Planning Committee
Meeting Agenda

28th June, 2016

Time	Topic
08:30-09:00	Registration
09:00-09:10	Welcome Address by ADG(CD) Mr. B.V.D.N. CHANDRASIRI
09:10-09:25	Proposal of Planning Committee Mr. Shuntaro KAWAHARA JICA Head Quarters/ Senior Representative
09:25-09:40	Opinion of PC from RDA WG Mr. B.V.D.N. CHANDRASIRI RDA/ ADG(CD)
09:40-09:55	Current issues on Bridge Maintenance in RDA Mr. Hideaki TAKAURA JICA Project Team/ Team Leader
09:55-10:15	Topics to be Discussed in Planning Committee Mr. Kazuya URANO JICA Project Team/ Deputy Team Leader
10:15-10:20	Agreed on PC schedule Mr. Hideaki TAKAURA JICA Project Team/ Team Leader
10:20-10:55	Discussion
10:55-11:00	Next program of PC Mr. Hideaki TAKAURA JICA Project Team/ Team Leader
11:00-11:15	Closing Remarks Mr. L.S. PREMATHILAKE RDA/ Director(ES)

Issues on Current Bridge Management in RDA

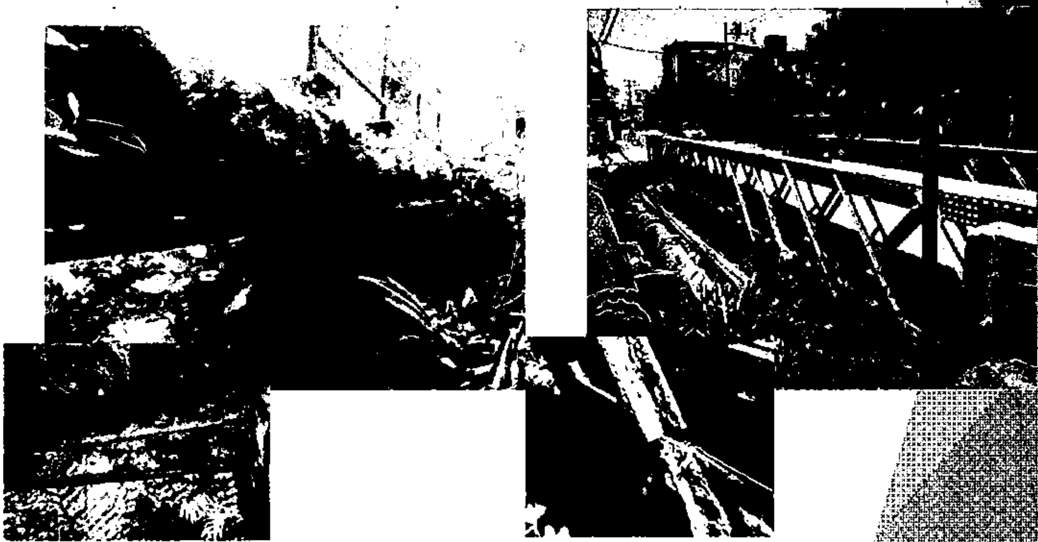
JICA Project Team:
Hideaki TAKAURA

1. Outline and Features of National Highway Bridges in RDA

- 4,800 bridges (A,B Roads)
- Structure type, Length, Construction Year— Now inspecting!
- Features : RC bridges -50%,short span bridge is majority (Bridge length more than 30m is 510 (11%)
- Typical damages:
  - ✓ Coastal area: Salt Attack
  - ✓ Inland area: Neutralization of RC bridge
  - ✓ Steel bridge : Corrosion of members and section loss of members are observed.
  - ✓ Bridge Surface: Damages of Pavement, Handrail, Expansion joint

Sample of Inspected Bridges-1

- Steel Bridge
- **Evaluation D** : Section loss of main beam, Separation of truss members



Sample of Inspected Bridges-2

- RC bridge
- **Evaluation D** : Damage by salt attack near coastal area

2. Present Status of Bridge Maintenance and Management

- Measures only for bridge surface, not seeing the un
  bridges. Thus finding of critical damages is delayed a
  bridges should be reconstructed
- Specialized bridge Engineers are not engaged to mai
  work
- Inspection record is not properly recorded. Actual condi
  bridges is not shown in the records
- Inspection record is not reliable, unable to use for plannin
- Proper repair work is not carried out
- Reconstruction is done based on foreign Donor funds

3. Bridge Maintenance and condition of Bridges

- Numbers of categorized damaged bridges
  - A: No damage, slight damage and no further action is required
  - B: Repair is necessary depends on conditions
  - C: Early repair work is necessary
  - D: Exchange of members ,repair, reinforcement, reconstruction is needed
- Lack of budget?
- Low implementation of budget, Allocation of budget is delayed?

Within limited budget, considering features of bridges and find ou
best solution for Bridge Management Plan

4. Current Status and problems of Bridge maintenance and management in RDA

Output-1 policy,Plan

Policy

Current Status

- There are no systems or plans on bridge maintenance.
- No descriptions of Bridge Maintenance on National Road Master Plan at RDA
- Maintenance level (Relation of health index to measures are not setup)
- Budget allocation is based on new construction of Bridges
- Usage of bridges till they are dilapidated and reconstructed.

Issues

- Definition of Prioritization of bridges

Plan

Current Status

- Short term repair plan is not established.
- Middle/long term repair plan is not established..

Issues

- Bridge repair plan (Draft) should be established based on feasible maintenance level of bridges.
- Establish BMS as support tool to make repair plan.
- Prioritization of reconstruction of bridges, including Reconstruction/Major repair/Minor repair

Not only New construction, Maintenance

Budget

Current Status

- Bridge maintenance budget is not calculated scientifically.
- Inspection result is not accurate and not reliable, cannot utilize for budget drafting.
- Implemented budget for bridge maintenance is not clearly categorized.

Issues

- Capacity development of RDA staff in charge of bridge maintenance to get reliable inspection data.
- Implementation amount of bridge maintenance should be clarified.
- BMS should support planning of Bridge Management

Maintenance Procedure

Current Status

- No documentation of procedure of bridge maintenance
- No bridge inspection plan.

Issues

- Document of bridge maintenance procedure should be prepared.

5. Current Status and Issues of Institutional framework and role of RDA

Output 2 Instisutional framework of Bridge Management

Maintenance work items

- Inspection plan
- Inspection work
- Feedback from inspection
- Database maintenance
- Diagnosis of bridge
- Prioritization of measures
- Preparation of bridge repair plan
- Budget request
- Budget allocation
- Alternation / increase of budget category
- Budget implementation
- Repair Design
- Implementation of repair work
- Payment
- Routine Inspection
- Minor Repair
- Reconstruction
- Inspection plan

Feedback from Inspection

- Feedback Confirmation of inspection result is not carried out

Prioritization of Measures

- Planning Division collects all the inspection data, prioritization not done.

Budget Request

- Based on bridge repair plan, EE office submits request to MM&C Director and Director of Planning through CE, PD Office.

Budget Implementation

- The maintenance work by direct labor is possible to be implemented within the budget of the EE office by their own decision.

Relating Organization for Bridge Management

Relating Divisions	Planning Div.	Engineering Service Div.	MM&C Div.
Basic Function	Budgeting	Bridge Design	Management of road and bridges by local [illegible] in 9 Provinces
Work Infrastructure	Support for BM&AU	BM&AU Head Office	BM&AU Provincial office in PD
		• Arrangement of staff • Maintenance of BMS • Budgeting • Maintenance plan	• Bridge Maintenance Work
Issues to be discussed	• Support from Plannning to BM&AU • Maintenance Plan • Financial Resources	• ES administrate BM&AU Head office • Function of BM&AU Head office • Role and responsibility:BM&AU Head offic • Estimation of budget request	• BM&AU Provincial office are located in PD • Role and responsbility: MM&C and BM&AU • Inspection/repair work of BM&AU Provincial office • Role and responsbility of EE offics • Repair work: Direct labour or Contract to outsorced • Repair work : Collabolarion with RBCU,having repair of steel bridge • Continuous human develpoment plan Appointment of staff and training

Direction of Future Bridge Maintenance and Management of RDA?

Bridge Management Strategy / Plan (Output 1) & Institutional Framework (Output 2)
** Planning Committee Activities **

THE PROJECT
FOR CAPACITY DEVELOPMENT
ON BRIDGE MANAGEMENT

Kazuya URANO

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Activities at Planning Committee (PC) Meeting

Briefing

- Outlines of Bridge Management Strategy
- Directions to Future Bridge Management in Sri Lanka
- Elemental Technologies on Bridge Management

Themes to be Discussed

- Development of Short Term Bridge Repair Plan
- Institutional Framework
- Bridge Management Strategy

Reference

- Further Bridge Management Image

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Outlines of Bridge Management Strategy

- Bridge management strategy should be developed based on the short-term bridge repair plan and middle / long term investment plan.

ge Management Strat

hort Term Bridge Repair Pla

- It is the plan to repair / strengthen / reconstruct the bridges under management within the limited budget.
- It is to assess the current condition of individual bridge, and to plan the specific measures to be taken, timing and priority for bridges.

▽

Plan of Action for Bridge Management

- **Plan of action** to efficiently ensure the soundness and safety of bridges within limited budget.

dle / Long Term Investment

- It is the investment plan for maintenance / management of bridges under management.
- It is to estimate the future necessary investment and trend of bridge conditions, and to plan the budget increase / decrease, budget allocation to provinces, directions to future bridge management.

▽

Plan of Action for Financial Management

- **Plan of action** to optimize the necessary costs of bridge maintenance under specific bridge management level.

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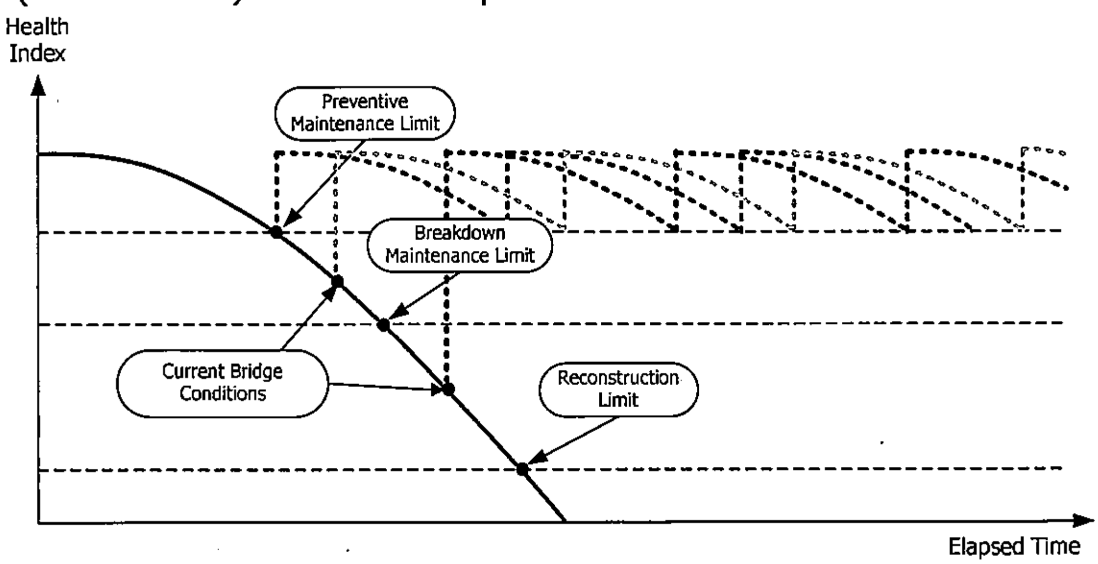
- Bridge management / maintenance costs:
  Preventive < Reactive (Breakdown) < Reconstruction
- Cyclic preventive maintenance is preferred (future target).
- What you should do is to recover the damaged / deteriorated bridges above preventive maintenance limit, if the current bridge soundness (health index) is lower than preventive maintenance limit.



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Directions to Future Bridge Management in Sri Lanka

- In future, you should go towards the preventive maintenance; however, because you still have many seriously deteriorated bridges, before starting the preventive maintenance management, **you should work for major / minor repairs for bridges under preventive maintenance limit.**
- In this Project, it is to develop the **Short Term Bridge Repair Plan** (middle / long term investment plan NOT developed).
  - → Inspect bridges and record the results accurately and fully.
  - → From the results, quantify the soundness of each bridge member as well as soundness of entire bridge (health index).
  - → Quantify the importance of bridge (importance factor).
  - → Quantify the order of relative priority of bridges for taking measures (prioritization).
  - → Simulate the bridge maintenance costs for the coming 5 years, for example, for several options of bridge management level, and study the feasible option.
  - → Develop the short term bridge repair plan.

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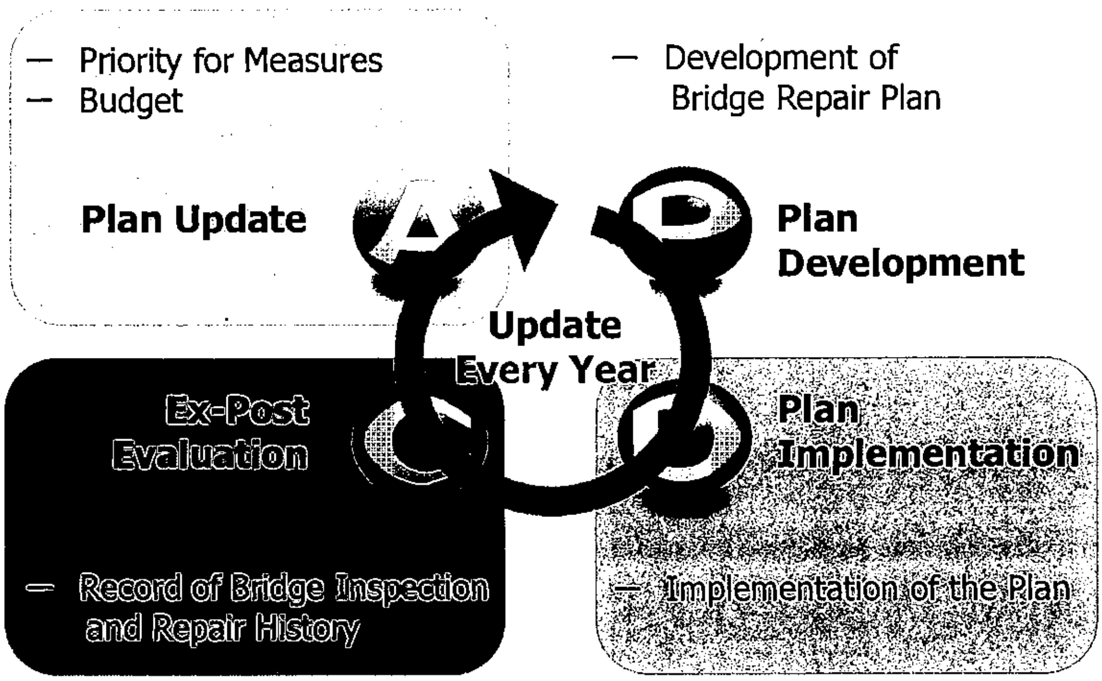
- PDCA for Short Term Bridge Repair Plan



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Elemental Technologies on Bridge Management

Elemental technologies on bridge management are as follows:

- Quantification of bridge inspection results (soundness): **Health Index (HI)**
- Quantification of importance of bridge: **Importance Factor**
- Quantification of the order of relative priority of bridges for taking measures: **Prioritization**
- Study of the **Bridge Management Level**
- Development of **Short Term Bridge Repair Plan**

As a Road Administrator, RDA needs to well understand these elemental technologies.

