damage types are rebar exposure and deck cracking. The repair methods of patching and CFR are listed referring to the experience in Japan.
Planned repair is intended for deck cracking to maintain whose deterioration appears previous to rebar exposure considering the direct loading of live load on it. The repair cycle is decided to be 30 years referring to the experience in Japan.
In case of PC deck the damage at the anchorage of PC tendon is added to the damage types of RC deck. This repair method is CFR on the upper & bottom sides. The other methods are similar to RC deck.
Planned repair is intended for deck cracking similar to RC-deck. The repair cycle is decided to be 50 years referring to the experience in Japan.

2) Girder and crossbeam

In case of RC member damage type is cracking / water leakage / free lime. These repair methods are resin injection and patching respectively referring to the experience in Japan.
Planned repair is intended for rebar exposure considering the relatively small influence from live load. The repair cycle is decided to be 30 years referring to the experience in Japan.
In case of PC member the damage at the anchorage of PC tendon is added to the damage types of RC member. This repair method for the anchorage is the application of external cables.
The repair cycle is decided to be 30 years referring to the experience in Japan.

(3) Long-term maintenance plan for steel bridges

1) Deck

Basically similar to PC bridge.

2) Steel member

The damage types are corrosion, cracking, missing bolts, fracture, and deformation & loss. The repair methods listed are repainting, reinforcement with steel plate, bolt replacement (by splice plate), and replacement of deformed steel. In the estimation of the approximate repair cost for repainting scaffolding area also need to be considered.
Planned repair is intended for corrosion to maintain. The repair cycle is decided to be 20 years referring to the experience in Japan.

(4) Long-term maintenance plan for cable stayed bridges

1) Deck

Basically similar to PC bridge.

2) Steel member
Basically similar to steel bridge.

3) Cable
In case the damage is detected in vicinity of the anchorage zone of cable the repair method is assumed to be CFR on the upper & bottom sides similar to PC tendon.
Planned repair is not intended due to extremely high durability with coating, etc..

(5) Long-term maintenance plan for common members

Planned renewal applies to all common members in each repair cycle.

1) Substructure
Refer to girder and crossbeam of PC bridges and steel member of steel bridges for concrete and steel substructure respectively.

2) Bearing
The damage type is functional damage (corrosion). The repair method of metal spraying is listed referring to the experience in Japan. The repair cycle is decided to be 30 years.

3) Pavement
The damage types are level difference of road surface and damages in pavements. The repair method listed for both damages is replacement of pavement including waterproofing for bridge surface. The repair cycle is decided to be 30 years.

4) Barrier and railings
The damages for concrete barriers and steel railings are corrosion and rebar exposure respectively. The repair methods are renewal of railings and patching on barriers. The repair cycle is decided to be 30 years for both methods.

5) Expansion joint
The types of expansion joint are classified into rubber type, steel type, and filling material. The repair methods listed are replacement of expansion joint and refilling.
The repair cycles are decided to be 15 years for rubber type, 30 years for steel type, and 10 years for filling material considering to the durability in Japan.

4.4.4 Countermeasure classification for individual bridge

(1) Rama 4

Table 4.4.4: Countermeasure classification of Rama 4

Member	No.	Damage	Span No.1	Span No.2	Span No.3
Girder	01	Cracking/Water leakage/Free lime	5	5	3
		Rebar exposure	5	5	5
		Damages at anchorage of PC tendon	5	5	5
	02	Cracking/Water leakage/Free lime	5	5	3
		Rebar exposure	5	5	5
		Damages at anchorage of PC tendon	5	5	5
Deck	01	Rebar exposure	5	5	5
		Pop-outs	5	5	5
		Deck cracking	5	5	5
	03	Rebar exposure	5	5	5
		Pop-outs	5	5	5
		Deck cracking	5	5	5
	04	Rebar exposure	5	5	5
		Pop-outs	5	5	5
		Deck cracking	5	5	5
	06	Rebar exposure	5	5	5
		Pop-outs	5	5	5
		Deck cracking	5	5	5
Pier	01	Cracking/Water leakage/Free lime	5	3	5
		Rebar exposure	5	5	5
		Damages in substructures	5	5	5
	02	Cracking/Water leakage/Free lime	5	5	5
		Rebar exposure	5	5	5
		Damages in substructures	5	5	5
Bearings	101	Functional damage of bearings	5	5	5
	102	Functional damage of bearings	5	5	5
	103	Functional damage of bearings	5	5	5
	104	Functional damage of bearings	5	5	5
	105	Functional damage of bearings	5	5	5
	106	Functional damage of bearings	5	5	5
Road surface	01	Level difference of road surface	5	5	5
	01	Damages in pavements	5	5	5
Barriers Railings	01	Damages in barriers	2	5	5
	02	Damages in barriers	2	2	2
	03	Damages in barriers	5	5	2
	04	Damages in barriers	5	5	5
Expansion joints	01	Damages in expansion joints	5	5	5

(2) Rama 5

Table 4.4.5: Countermeasure classification of Rama 5

Member	No.	Damage	Span No.1	Span No.2	Span No.3	Span No.4	Span No.5	Span No.6	Span No.7
Girder	01	Cracking/Water leakage/Free lime	5	5	5	5	5	3	5
		Rebar exposure	5	5	5	5	5	5	5
		Damages at anchorage of PC tendon	5	5	5	5	5	5	5
	02	Cracking/Water leakage/Free lime	5	5	5	3	5	3	5
		Rebar exposure	5	5	5	5	5	5	5
		Damages at anchorage of PC tendon	5	5	5	5	5	5	5
Deck	01	Rebar exposure	5	5	5	5	5	5	5
		Pop-outs	5	5	5	5	5	5	5
		Deck cracking	5	5	5	5	5	5	5
	03	Rebar exposure	5	5	5	5	5	5	5
		Pop-outs	5	5	5	5	5	5	5
		Deck cracking	5	5	5	5	5	5	5
	04	Rebar exposure	5	5	5	5	5	5	5
		Pop-outs	5	5	5	5	5	5	5
		Deck cracking	5	5	5	5	5	5	5
	06	Rebar exposure	5	5	5	5	5	5	5
		Pop-outs	5	5	5	5	5	5	5
		Deck cracking	5	5	5	5	3	5	5
Pier	01	Cracking/Water leakage/Free lime	5	5	5	5	5	5	5
		Rebar exposure	5	5	5	5	5	5	5
		Damages in substructures	5	5	5	5	5	5	5
	02	Cracking/Water leakage/Free lime	5	5	5	5	5	5	5
		Rebar exposure	5	5	5	5	5	5	5
		Damages in substructures	5	5	5	5	5	5	5
Bearings	101	Functional damage of bearings	5	5	5	5	5	5	5
	102	Functional damage of bearings	5	5	5	5	5	5	5
	103	Functional damage of bearings	5	5	5	5	5	5	5
	104	Functional damage of bearings	5	5	5	5	5	5	5
Road surface	01	Level difference of road surface	5	5	5	5	5	5	5
		Damages in pavements	5	5	5	5	5	5	5
Barriers Railings	01	Damages in barriers	5	5	5	2	5	2	5
	02	Damages in barriers	5	5	5	2	5	2	5
	03	Damages in barriers	5	5	5	5	5	2	5
Expansion joints	01	Damages in expansion joints	5	-	-	-	-	-	5

(3) Rama 7

Table 4.4.6: Countermeasure classification of Rama 7

Member	No.	Damage	Span No.1	Span No.2	Span No.3
Girder	01	Cracking/Water leakage/Free lime	3	5	3
		Rebar exposure	5	5	5
		Damages at anchorage of PC tendon	5	5	5
	02	Cracking/Water leakage/Free lime	3	5	3
		Rebar exposure	5	5	5
		Damages at anchorage of PC tendon	5	5	5
Deck	01	Rebar exposure	5	5	5
		Pop-outs	5	5	5
		Deck cracking	3	5	3
	03	Rebar exposure	5	5	5
		Pop-outs	5	5	5
		Deck cracking	3	5	5
	04	Rebar exposure	5	5	5
		Pop-outs	5	5	5
		Deck cracking	5	5	5
	06	Rebar exposure	5	5	5
		Pop-outs	5	5	5
		Deck cracking	3	5	3
Pier	01	Cracking/Water leakage/Free lime	5	5	5
		Rebar exposure	5	5	5
		Damages in substructures	5	5	5
	02	Cracking/Water leakage/Free lime	5	5	5
		Rebar exposure	5	5	5
		Damages in substructures	5	5	5
Bearings	101	Functional damage of bearings	5	-	5
	102	Functional damage of bearings	5	-	5
	103	Functional damage of bearings	5	-	5
	104	Functional damage of bearings	5	-	5
Road surface	01	Level difference of road surface	5	5	5
		Damages in pavements	5	5	5
Barriers Railings	01	Damages in barriers	2	2	2
	02	Damages in barriers	2	2	2
	03	Damages in barriers	2	2	2
Expansion joints	01	Damages in expansion joints	2	-	5

(4) Krung Thon

Table 4.4.7: Countermeasure classification of Krung Thon

Member	No.	Damage	Span No.1	Span No.2	Span No.3	Span No.4	Span No.5	Span No.6
Upper chord	01・02	Corrosion	5	5	5	5	5	5
		Cracking	5	5	5	5	5	5
		Missing bolts	5	5	5	5	5	5
		Fracture	5	5	5	5	5	5
Bottom chord	01	Corrosion	5	5	5	5	5	5
		Cracking	5	5	5	5	5	5
		Missing bolts	5	5	2	5	5	5
		Fracture	5	5	2	2	5	5
	02	Corrosion	5	5	5	5	5	5
		Cracking	5	5	5	5	5	5
		Missing bolts	5	5	2	5	5	5
		Fracture	5	5	2	2	5	5
Diagonal	01・02	Corrosion	5	5	5	5	5	5
		Cracking	5	5	5	5	5	5
		Missing bolts	5	5	5	5	5	5
		Fracture	5	5	5	5	5	5
Vertical member	01	Corrosion	5	4	5	5	5	5
		Cracking	5	5	5	5	5	5
		Missing bolts	5	5	5	5	5	5
		Fracture	5	5	5	5	5	5
	02	Corrosion	4	5	5	5	5	5
		Cracking	5	5	5	5	5	5
		Missing bolts	5	5	5	5	5	5
		Fracture	5	5	5	5	5	5
Lateral bracing (Upper) Lateral bracing (Lower) Sway bracing (Upper)	01 01 01～03	Corrosion	5	5	5	5	5	5
		Cracking	5	5	5	5	5	5
		Missing bolts	5	5	5	5	5	5
		Fracture	5	5	5	5	5	5
Stringer Floor beam	01～12 01～03	Corrosion	5	5	5	5	5	5
		Cracking	5	5	5	5	5	5
		Missing bolts	5	5	5	5	5	5
		Fracture	5	5	5	5	5	5
Sway bracing (Lower)	01・03	Corrosion	5	5	5	5	5	5
		Cracking	5	5	5	5	5	5
		Missing bolts	5	5	5	5	5	5
		Deformation & loss	5	5	5	5	5	5
	02	Corrosion	5	5	5	5	5	5
		Cracking	5	5	5	5	5	5
		Missing bolts	5	5	5	5	5	5
		Deformation & loss	5	5	2	2	5	5
Deck	01	Rebar exposure	5	5	5	5	5	5
		Pop-outs	5	5	5	5	5	5
		Deck cracking	5	3	3	3	3	3
		Damages at anchorage of PC tendon	5	5	5	5	5	5
	02～12	Rebar exposure	5	5	5	5	5	5
		Pop-outs	5	5	5	5	5	5
		Deck cracking	5	5	5	5	5	5
		Damages at anchorage of PC tendon	5	5	5	5	5	5
	13	Rebar exposure	5	5	5	5	5	5
		Pop-outs	5	5	5	5	5	5
		Deck cracking	5	3	3	3	3	3
		Damages at anchorage of PC tendon	5	5	5	5	5	5
Substructure	01・02	Cracking etc.	5	5	5	5	5	5
		Rebar exposure	5	5	5	5	5	5
		Damages in substructures	5	5	5	5	5	5
Bearings	101	Functional damage of bearings	5	5	5	5	5	3
	102	Functional damage of bearings	5	5	5	5	5	3
	201	Functional damage of bearings	5	5	5	5	5	5
	202	Functional damage of bearings	5	5	5	5	5	5
Road surface	01	Level difference of road surface	5	5	5	5	5	5
		Damages in pavements	5	5	5	5	5	5
Barriers	01	Damages in barriers	5	2	2	2	2	2
	02	Damages in barriers	2	2	2	2	2	2
Expansion joints	01	Damages in expansion joints	5	5	5	5	5	5
	02	Damages in expansion joints	5	-	-	-	-	5

(5) Phra Pinklao

Table 4.4.8: Countermeasure classification of Phra Pinklao

Member	No.	Damage	Span No.1	Span No.2	Span No.3
Girder	01	Cracking/Water leakage/Free lime	5	3	5
		Rebar exposure	5	5	5
		Damages at anchorage of PC tendon	5	5	5
	02	Cracking/Water leakage/Free lime	3	3	3
		Rebar exposure	5	5	5
		Damages at anchorage of PC tendon	5	5	5
Deck	01	Rebar exposure	5	5	5
		Pop-outs	5	5	5
		Deck cracking	3	3	3
	03	Rebar exposure	5	5	5
		Pop-outs	5	5	5
		Deck cracking	5	5	5
	05	Rebar exposure	5	5	5
		Pop-outs	5	5	5
		Deck cracking	3	3	3
Pier	01	Cracking/Water leakage/Free lime	3	3	5
		Rebar exposure	5	5	5
		Damages in substructures	5	5	5
	02	Cracking/Water leakage/Free lime	5	5	5
		Rebar exposure	5	5	5
		Damages in substructures	5	5	5
Bearings	101	Functional damage of bearings	3	-	3
	102	Functional damage of bearings	3	-	3
	103	Functional damage of bearings	3	-	3
	104	Functional damage of bearings	3	-	3
Road surface	01	Level difference of road surface	5	5	5
		Damages in pavements	2	5	5
Barriers Railings	01	Damages in barriers	2	2	2
	02	Damages in barriers	2	2	2
	03	Damages in barriers	2	2	2
	04	Damages in barriers	5	5	5
Expansion joints	01	Damages in expansion joints	2	2	2