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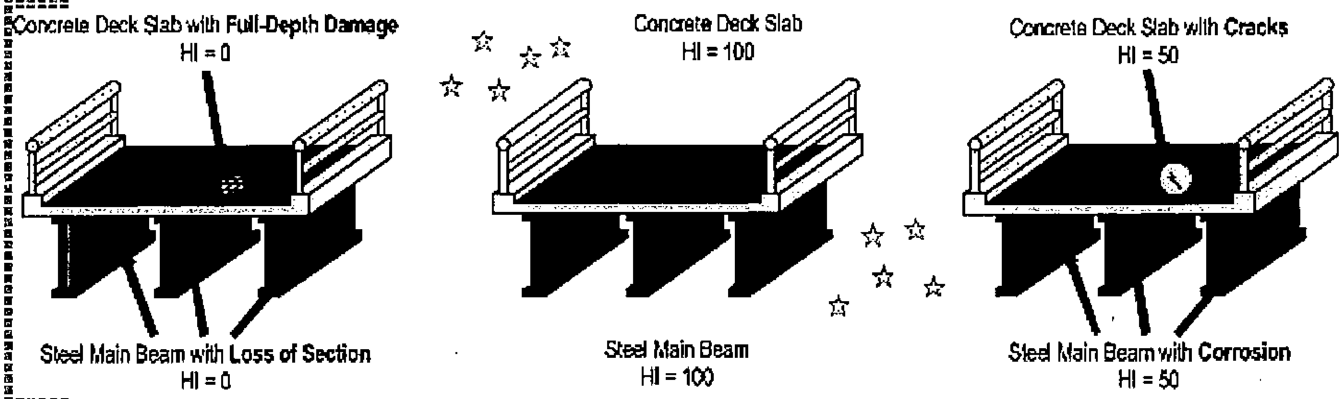
(1) Quantification of Bridge Inspection Results: Health Index (HI)

Condition of each bridge member and entire bridge are quantified based on the degree / extent of defects / damage / deterioration and effects to the bridge functions

HI =100 → Without any defects / damage, bridge member exhibits its functions sufficiently.

HI = 0 → With degradation of load carrying capacity and durability, bridge member lost its functions

→ State of HI =0 should be defined for each member



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(2) Quantification of Bridge Conditions (Evaluation Criteria)

For example, evaluation criteria of concrete bridge superstructure.

Level 1	Level 2	Level 3	Level 4
Bridge Structure (Concrete)	Superstructure	Main Girder	Spall / Exposed Steel
			Cracks
			Damage on Anchorage
		Deck Slab	Spall / Exposed Steel
			Cracks
		Diaphragm	Spall / Exposed Steel
			Cracks
	Substructure		Scour
			Spall / Exposed Steel
			Crack
			Dirt Deposition, Vegetation

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(3) Quantification of Importance of Bridge (Evaluation Criteria)

For examples, evaluation criteria for importance of bridge

Level 1	Level 2	Level 3	Points of View
Effects due to Closure to Traffic	At normal times	Traffic Volume	Heavy traffic
		Traffic Conditions	Heavy vehicles, bus route
	At disaster times	Roadside Conditions	Densely inhabited districts
		Emergency Transportation Route	Secure the transportation route at disaster times for emergency
		Detour	With or without detour
	Effects to the Public	Landscape	Nice view to the public
		Historically Valuable	Historically valuable bridges
Effects due to Collapse	Crossings		Adverse effects to roads / rails
	Utilities Attached		Gas, electric line or water pipe
Efficiency	Ease of Measures		Ease of land acquisition
	Costs of Measures		Costs for repair / reconstruction

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(4) Quantification of Priority for Measures (several options)

- ✓ Comprehensively determine from the health index and importance factor

$$\text{Priority} = \alpha \times \text{Health Index (HI)} + \beta \times \text{Importance Factor}$$

- ✓ Determine only from the health index
- ✓ Others

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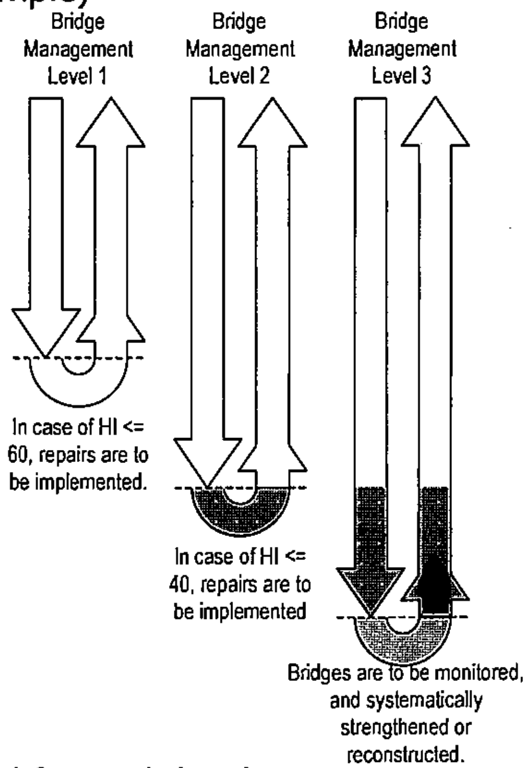
(5) Bridge Management Level (for example)

Health Index (HI)	Condition of Members
80 < HI <= 100	- Sound Conditions - No measure is required at present
60 < HI <= 80	- Slightly damaged / deteriorated - Periodical inspection is needed. - Repairs are to be implemented as needed.
40 < HI <= 60	- Defects / damage/ deterioration are identified. - Repairs are to be implemented from preventive maintenance perspective.
20 < HI <= 40	- Defects / damage/ deterioration are identified. - Repairs are to be implemented.
0 <= HI <= 20	- Considerable defects / damage / deterioration are identified. - Large scale of strengthening/ repair are to be implemented.



Bridge maintenance cost will be estimated for each level.

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Development of Short Term Bridge Repair Plan

- Feasible Bridge Management Level?
  - ✓ RDA Budget on Bridge Management and Maintenance
    - → Foreign fund (reconstruction)
    - → Maintenance of Roads & Bridges (RMTF) for daily bridge maintenance works
    - → Widening & Improvement of Roads
    - → Reconstruction of Damaged / Weak Bridges for major bridge repairs, strengthening and reconstruction
    - → New budget item (vote) for minor **bridge** repair?
    - → New financial resources?
- Bridge Repair Plan for 5 Years will include:
  - ✓ Bridge inspection / diagnosis plan (target bridges, time schedule)
  - ✓ Bridge maintenance work plan (what to do, time schedule)
  - ✓ List of bridges for reconstruction (target bridges, costs)
  - ✓ List of bridges for major / minor repairs (target bridges, what to do, time schedule, costs)

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Institutional Framework

- Bridge management procedures (reporting and approval process included)
- Bridge inspection system (inspection plan, implementation, confirmation)
- Bridge diagnosis and evaluation system (review and adjustment by the head office)?
- Bridge maintenance works, minor repairs, major repairs, strengthening and reconstruction, using force accounts or outsourcing?
- Tools, machinery and equipment to be procured / managed
  - ✓ Bridge inspection tools / equipment
  - ✓ Bridge maintenance work machinery / equipment
  - ✓ Machinery / equipment for minor repairs
  - ✓ Machinery / equipment for major repairs

- Scale of Organization?
  - ✓ Large scale organization, using force accounts
  - ✓ Small scale organization, using outsourcing
- Necessary Human Resources?
  - ✓ Professionals in a wide variety of fields, including engineering, project management and organization operation, using force accounts
  - ✓ Professionals in the limited fields, such as project management and organization operation, using outsourcing
- Organization Structure and Allocation of Personnel?
- Roles and Responsibilities for each Division / Unit and Personnel?
- Necessary budget, including the administration costs?

Contents of Bridge Management Strategy

- Management level for bridges on national roads?
- Annual investment for bridge management?
- How many bridges are to be reconstructed annually? → reduce the number of seriously damaged / deteriorated (dangerous) bridges
- How many bridges major repairs are to be implemented annually?
- How many bridges minor repairs are to be implemented annually?
- Budget shift from the "development" to "management and maintenance".
- Human resources development and introduction of license system for professional bridge maintenance expert.

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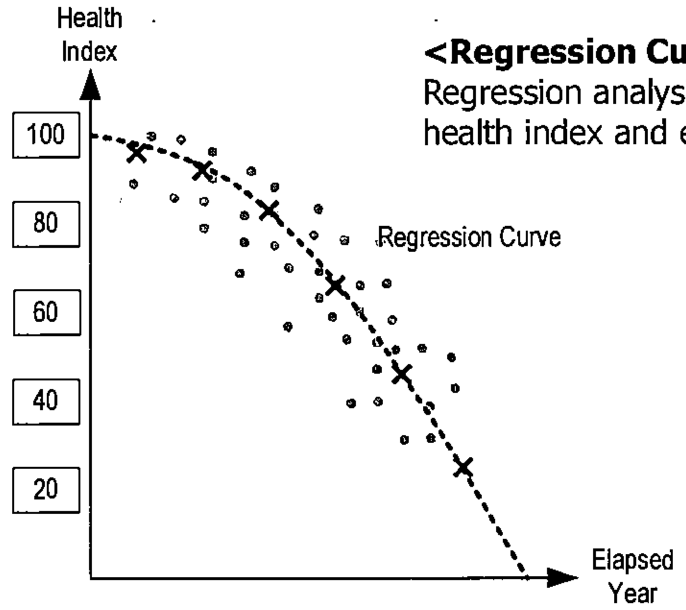
<<Reference>> Further Bridge Management Image

- When you have collected sufficient numbers of bridge inspection data,
  → Possible to predict **future deterioration** for each bridge member
  → Possible to optimize the life cycle costs (LCC) and to predict future bridge conditions (HI) (Middle / Long Term Investment Plan)



<Regression Curve for Each Member>
Regression analysis will be made from the health index and elapsed time period.

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- Middle / Long Term Investment Plan (Future Bridge Conditions)

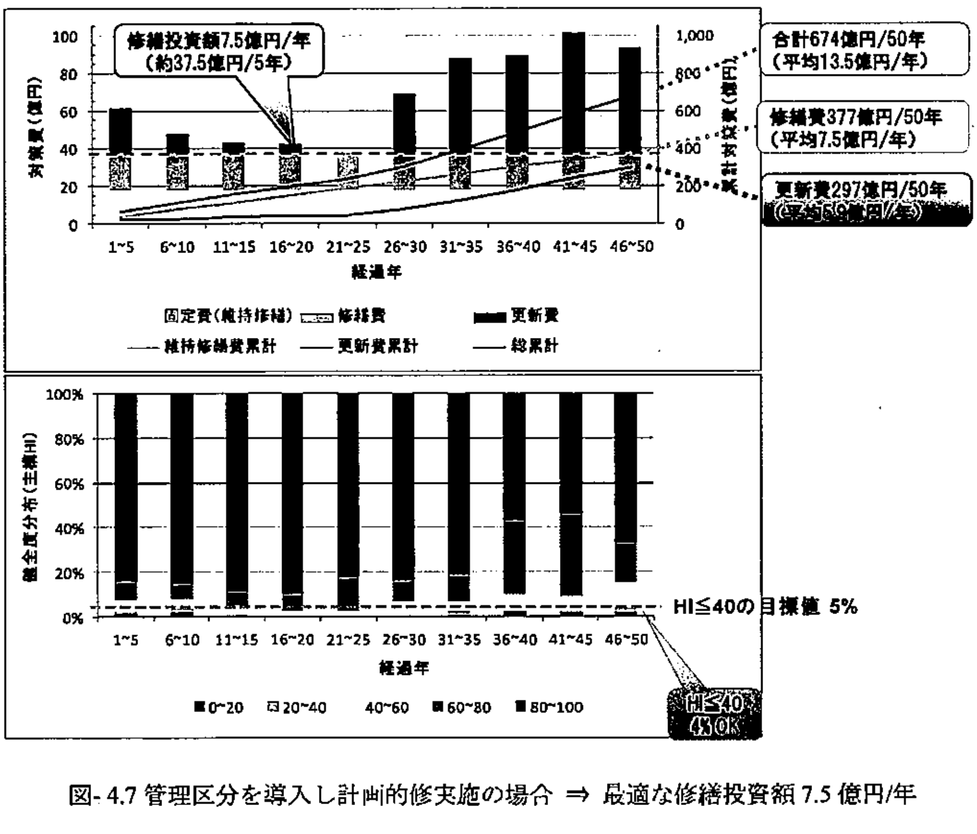


図- 4.7 管理区分を導入し計画的修実施の場合 ⇒ 最適な修繕投資額 7.5 億円/年

Tentative Schedule

PC	Themes	Time
1st PC	• Proposal on Establishment of PC • Mutual understanding of issues on current bridge management • Agreement of tentative schedule and themes	Jun. 2016
2nd PC	• Features of RDA bridges and typical defects / damage / deterioration • Current issues on bridge management and maintenance • Discussion on future image of bridge management and maintenance	Sep. 2016
3rd PC	• Elemental technologies on bridge management • Simulation of bridge management levels • Short Term Bridge Repair Plan (Micro Management)	Nov. 2016
4th PC	• Roles and responsibilities of relevant divisions / units and personnel of RDA related to bridge management	Dec. 2016
5th PC	• Discuss the contents of bridge management strategy	Jan. 2017

PC-2

2nd Planning Committee Meeting Agenda

June 1 2017

TIME	Contents	Presenter
9.00 - 9.05	Welcome address	ADG CD
9.05 - 9.15	Achievement of WS and PC from 2016 to 2017	Mr.H.Takaura
9.15 - 9.25	Remaining topics of WS,PC	Mr.H.Takaura
9.35 - 9.55	Discussion	
9.55 - 10.10	Important issues to be finalized	Mr.H.Takaura
10.10 - 10.20	Discussion	
10.20 - 10.25	Break	
10.25 - 10.40	Draft Budget Plan	Mr.H.Takaura
10.40 - 10.50	Discussion	
10.50 - 10.55	Closing Remarks	ADG CD

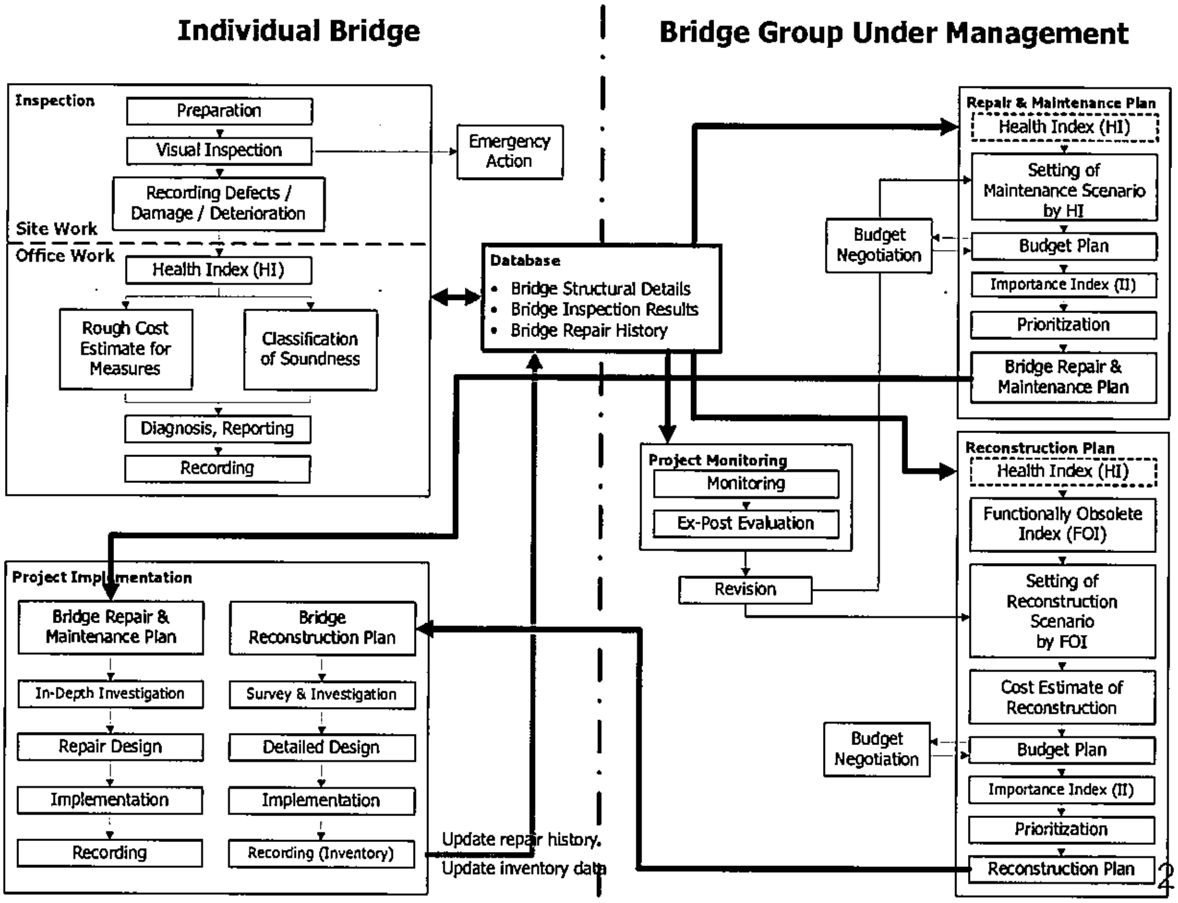
2nd Planning Committee Meeting

JICA Project Team

Hideaki TAKAURA
Kazuya URANO

Contents

1. Flow of Bridge Management



❑ No prediction of future condition (degradation).

❖ Now, RDA does not have sufficient records of bridge conditions. Therefore, degradation curve of future bridge conditions will not be able to develop.

❖ Bridge Repair and Maintenance Plan is developed based on the bride conditions recorded at periodic inspection (no change until the next bridge inspection).

❖ Long- and Middle-Term Bridge Investment Plan (Budget Plan) for 30 to 50 years will NOT be developed.

2. Evaluation of Bridge Conditions

- See the soundness of the bridge members directly.
  - Defects, damage and deterioration are not evaluated. (no detail information recorded)
  - Evaluate the soundness of bridge members directly (ratings are given qualitatively)
- See the damage first, thereafter see the soundness.
  - Evaluate the defect, damage and deterioration (called “damage”) individually. Thereafter give the rating for each damage (objective evaluation)
  - Give soundness classification for each member what measures are needed (qualitative evaluation)

3. Bridge Inspection

- Collect the necessary data and information for the bridge management (not for the bridge repair works), including major and minor damage.
  - Objectively recorded bridge conditions with less variations from person to person
  - Not absolute value, but relative value for comparable
  - Consider not only “extent” (plan area of damage), but also “severity” (depth of damage) → grading of damage (5 grades, or 3 grades, or 2 grades)
  - Consider the extent of damage to the entire bridge member → concept of “**element**” introduced

- **Bridge management** means:
  - → Detect the damage at an earlier stage which may affect to the safety, load carrying capacity and durability of bridges, thereafter take necessary measures.
  - → Prioritize the bridges for efficient and effective bridge management within limited human and financial resources.
- Inspect the bridges visually as close to the bridge structure as possible, supplemented with test hammer, pole camera and/or Bridge Inspection Vehicle (BIV).

- Damage Types in Bridge Inspection & Diagnosis Manual

Bridge Surface		Bridge Structure	
1	Pothole	12	Spall / Dela / Ex-Rebar
2	Pavement Crack	13	Crack
3	Rutting	14	Damage on Anchorage
4	Waving	15	Water Leakage from Exp. Joint
5	Damage on Expansion joint	16	Damage on Bridge Bearing
6	Difference in Levels	17	Scour
7	Damage on Drainage	18	Mud Deposition / Vegetation
8	Damages on Service Duct	19	Paint Degradation
9	Damages on Railing / Parapet	20	Corrosion
10	Settlement of Surface	21	Damage (Rivet / HSFG)
11	Approach Road / River Bank	22	Damage of Deck Slab
		23	Arch Line (Displacement)
		24	Deteriorated (Loose)

- Type of bridge inspection
  - Routine inspection (patrol)
  - Periodic inspection → collection of necessary data for bridge management
  - Emergency inspection
- Frequency of bridge periodic inspection?
- Work team members of bridge periodic inspection?
- Necessary equipment for bridge periodic inspection?

4. Bridge Management Indicator

- Health Index (HI) is used as an indicator.
  - Soundness classification, which is subjectively determined by the inspector / evaluator, may have large variations among the inspectors / evaluators. → not suitable as an indicator
  - Health Index, which is objectively quantified from the types of damage occurred on bridge member, degree of damage thereof and seriousness of such damage to the soundness (weighing factor).
- Health Index (HI) is for a bridge member, a span and an entire bridge.

- Health Index (HI) of a bridge member is calculated as:

$$HI = 100 - \sum_{i=1 \text{ to } n} \underbrace{\boxed{\begin{array}{l}\text{Degree of Damage}\\ \text{5 ratings}\\ \text{(a, b, c, d, e)}\end{array}} \times \boxed{\begin{array}{l}\text{Extent of Damage to}\\ \text{Entire Bridge Member}\\ \text{0 to 100 \%}\end{array}} \times \boxed{\begin{array}{l}\text{Weighing Factor}\\ \text{(Seriousness of damage to}\\ \text{bridge member soundness)}\end{array}}}_{\text{Damage Point (DP)}}$$

i = type of defects, damage and deterioration

- Weighing Factor shall be converted to Correlation Factor, depending on "HI=0" condition.

Example on Steel Main Beam

Among 5 types of damage, only 2 types of damage come to "HI=0" condition.

() : weighing factor

<> : correlation factor

Steel Main Beam
- Paint Degradation (0.09) <0.20>
- Corrosion (0.37) <0.80>
- Damage (Rivet / HSFG) (0.46) <1.00>
- Mud Deposition / Vegetation (0.08) <0.17>
- Others (0.00) <0.00>

Paint Degradation
100% of members are in "e" grade condition

Corrosion
100% of members are in "e" grade condition

Other Type of Damage
100% of members are in "a" grade condition

DP = (0.09 x 100 x 100% + 0.37 x 100 x 100%) x alpha = 100

Alpha = 100 / 46 = 2.17
(0.09) x 2.17 = <0.20>
(0.37) x 2.17 = <0.80>

Paint Degradation

Longitudinal (Start – Center – End); Cross Section (Left – Center – Right)

	Start	Center	End
Left	e	e	e
Center	e	e	e
Right	e	e	e

Corrosion

Longitudinal (Start – Center – End); Cross Section (Left – Center – Right)

	Start	Center	End
Left	e	e	e
Center	e	e	e
Right	e	e	e

Other Types of Damage

Longitudinal (Start – Center – End); Cross Section (Left – Center – Right)

	Start	Center	End
Left	a	a	a
Center	a	a	a
Right	a	a	a

Definition of "HI=0" Condition of Steel Main Beam	Grade of Damage					
	a	b	c	d	e	f
	0	25	50	75	100	
Paint Degradation	0	0	0	0	9	9
Corrosion	0	0	0	0	9	9
Damage (Rivet / HSFG)	9	0	0	0	0	9
Mud Deposition / Vegetation	9	0	0	0	0	9
Others	9	0	0	0	0	9

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- Health Index (HI) of a bridge component is calculated as:

Example on Steel Superstructure

() : weighing factor

<> : correlation factor

Steel Superstructure →
- Main Beam (0.65) <1.00>
- Deck Slab (0.15) <0.23>
- Cross Beam (0.20) <0.31>

Only main beam comes to "HI=0" condition.

(0.65) x alpha = 1.00

Alpha = 1.00 / 0.65 = 1.54
(0.15) x 1.54 = <0.23>
(0.20) x 1.54 = <0.31>

❑ Health Index (HI) of a bridge span is calculated as:

Example on Steel Bridge

() : weighing factor

<> : correlation factor

Steel Bridge (Span) →
- Superstructure (0.67) <1.00>
- Bridge Bearing (0.12) <0.18>
- Substructure (0.21) <0.31>

Only superstructure comes to "HI=0" condition.

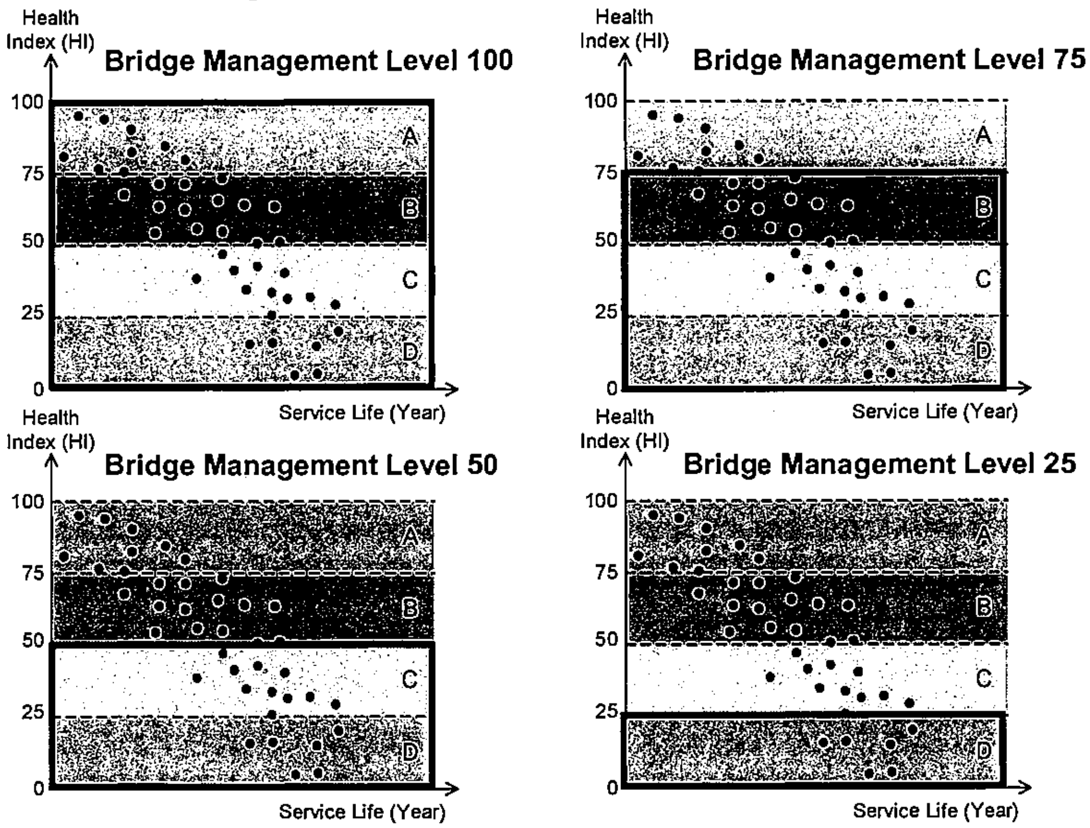
(0.67) x alpha = 1.00

Alpha = 1.00 / 0.67 = 1.49
(0.12) x 1.49 = <0.18>
(0.21) x 1.49 = <0.31>

❑ Health Index (HI) of an entire bridge is the minimum value among those of all the spans of a bridge.

5. Target Bridge Management Level (Repair)

❑ Which management level is used?



6. Soundness Classification

- Soundness of a bridge member / a span / an entire bridge is classified into four (4) categories with reference to the value of Health Index (HI).

- It is noted, however, that values of health index are just for reference in order to prevent the variations in determining the soundness classification from person to person, and that soundness should not be classified only by the value of health index.

Soundness Classification	General Conditions	Health Index
A	Sound	100 – 75
B	Preventive Maintenance Stage	75 – 50
C	Reactive Maintenance Stage	50 – 25
D	Urgent Action Stage	25 - 0

- Threshold values of Health Index (HI) for soundness classification shall be changed to meet the general conditions after RDA collected sufficient number of bridge inspection data and analysed.

7. Bridge Diagnosis

- Soundness classification is determined for a bridge member, a span and an entire bridge from the Health Index (HI) thereof in the system.
- For the selection of bridges (prioritization) for repair and maintenance, highly experienced experts shall review the soundness classification of an entire bridge at the end of periodic inspection in consideration of:
  - Influence of damage other than that specified in the Bridge Inspection & Diagnosis Manual, if any
  - Influence of location of damage to the soundness of an entire bridge
  - Rate of progress of damage (rapid, slow, dormant)

8. Degree of Relative Priority of Repair / Reconstruction

- Degree of relative priority (Priority Point: PP) of bridge repair is calculated as:

  PP of Bridge Repairs = α x (100 – HI) + β x II,

  where, $\alpha = 0.70$, $\beta = 0.30$ ← to be determined by RDA

- Degree of relative priority (Priority Point: PP) of bridge reconstruction is calculated as:

  PP of Bridge Reconstruction

  = α' x (100 – HI) + β' x II + γ' x FOI,

  where, $\alpha' = 0.20$, $\beta' = 0.20$, $\gamma' = 0.60$ ← to be determined by RDA

- **Importance Index (II):** extent of obstruction to surrounding areas when the bridge is out-of-service.

Indicators for Importance Index

- Importance of Providing Access (Region) (0.32)
  - Densely inhabited districts (0.19)
  - Connectivity to important facilities (0.26)
  - Difficulty in restoration (0.30)
  - Isolated villages / towns (0.25)
- Importance of Providing Mobility (Wide Area Network) (0.27)
  - Traffic characteristics (0.28)
  - Detour (0.33)
  - Specific important route (0.39)
- Third Party Effects (0.41)
  - Crossings (0.50)
  - Utilities attached (0.28)
  - Disturbance to water flow at flood times (0.22)

(weighing factor)

- **Functionally Obsolete Index (FOI):** extent of obstruction to surrounding areas due to functional obsolescence.

Indicators for Functionally Obsolete Index

- Structural Details (0.40)
  - Bridge Width (0.40)
  - Alignment / clearance (0.40)
  - Design loading (0.20)
- Nature of Bridge (0.30)
  - Nature of bridge (1.00)
- Resistance to Disaster (0.30)
  - Year-round mobility (0.40)
  - History of disaster (0.60)

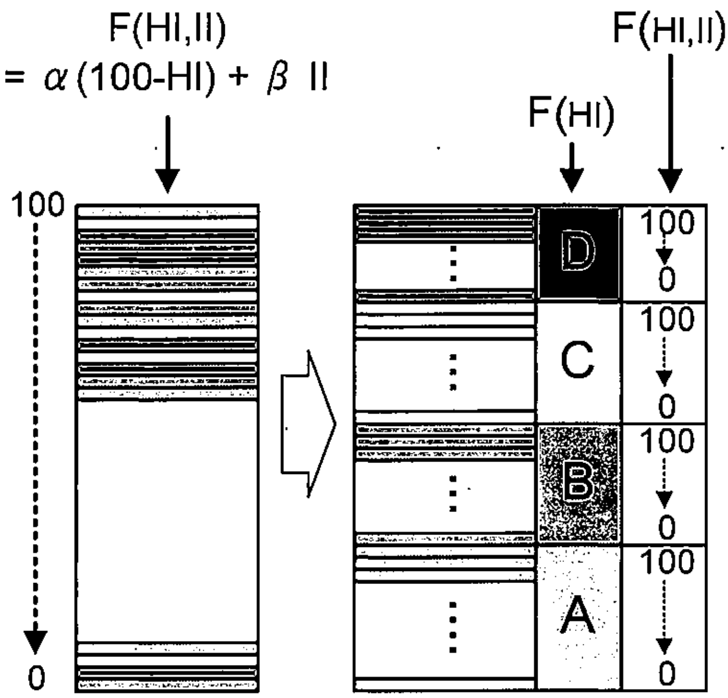
(weighing factor) shall be determined by RDA

❑ Order of relative priority of bridge repairs:

In order to ensure minimum safety, consideration should be given not to omit the bridges with low health indices.