(6) Memorial

Table 4.4.9: Countermeasure classification of Memorial

Member	No.	Damage	Span No.1	Span No.2	Span No.3
Upper chord	01	Corrosion	5	4	5
		Cracking	5	5	5
		Missing bolts	5	5	5
		Fracture	5	5	5
	02	Corrosion	5	4	5
		Cracking	5	5	5
		Missing bolts	5	5	5
		Fracture	5	5	5
Bottom chord	01	Corrosion	5	2	4
		Cracking	5	5	5
		Missing bolts	5	2	2
		Fracture	5	5	5
	02	Corrosion	4	2	4
		Cracking	5	5	5
		Missing bolts	5	2	2
		Fracture	5	5	5
Diagonal	01	Corrosion	5	5	5
		Cracking	5	5	5
		Missing bolts	5	5	5
		Fracture	5	5	5
	02	Corrosion	5	4	5
		Cracking	5	5	5
		Missing bolts	5	5	5
		Fracture	5	5	5
Vertical member	01	Corrosion	5	5	5
		Cracking	5	5	5
		Missing bolts	5	5	5
		Fracture	1	5	5
	02	Corrosion	5	5	5
		Cracking	5	5	5
		Missing bolts	5	5	2
		Fracture	5	5	5
Lateral bracing (Upper) Lateral bracing (Lower) Sway bracing (Upper)	01・02 01・02 01	Corrosion	5	5	5
		Cracking	5	5	5
		Missing bolts	5	5	5
		Fracture	5	5	5
Stringer Floor beam	01~10 01~03	Corrosion	5	5	5
		Cracking	5	5	5
		Missing bolts	5	5	5
		Fracture	5	5	5
Sway bracing (Lower)	01	Corrosion	4	2	4
		Cracking	5	5	5
		Missing bolts	5	2	5
		Fracture	5	5	5
Deck	01	Rebar exposure	5	5	5
		Pop-outs	5	5	5
		Deck cracking	3	3	3
		Damages at anchorage of PC tendon	5	5	5
	02~12	Rebar exposure	5	5	5
		Pop-outs	5	5	5
		Deck cracking	5	5	5
		Damages at anchorage of PC tendon	5	5	5
	13	Rebar exposure	5	5	5
		Pop-outs	5	5	5
		Deck cracking	3	3	3
		Damages at anchorage of PC tendon	5	5	5
Substructure	01	Cracking etc.	5	3	3
		Rebar exposure	5	5	5
		Damages in substructures	5	5	5
	02	Cracking etc.	3	3	5
		Rebar exposure	5	5	5
		Damages in substructures	5	5	5
Bearings	all	Functional damage of bearings	5	5	5
Road surface	01	Level difference of road surface	5	5	5
		Damages in pavements	2	5	5
Barriers	01	Damages in barriers	5	5	5
Railings	02	Damages in barriers	5	5	5
Expansion joints	01	Damages in expansion joints	5	5	5
	02	Damages in expansion joints	5	-	5

(7) Phra Pokklao

Table 4.4.10: Countermeasure classification of Phra Pokklao

Member	No.	Damage	Span No.1	Span No.2	Span No.3	Span No.4	Span No.5
Girder	01	Cracking/Water leakage/Free lime	5	3	5	5	5
		Rebar exposure	5	5	5	5	5
		Damages at anchorage of PC tendon	5	5	5	5	5
	02	Cracking/Water leakage/Free lime	5	3	5	5	5
		Rebar exposure	5	5	5	5	5
		Damages at anchorage of PC tendon	5	5	5	5	5
Deck	01	Rebar exposure	5	5	5	5	5
		Pop-outs	5	5	5	5	5
		Deck cracking	5	3	5	3	5
	03	Rebar exposure	5	5	5	5	5
		Pop-outs	5	5	5	5	5
		Deck cracking	5	5	5	5	5
	04	Rebar exposure	5	5	5	5	5
		Pop-outs	5	5	5	5	5
		Deck cracking	5	5	5	5	5
	06	Rebar exposure	5	5	5	5	5
		Pop-outs	5	5	5	5	5
		Deck cracking	5	3	5	3	5
Pier	01	Cracking/Water leakage/Free lime	5	5	3	5	5
		Rebar exposure	5	5	5	5	5
		Damages in substructures	5	5	5	5	5
	02	Cracking/Water leakage/Free lime	5	5	5	5	5
		Rebar exposure	5	5	5	5	5
		Damages in substructures	5	5	5	5	5
Bearings	101	Functional damage of bearings	5	-	-	-	5
	102	Functional damage of bearings	5	-	-	-	5
	103	Functional damage of bearings	5	-	-	-	5
	104	Functional damage of bearings	5	-	-	-	5
Road surface	01	Level difference of road surface	5	4	5	5	5
		Damages in pavements	5	2	5	5	5
Barriers Railings	01	Damages in barriers	5	2	2	2	5
	02	Damages in barriers	5	5	5	5	5
	03	Damages in barriers	5	5	2	5	5
	04	Damages in barriers	5	2	2	2	5
Expansion joints	01	Damages in expansion joints	5	-	-	-	5

(8) Taksin

Table 4.4.11: Countermeasure classification of Taksin

Member	No.	Damage	Span No.1	Span No.2	Span No.3
Girder	01	Cracking/Water leakage/Free lime	3	3	3
		Rebar exposure	5	5	5
		Damages at anchorage of PC tendon	5	5	5
	02	Cracking/Water leakage/Free lime	3	3	3
		Rebar exposure	5	5	5
		Damages at anchorage of PC tendon	5	5	5
Deck	01	Rebar exposure	5	5	5
		Pop-outs	5	5	5
		Deck cracking	3	5	3
	03	Rebar exposure	5	5	5
		Pop-outs	5	5	5
		Deck cracking	3	5	3
	04	Rebar exposure	5	5	5
		Pop-outs	5	5	5
		Deck cracking	3	5	3
	06	Rebar exposure	5	5	5
		Pop-outs	5	5	5
		Deck cracking	3	5	3
Pier	01	Cracking/Water leakage/Free lime	5	3	5
		Rebar exposure	5	5	5
		Damages in substructures	5	5	5
	02	Cracking/Water leakage/Free lime	5	5	3
		Rebar exposure	5	5	5
		Damages in substructures	5	5	5
Bearings	101	Functional damage of bearings	3	-	5
	102	Functional damage of bearings	3	-	5
	103	Functional damage of bearings	3	-	5
	104	Functional damage of bearings	3	-	5
Road surface	01	Level difference of road surface	5	5	4
		Damages in pavements	5	5	2
Barriers Railings	01	Damages in barriers	2	2	5
	02	Damages in barriers	2	2	2
	03	Damages in barriers	5	5	5
	04	Damages in barriers	2	5	5
Expansion joints	01	Damages in expansion joints	5	-	5

(9) Rama 3

Table 4.4.12: Countermeasure classification of Rama 3

Member	No.	Damage	Span No.1	Span No.2	Span No.3
Girder	01	Cracking/Water leakage/Free lime	3	5	3
		Rebar exposure	5	5	5
		Damages at anchorage of PC tendon	5	5	5
Deck	01	Rebar exposure	5	5	5
		Pop-outs	5	5	5
		Deck cracking	5	3	5
	03	Rebar exposure	5	5	5
		Pop-outs	5	5	5
		Deck cracking	5	5	3
Pier	01	Cracking/Water leakage/Free lime	3	5	5
		Rebar exposure	5	5	5
		Damages in substructures	5	5	5
	02	Cracking/Water leakage/Free lime	3	3	3
		Rebar exposure	5	5	5
		Damages in substructures	5	5	5
Road surface	01	Level difference of road surface	5	5	5
		Damages in pavements	5	5	5
Barriers Railings	01	Damages in barriers	5	5	5
	02	Damages in barriers	5	5	5
	03	Damages in barriers	5	5	5
Expansion joints	01	Damages in expansion joints	5	-	5

(10) Krung Thep

Table 4.4.13: Countermeasure classification of Krung Thep

Member	No.	Damage	Span No.1	Span No.2	Span No.3	Span No.4	Span No.5
Upper chord	01	Corrosion	5	5	4	5	5
		Cracking	5	5	5	5	5
		Missing bolts	5	5	5	5	5
		Fracture	5	5	5	5	5
	02	Corrosion	5	5	5	5	5
		Cracking	5	5	5	5	5
		Missing bolts	5	5	5	5	5
		Fracture	5	5	5	5	5
Bottom chord	01・02	Corrosion	5	4	5	4	5
		Cracking	5	5	5	5	5
		Missing bolts	5	5	5	5	5
		Fracture	5	5	5	5	5
Diagonal	01	Corrosion	5	4	5	4	4
		Cracking	5	5	5	5	5
		Missing bolts	5	5	5	5	5
		Fracture	5	5	5	5	5
	02	Corrosion	4	4	5	4	4
		Cracking	5	5	5	5	5
		Missing bolts	5	5	5	5	5
		Fracture	5	5	5	5	5
Vertical member	01	Corrosion	4	4	5	4	4
		Cracking	5	5	5	5	5
		Missing bolts	5	5	5	5	5
		Fracture	5	5	5	5	5
	02	Corrosion	5	4	5	5	4
		Cracking	5	5	5	5	5
		Missing bolts	5	5	5	5	5
		Fracture	5	5	5	5	5
Lateral bracing (Upper)	01	Corrosion	4	4	4	4	4
		Cracking	5	5	5	5	5
		Missing bolts	5	5	5	5	5
		Fracture	5	5	5	5	5
Lateral bracing (Lower)	01	Corrosion	5	5	5	5	5
		Cracking	5	5	5	5	5
		Missing bolts	5	5	5	5	5
		Fracture	5	5	5	5	5
Sway bracing (Upper)	01	Corrosion	4	5	5	4	4
		Cracking	5	5	5	5	5
		Missing bolts	5	5	5	5	5
		Fracture	5	5	5	5	5
Stringer	01～04 06～10	Corrosion	5	5	5	5	5
		Cracking	5	5	5	5	5
		Missing bolts	5	5	5	5	5
		Fracture	5	5	5	5	5
	05	Corrosion	5	5	5	5	5
		Cracking	5	5	2	5	5
		Missing bolts	5	5	5	5	5
		Fracture	5	5	5	5	5
Floor beam	01～03	Corrosion	5	5	5	5	5
		Cracking	5	5	5	5	5
		Missing bolts	5	5	5	5	5
		Fracture	5	5	5	5	5
Sway bracing (Lower)	01	Corrosion	5	5	5	4	5
		Cracking	5	5	5	5	5
		Missing bolts	5	5	5	5	5
		Fracture	5	5	5	5	5
Substructure	01・02	Cracking etc.	5	5	5	3	5
		Rebar exposure	5	5	5	5	5
		Damages in substructures	5	5	5	5	5
Bearings	all	Functional damage of	5	5	5	5	5
Road surface	01	Level difference of road	5	5	5	5	5
		Damages in pavements	2	5	5	5	5
Barriers	01	Damages in barriers	2	2	5	2	2
Railings	02	Damages in barriers	2	2	5	2	2
Expansion joints	01・02	Damages in expansion joints	5	5	5	5	5

(11) IRR North

Table 4.4.14: Countermeasure classification of IRR North

Member	No.	Damage	Span No.1	Span No.2	Span No.4	Span No.5
Girder	01	Cracking/Water leakage/Free lime	5	5	5	5
		Rebar exposure	5	5	5	5
		Damages at anchorage of PC tendon	5	5	5	5
	02	Cracking/Water leakage/Free lime	5	5	5	5
		Rebar exposure	5	5	5	5
		Damages at anchorage of PC tendon	5	5	5	5
	03	Cracking/Water leakage/Free lime	5	5	5	5
		Rebar exposure	5	5	5	5
		Damages at anchorage of PC tendon	5	5	5	5
Crossbeam	01	Cracking/Water leakage/Free lime	5	5	5	5
		Rebar exposure	5	5	5	5
		Damages at anchorage of PC tendon	5	5	5	5
	02	Cracking/Water leakage/Free lime	5	5	5	5
		Rebar exposure	5	5	5	5
		Damages at anchorage of PC tendon	5	5	5	5
	03	Cracking/Water leakage/Free lime	5	5	5	5
		Rebar exposure	5	5	5	5
		Damages at anchorage of PC tendon	5	5	5	5
Deck	01	Rebar exposure	5	5	5	5
		Pop-outs	5	5	5	5
		Deck cracking	3	5	3	3
	02	Rebar exposure	5	5	5	5
		Pop-outs	5	5	5	5
		Deck cracking	5	5	5	5
	03	Rebar exposure	5	5	5	5
		Pop-outs	5	5	5	5
		Deck cracking	3	5	3	3
Substructure	01	Cracking/Water leakage/Free lime	3	3	3	3
		Rebar exposure	5	5	5	5
		Damages in	5	5	5	5
	02	Cracking/Water leakage/Free lime	3	-	-	3
		Rebar exposure	5	-	-	5
		Damages in	5	-	-	5
Road surface	01	Level difference of road surface	5	5	5	5
		Damages in pavements	5	5	5	5
Barriers Railings	01	Damages in barriers	5	5	5	5
	02	Damages in barriers	5	5	5	5
	03	Damages in barriers	5	5	5	5
	04	Damages in barriers	5	5	5	5
Expansion joints	01	Damages in expansion joints	5	5	5	5

Member	No.	Damage	Span No.3
Girder	01~04	Corrosion	5
		Cracking	5
		Missing bolts	5
		Fracture	5
Crossbeam	01~03	Corrosion	5
		Cracking	5
		Missing bolts	5
		Fracture	5
Deck	01~05	Rebar exposure	5
		Pop-outs	5
		Deck cracking	5
		Damages at anchorage of PC tendon	5
Pylon	01	Cracking/Water leakage/Free lime	3
		Rebar exposure	5
		Damages at anchorage of PC tendon	5
	02	Cracking/Water leakage/Free lime	3
		Rebar exposure	5
		Damages at anchorage of PC tendon	5
Bearings	101	Functional damage of bearings	5
	102	Functional damage of bearings	5
	103	Functional damage of bearings	5
	104	Functional damage of bearings	5
	201	Functional damage of bearings	5
	202	Functional damage of bearings	5
	203	Functional damage of bearings	5
	204	Functional damage of bearings	5
Road surface	01	Level difference of road surface	5
		Damages in pavements	5
Barrier	01	Damages in barriers	5
	02	Damages in barriers	5
	03	Damages in barriers	5
	04	Damages in barriers	5