Step-1: order of soundness classification of D → C → B → A

Step-2:
Within each classification, order of PP

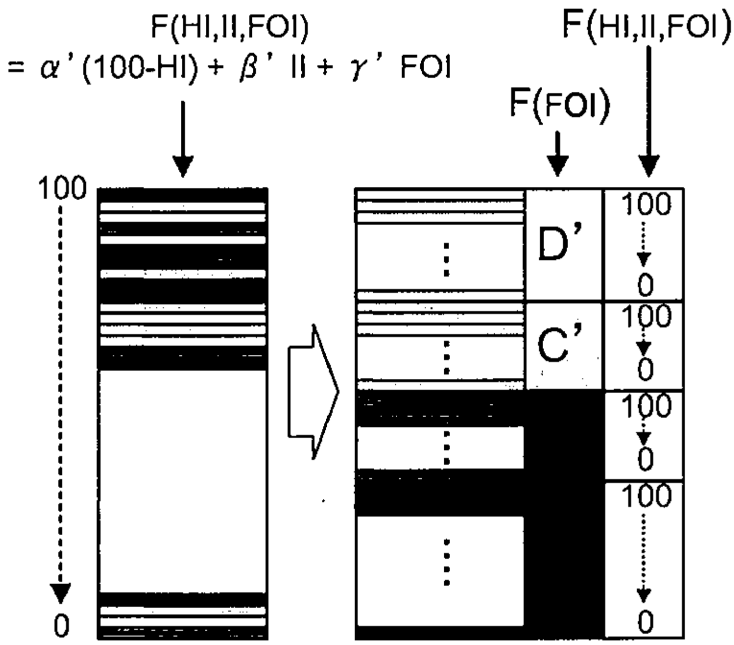


❑ Order of relative priority of bridge reconstruction:

Consideration should be given not to omit the extremely functionally obsolete bridges.

Step-1: order of FO classification of D’ → C’ → B’ → A’

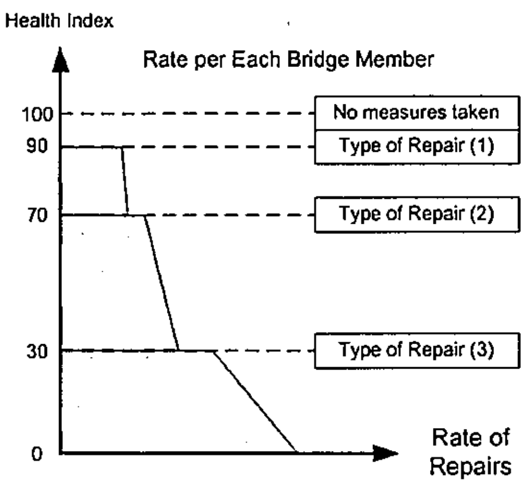
Step-2:
Within each classification, order of PP

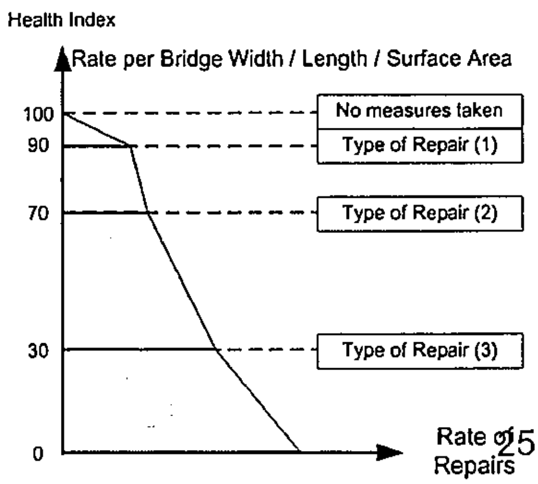


9. Costs of Bridge Repair

- Not all the bridges / bridge members are repaired.
  - Bridges below target management level are repaired.
  - For the selected bridges, only the bridge members below target management level are repaired.
  - Repair cost will vary depending on target management level (Health Index).
- Cost estimate of repairs shall not be based on the quantity of damage recorded at site.
  - We do not know such damage is to be repaired or not at bridge inspection time (it depends on target management level to be determined later).
  - Mechanism of estimating the repair costs depending on Health Index (HI) shall be developed.

- Set up the standard bridge repair unit cost depending on Health Index (HI).
  - Assume the types of damage, extent and severity of each damage, extent of each damage to the entire bridge member, corresponding to HI.
  - Assume the repair method, corresponding to HI.





- Bridge repair costs shall include temporary works, indirect costs, mobilization and demobilization costs.
- Bridge repair costs are for budget preparation; not for works (work order, tendering).
- After the target bridge is selected, in-depth inspection as well as repair design shall be implemented to estimate the bridge repair costs accurately for work order / tendering.

10. Costs of Bridge Reconstruction

- Bridges below target management level are considered for reconstruction, when the budget is available.
- Bridge reconstruction costs shall be based on the typical bridge type commonly used in Sri Lanka
    - A bridge with its length shorter than 10 meters is of RC slab type.
    - A bridge with its length of 10 meters or longer is of pretensioned beam type.
- Reconstruction costs shall include demolition of existing bridge, temporary work, detour with temporary bridge, mobilization and demobilization costs.

11. Bridge Repair / Maintenance & Reconstruction Plan

- ❑ Bridge repair and maintenance plan is the list of bridges in the order of priority, including:
  - ❖ Bridge information
  - ❖ Health index, important index, with breakdown of indices
  - ❖ Repair and maintenance cost
- ❑ Bridge reconstruction plan is the list of bridges in the order of priority, including:
  - ❖ Bridge information
  - ❖ Health index, important index, functionally obsolete index, with breakdown of indices
  - ❖ Reconstruction cost

- ❑ Bridge repair and maintenance plan

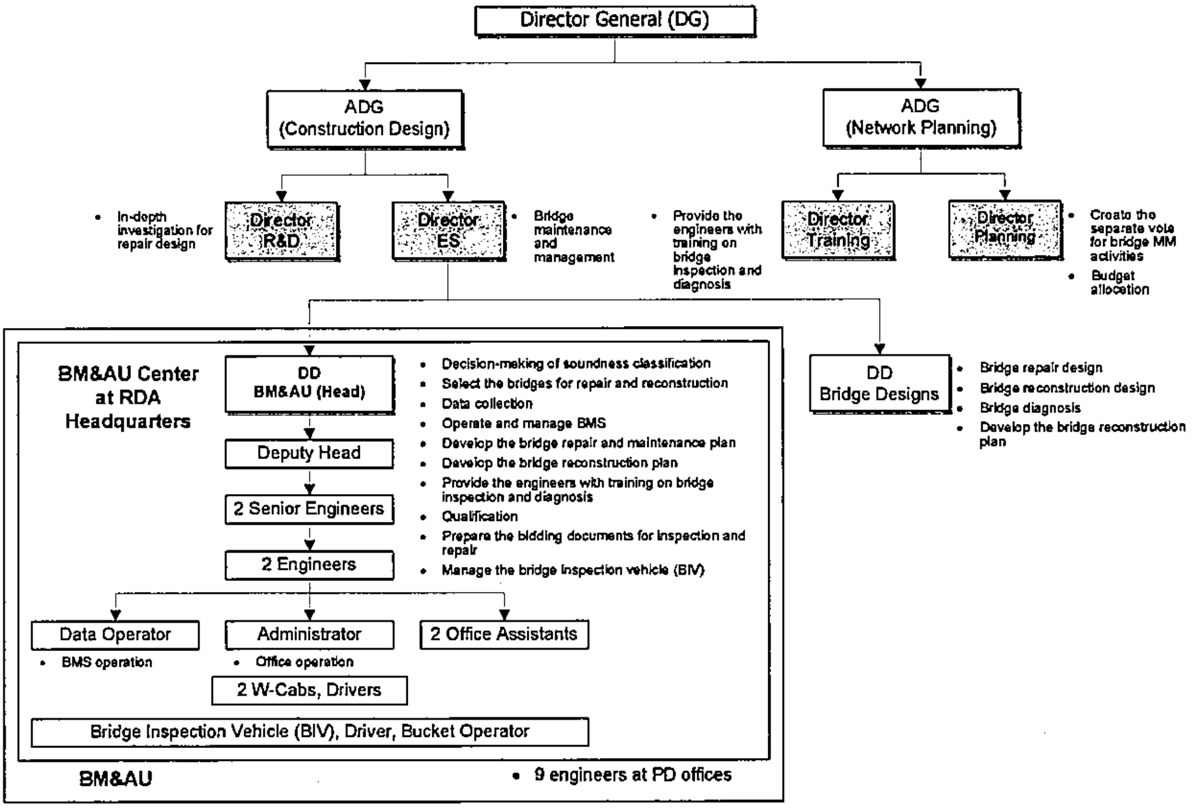
Priority of Bridge Repair	Bridge ID	Bridge No.		Name of Bridge	Health Index of Bridge	Soundness Classification of Bridge	Importance Index	Repair Priority Point	Repair Cost (Unit: 1,000 SL Rupee)				
		km	No.						Bridge	Bridge Surface	Superstructure	Bridge Bearing	Substructure
1	100	14	2		0.0	D	44	83.2	210.1	1.4	76.5	0	132.2
2	801	14	1	BRIDWELL	0.0	D	44	83.2	405	1	315.8	0	88.2
3	296	17	1		0.0	D	37.6	81.3	823.8	17.4	573.9	226.9	5.6
4	120	4	2	Nuga Ela B	0.0	D	37	81.1	521.1	0.4	294	0	226.7
5	797	2	1		0.0	D	35.1	80.5	200.6	0	0	0	200.6
6	823	19	1	Dandugam	0.0	D	34.1	80.2	3664.1	376.6	0	2531.6	755.9
7	1024	11	5		0.0	D	29.3	78.8	299	42	169.3	87.7	0
8	24	53	3		0.0	D	28.6	78.6	1349.4	51.5	19.5	440.5	837.9
9	262	3	3		0.0	D	28.4	78.5	354.6	0.5	178.1	50.4	125.6
10	104	8	1		0.0	D	28.1	78.4	577.6	7.6	345.2	0	224.8
161	1167	4	5		25.4	D	14.7	56.6	188.3	5.5	182.8	0	0
162	1426	23	9		24.0	D	9.5	56.1	557.4	5.4	76	286.6	189.4
163	1254	1	2		25.3	D	7.6	54.6	128.8	15.2	0	12.2	101.4
164	443	92	12		25.3	D	3.8	53.4	268.2	36.9	0	0	231.3
165	208	16	2		25.8	C	42.1	64.6	247.1	41.5	0	127.3	78.3
166	743	32	3		26.8	C	29	59.9	109.1	6.1	0	0	103
167	1309	1	5	Galmulle B	27.5	C	27.7	59.1	259.4	6.2	247.7	0	5.5
168	668	61	5		28.0	C	27.4	58.6	365.2	0	365.2	0	0
169	508	1	1		26.3	C	22.3	58.3	717.1	0.7	680.8	0	35.6
170	226	7	6		25.7	C	20.4	58.1	158.1	6.7	138.5	0	12.9
171	1402	2	2		27.5	C	24.2	58	170.3	0	28.3	0	142
287	1295	42	3		50.0	C	14.7	39.4	52.3	0	0	0	52.3
288	1028	6	4		46.5	C	5.7	39.2	221.6	29.5	8.2	180.7	3.2
289	1140	58	1		49.0	C	11.4	39.1	1245.4	0	744.6	500.8	0
290	66	13	1		48.7	C	7.6	38.2	49.1	0	0	0	49.1
291	47	34	4		49.9	C	5.7	36.8	897.6	124.8	0	764.2	8.6
292	1398	4	3		52.9	B	41.4	45.4	813.8	41.5	661.3	78.8	32.2
293	859	2	1	Palam Thur	50.9	B	29.4	43.2	1002	87.4	78.5	718.5	117.6
294	835	2	1		51.1	B	29	42.9	399.9	41.9	0	342.1	15.9
295	328	2	2	GALA JUN	51.3	B	29	42.8	81.5	21.2	25.9	0	34.4
296	1364	4	4		58.7	B	44	42.1	272.2	20.5	0	226.9	24.8
297	335	1	5		51.0	B	25.5	42	426	59.8	0	366.2	0

❑ Bridge reconstruction plan

Bridge ID	Bridge No.		Name of Bridge	Health Index of Bridge	Soundness Classification of Bridge	Importance Index	Functionally Obsolute Index	FO Classification	Reconstruction Priority Point	Priority of Bridge Reconstruction	Reconstruction Cost	Repair Priority Point	Repair Cost of Bridge
	km	No.											
100	14	2		0.0	D	44.0	16.0	A'	38.4	1	5,852	83.2	210
296	17	1		0.0	D	37.6	16.0	A'	37.1	2	3,574	81.3	824
120	4	2	Nuga Ela B	0.0	D	37.0	16.0	A'	37.0	3	6,747	81.1	521
797	2	1		0.0	D	35.1	16.0	A'	36.6	4	5,016	80.5	201
823	19	1	Dandugam	0.0	D	34.1	16.0	A'	36.4	5	470,728	80.2	3,664
24	53	3		0.0	D	28.6	16.0	A'	35.3	6	65.527	78.6	1.349
262	3	3		0.0	D	28.4	16.0	A'	35.3	7	4,953	78.5	355
104	8	1		0.0	D	28.1	16.0	A'	35.2	8	5,620	78.4	578
535	62	2	Benthara B	0.0	D	28.1	16.0	A'	35.2	9	111,007	78.4	10,656
51	12	1		0.0	D	25.2	16.0	A'	34.6	10	7,644	77.6	604
1230	1	7		0.0	D	24.3	16.0	A'	34.5	11	69,877	77.3	8,290
90	1	5		0.0	D	23.3	16.0	A'	34.3	12	5,242	77.0	138
248	8	1		0.0	D	23.3	16.0	A'	34.3	13	7,900	77.0	1,006
933	11	3	Medagampi	0.0	D	23.3	16.0	A'	34.3	14	6,026	77.0	799
1330	4	6		4.5	D	27.7	16.0	A'	34.2	15	22,698	75.2	376
1282	1	2		0.0	D	22.3	16.0	A'	34.1	16	23,464	76.7	2,774
233	19	2		19.2	D	41.4	16.0	A'	34.0	17	8,470	69.0	240
228	2	2		24.6	D	45.9	16.0	A'	33.9	18	6,970	66.6	119
8	31	1		12.9	D	33.7	16.0	A'	33.8	19	60,140	71.1	717
1302	8	3		0.0	D	21.0	16.0	A'	33.8	20	18,571	76.3	125
801	14	1	BRIDWELL	0.0	D	44.0	8.0	A'	33.6	21	4,752	83.2	405
496	1	4		0.0	D	19.5	16.0	A'	33.5	22	3,036	75.9	496
434	10	5	Talathuoya	0.0	D	18.5	16.0	A'	33.3	23	31,626	75.6	3,710
690	19	1		0.0	D	18.5	16.0	A'	33.3	24	3,689	75.6	375
803	25	6		0.0	D	18.5	16.0	A'	33.3	25	5,544	75.6	394
891	4	11		0.0	D	18.5	16.0	A'	33.3	26	2,869	75.6	372
893	5	7		0.0	D	18.5	16.0	A'	33.3	27	18.371	75.6	989
208	16	2		25.8	C	42.1	16.0	A'	32.9	28	6.336	64.6	247

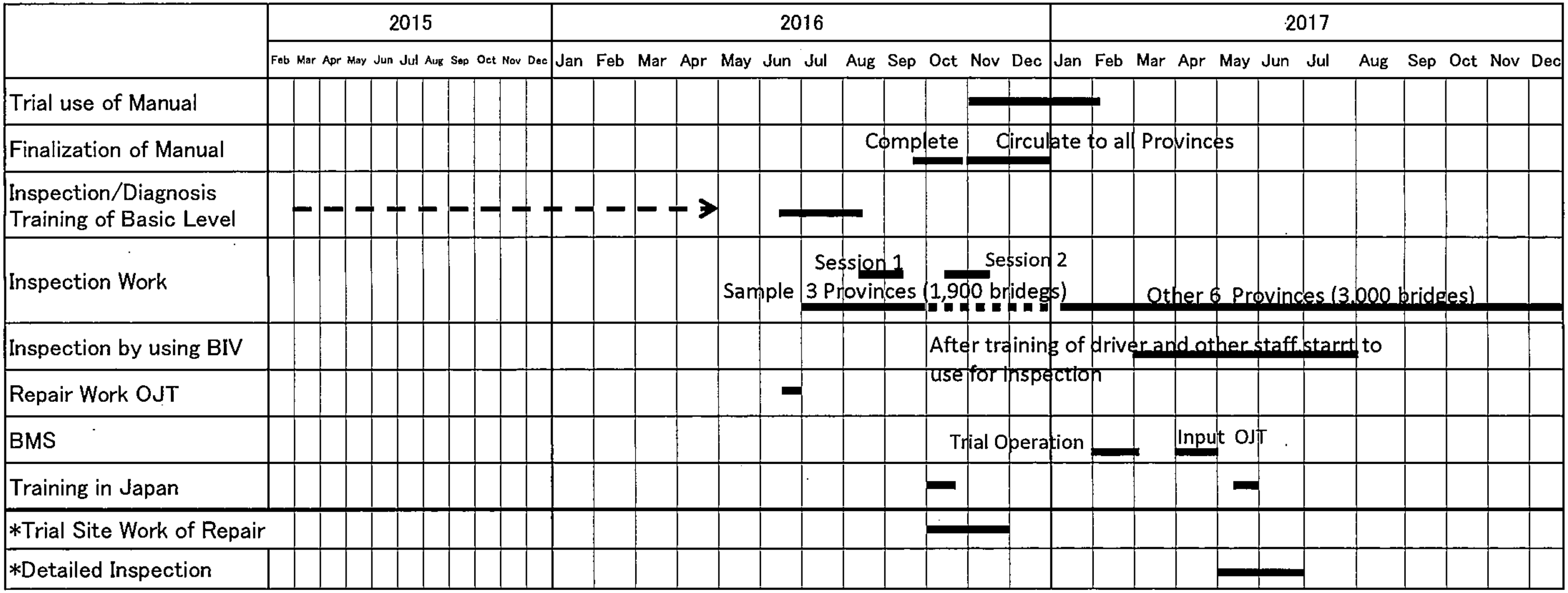
12. Institutional Framework of Bridge Management

❑ Organization of Bridge Management:



BM&AU Activity Plan

06/27 2016



＊ Not yet finalized

PC-3

PC Meeting Agenda

October 17, 2017

No	Time	Topic	Presentation by
1	9.00 - 9.20	RDA Bridge Maintenance Strategy	Ms. R.A.S.K Kaluarachchi (Acting. ADG -CD)
2	9.20 -9.35	Bridge Management Plan	Mr. K.Urano
3	9.35-9.50	Institutional Framework of Bridge Management in RDA	Mr. D.Hajima
4	9.50 -10.00	Progress of Bridge Management Action in RDA	Mr. T. Vasanthakumar (DD/BM&AU)
5	10.00 - 10.10	Human Resource Development Plan	Mr. S. Fernando (D/Training)
6	10.10-10.20	Discussion	
7	10.20 - 10.25	Break	
8	10.25 - 10.35	Progress of Project Activities	Mr. H.Takaura (JICA-PT)
9	10.35 - 10.55	Discussion	
10	10.55-11.00	Closing Remarks	Mr. L. S. Premathilaka (D/ES)

The Project for Capacity Development on Bridge Management

JICA Project Team
Kazuya URANO

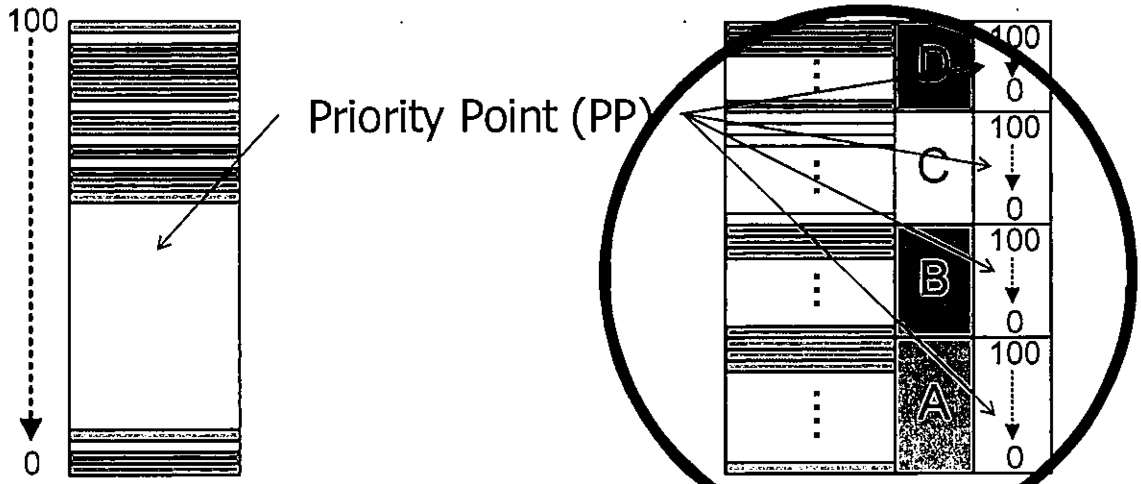
1. Bridge Repair & Maintenance Plan

- The plan was developed using the Bridge Repair & Maintenance System (BRMS) for 1,392 bridges with condition data, registered in the database.
- Prioritization was made by "Soundness Classification (SC) & Priority Point" option (2 options: by only priority point, by SC and priority point).
- The plan was developed not by budget limit, but by target repair period (2 options: budget limit, target repair period).
- Weighing factors are of default ones.
- Bridge Management Levels are 100, 75, 50 and 25.

Do you remember?

- Prioritization options:

Priority Point (PP) = α x (100 - HI) + β x II

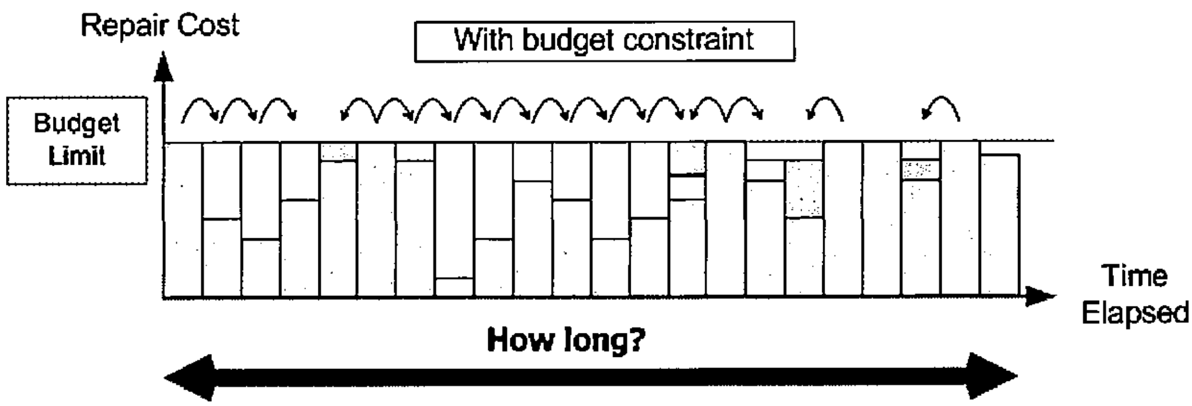


By Priority Point (PP) only

By Soundness Classification (SC) & Priority Point (PP)

Do you remember?

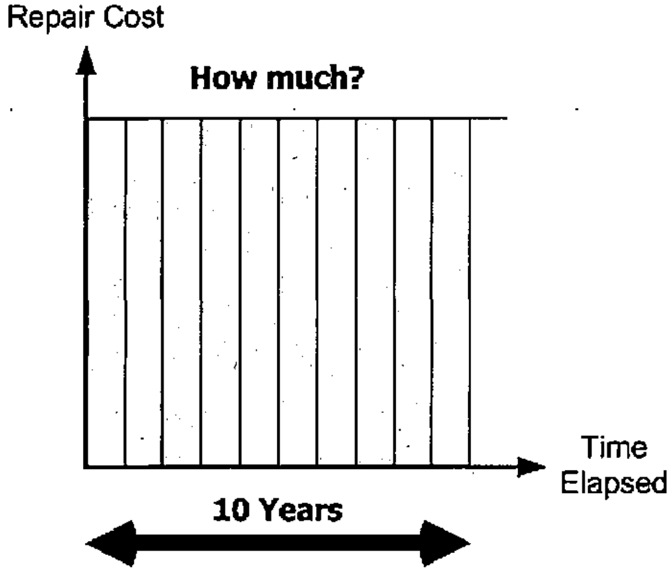
- Maintenance plan options:



"Budget Limit" Option

Do you remember?

- Maintenance plan options:



"Target Repair Period" Option

Bridge Repair & Maintenance Plan (1,392 bridges in sample provinces)

Management Level	Breakdown				Total (1,000 Rs.)
	Surface	Superst.	Bearing	Substr.	
100	13,187	782,074	0	143,935	**939,196**
75	3,446	760,238	0	134,479	**898,163**
50	2,037	723,396	0	132,403	**857,836**
25	1,124	684,301	0	130,427	**815,852**

Which management level will RDA use??
How long will RDA complete these repairs?

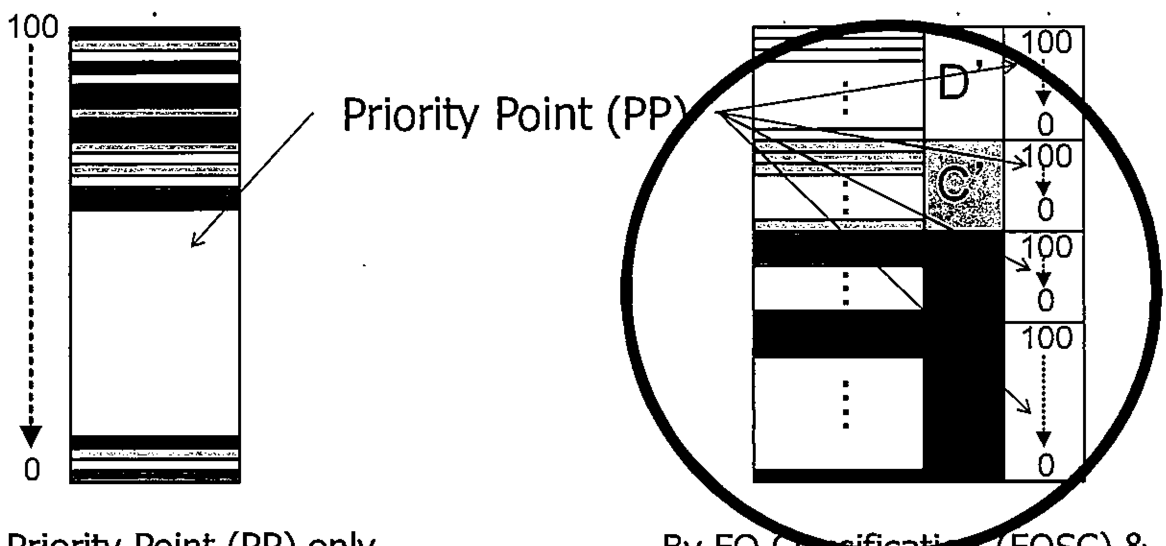
2. Bridge Reconstruction Plan

- The plan was developed using the Bridge Repair & Maintenance System (BRMS).
- Prioritization was made by "Functionally Obsolete Classification (FOC) & Priority Point" option (2 options: by only priority point, by FOC and priority point).
- The plan is the list of bridges in the order of priority for reconstruction. When the budget is available, RDA will select the bridges from the list.

Do you remember?

- Prioritization options:

  Priority Point (PP) = $\alpha' \times (100 - HI) + \beta' \times II + \gamma' \times FOI$



By Priority Point (PP) only

By FO Classification (FOSC) & Priority Point (PP)

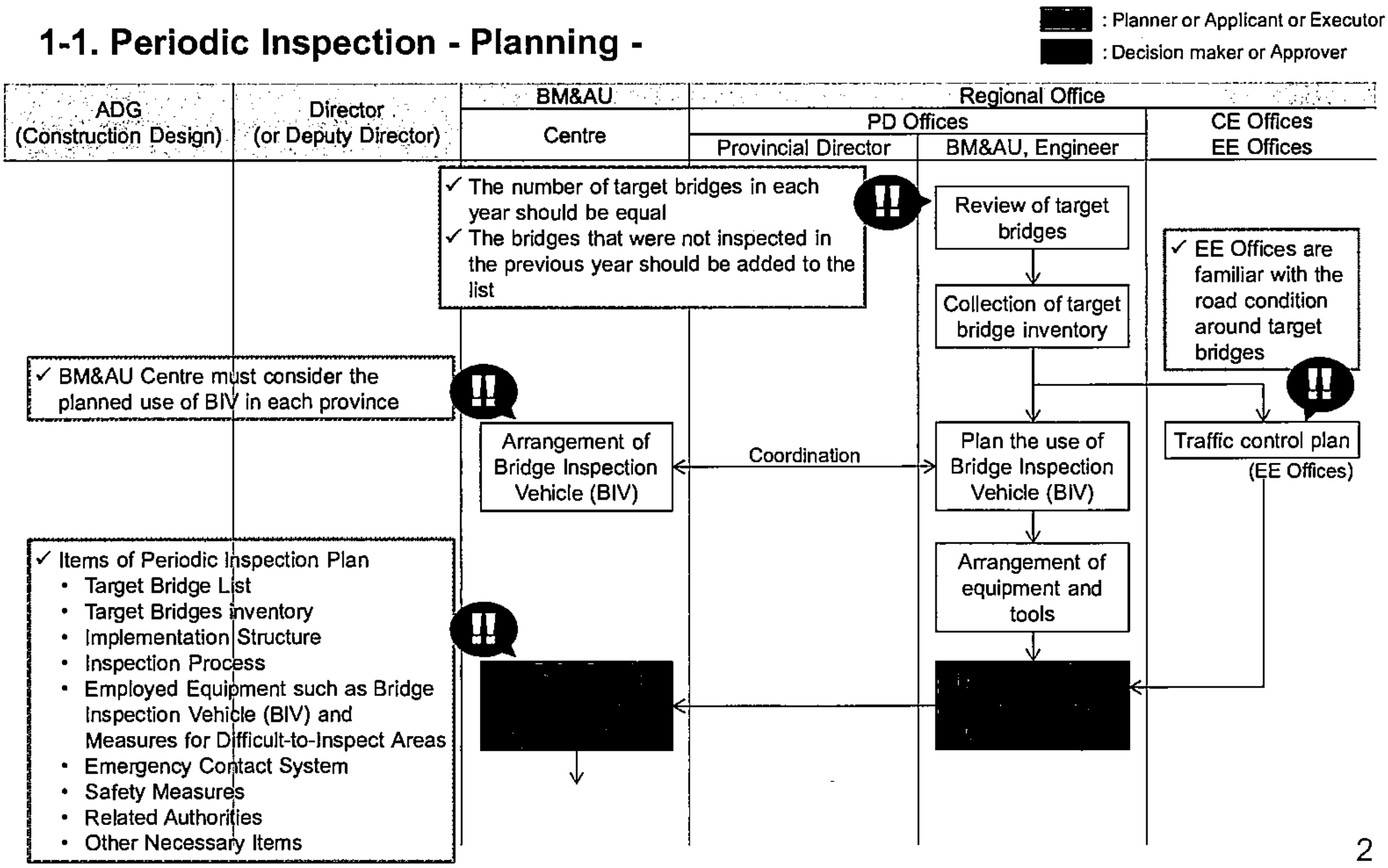
Procedure, Roles & Responsibilities and Institutional Framework for Bridge Management