(12) IRR South

Table 4.4.15: Countermeasure classification of IRR South

Member	No.	Damage	Span No.1	Span No.2	Span No.4	Span No.5
Girder	01	Cracking/Water leakage/Free lime	5	5	5	5
		Rebar exposure	5	5	5	5
		Damages at anchorage of PC tendon	5	5	5	5
	02	Cracking/Water leakage/Free lime	5	5	5	5
		Rebar exposure	5	5	5	5
		Damages at anchorage of PC tendon	5	5	5	5
	03	Cracking/Water leakage/Free lime	5	5	5	5
		Rebar exposure	5	5	5	5
		Damages at anchorage of PC tendon	5	5	5	5
Crossbeam	01	Cracking/Water leakage/Free lime	5	5	5	5
		Rebar exposure	5	5	5	5
		Damages at anchorage of PC tendon	5	5	5	5
	02	Cracking/Water leakage/Free lime	5	5	5	5
		Rebar exposure	5	5	5	5
		Damages at anchorage of PC tendon	5	5	5	5
	03	Cracking/Water leakage/Free lime	5	5	5	5
		Rebar exposure	5	5	5	5
		Damages at anchorage of PC tendon	5	5	5	5
Deck	01	Rebar exposure	5	5	5	5
		Pop-outs	5	5	5	5
		Deck cracking	3	3	3	3
	02	Rebar exposure	5	5	5	5
		Pop-outs	5	5	5	5
		Deck cracking	5	5	5	5
	03	Rebar exposure	5	5	5	5
		Pop-outs	5	5	5	5
		Deck cracking	3	5	3	3
Substructure	01	Cracking/Water leakage/Free lime	3	5	3	3
		Rebar exposure	5	5	5	5
		Damages in substructures	5	5	5	5
	02	Cracking/Water	3	-	-	3
		Rebar exposure	5	-	-	5
		Damages in substructures	5	-	-	5
Road surface	01	Level difference of road surface	5	5	5	5
		Damages in	5	5	5	5
Barriers Railings	01	Damages in barriers	5	5	5	5
	02	Damages in barriers	5	5	5	5
	03	Damages in barriers	5	5	5	5
	04	Damages in barriers	5	5	5	5
Expansion joints	01	Damages in expansion joints	5	5	5	5

Member	No.	Damage	Span No.3
Girder	01～04	Corrosion	5
		Cracking	5
		Missing bolts	5
		Fracture	5
Crossbeam	01～03	Corrosion	5
		Cracking	5
		Missing bolts	5
		Fracture	5
Deck	01～05	Rebar exposure	5
		Pop-outs	5
		Deck cracking	5
		Damages at anchorage of PC tendon	5
Pylon	01	Cracking/Water leakage/Free lime	3
		Rebar exposure	5
		Damages at anchorage of PC tendon	5
	02	Cracking/Water leakage/Free lime	3
		Rebar exposure	5
		Damages at anchorage of PC tendon	5
cable	01	Damages at anchorage of PC tendon	2
	02	Damages at anchorage of PC tendon	2
Bearings	101	Functional damage of bearings	5
	102	Functional damage of bearings	5
	103	Functional damage of bearings	5
	104	Functional damage of bearings	5
	201	Functional damage of bearings	5
	202	Functional damage of bearings	5
	203	Functional damage of bearings	5
	204	Functional damage of bearings	5
Road surface	01	Level difference of road surface	5
		Damages in pavements	5
Barrier	01	Damages in barriers	5
	02	Damages in barriers	5
	03	Damages in barriers	5
	04	Damages in barriers	5

4.4.5 Preparation of action plans for execution and revision of the maintenance plan

In general, a considerably large amount of accumulated data from periodic inspection results is necessary in order to prepare a long-term maintenance plan based on preventive maintenance, however in current situation, no organization has established sufficiently yet.
The situation in DRR is also essentially similar to the above. They have various issues to solve which are not yet in a stage to fully execute preventive long-term maintenance.
In the near future, they are expected to carry out inspection and evaluation in a synthetic manner and formulate a long-term maintenance plans according to "Inspection and evaluation manual" and thereby to solve those issues. Note that this process is not stable but should be revised at all times.

(1) PDCA cycle in the maintenance plan

The PDCA cycle applied to the long-term bridge maintenance system can be expressed as follows:

- Plan : formulation of a long-term maintenance plan
- Do : execution of repair and reinforcement measures
- Check : periodic inspection of bridge
- Action : sustainable improvement and revision

In a long-term maintenance plan for preventive maintenance, improvement of prediction accuracy is essential and therefore it is necessary to run the PDCA cycle in accordance with the changes in the surrounding condition such as technical, social, or environmental changes and always update the plans.

(2) Proposal of action plans for execution and revision of the maintenance plans

1) General items
Considering the following general items common for all the bridges, it is necessary to update the long-term maintenance plan according to the changes in the surrounding condition:

- a) Change in technical condition : Repair method (repair scenario), deterioration prediction method, etc.
- b) Change in social condition : traffic volume, repair budget, etc.
- c) Change in environmental condition : prediction of the deterioration degree, etc
- d) Change in maintenance system : maintenance organization, personnel training, periodic inspection frequency, etc.

Those changes may be appropriately coped with if the PDCA cycle is performed basically in accordance with periodic inspections once in every five years.

2) Action plans for steel truss bridges

Major damages common for steel truss bridges including bridges of Krung Thon, Krung Thep, and Memorial are caused by collision by ships or vehicles and corrosion in the main members.

Since the former cause is not related to deterioration over time, the damages will drastically decrease if measures to prevent such collision successfully work. For revision of the deterioration prediction accuracy by PDCA, simultaneous implementation for all those bridges is considered appropriate.

The latter cause is the result of deterioration over time, and periodic inspection once in every five years as the basic point of the PDCA cycle will do. Since the bridges are re-painted every four years, it would be recommendable for efficient improvement of inspection if the cycle of the periodic inspection could be changed to every four years, the scaffolding for repainting work be used also for inspection, and reports be provided at least on the existence and the position of serious damages.
Shifting to high-performance and high-durability painting may be also a recommendable option to consider as part of the PDCA cycle.

3) Action plans for concrete bridges

Major damage common to the concrete bridges including those of Rama 4, Rama 5, Rama 7, Phra Pinklao, Phra Pokklao, Taksin and Rama 3 is caused by the initial damage during construction and free lime occurring from the girder bottom due to water leakage from expansion joints. Since those causes are within the range of general damage, periodic inspection and repair every five years would be able to handle the condition for the time being. The bridge piers of Rama 5 are inclined and can cause a problem to the structure. It is recommended urgent advanced inspection be conducted separately from the periodic inspection.

4) Action plans for cable-stayed bridges

Major damage common to the cable-stayed bridges, including IRR South and IRR North, is caused by cracks on the overhanging deck, the corner part of the main tower, the bottom part of the main tower, and the side of the bridge piers.
Although the first two are not influential enough to affect the entire structure of the bridge, it is recommended to check the design drawings and consider installation of waterproofing layers

for the cracks on the overhanging deck and to give close visual checks using scaffolding to be set up for the periodic inspection next year for the cracks on the corner part of the main tower.

It is speculated that the latter two are not likely to be related to the structure but were originated during construction, and those are considered to cause no serious condition for the time being if periodic inspection and repair are surely conducted every five years.

Chapter 5 Proposal regarding the bridge maintenance and management system

5.1 Issues concerning the maintenance system for the bridges over the Chao Phraya River

(1) Availability of the legal systems, standards, guidelines, manuals and the like

As shown in Section 2.2.1 DRR has developed four kinds of manual listed below regarding the bridge maintenance:

1) *Bridge Inspection and Improvement Manual, Nov. 2005, Bureau of Bridge Construction DRR, IMMS*

   This is prepared for the purpose of inspecting and investigating Memorial Bridge etc. built over the Chao Phraya River;

2) *Manual for Bridge Inspection and Evaluation, Development of Network System under Administration of DRR (1st Step), Feb. 2007, Bureau of Road Maintenance DRR, Institute of Transportation Chulalongkorn University*

   This is completed by the burueau of Testing, Research, and Development on the basis of a draft prepared by the bureau of Maintenance; Not widely available;

3) *Study Project for Repair of Bridges due to Material Damage and Lifetime of Bridges in the DRR Network, Aug. 2008, Bureau of Testing, Research and Development DRR,*

   This is prepared incorporating repair construction methods taking the actual condition of local bridges into account; this also is not widely available;

4) *The Industrial Ring Road Project - Maintenance manual 2008, Bureau of Bridge construction DRR, AEC, TEAM, TEC, INDEX, JEI*

   This is prepared for the management of the IRR North and South cable stayed bridges in a simple form at the time of the construction of the bridges. This also does not serve its purpose sufficiently.

(2) Current state of the executing system

In DDR, the maintenance offices shown in Table 5.1.1 have been established to carry out maintenance of roads and bridges in the Bangkok Metropolitan Region. The Maintenance offices are staffed with 22 persons (2 engineers and 20 technicians). 6 maintenance offices under the operation of bureau of maintenance at the head office take care of roads and bridges in Bangkok Metropolitan Administration and Nonthaburi Province.

Note: Engineer : The personnel who is qualified in design and construction of road and bridge and capable to investigate the inspection results, etc. and propose countermeasures.
Technician : The personnel who possesses a basic knowledge and experience of design and construction of road and bridge

Table 5.1.1 Overview of maintenance offices and maintenance activities

Maintenance Office	Managed Bridge	Number of Stuff
Maintenance office for Rama 7 and Phra PinKlao bridges	Rama 7	1 Senior Technician (common to Phra PinKlao bridge) 15 Workers (Gardeners & Park keepers) 6 Workers (Guardians) 6 Workers (Drivers for lift & clean cars)
	Phra PinKlao	1 Senior Technician (common to Rama 7 bridge) 1 Technician Civil 4 Workers (Gardeners & Park keepers) 2 Workers (Guardians)
Maintenance office for Taksin bridge	Taksin	1 Senior Technician 1 Technician Civil 10 Workers
Maintenance office for Krung Thon, Krung Thep and Rama 3 bridges	Krung Thon	1 Senior Technician (common to Krung Thep and Rama 3 bridges) 2 Workers (Guardians) 2 Workers (for cleaning etc.)
	Krung Thep	1 Senior Technician (common to Krung Thon and Rama 3 bridges) 2 Workers (Guardians common to Rama 3 bridges) 2 Workers (for cleaning etc.)
	Rama 3	1 Senior Technician (common to Krung Thon and Krung Thep bridges) 2 Workers (Guardians common to Krung Thep bridges) 2 Workers (for machine)
Maintenance office for Rama 5, Phra Pokklao and Memorial bridges	Rama 5	1 Senior Technician (common to Phra Pokklao & Memorial bridges) 1 Technician Civil 4 Technician Electric 1 Clark 2 Workers (Guardians) 4 Workers (for cleaning etc.)
	Phra Pokklao and Memorial	1 Senior Technician (common to Rama 5 bridges) 1 Technician Civil 1 Workers (Supervisor of workers, CCTV for daytime) 2 Workers (Guardians) 3 Workers (for cleaning etc.)
Maintenance office for Rama 4 Bridge	Rama 4	1 Civil Engineer 1 Technician Civil 3 Technician Electric 1 Clark 2 Workers (for cleaning etc.) 2 Workers (Guardians) 2 Workers (Assistant drivers)
Maintenance office for IRR bridges	IRR	1 Senior Engineer (DRR head office) 2 Senior Technician Civil 1 Technician Electric 1 Technician Mechanic 6 Workers (CCTV for 24h in 3 shifts) 2 Workers (Foreman) 10 Workers (Construction & electric) 30 Workers (Guardians outsource) 20 Workers (Gardeners outsource) 25 Workers (for cleaning etc. outsource)

The maintenance system differs between the five-maintenance-office group that is responsible for the 10 bridges of Rama 4, Rama 5, Rama 7, Krung Thon, Phra Pinklao, Memorial, Phra Pokklao, Taksin, Rama 3, and Krung Thep and one maintenance office that is responsible for the IRR North and the IRR South bridge.

1) Bridge and road maintenance group in charge of the Bangkok peripheries and suburban areas

Figure 5.1.1 shows the organizational chart for the maintenance offices in charge of the 10 bridges. Each office administers one to three bridges, with one representative technician allocated to each office. Every office is understaffed.

Figure 5.1.2 shows the details of maintenance activities.

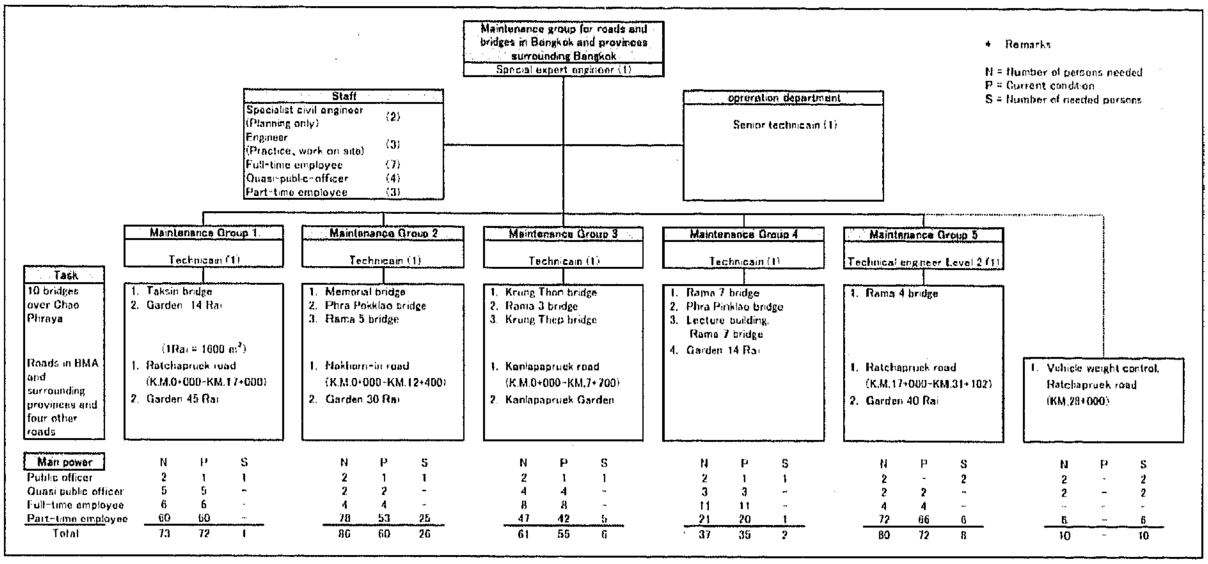


Figure 5.1.1 Organizational chart for the maintenance of roads and bridges in Bangkok and provinces surrounding Bangkok