THE PROJECT
FOR CAPACITY DEVELOPMENT
ON BRIDGE MANAGEMENT

Daisuke HAJIMA

1. Procedure

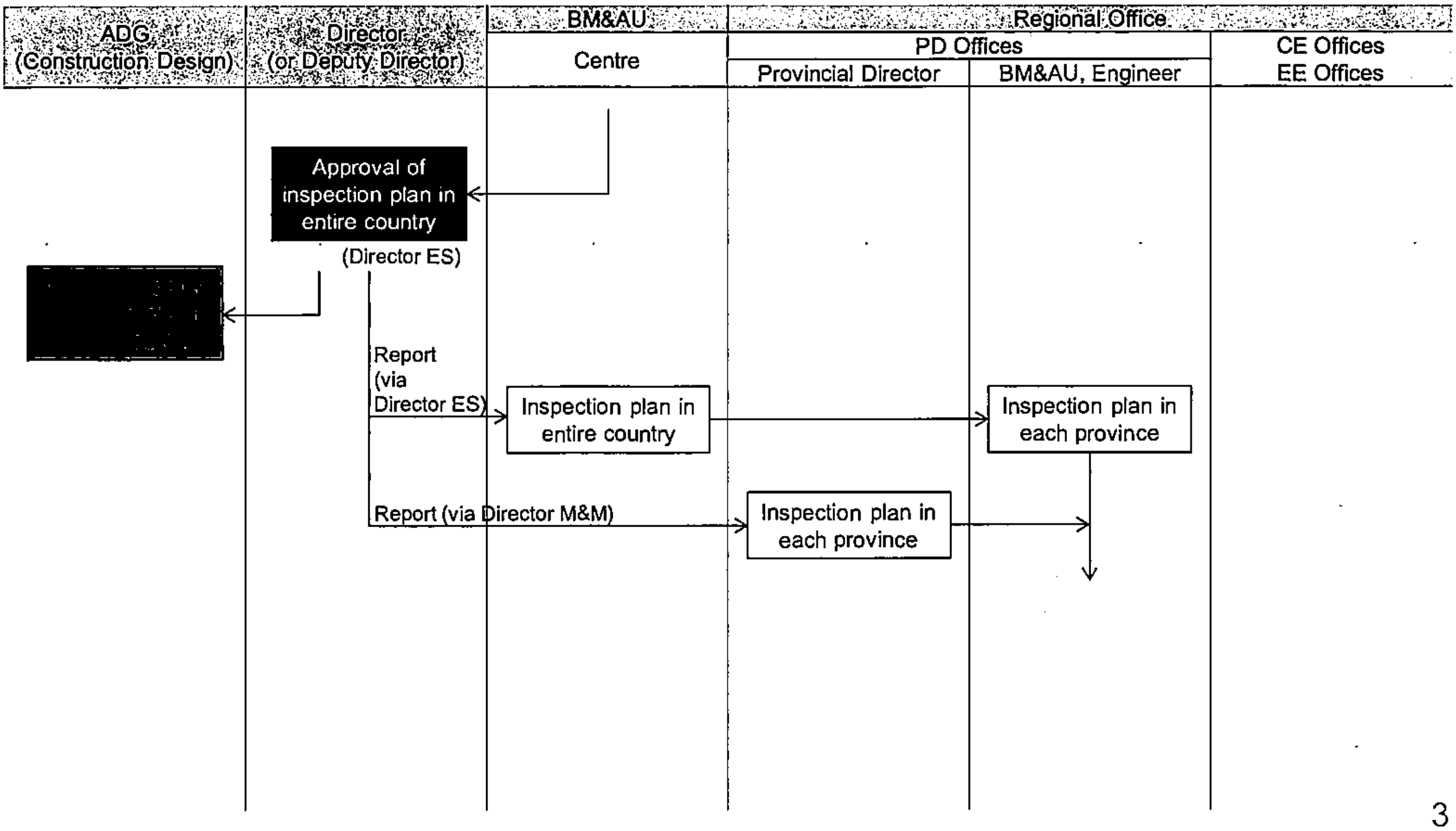
1-1. Periodic Inspection - Planning -



1. Procedure

1-1. Periodic Inspection - Planning -

: Planner or Applicant or Executor
: Decision maker or Approver

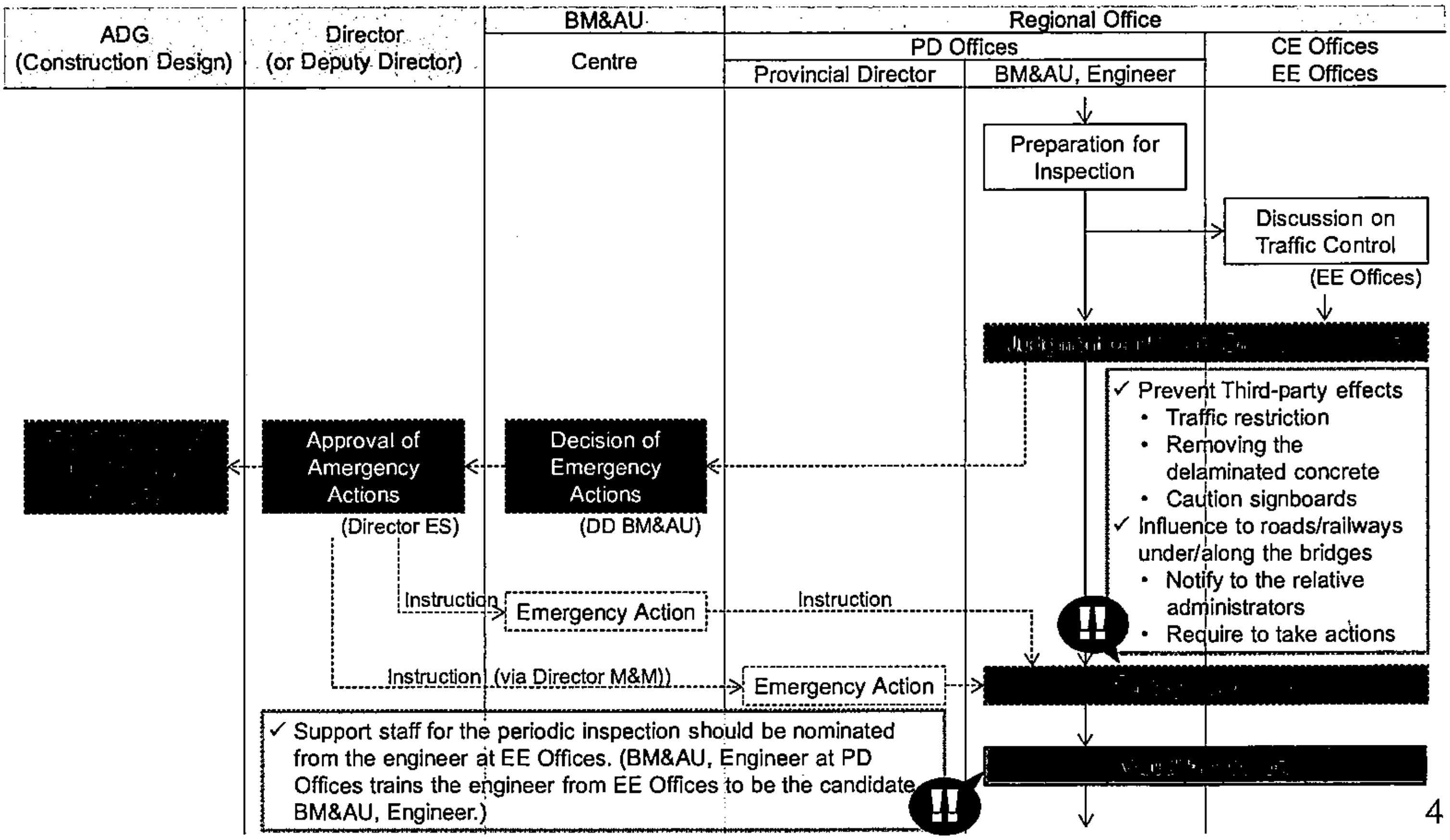


3

1. Procedure

1-2. Periodic Inspection - Site Work -

: Planner or Applicant or Executor
: Decision maker or Approver

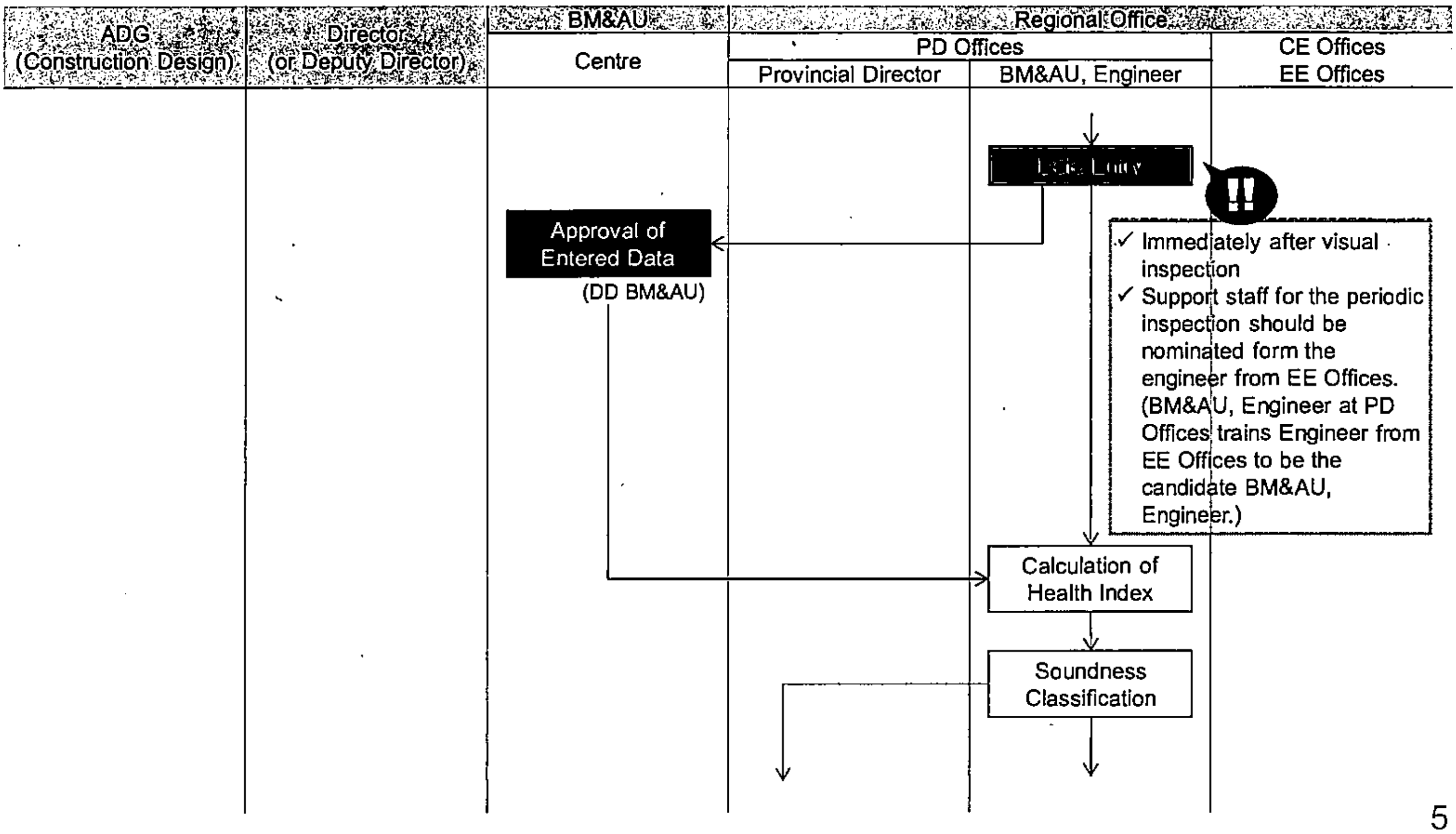


4

1. Procedure

1-3. Periodic Inspection - Office Work -

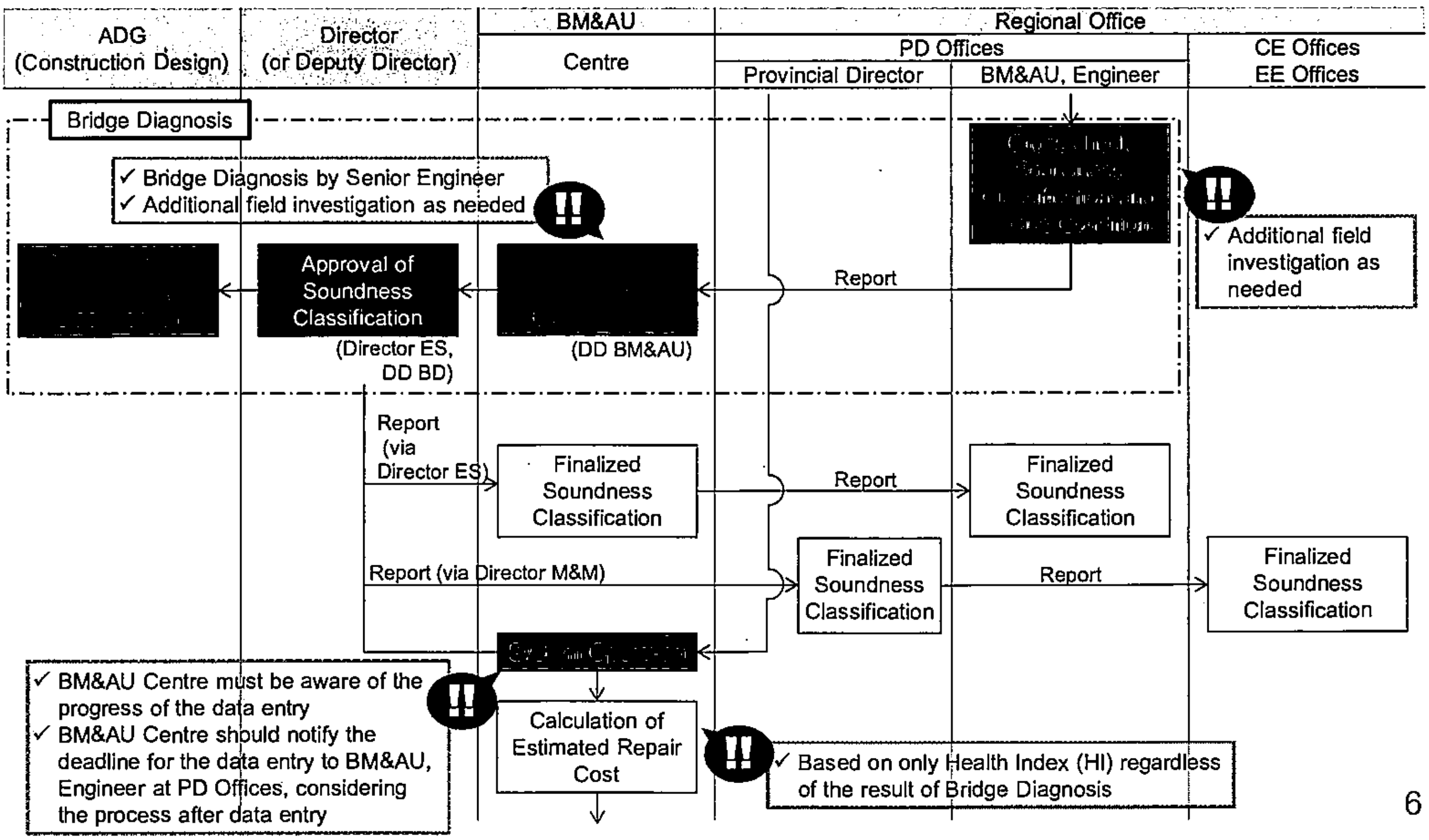
: Planner or Applicant or Executor
: Decision maker or Approver