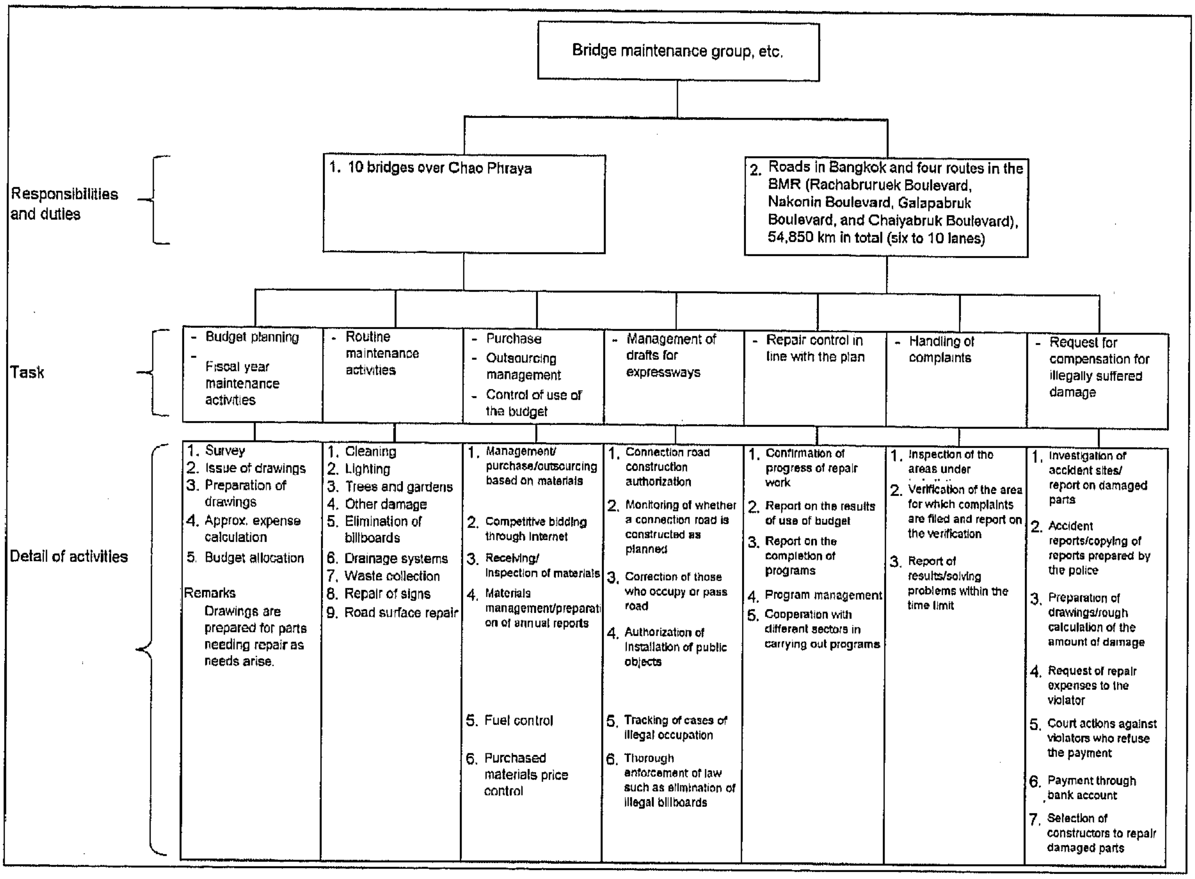


Figure 5.1.2 Details of activities of the Maintenance Department

2) Maintenance group for IRR bridges

Figure 5.1.3 shows the organizational chart for the IRR maintenance organization. The IRR maintenance personnel consist of a director, two chiefs under the director, and persons in charge and workers under a chief. This group has more persons engaged in work than the groups presented above, with the need for personnel satisfied. Figure 5.1.4 shows the details of activities.

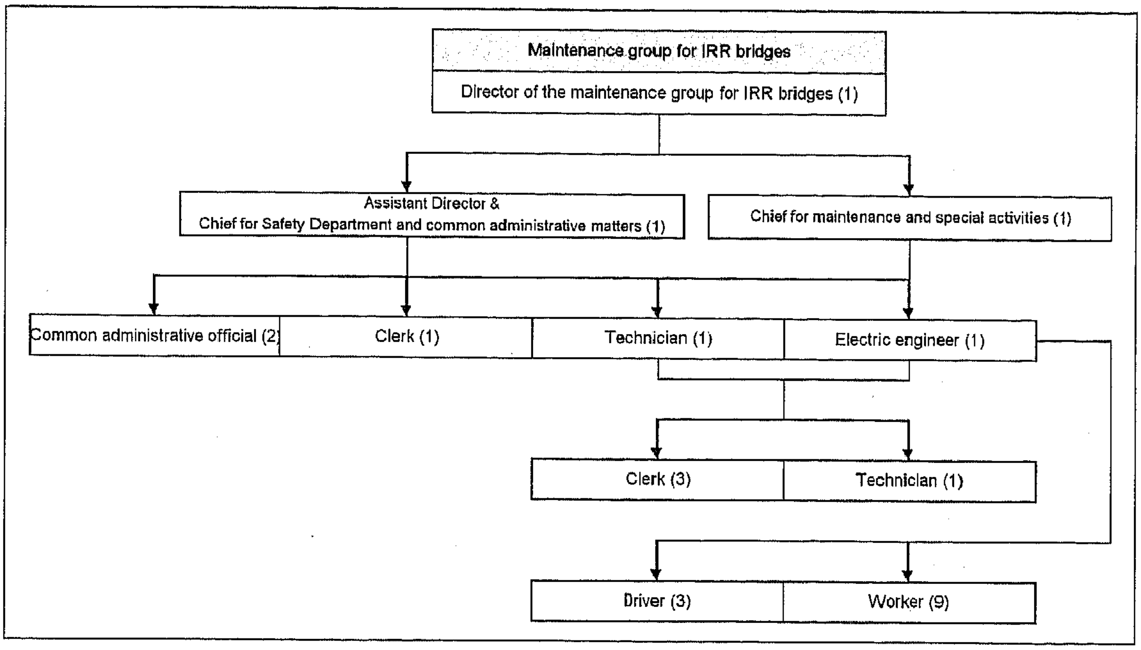


Figure 5.1.3 Organizational chart for the maintenance of IRR bridges

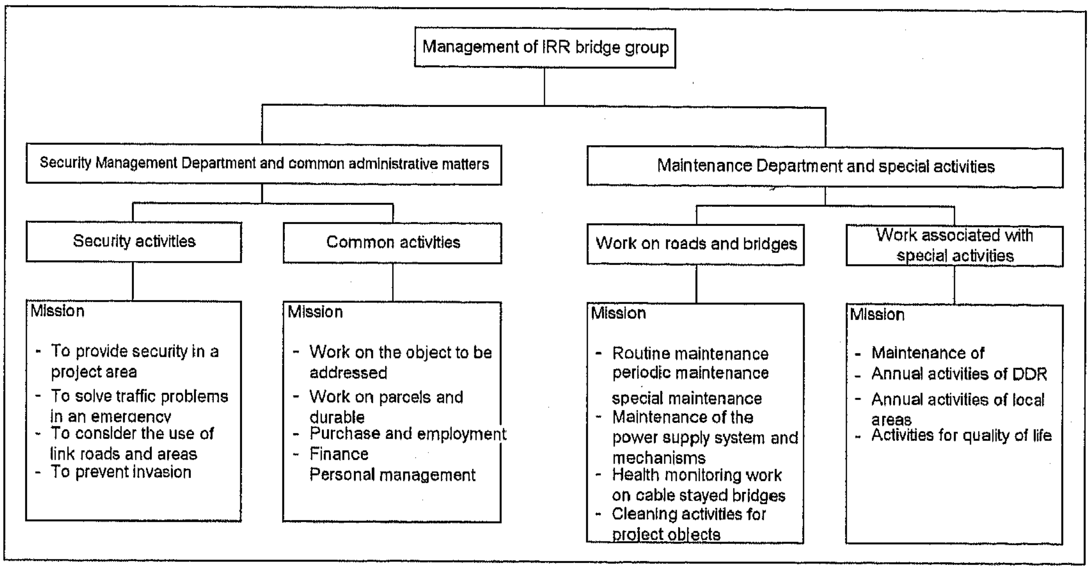


Figure 5.1.4 Details of work on IRR bridges

(3) State of activities to improve ledgers and inspection documents

DRR compiled its maintenance activities in the past up to fiscal 2008 in a booklet titled "Bridges over Chao Phraya." According to DRR, there are no other reference materials that record past maintenance activities. To list 8 bridges mentioned in the booklet from upstream to downstream, they are Rama 7, Krung Thon, Phra Pinklao, Memorial, Phra Pokklao, Taksin, Rama 3 and Krung Thep. Descriptions given to each bridge are its specifications, drawings, repair history and so on. No information is contained in this booklet about other 4 bridges, Rama 4, Rama 5, IRR North and IRR South, probably due to the fact that not much time has passed yet since these bridges were constructed.

General drawings and cross-sectional specifications shown in the booklet "Bridges over Chao Phraya" are all too schematic. For example, the dimensions of bridge spans can be located in them, but those of cross-sections (dimensions in bridge's width direction, girder height etc.) are difficult to identify. Therefore, this is in no way a document that can be called a register. Also, no digitized version of the booklet exists, making it difficult to obtain relevant data swiftly. Furthermore, there seems to be no plan to add information about the remaining 4 bridge. To keep bridges in safe condition over the long-term, it is important to manage information on past inspections and repair history. This kind of recognition was not, it seemed, pervasive within the Bureau.

(4) State of maintenance activities

There is no long-term maintenance plan, and the maintenance activities at the Bureau did not seem to be carried out according to a long-term point of view. Although periodic inspections are implemented, the maintenance there seemed to be based on the principle of responsive maintenance where maintenance means repairs of damages that have taken place.

Not much thought is given to possible implementation of measures to counter the aging of the bridges probably because they are still relatively young, and not much concern exists about their safety and durability. It is necessary, however, to draft a long-term maintenance plan based on the principle of preventive maintenance, where maintenance is carried out as soon as possible, in order to carry out maintenance activities based on such a plan.

It is ruled that technician in charge of each bridge inspects visually it and reports the presence of the damage with photographs. However, with an useful inspection manual or a example collection not available, inspections are conducted solely on the evaluation based on the technician's experience of long years, being susceptible to variations among individuals.

In addition, with no electronic information management (including data accumulation) available, it is difficult to continuously track damage, repair record, and make comparison with other bridges, with the trend in damage having not analyzed and predicted.

1) Table showing the budget and its breakdown for the bridge and road maintenance group in charge of the Bangkok peripheries and suburban areas

Table 5.1.2 shows the budget for bridges and roads from fiscal 2004 to 2010, obtained from the bureau of maintenance.

Table 5.1.2 Budget by fiscal year for the bridge and road maintenance group in charge of the Bangkok peripheries and suburban areas

(in thousand Bahts)

Fiscal year	2004	2005	2006	2007	2008	2009	2010
Budget	11.044	50.000	70.000	80.000	103.926	70.000	135.000

Table 5.1.3 shows the details of the work plan for fiscal 2010.

Table 5.1.3 Fiscal 2010 work plan for the maintenance group

No.	Plan	Number of plans	Amount (baht)	Ratio in the budget
1	Usual maintenance (to be performed by DRR)	5 plans	38,190.000	28.289
	1.1 Ten bridges across Chao Phraya River in the Bangkok periphery	1 plan	5,610.000	
	1.2 Roads in the Bangkok periphery and suburban areas	4 plans	32,580.000	
2	Periodic maintenance	8 plans	20,852.000	15.446
3	Special maintenance	10 plans	45,588.000	33.769
4	Maintenance of landscape around the bridges	4 plans	30,370.000	22.496
Total		27 plans	135,000.000	100.000

Work plans are classified into 4 types, namely, routine maintenance, periodic maintenance, special maintenance, and bridge environment maintenance. The following are the overviews of the four types of maintenance:

a) Routine maintenance:

Work performed as routine maintenance in a simplified method using simple inspection devices and tools. For example, replacement of light bulbs and lighting fixtures including cleaning, cleaning of drain pipes, elimination of weeds, cleaning of steel structures and tree pruning and maintenance.

b) Periodic maintenance:

Replacement of deteriorated or damaged main members of bridges and maintenance work on them. For example, replacement of expansion joints, re-painting of traffic lane lines, maintenance on bridge road surfaces, and re-painting on steel structures

c) Special Maintenance:

Work to keep bridges in a sound condition to secure smooth traffic. Damaged main members affecting bridge structures are repaired and large-scale improvement is also executed.

d) Environment Maintenance

Work being not intended to maintain the soundness of steel structures and bridges, environment surrounding bridges is given maintenance to provide places where people can do exercise and relax. For example, provision of fences around an area below a bridge or looking after street trees.

2) Maintenance group for IRR bridges

Figure 5.1.4 shows the fiscal 2010 IRR budget and its breakdown obtained from the Maintenance Department.

Table 5.1.4 Budget and its breakdown for the maintenance group for IRR bridges

No.	Description	Budget (baht)
	Usual maintenance work	
1	IRR road maintenance expenses	16,500,000
	Periodic maintenance work	
1	Bridge lighting systems	500,000
2	Basket for the maintenance work for the lift systems in the main pillar	200,000
3	Monitor camera systems, emergency telephone systems, and lighting sign boards	300,000
	Special maintenance work	
1	Installation of noise barriers on the elevated road on the Rama 3 Bridge side	2,000,000
2	Installation of noise barriers on the elevated road on the Sukusawat side	1,500,000
3	Installation of traffic signs on the Rama 3 road	2,000,000
4	Maintenance of expansion joints (335 m)	2,000,000
5	Cleaning of cables	2,000,000
	Gardening work	
1	Maintenance of running lanes, toilets, and health parks	2,000,000
2	Maintenance of landscape, fountains, and health parks	2,000,000
3	Maintenance of parking lots, security guards' standby rooms, and health parks	2,000,000
4	Maintenance of fences and sports ground below the elevated road on the Rama 3 road side	2,000,000
5	Construction work for resting cottages, resting facilities, and foot paths in health parks	2,000,000
6	Installation of a system management system and a result display system in the traffic control system facility	8,000,000
Total		45,000,000

5.2 Proposal for the maintenance system for the bridges over Chao Phraya River

The following subjects are proposed regarding the maintenance of bridges across Chao Phraya River:

- DRR should establish an inspection method based on a unified form and evaluation method
- Results of inspection should be electronically so that monitoring and analysis based on continuous data tracking may be performed easily
- Technicians should be trained and the number of engineers should be increased, with the aim of making it their tasks to formulate and review how repair following inspection should be and maintenance plans
- Systematization should be in place so that results of inspection and repair at a maintenance office may be grasped by the bureau of maintenance of the DRR head office.
- Regarding the above matter, a maintenance system is proposed that includes all of integrated bridge maintenance records such as applied in Japan consist of the bridge ledgers, inspection results, repair history records, and long-term maintenance programs. Regarding bridge ledgers and repair histories records, Appendix 3 shows them organized in a bridge maintenance sheet form on the basis of the existing materials and past repair histories.

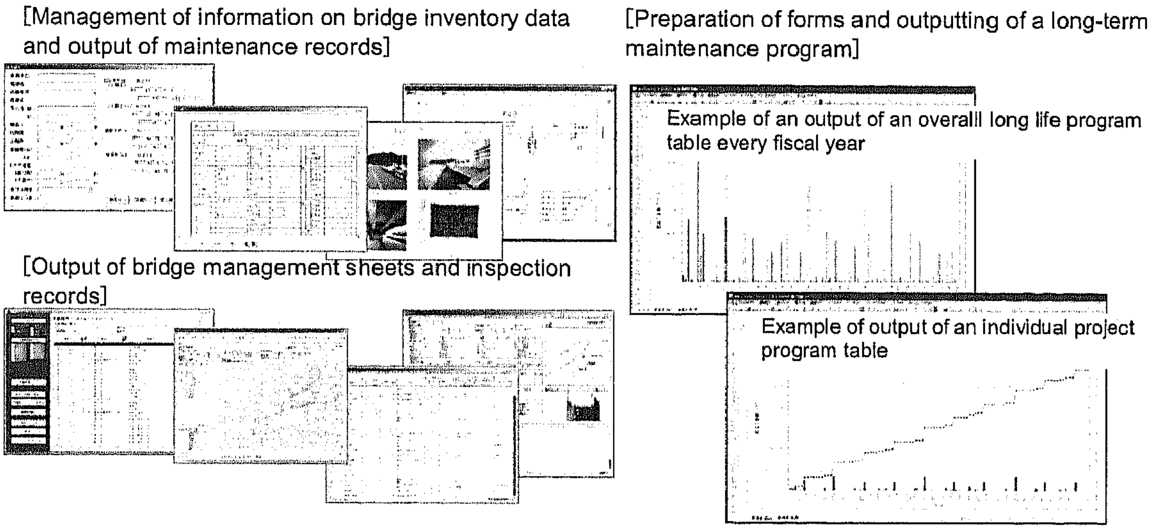


Figure 5.2.1 Bridge information management system

- For the existing maintenance manual for the IRR bridges, the following points are recommended to be improved:

  - The current manual seems slightly complex; it is advisable to prepare a simpler, worker-friendly edition;

- It is difficult for a technician or a worker to determine on-site whether immediate repair is needed or repair can be put off until the next inspection; this should be determined by a well-trained engineer.
- More photographs may be used to promote the sharing of the recognition of damage evaluation.
- In consideration of maintenance budget limitation that is set normally, priorities for repair should be established and incorporated in the manual.

- It is said that preventive maintenance reduces costs and lengthens the life of bridges. It is recommended to start reasonable data collection and accumulation as well as the PDCA cycle.

5.3 Current state and issues of maintenance system for rural bridges

With the aim of being informed of the current state of rural bridges managed by DRR, hearings on maintenance systems were conducted in a schedule of visit to rural maintenance offices. After finishing a hearing, a speech titled "Maintenance Management for Bridges in Japan" is demonstrated. The offices to be visited were decided by consulting DRR and the selection was carried out so that one or more offices might be selected from 4 rural districts. Before visiting a maintenance office, investigation survey of 3 or more bridges managed by the office was carried out in order to be enough informed of the actual state of management before making a hearing on the maintenance system.

The items to be investigated and objects to be analyzed at local maintenance offices are as shown in Table 5.3.1.

Table 5.3.1 Items to be investigated and objects to be analyzed at local offices

Purpose	Item	Object to be analyzed
Bridge	Number and type of bridges in the jurisdiction and fiscal years in which they were built	Comparison between bridges in local areas and large ones in the Bangkok city area. Resume of the relations between local environmental characteristics and maintenance
	Feature of bridges in the jurisdiction and special environments they are exposed to (coasts, freezing, etc,)	
Office organization and technical level	Organization of the office	Is the organization structure intended for sustained maintenance? Systematic arrangement of problems concerning technical level for inspection and organization. Is the budget equalized?
	Organization of the extension maintenance office	
	Details of work done by the extension maintenance office	
	Personnel engaged in maintenance activities	
	Use of private sectors	
	Technical level	
Budget	Year-by-year maintenance budget by purpose	Hearing and analysis on problems concerned to the maintenance budget
	Ratio to construction expenses; rate of budget execution	
Maintenance	State of maintenance equipment and tools; their types	Grasping of the progress of periodic inspection. Analysis to identify items lacking in accumulating data to formulate a long-term maintenance program.
	State of retention of bridge ledgers	
	Frequency of bridge inspection	
Repair program	Method of inspection and evaluation	Does the investigation level allow one to determine the emergency of repair? Is a condition available in which data can be accumulated to create a long-term maintenance program? Are priorities determined properly to carry out repair and reinforcement?
	Method of determining whether repair is needed or not	
	Method of giving priority to bridges to be repaired	
	State of repair work	

5.3.1 Organization and bridges under jurisdiction of rural maintenance offices

(1) Central Region

Commonly each maintenance office manages 4 to 5 provinces and builds and maintains roads and bridges on roads under the jurisdiction of DRR, also carrying out exclusively maintenance work of designated bridges (local connecting bridges) on roads other than those under the jurisdiction of DRR.

Characteristically, the director at each maintenance office is always an engineer, the construction and maintenance of roads are not under different organizations, and notification volunteers are registered. The volunteer system is a nationally unified one, in which a volunteer is normally engaged in his or her own occupation but once damage is found, he or she notifies the province or DRR contact so that provincial personnel may be dispatched to the site to address the situation. A volunteer may participate in repair work but not compulsorily. A volunteer receives lectures and training at the time of registration as volunteer and is required to accumulate an annual lecture.

Table 5.3.2 shows the results of investigation at the District 1 office (Pathum thani) where a hearing was held.

Table 5.3.2 Results of hearings (Central region; organizations and bridges under jurisdiction)

		District 1	Nonthaburi Province	Pathumthani Province	Ayuttaya Province	Samutprakhan Province	Angthun Province
Organization	Engineer (number of persons)	6	2	2	2	2	2
	Senior technician (number of persons)	0	1	1	1	1	1
	Technician (number of persons)	9	5	4	1	1	1
	Electrical (number of persons)	0	0	0	0	0	0
	Secretary (number of persons)	0	0	0	0	0	0
	Labor (number of persons)	15	15~20	15~20	15~20	15~20	15~20
	Volunteer (number of persons)	0	53	101	72	21	64
	Major maintenance work (Labor)	Part of road maintenance work: painting, lane marking, installation of signs, signals, and lights, weed cutting, etc.					
Bridge under jurisdiction	Number of routes under road management	32					
	Total length of roads under jurisdiction (km)	1400					
	Number of bridges on DRR-managed roads	Not answered					
	Number of bridges managed by DRR on roads other than those managed by DRR	29					
	Type of bridge and features	99-% concrete (mostly PC); in the past, steel bridges were built as bascule ones in canals; with no ship traffic now, they have been replaced by steel bridges that need less maintenance expenses.					
	Local features of a bridge	No particular local features (based on standard design)					

(2) Southern District

Table 5.3.3 shows the results of investigation at the District 11 office (Surat Thani) where a hearing was held.

Table 5.3.3 Results of hearing (Southern District: organization and bridges under jurisdiction)

		District 1	Chumphon Province	Si Tammarat Province	Ranog Province	Surat Thani Province
Organization	Engineer (number of persons)	4	1	3	2	2
	Senior technician (number of persons)	1	1	2	1	1
	Technician (number of persons)	14	7	14	4	8
	Electrical (number of persons)	0	0	0	0	0
	Secretary (number of persons)	0	0	0	0	0
	Labor (number of persons)	6	39	15	23	15
	Volunteer (number of persons)	0	90	58	51	82
	Major maintenance work (Labor)	Part of road maintenance work: painting, lane marking, installation of signs, signals, and lights, weed cutting, etc.				
	Number of routes under road management	-	34	55	21	29
	Total length of roads under jurisdiction (km)	-	517.47	847.321	305.951	442.559
	Number of bridges on DRR-managed roads	-	97	206	85	73
	Number of bridges managed by DRR on roads other than those managed by DRR	-	21	24	6	19
	Type of bridge and features	Less than 10% of bridges are made of RC and more than 90% of PC; RC has been replaced by PC in many of the bridges.				
	Local features of a bridge	No particular local features (based on standard design) (Some bridges in Chumphon Privince are damaged by chloride.)				

(3) Northeastern District

Table 5.3.4 shows the results of investigation at the District 7 office (Ubon Ratchathani) where a hearing was held.

Table 5.3.5 Results of hearing (Northeastern District: organization and bridges under jurisdiction)

		District7	Amnat Charoen Province	Yasothon Province	Si Sa Ket Province	Ubon Ratchathani Province
Organization	Engineer (number of persons)	4	2	1	2	2
	Senior technician (number of persons)	0	1	1	1	1
	Technician (number of persons)	15	7	9	6	9
	Electrical (number of persons)	0	0	0	0	0
	Secretary (number of persons)	4	0	0	0	0
	Labor (number of persons)	About 70	About 30	About 30	About 30	48
	Volunteer (number of persons)	0	104	111	225	300
	Major maintenance work (Labor)	Usual maintenance work including lawn mowing, road repair, and painting; transfer and assembly of temporary bridges (A temporary bridge is used in District 7.)				
Bridge under jurisdiction	Number of routes under road jurisdiction	—	25	22	56	87
	Total length of roads under jurisdiction (km)	—	401	456	965	1605
	Number of bridges on DRR-managed roads	—	73	80	105	291
	Number of bridges managed by DRR on roads other than those managed by DRR	The District maintenance office manages all of the bridges enumerated in the boxes at right.	10	8	16	27
	Type of bridge and features	Seventy percent of bridges are made of RC while 30% are made of PC.				
	Local features of a bridge	No particular local features				

(4) Northern District

Table 5.3.5 shows the results of investigation at the District 10 office (Chiang Mai) where a hearing was held.

Table 5.3.6 Results of hearing (Northern District: the organization and bridges under jurisdiction)

		District10	Chiang Mai Province	Phrae Province	Mae Hong Son Province	Lampang Province	Lamphun Province
Organization	Engineer (number of persons)	4	2	2	2	2	2
	Senior technician (number of persons)	0	1	1	1	1	1
	Technician (number of persons)	12	5～6	5～6	5～6	5～6	5～6
	Electrical (number of persons)	1	0	0	0	0	0
	Secretary (number of persons)	0	0	0	0	0	0
	Labor (number of persons)	15	30	30	30	30	30
	Volunteer (number of persons)	0	125	93	51	64	102
	Major maintenance work (Labor)	General road maintenance work including lawn mowing, painting, lane marking, and cleaning of signs and drainage facilities					
Bridge under jurisdiction	Number of routes under road management	146					
	Total length of roads under jurisdiction (km)	2415					
	Number of bridges on DRR-managed roads	320					
	Number of bridges managed by DRR on roads other than those managed by DRR	89					
	Type of bridge and features	Eighty percent of bridges are made of RC while 20% are made of PC.					
	Local features of a bridge	No particular local features					

5.3.2 Current state of roads and bridges

(1) Results of investigation survey

The outline of the results of the investigation survey of individual bridges is described below. Details and photographs of damage are shown in Appendix 8.

1) July 15, 2010 (Thurs.): District 1, Samutprakhan Province

3 bridges managed by the Samutprakhan Province Office of the District 1 Office

(a) Wat Sukhan Thawat Bridge

(b) Kho Lat Bridge

(c) Khlong Jao Moo Bridge

All bridges have pile bent abutments, which are structured to allow their front face to be scoured easily when the river water level rises as a result of discharge of water from a dam, for example. As long as the standard design is not corrected, the problem at the source is not likely to be solved.

2) July 28, 2010 (Wed.): District 13, Chachemgsao

4 bridges managed by the Chachemgsao Province Office of the District 13 Office:

(a) Huasai Bridge

(b) Klong Phii Khut Bridge

(c) Sakat 40 Bridge

(d) Wat Hong Thong Bridge

Effects of scouring and defective work execution are seen as in case 1). In addition, effects of salt damage are seen on bridges across tidal rivers in areas where seawater flows back.

3) September 2, 2010 (Thurs.): District 10, Chiang Mai

5 bridges managed by Lamphun Province, District 10:

One of them (a bridge over Khan River) a new one while other four are existing ones.

(a) Bridges over Khan River

(b) Chaloem Phragan Bridge

(c) Phan Wang Bridge

(d) Thun Manung Bridge

(e) Mahathai 100 Year Bridge

The newly built Khan River Bridge, too, adopts pile bents according to the standard design, leaving the concern of experiencing continued scouring in future. The necessity of reviewing the design concept at its source is felt again. Phan Wan Bridge suffered a fall as a result of pier P7 being scoured during the work to reinforce pier P5.

4) September 6, 2010 (Mon.): District 11, Surat Thani

3 bridges managed by Surat Thani Province, District 11:

(a) Parkung Bridge

(b) Bhangupor Bridge

(c) Klungkor Bridge

Damage arising from insufficient concrete cover is often observed, with exposed rebar and corroded rebar observed also. Defective work execution is a major cause leading to and contributing to damage also.

5) September 9, 2010 (Thurs.): District 7, Ubon Ratchathani

3 bridges managed by Amnat Charoen Province, District 7:

(a) Kwayang Bridge

(b) Mittosamphan Bridge

(c) Huaitom Bridge

With scouring in an advanced stage, a repetition of the problem will be inevitable as long as the design concept is not changed basically, as exemplified by the replacement of pile bents with walls.

6) Bridges managed by other agencies (for reference)

2 additional bridges that are judged as needing immediate measures, though they are not under DRR jurisdiction:

(a) DOH-managed bridge

(b) Bridge managed by the State Railways of Thailand (River Kwae Bridge)

(2) Bridge inspection results

6 bridges in the Province adjoining to Bangkok were inspected for three days from November 2 to 4. The inspection was visual and nondestructive inspection, with the latter conducted to check concrete strength. The methods of inspection and recording were the same as those used in the inspection of 12 bridges over Chao Phraya River. The results of the inspection are contained in detail in Appendix 6 "Results of inspection of bridges in local areas around the Bangkok periphery."

1) List of bridges inspected

Table 5.3.6 List of bridges inspected

Date	Province	Name of bridge	Structure
2nd Nov. 2010	Chachoengsao	1. Wat Hong thong	Upper: RC Simple beam Lower : RC Pile bent
		2. Saphan kham khlong sii long	Upper : PC Simple Pre-cast beam Lower : RC Pile bent
3rd Nov. 2010	Samut Prakan	1. Saphan wat khor lad	Upper : PC Simple Pre-cast beam Lower : RC Pile bent
		2. Khlong law muu	Upper : RC Simple beam Lower : RC Pile bent
4th Nov.2010	Nonthaburi	1. Khlong phra phimonracha	Upper : RC Simple beam Lower : RC Pile bent
		2. Khlong Thawiiwattana	Upper : RC Simple beam Lower : RC Pile bent

2) Results of visual inspection (an overview)

Among the six bridges inspected, the two showing particularly remarkable damage are examined to estimate the state and cause of the damage.