1. Procedure

1-3. Periodic Inspection - Office Work -

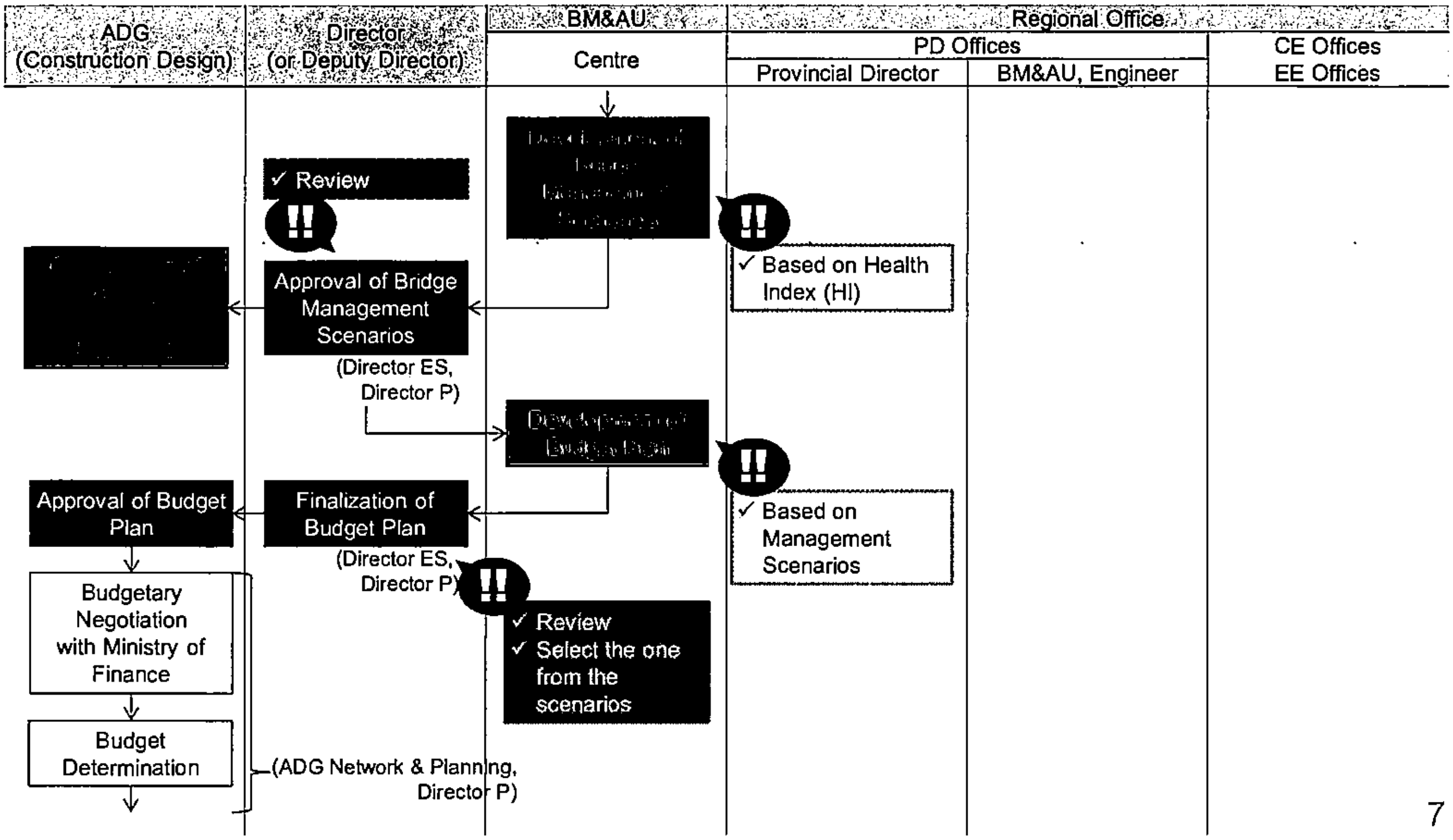
: Planner or Applicant or Executor
: Decision maker or Approver



1. Procedure

1-4. Development of Bridge Repair & Maintenance Plan

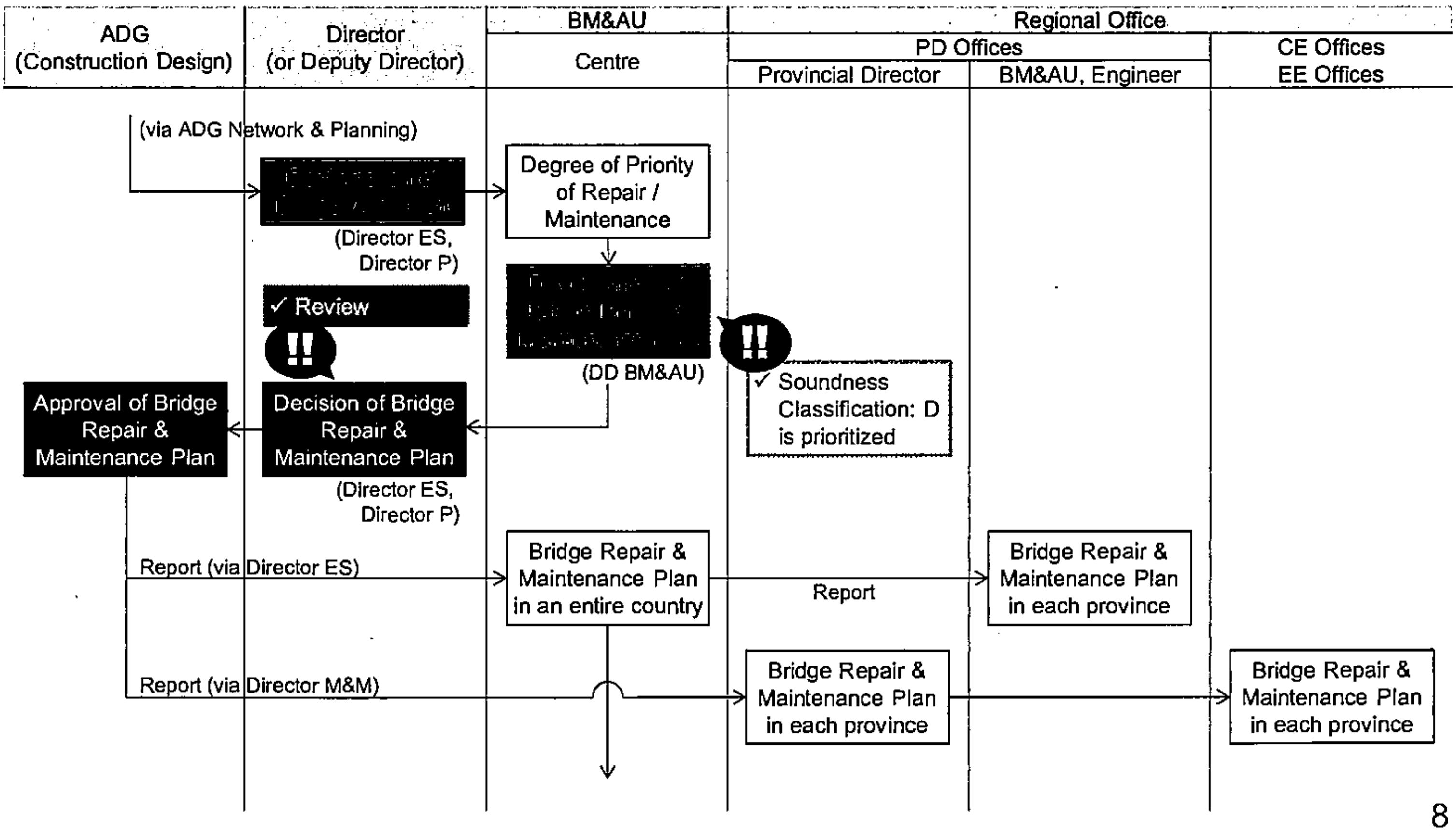
: Planner or Applicant or Executor
: Decision maker or Approver



1. Procedure

1-4. Development of Bridge Repair & Maintenance Plan

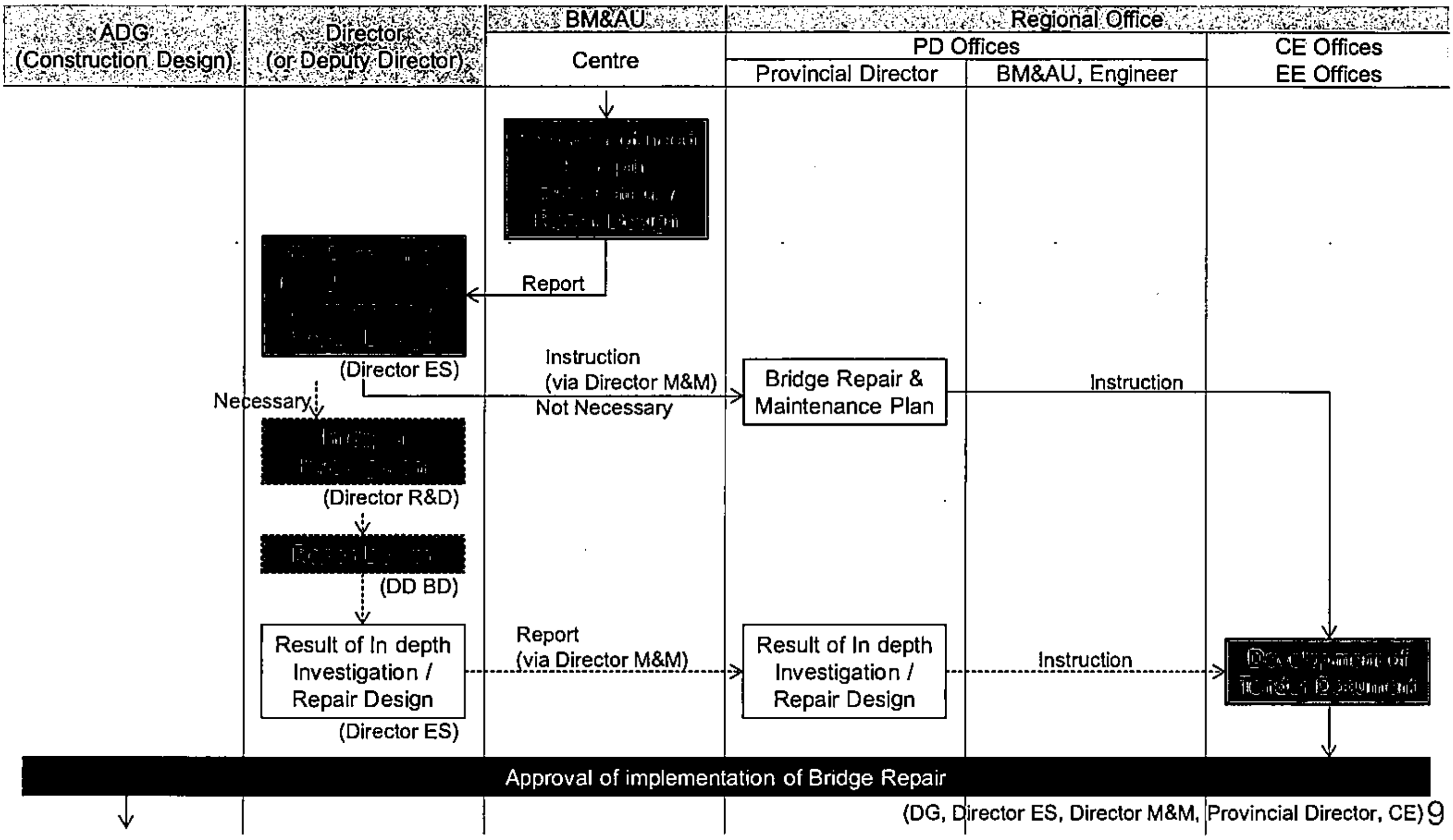
: Planner or Applicant or Executor
: Decision maker or Approver



1. Procedure

1-5. Bridge Repair and Maintenance

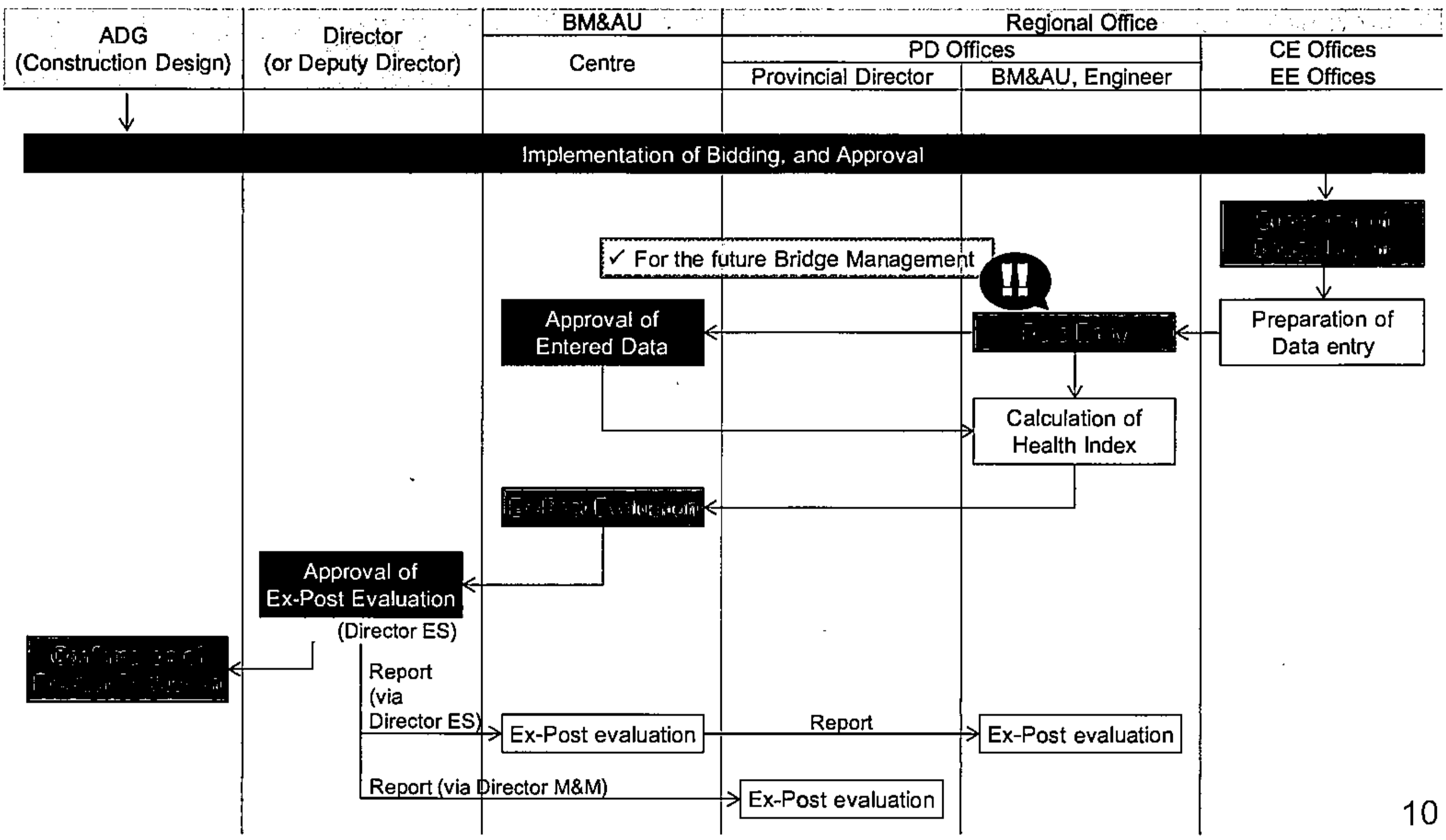
: Planner or Applicant or Executor
: Decision maker or Approver