- Wat Hong Thong Bridge

  The bridge is located three minutes' walk from the seashore. On the underside of the main beam, the main rebars (tension reinforcements) were found separated from the main beam. Judging from the surrounding environment, this is thought to be due to salt damage.

- Khlong Law Muu Bridge

  With soil and dirt on the back of the abutment having been washed away, a cavity was confirmed below the approach section. It is considered to be due to the effect of water.

3) Results of nondestructive test

Judging from Japanese design standards, some bridges exhibited slightly lower strength in the main girders and piers; however, the lack of materials from the time of the construction prevented the conclusion from being drawn.

4) Summary

The bridges to be inspected were selected on the basis of the request from the Province offices. Viewed overall, damage considered to have occurred in the construction phase was often observed. On the other hand, we were able to identify bridges that need immediate remedies from the viewpoint of the structural safety and the safety of public passage.

5.3.3 Current state of the maintenance system of rural districts

The following table shows the results of hearings carried out at 4 District Offices in a form of comparison between the offices by item.

(1) State of collection and management of information on bridges

Table 5.3.7 Results of hearings
(Grasping of the fiscal year in which a bridge was built and the bridge ledger)

	Central Region (District 1)	Southern Region (District 11)	Northeaster Region (District 7)	Northern Region (District 10)
Grasping of the fiscal year in which a bridge was built	The fiscal year in which a bridge was built is known. (However, data is not organized.)	Items of data on more bridges on roads not under jurisdiction than those on roads under jurisdiction are organized. The data is stored in the BMMS system (developed by Chulalongkorn University) and kept at the DDR Department of Road Maintenance.	Some items of data for which the management classification has been modified are unknown, with 70% of all grasped.	For bridges on roads not under jurisdiction, the fiscal year in which a bridge was built is made known by investigation because the management of such bridges is confined within a narrow scope. Items of data on bridges on roads under jurisdiction are not organized but can be found. (Items of data are managed comprehensively as part of road data.)
Bridge ledger	A bridge ledger and an inspection document are unified on a single sheet.	The inspection document is the same as that of Districts 1 and 10.	The same case as that of District 7	Bridges on roads not under jurisdiction are large-scaled and their locations cannot be known without the help of ledgers; for this reason, ledgers are retained. Many of bridges on roads under jurisdiction are small-scaled and not registered, but maintenance office personnel know the locations well; this allows them to feel free from problems.

*BMMS : Bridge maintenance management system (refer to 6.4)

The common problems are as follows:

1) Items of data are not classified and organized by the fiscal year in which a bridge was built, however, mostly known. On the other hand, some items of data for which the

management classification has been modified are unknown.

2) Items of data are organized in the common form unifying a bridge ledger and an inspection document.

(2) Method of determining the necessity of repair

Table 5.3.8 Results of hearings (Determination of the necessity of repair)

	Central Region (District 1)	Southern Region (District 11)	Northeastern Region (District 7)	Northern Region (District 10)
Determination of the necessity of repair	Technician work as inspectors. If a technician is unable to grasp the problem, he or she is accompanied by an engineer. When a problem is detected, a report for this purpose alone is submitted with photographs (occasionally with a CD containing a video presentation). Province to District to DRR (A problem is addressed in this order; if the problem is not solved at a lower level, it is brought to another higher level.)	Smaller damage is repaired according to the Province's judgment, while larger damage is reported to DRR. Roads and bridges on roads under jurisdiction are not separated in requesting an overall budget for them.	The determination of the necessity of repair is referred to higher authorities from the Province to the District to the DRR head office.	Matters that cannot be judged at a lower level are brought to higher levels, from the Province to the District to the DRR head office, for example.

The shared problems are as follows:

1) Basically, the Province addresses problems; however, difficult ones are brought to higher levels from the Province to the District to DRR.
2) With competent engineers in want, problems are often brought to higher level authorities.

(3) Method of prioritization to bridges to be repaired

Table 5.3.9 Results of hearings (How to handle priorities)

	Central Region (District 1)	Southern Region (District 11)	Northeastern Region (District 7)	Northern Region (District 10)
How to handle priority	Two ways to address priorities: (1) When the matter is not urgent, it is referred upward to DRR. (2) If the matter is urgent, the budget is used for repair.	No answer	Depends on the traffic and the scale of damage.	A judgment is made depending on the part and degree of damage. Places of high traffic are given high priority. An emergency budget is available. For example, when a levee road suffers corrosion, the emergency budget is used to the extent that a mere passage is secured (without pavement) and the ordinary budget is used for measures to be taken beyond that.

The common problems are as follows:

1) Emergency measures are taken care of by the Province.
2) Priority depends on the traffic and the scale of damage.

(4) Method of inspection and evaluation

Table 5.3.10 Results of hearings (Methods of inspection and evaluation; frequency of inspection)

	Central Region (District 1)	Southern Region (District 11)	Northeastern Region (District 7)	Northern Region (District 10)
Method of inspection and evaluation	District 1 carries out periodic inspection starting at least seven years ago. (Inspection documents are available but manuals are not. Instructions from DRR are yet to be given.)	Maintenance and inspection are carried out using the same documents as those used by Districts 1 and 10. Inspection is performed according to the manual in BMMS. Problems are reported using photographs taken on-site. Drawings are prepared under the guidance of DRR Maintenance Department.	Technicians conduct visual inspection. No manuals are available.	Inspection is conducted using the same document as that of District 1. (They say documents are in the DRR unified form.)
Frequency of inspection	Basically once/year (Reports are sent to District from Provinces.) If problems exist, inspection is conducted frequently.	Once/year. Technicians conduct inspection.	Provinces: once/year; District: once/year; however, the three bridges with larger traffic are patrolled once/month (using vehicles).	Once/year. Ordinary maintenance work is conducted once/year in the jurisdiction and once/two years on roads not under jurisdiction.

The common problems are as follows:

1) Technicians conduct periodic inspection once/year, using an inspection document in the DRR unified form. (Examples are shown in Appendix 9.)
2) No unified manuals on inspection are available.
3) Results of inspection are reported to District in hard copy, but they are not in an electronic form, with trend analysis and the like not performed.

(5) State of repair condition

Table 5.3.11 Results of hearings (State of repair activities)

	Central Region (District 1)	Southern Region (District 11)	Northeastern Region (District 7)	Northern Region (District 10)
Maintenance equipment and tools	Possesses a Benkelman beam (not used for bridges). Overlaying is outsourced.	No answer	Lawn mowers, brushes, and road-sprinklers (for road cleaning)	No tools are available to check the strength of bridges. Tools for maintenance work only are available.
State of repair activities	The practice in the handling of priorities remarks, "(1) When the matter is not urgent, it is referred upward to DRR," is likely to continue (in expectation of the budget).	No answer	There are cases where repair activities are delayed waiting for DRR instructions.	It does not take long to refer information upward to higher authorities but instructions from the DRR head office takes time to come down, and when reinforcement takes time, the work has to wait for the next year budget depending on the situation. (A problem could be left unattended for a long time.)

The common problems are as follows:

1) For an extreme lack of the budget (refer to (6) "Allocation of the budget and personnel to maintenance"), maintenance work beyond the painting of bridge surfaces and lawn mowing cannot be done normally.
2) Even if a case is referred upward to DRR, repair work may be delayed waiting for instructions from DRR.

(6) Allocation of the budget and personnel to maintenance works

Table 5.3.12 Results of hearings (Allocation of the budget and personnel to maintenance activities)

	Central Region (District 1)	Southern Region (District 11)	Northeastern Region (District 7)	Northern Region (District 10)
State of the budget for maintenance activities	Given no information, the person in charge does not know the budget state.	No answer	District 7: 400, 000 B for this fiscal year (for bridges on roads not under jurisdiction) The budget for the next fiscal year is unknown. Provinces: the road maintenance expenses including those for bridges are 26,000 B/km (= 26 B/m). When damage is on a larger scale, the expenses are demanded separately.	No data available. About 600,000 to 700,000 B (for bridges and access roads before and after bridges). Three ways to handle problems: (1) Regular budget for painting, cleaning and the like (maintenance expenses) (2) Usual maintenance expenses (non-periodic repair: repair expenses) (3) Emergency expenses to address the problem of piers (Expenses falling under categories (2) and (3) are reported to DRR together with drawings.); construction expenses: 80,000 to 100,000 B/m; maintenance expenses: 200 B/m
Allocation of personnel	Construction and maintenance are not separated in allocating personnel. Persons who want to be notification volunteers are registered.	No answer	Bridge maintenance is included in road maintenance. The volunteer system is unified throughout the country. A volunteer is normally engaged in his or her own occupation but once damage is found, he or she notifies the province or DRR contact so that provincial personnel may be dispatched to the site to address the situation; there are cases where a volunteer joins for help. (this is not compulsory.) A volunteer receives lectures and training at the time of registration as volunteer and accumulates an annual lecture.	Maintenance work for bridges and that for roads are not separated. The volunteer notification/maintenance system is based on volunteerism and registration. (Common to 18 Districts: Receives training and guidance as repairing bridges. However, it depends on the mood of the instructor. The difference between a volunteer and labor force is whether a salary is paid or not. The traffic is scarce and no accident occurs.)

The common problems are as follows:

1) The budget for the maintenance expenses is extremely scarce. For reference values, the overall maintenance expenses for roads including bridges are 26 B/m (for the Northeastern Region (District 7)) and the maintenance expenses for bridges are 200 B/m (for the Northern Region (District 10))
2) 2 engineers are assigned to each maintenance office; however, one of them must serve as director, and therefore only one engineer is actually available in each Province. For this reason, engineers who should diagnose the result of inspection done by technicians are in short supply.
3) A volunteer notification/maintenance system is available and unified throughout the country. A volunteer is normally engaged in his or her own occupation but once damage is found, he or she notifies the province or DRR contact so that provincial personnel may be dispatched to the site to address the situation; there are cases where a volunteer joins for help. (this is not compulsory.) A volunteer receives lectures and training at the time of registration as volunteer and accumulates an annual lecture.

5.3.4 Current state and issues of the maintenance plan

The investigation survey of 18 bridges in total managed by the District Maintenance Offices in four regions under the jurisdiction of DDR of Thailand and the results of hearings at the District Maintenance Offices are summarized as follows:

1) Provinces conduct periodic inspection every year, but the maintenance program based on the results of the periodic inspection is not formulated on a province-by-province basis. For this reason, no maintenance program is created either on the District basis or on the basis of the DDR as a whole, and this allows one to conclude that no planned maintenance is being carried out.
2) In many instances, bridges on which damage is found are left unattended unless the damage poses imminent problems; for this reason, a number of cases of damage needing immediate repair/reinforcement (in particular, scouring and water leakage, exposure of stripped rebars, and corroded rebars) are left unattended.
3) The primary reason for such situation in which even corrective maintenance is not carried out, let alone preventive maintenance, is the shortage of maintenance budgets.
4) The following can be enumerated as additional causes for such a situation:

- Defects in the standard design itself (structures susceptible to scouring are adopted: frequent use of pile bents and imperfect end dams on the front face of a pier (not a wall type but a column type))
- Defective work execution (water leakage, exposure of stripped rebars, corrosion of rebars occur easily: insufficient concrete cover, defective processing of construction joints, etc.)
- Shortage of engineers (Even if technicians conduct many inspections, there is a shortage of persons who have to diagnose remedies.)

5.4 Proposal regarding the maintenance system for bridges in local areas

On the basis of the results explained in the previous section, a proposal for a possible solution of the current state of DRR is shown below.

5.4.1 Ideal maintenance system

1) Improvement of inspection and education for technical personnel

- Allowing bridge inspection to be done only for a report of the presence or absence of damage will make it difficult to determine the necessity of repair, or make it necessary to inspect the bridge again for a repair design. Determining the size of damage or estimating the cause or repair method on site will improve inspection; however, this requires knowledge and experience of those who perform inspection.
- At DRR, technicians inspect bridges, and they are enthusiastic in carrying out their tasks indeed, but they lack professional knowledge undeniably. Judging from the fact of a lack of engineers at DRR, it is essential to educate technicians to enhance the quality of inspection personnel with the aim of nurturing those who are capable of making a diagnosis.
- Safety education also is important to inspection personnel. As shown in this report, knocking down cracked parts in an RC member may be not dangerous, but doing so with a PC member is dangerous. In addition, dangerous acts such as applying live load with the rivet removed should be avoided, and it may be a useful means for safety education to give lectures from the viewpoint of dynamics with reference to such examples.
- The following illustration shows a dress and outfits for an inspecting employee recommended to enhance the safety of inspecting personnel and the efficiency of inspecting tasks.

2) Improvement and utilization of the bridge database

- It is recommended to enrich the bridge database containing bridge specifications and general drawings by inputting results of inspection and repair histories (including construction expenses) and other data (electronic filing and visualization), with the aim of structuring a database system easy for the road administrator to manage.
- It is recommended to increase the efficiency of inspection and repair by extracting important details and locations of damage through the analysis of accumulated data and to enhance the maintenance of bridge by systematizing the formulation, execution and reviewing of a long-term maintenance program based on the LCC calculation.

5.4.2 Provision and execution of standards for planned maintenance

To execute maintenance in a planned manner, it is required to grasp features of damage of the bridges under DRR jurisdiction and provide standards specifying preventive measures for such features of damage.

Features of damage and countermeasures aimed at the prevention of recurrence are demonstrated as follows:

(1) Scouring

- Scouring is observed throughout the country. The reason for this is that the standard design adopts a structure vulnerable to scouring in abutments and piers. For this reason, bridges susceptible to scouring are still constructed. Ideas have been given to the design of abutments to minimize the earth load received, with the same pile bent type as that of piers being adopted. However, combined with imperfect revetment works, abutments allow water to enter the back and cause souring at times of flooding. Piers are of a pile bent type and the bottom face is set at the riverbed at the time of the design; besides, no consideration of foot protection work is found, with measures taken against scouring at times of flooding being poor.
- Many bridges have suffered scouring and a large pool of bridges with the potential fear of scouring exist; under such circumstances, a large amount of reinforcement work expenses will be needed, and it will be difficult to take fundamental measures. For the time being, makeshift measures are needed such as reinforcement of parts around the substructure by means of revetment work/foot protection work and reinforcement of the main body of the substructure. (Possible measures are, for example, the reinforcement of the foundation by means of making the abutment front a wall providing an earth-pressure resisting structure and the support of a pier with an enlarged footing and by foundation pillars that reach the bearing layer securely.)
- For a newly built bridge, a standard such as a river law or an ordinance concerning river management facilities in Japan should be established so that a bridge substructure may be designed to provide a secure scouring countermeasure.
- As an reference example in Japan, an image of embedment depth for a pier and the concepts of the impediment ratio of river flow, revetment work, foot protection work, and others are shown below:

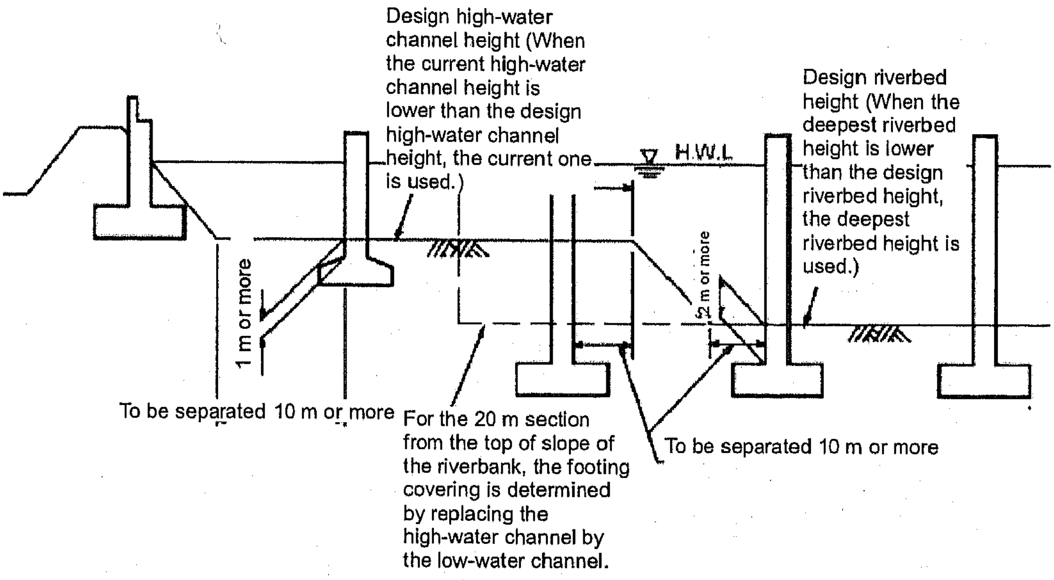


Figure 5.4.1 Conceptual drawing of the restrictions on the position of a pier and on the depth of embedment of a pier foundation

Impediment ratio of river flow

The impediment ratio of river flow is defined as the ratio of the total width of a pier to the river width. In this definition, the river width and the total width of piers refer to the following:

(1) River width: the distance, measured at right angle to the direction of flow, between the intersection points of the design high-water level with the bank face of slope.

(2) Total width of piers: Total of the width of piers, measured at right angle to the direction of flow, at the position of the design high-water level

The impediment ratio of a bridge should be within the following values as guidelines:

(3) Ordinary bridges: within 5% as a rule;

(4) Shinkansen railway bridges and expressway national route bridges: within 7% (as an exception value).

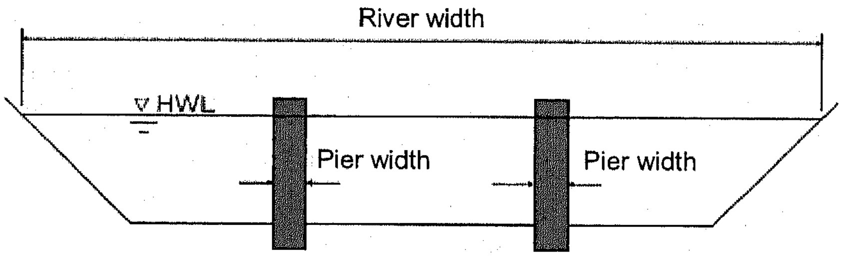


Figure 5.4.2 Conceptual drawings of a river width and a pier width

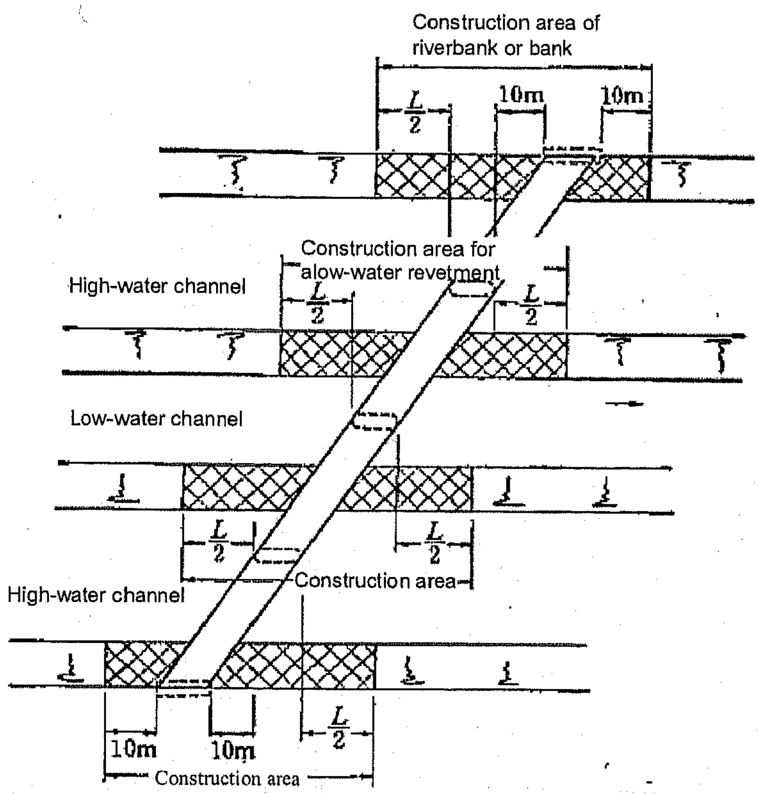


Figure 5.4.3 Length of the revetment as required in the bridge arrangement

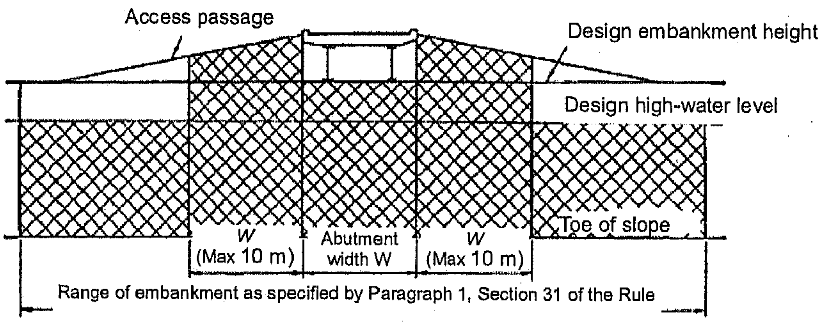


Figure 5.4.4 Height of a bank revetment required as a result of the installation of a bridge

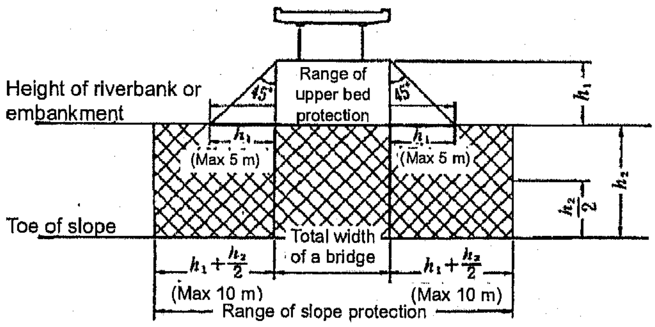


Figure 5.4.5 Range of protection for the riverbank or embankment below a bridge

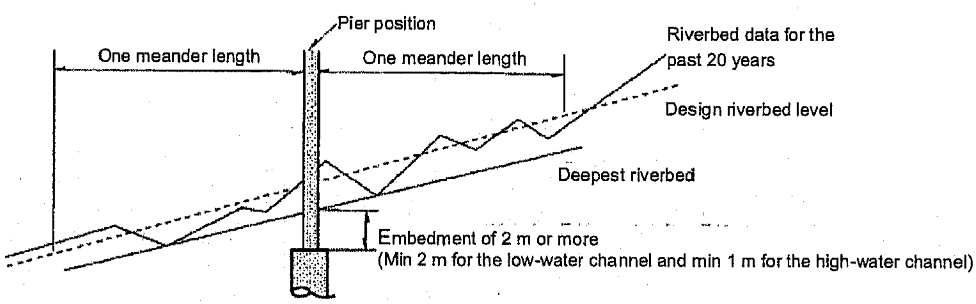


Fig. 5.4.6 Embedment depth for a pier

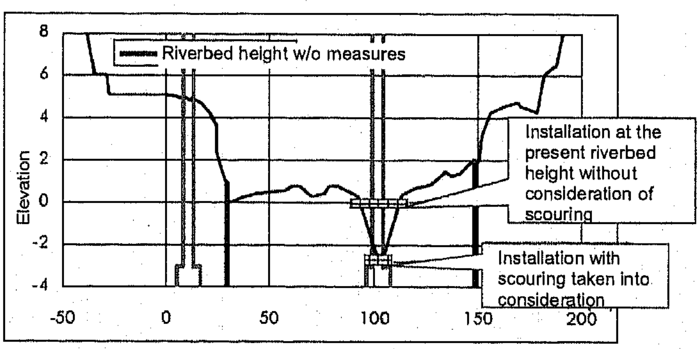
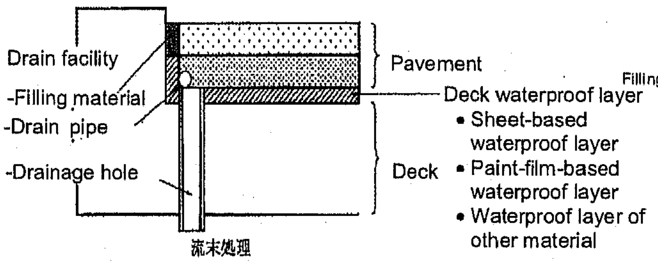
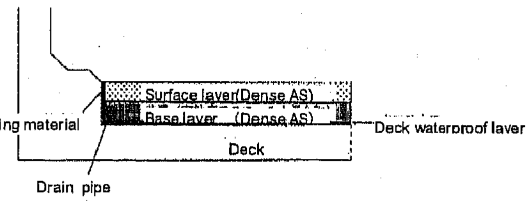


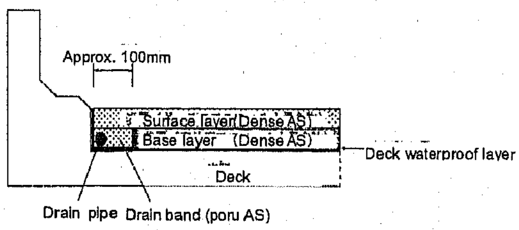
Figure 5.4.7 Example of the depth of installation of foot protection work

(2) Water leakage, spalling/rebar exposure, rebar corrosion

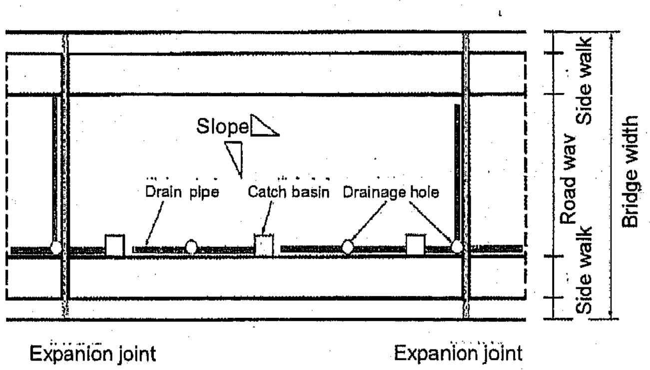
- spalling, rebar exposure, and rebar corrosion due to water leakage from the bridge surface, in particular from expansion joints (mostly due to the falling of Elastite), are observed at girder ends and on the surface of substructure in many locations.
- Many of such defects are accelerated by insufficient concrete cover due to construction error, and in some cases, further worsened by chloride damage.
- The installation of waterproofing work on the bridge surface (usually installed between asphalt paving and concrete deck (waterproofing work based on asphalt-based sheets and paint coating)) and the installation of undrained expansion joints are possible measures.







Longitudinal slope	Installation space [m]
1% or less than 1%	5
More than 1%	10



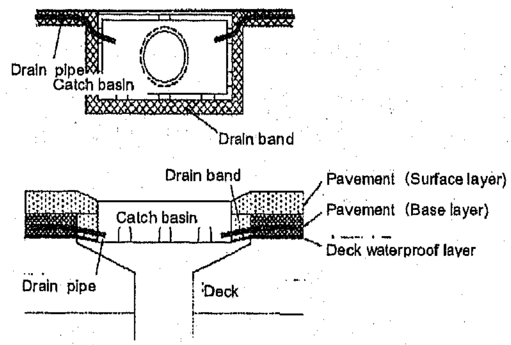


Figure 5.4.8 Example of installation of deck waterproofing

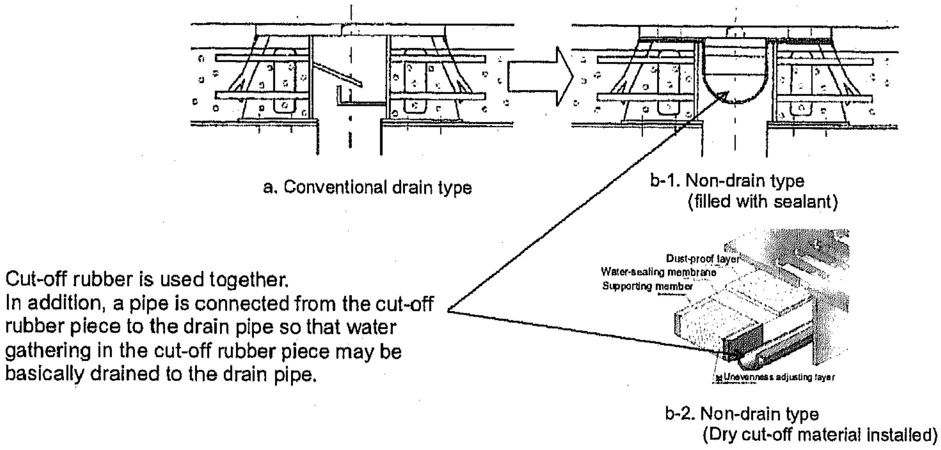


Figure.5.4.9 Drain-free expansion joint

5.5 Summary

Based on the above discussion, we compile proposals concerning the bridges over Chao Phraya River and proposals concerning bridges in local areas, and we would like to make them a proposal for the maintenance system of the entire DRR.

- At DRR, technicians inspect bridges, and they are enthusiastic in carrying out their tasks indeed, but they lack professional knowledge undeniably. Judging from the fact of a lack of engineers at DRR, it is essential to educate technicians to enhance the quality of inspection personnel with the aim of nurturing those who are capable of making a diagnosis. This is because by making it the task of a technician-turned-engineer to formulate and review how repair following inspection should be and maintenance programs, a shortage of engineers at the DRR head office is eliminated and the possibility can be found of quickly diagnosing a number of problems from various local areas on-site before they are brought upward.
- For this purpose, an inspection technique should be established that incorporates not only examples for the ease of understanding and unified judgment but also, in addition to instruction for inspection, how repair after inspection should be.
- Safety education also is important to inspection personnel. As shown in this report, knocking down cracked parts in an RC member may be not dangerous, but doing so with a PC member is dangerous. In addition, dangerous acts such as applying live load with the rivet removed should be avoided, and it may be a useful means for safety education to give lectures from the viewpoint of dynamics with reference to such examples.
- Results of inspection should be electronic filed so that monitoring and analysis based on continuous data tracking may be performed easily; in addition, for the purpose of data sharing and the immediacy of taking actions, systematization should be in place so that results of inspection and repair at a maintenance office may be grasped by the bureau of maintenance of the DRR head office.
- Regarding the above matter, a maintenance system is proposed that includes all of integrated bridge maintenance records such as applied in Japan consist of the bridge ledgers inspection results, repair history records, and long-term maintenance programs.

Chapter 6 Proposal for an efficient maintenance system

6.1 Investigation for the master plan

While a master plan for bridge construction has been developing by the bureau of planning of DRR from the viewpoint of maintaining the road network, master plan for the bridge maintenance has not yet.

Until now, bridge construction has been governed by the scale of local desires and budgets without a comprehensive synthetic plan, and it is recognized that this is irrational in many ways. Therefore, DRR has done research in order to determine priorities and decide the locations where construction should be done. Based on this research, construction has been pursued on projects that address a missing link in the road system or bypasses and shortcuts that address various traffic problems.

6.2 Interviews of other maintenance institutions

(1) EXAT

July 20, 2010, Dr. Sakda, Director of Research and Development office, others

- EXAT was using a maintenance manual developed between 1993 and 1994 by a JICA specialist. In order to amend the manual with the passage of time, the manual was reviewed internally at EXAT in 2004 and 2006 and later with the cooperation of AIT (Asia Institute of Technology). In reality theory has taken priority and these amendments have not been directly reflected in maintenance practice.
- The accumulation of inspection data has progressed, but there is no prioritization system for repairs for properly implementing the budget and it is considered necessary to develop these systems.
- In Japan where there are many earthquakes, it is likely that a management method has been well thought out for emergent conditions such as the partial destruction of the bridges making up the road network and Dr. Sakda desires assistance in this area.
- Dr. Sakda would like to be informed regarding the most updated information on methods of repair and reinforcement and materials. He is thinking of dispatching maintenance personnel to Japan and requesting technical instruction as a part of human resource development.

(2) DOH

December 2, 2010, Mr. Chusak, Director of the Bureau of Planning, others

- DOH belongs to a central government under the jurisdiction of the Ministry of Transport building highways between major cities. The purpose of this department is highway management.
- DOH is organized into the following 4 bureaus and the Bridge Construction and Maintenance Bureau is in charge of the new construction and maintenance of bridges.
  - Planning
  - Survey and Design
  - Bridge Construction and Maintenance
  - Research and Development
- DOH manages 5 of the bridges across the Chao Phraya River. These bridges are the Pathum Thani Bridge (PC box girder bridge, 1984), 2nd Pathum Thani Bridge(PC box girder Bridge, 2009), Nonthaburi Bridge (Steel truss bridge, 1959), Phra Nang Klao Bridge (PC box girder Bridge, 1985) and the New Phra Nang Klao Bridge(PC box girder Bridge, 2009).
- The Bridge Maintenance Management System (BMMS) has been improved many times in the past. Mr. Chusak has heard that it was also improved 4 or 5 years ago. Consultants and universities supported these improvements. Mr. Chusak has allocated 16 million B for this fiscal year to contract with a consultant for further improvements. Instead of requesting help from JICA, Mr. Chusak is determined to implement improvements independently. (The bureau of Bridge Construction and Maintenance is in charge.)
- Mr. Chusak wishes to request an inspection of the Nonthaburi Bridge by JICA and has submitted a request. Thereafter DOH has not canceled this request.

(3) BMA

November 30, 2010, Mr. Tawatchai, Chief of Highway Engineering, others

- BMA is under the jurisdiction of the Department of the Interior and is a local government that manages the Rama 8 amongst the bridges across the Chao Phraya.
- The BMA plans the construction of 4 bridges next year. All of these bridges are planned for the purpose of alleviating traffic congestion and are 4 lanes or more (2 or more lanes per side). However, local residents prefer to avoid the construction of a large-scale bridge and it is possible that ultimately the bridge may be a 2 lane (1 lane per side) bridge or a pedestrian bridge. In each of these projects the consultant is responsible for preparing the necessary documents for bidding.
- The construction sites of the 4 bridges are as follows.
  - Kieak Guy (Bang sue district) next to the new parliament building (Between the Rama 7 and the Krung Thon)
  - Ratchawong (near china town, between Phra Pokklao and Taksin)
  - Lardyha (Between Phra Pokklao and Taksin)
  - Thanon Jan (Between Taksin and Rama 3)

The plan for the approach roads for the above bridges on the Bangkok side and the Thonburi side is to use existing roads. A possible reason for this is that it is difficult to purchase land to be used for public projects within Bangkok city.

- The bridge maintenance of BMA is executed by the Road Construction Division, a subsidiary organization of the Public Civil Works Bureau. The primary task of this organization is the maintenance of roads and bridge maintenance is thought of as a special case. While this organization and ask daily operation, when a problem occurs an investigation is requested from a university or consultant.

This is significantly different from DOH or DRR.

6.3 Interviews of research institutes

An interview was conducted with academic experts in Thailand regarding the current condition and issues for maintenance and the direction of improvement efforts for bridges managed by DRR.
The academic experts that cooperated with the interview and their universities are as follows.

- Chulalongkorn University, Faculty of Engineering / Wisanu, Ph. D. and Tospol, Ph. D.
- Srinakharinwriot University, Department of Engineering / Wasan, D. Eng.

6.3.1 An interview with academic experts from Chulalongkorn University

October 13, 2010

(1) Current condition and issues for maintenance

- The management of bridges across the Chao Phraya River is relatively easy because there are few of these bridges and there are enough technicians.
- They say that there are more than 7,000 bridges in rural regions, but the maintenance of basic information such as bridge specifications is insufficient. Even in the daily work of management, it is necessary to obtain basic information from the region and correct it into working condition.
- We set up BMMS. The problem is that the information has not been gathered.
- The manager of BMMS retired early and there are not any personnel at DRR that can take leadership and manage this.
- In rural areas there are few engineers (approximately 2 per prefecture), and technicians visit the bridges site to check them. The checks of the bridges are primarily of the bridge surface and it is likely that they probably are not checking as far as the rear surfaces of the bridge.
- Rural managers are only providing information for bridges that have been damaged. Information collecting is not mandatory and because there is no incentive for it, it is difficult to get updated information for bridges that are not damaged.
- If the BMMS information is not input, under the system bridge maintenance related budgets will not be allocated. Because of this, if the rural manager does not input the information, only the ordinary maintenance amount of around 50,000 B/km (roads, bridges) is allocated.
- The greatest issue is that basic information is delayed.

(2) Current condition for inspection training course, etc. in Thailand

- Chulalongkorn University has given only one training for each region (North, Northeast, South and Central regions).
- The training is not offered periodically.

(3) Improvement of maintenance

- In order to practice sufficient maintenance, it is necessary to screen the basic information of more than 7,000 bridges being managed and either decrease the number of bridges being managed or respond by increasing the budget. These are the only two methods. However, because the latter is not realistic, it is necessary to make BMMS work.
- It is also a problem in attempting to do appropriate maintenance if there is not enough evidence when requesting a budget (documents explaining the need for maintenance costs; documents showing the damage to the bridge). If BMMS is operating properly, this problem will be solved.
- After obtaining basic information, it is necessary to reflect the results in BMMS and improve the accuracy of BMMS.
- It is difficult to achieve preventative maintenance without BMMS.

6.3.2 An interview with academic experts from Srinakharinwirot University

October 21, 2010

(1) Background of repair manual and its utilization situation

- After receiving a request from the research division at DRR we investigated 80 bridges and summarized the results in a maintenance manual.
- The degree of damage for rural bridges is evaluated according to 4 levels and divided into 3 types of damage and has been simplified for the rural areas.
- (Regarding the background of why the maintenance manual was desired) previously, absolutely no care was being taken to detect damage and the reason we made this manual was an increase in awareness of the need to make progress towards countermeasures.
- This manual is being utilized in training. The professor Wasan is working as the instructor in this training. Training is often requested by a bridge manager when a bridge is discovered with remarkable damage.
- We revised the maintenance manual so that it would be easy for rural workers who did not have a high level of construction techniques to do the work.

(2) Relation between repair manual and BMMS and problems

- It is likely that BMMS was not a system that covered all the way from evaluating the damage, selecting the repair to respond to the damage until calculating the budget. A system is necessary which can calculate the budget by simply inputting the condition of the damage.

(3) Issues on the management of the rural bridges

- We are managing more than 7000 bridges. If I assume that around half of those bridges are damaged, and I estimate a cost of around 500,000 B in costs for the repairs to 1 bridge, then the total base cost is 2 billion B, and a massive budget is required. The urgent issue is how do we obtain these budgets and move forward with repairs.
- Inspections also present an appropriate cost burden and more importantly, inspecting all of the bridges is a very large amount of work. That is why I think that the only realistic method is to subcontract these tasks.However, because there is a lack of technicians who have inspection skills (including DRR and subcontractors), in the future it is necessary to develop them through training.
- In many bridges in Thailand, bearings have not been installed or very thin bearings are installed and the number of cases stands out in which the impact from vehicles has caused shearing cracks in the superstructure at the front side of the bridge. I strongly feel the need to move forward on research into this problem.

(4) Requests to JICA

- It is desired experienced Japanese engineers to be dispatched to inspection training.

(5) Countermeasure to chloride damages

- As the manual was created, the materials which were available on site were used and no materials compatible to chloride damage were used.

(6) Organization of DRR

- DRR has not placed personnel with technical skills and knowledge in the appropriate positions. It seems improvement may be needed.

6.4 Proposals for the basic plan for the Bridge Maintenance Management System (BMMS)

DRR has developed BMMS (Bridge Maintenance Management System) to support an efficient long-term maintenance of bridges. This system aims at the prioritizing of the repair based on various basic data such as bridge inspection results, environmental conditions around bridge sites, etc. so that the bridges will be repaired in order of priority within the limited budget. It is desired its practical application to the rural bridges with a full operation.
However, there are many internal issues in BMMS and in reality the system is not fully operational. It is necessary to improve the safety of rural bridges which continue to deteriorate by overcoming these issues to improve the system and make progress towards efforts to do bridge maintenance that is planned and is focused on preventative maintenance.
The following are issues and improvement strategies for BMMS.

6.4.1 Issues on BMMS

The person in charge of BMMS at DRR are Professor Wisanu of Chulalongkorn University, who was involved in the development of BMMS and Professor Wasan from Srinakharinwirot University who developed together with DRR to develop the repair manual and is working vigorously on activities aiming to disseminate bridge maintenance in rural areas. Incorporating the results of the interviews to them, the issues facing BMMS are shown as the follows:

(1) Technical issues on the system

a) The management levels are not clear.
It is not clear which maintenance levels should be maintained for the healthiness of the bridge. In other words, because the maintenance goals appropriate for each bridge's characteristics are unclear, it is difficult to efficiently manage the massive number of bridges.

b) The predicting method for deterioration has not been established.
In the BMMS manual, there is a method of predicting deterioration using a theoretical formula based on the results of concrete tests (salt content, carbonation tests). However, it is not incorporated into BMMS itself as a technical element as a part of production leveling. When using the theoretical formula to predict deterioration, it is necessary to do the test to all bridges in order to understand the change in degree of damage. It is not realistic to do this test to all of the many bridges being managed while in reality there is a lack of technicians and budget.

c) The method of prioritization is complex.
The concept of prioritization in the BMMS includes a general classification according to indexes such as load resistance performance, safety and usability, and environmental

performance and then evaluating based on the total value including further detailed evaluation items. These indexes require a great deal of basic data including not only the bridge inventory data and inspection results, but also surrounding environmental conditions, etc. Because of this, prioritization is complex and while currently not even inspection data is being compiled, it is difficult to say that this system is practical.

d) The concept of budget equalization has not been incorporated.
It is difficult to implement countermeasures with the appropriate timing in consideration of the characteristics of the bridges being managed because the budget equalization has not been incorporated to respond to budget limitations. When budget limitations make it impossible to implement countermeasures, or in other words, when countermeasures are delayed, because it is impossible to track the deteriorating healthiness of the bridge over time, it is difficult to quantitatively describe the risk of delay.

5) Currently the documentation being output does not explain the appropriateness of the costs needed for maintenance.
Documentation (output) that explains why requested budget figures are appropriate is necessary in order to negotiate the budget with the Ministry of finance when seeking a budget for maintenance. In the current BMMS, maintenance costs continue to pileup every fiscal year. It is difficult to explain the appropriateness of the costs required for maintenance because the risk presented if maintenance fees are insufficient or figures for bridge health that could be achieved for each investment pattern are not being output.

(2) Issues on basic data accumulation

The most important reason that BMMS is not functioning properly is because the basic data such as inspection results from rural bridges is not being accumulated. Issues on basic data accumulation include the following:

a) Deficiency of engineers
In rural areas, there is an overwhelming lack of engineers (aproximate 2 per prefecture) compared to the number of bridges being managed. This makes it difficult to propose a maintenance plan focused on preventative maintenance because it is impossible to obtain information on bridges that are not visibly damaged.

b) The inspection results are not automatically incorporated into the system.
Technicians at rural offices use a simplified inspection sheet because it is difficult for them to create complex inspection sheets because they lack knowledge and experience related to maintenance plans. Instead, a person specialized in inputting these inspection results are inputting them into the system because the simplified inspection sheets cannot be automatically