1. Procedure

1-5. Bridge Repair and Maintenance

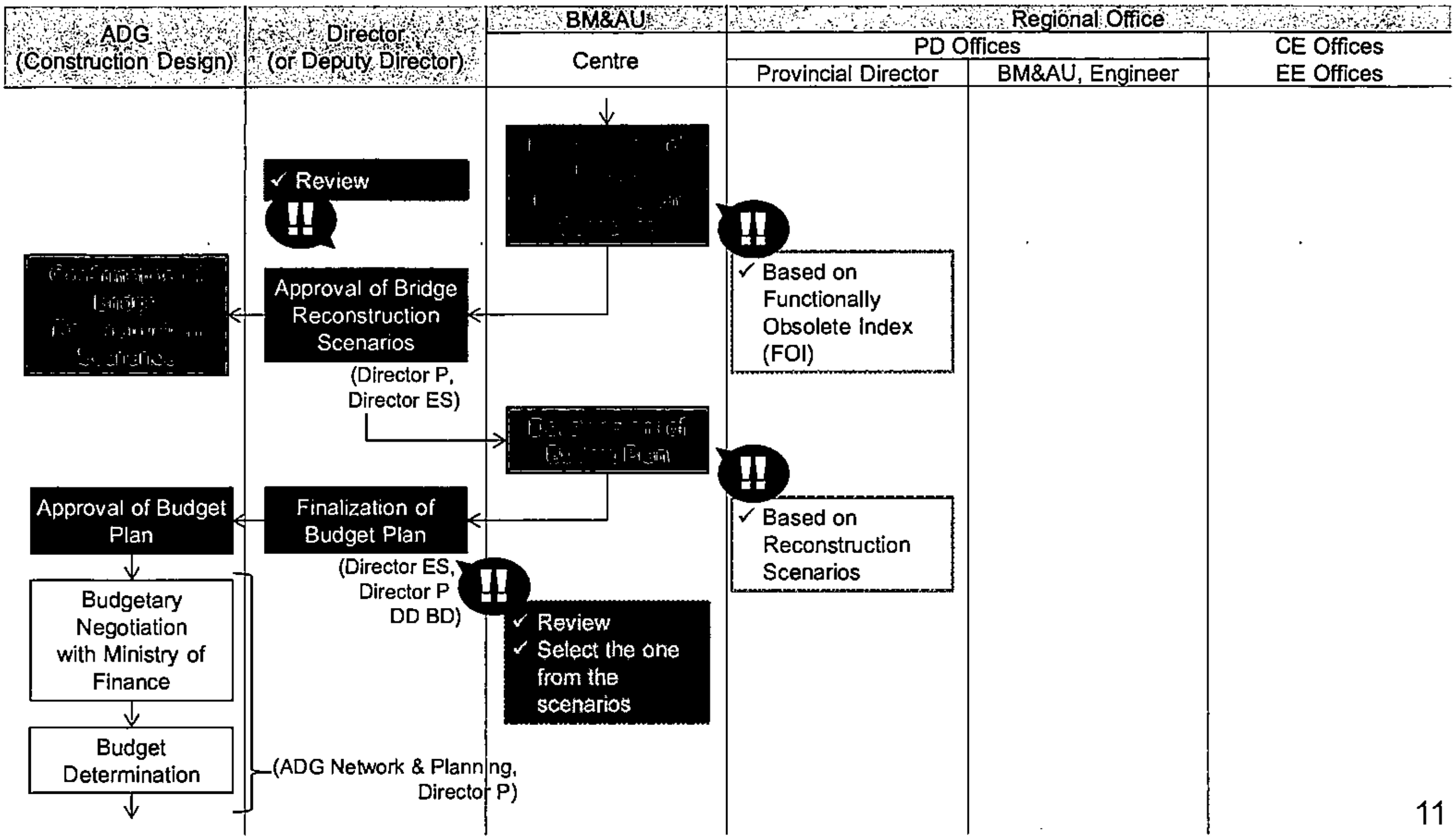
: Planner or Applicant or Executor
: Decision maker or Approver



1. Procedure

1-6. Development of Bridge Reconstruction Plan

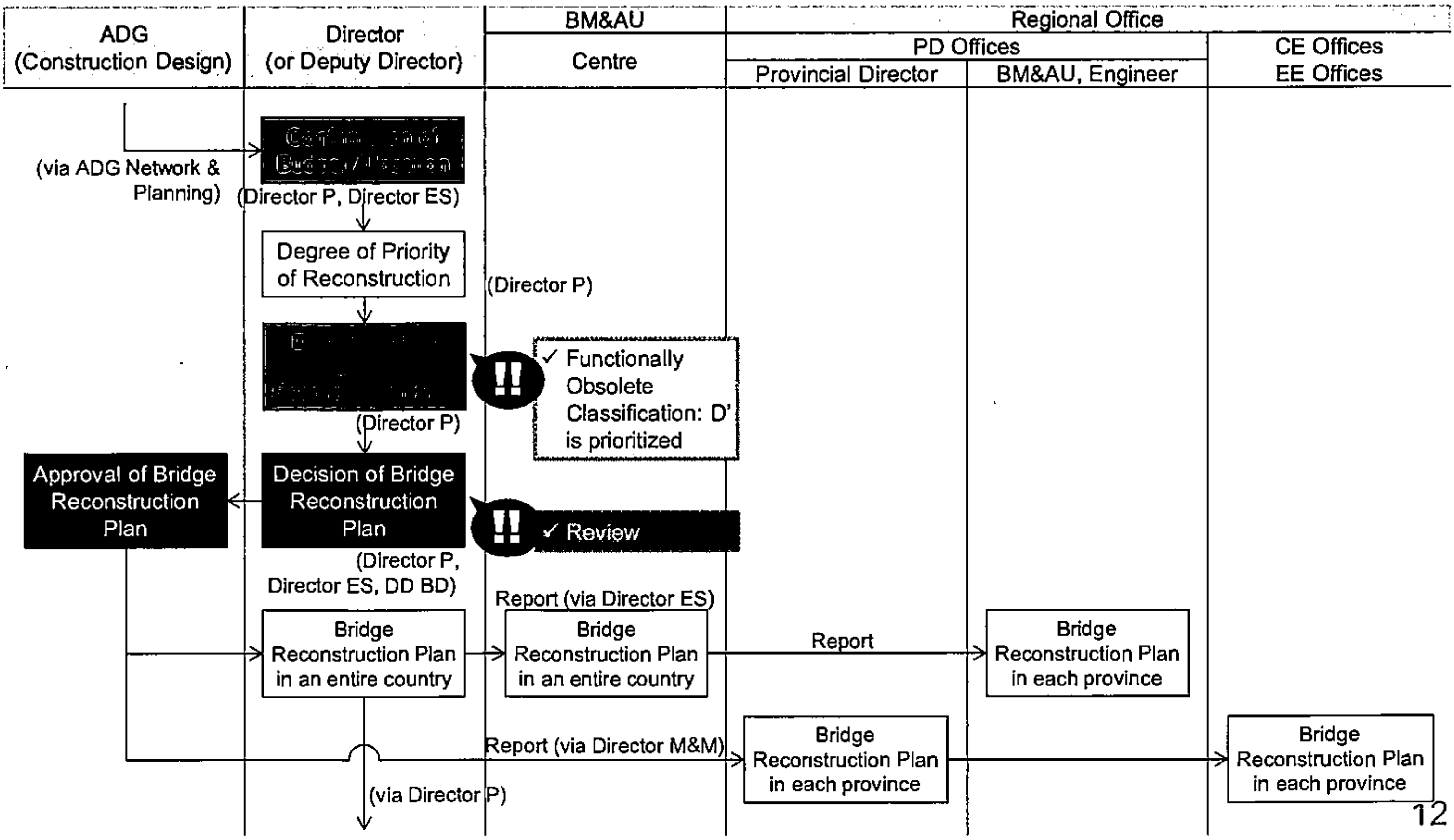
: Planner or Applicant or Executor
: Decision maker or Approver



1. Procedure

1-6. Development of Bridge Reconstruction Plan

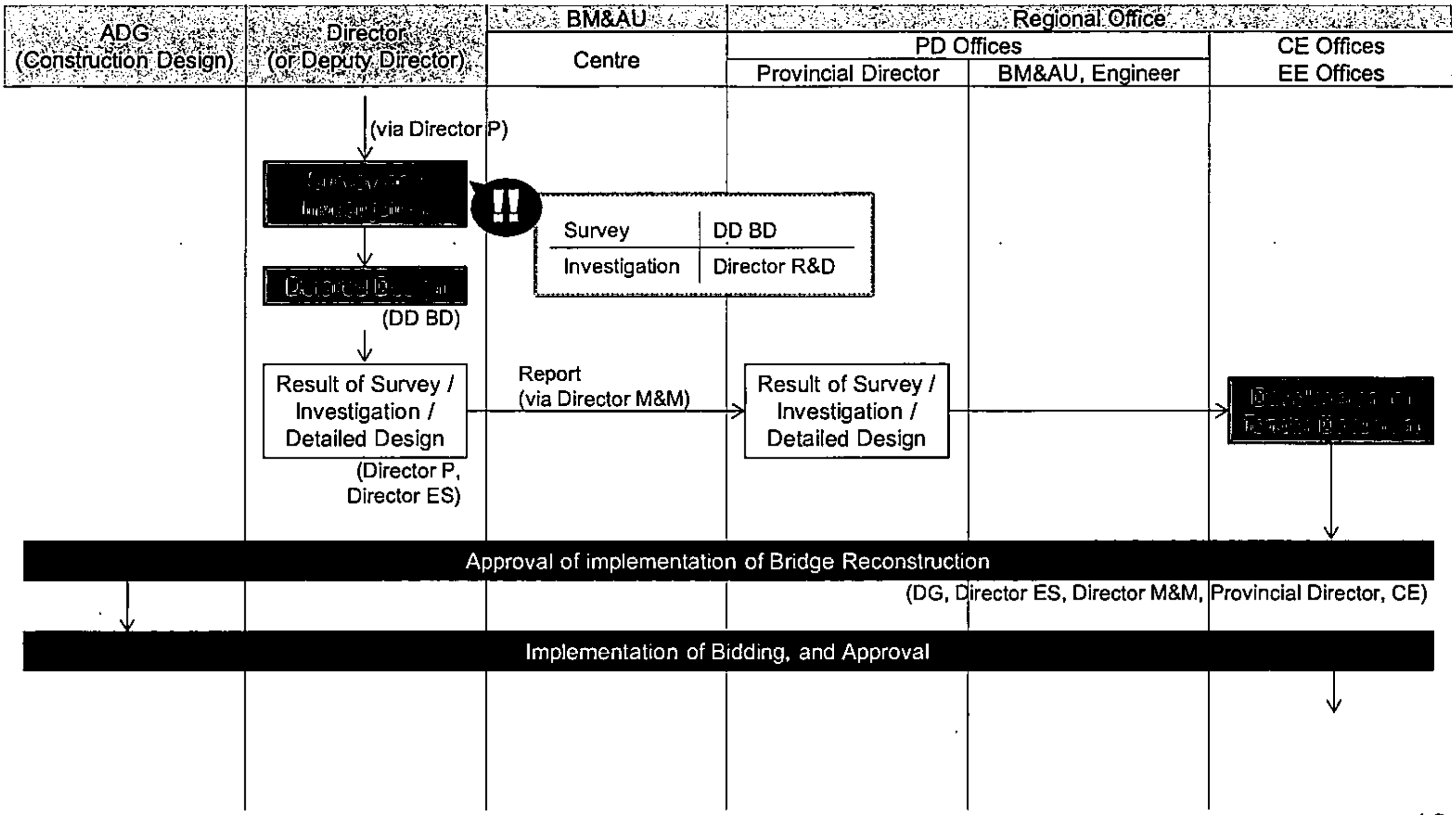
: Planner or Applicant or Executor
: Decision maker or Approver



1. Procedure

1-7. Bridge Reconstruction

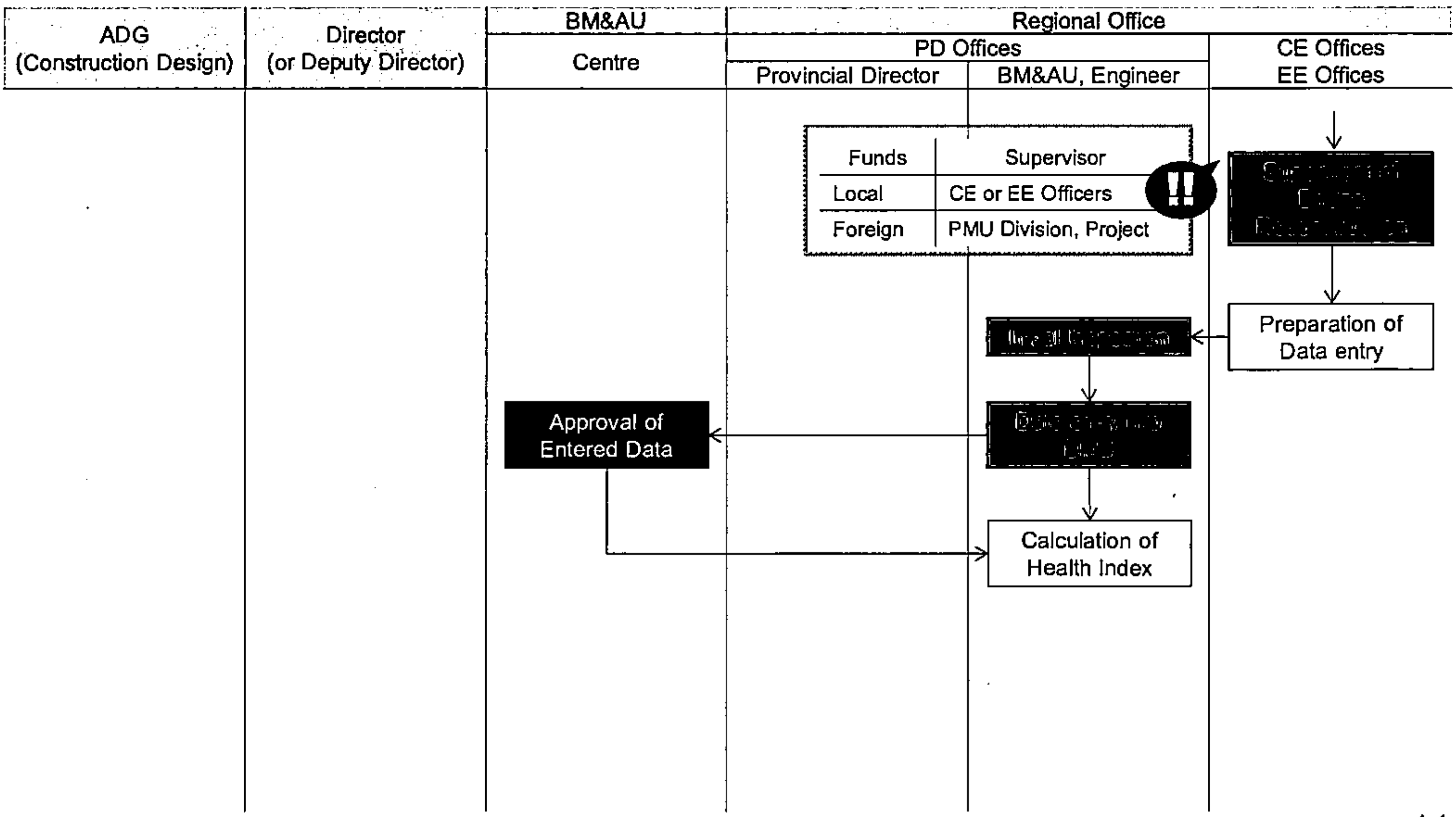
: Planner or Applicant or Executor
: Decision maker or Approver



1. Procedure

1-7. Bridge Reconstruction

: Planner or Applicant or Executor
: Decision maker or Approver



2. Roles & Responsibilities

Division (Position)	Roles and Responsibilities
ADG CD	**General Bridge Management** • Confirmation of Periodic Inspection Plan • Confirmation of Emergency Action • Confirmation of Soundness Classification • Confirmation of Bridge Repair & Maintenance Scenario • Approval of Bridge Repair & Maintenance Budget Plan and Bridge Repair & Maintenance Plan • Confirmation of Bridge Reconstruction Scenario • Approval of Bridge Reconstruction Budget Plan and Bridge Reconstruction Plan • Confirmation of Ex-Post Evaluation
Director, Engineering Service	• Approval of Periodic Inspection Plan • Approval of Emergency Action • Finalization of Soundness Classification • Approval of Bridge Repair & Maintenance Scenario, Finalization of Bridge Repair & Maintenance Budget Plan, and Decision of Bridge Repair & Maintenance Plan • Approval of Bridge Reconstruction Scenario, Finalization of Bridge Reconstruction Budget Plan and Decision of Bridge Reconstruction Plan • Confirmation of Budget Allocation • Approval of Ex-Post Evaluation
Director, R&D	• In-depth Investigation for Repair Design • Investigation for Reconstruction Detailed Design

2. Roles & Responsibilities

Division (Position)	Roles and Responsibilities
Director, Planning	• Approval of Bridge Repair & Maintenance Scenario, Finalization of Bridge Repair & Maintenance Budget Plan, and Decision of Bridge Repair & Maintenance Plan • Approval of Bridge Reconstruction Scenario, and Finalization of Bridge Reconstruction Budget Plan • Development and Decision of Bridge Reconstruction Plan • Budget Allocation
Director, Maintenance & Management	• Responsible for Maintenance & Management of Road Structures
Director, Training	• Provide the Engineers with Training on Bridge Management and Maintenance
Deputy Director, Bridge Designs	• Finalization of Bridge Reconstruction Budget Plan • Decision of Bridge Reconstruction Plan • Repair Design for Bridge Repair & Maintenance • Survey and Detailed Design for Bridge Reconstruction

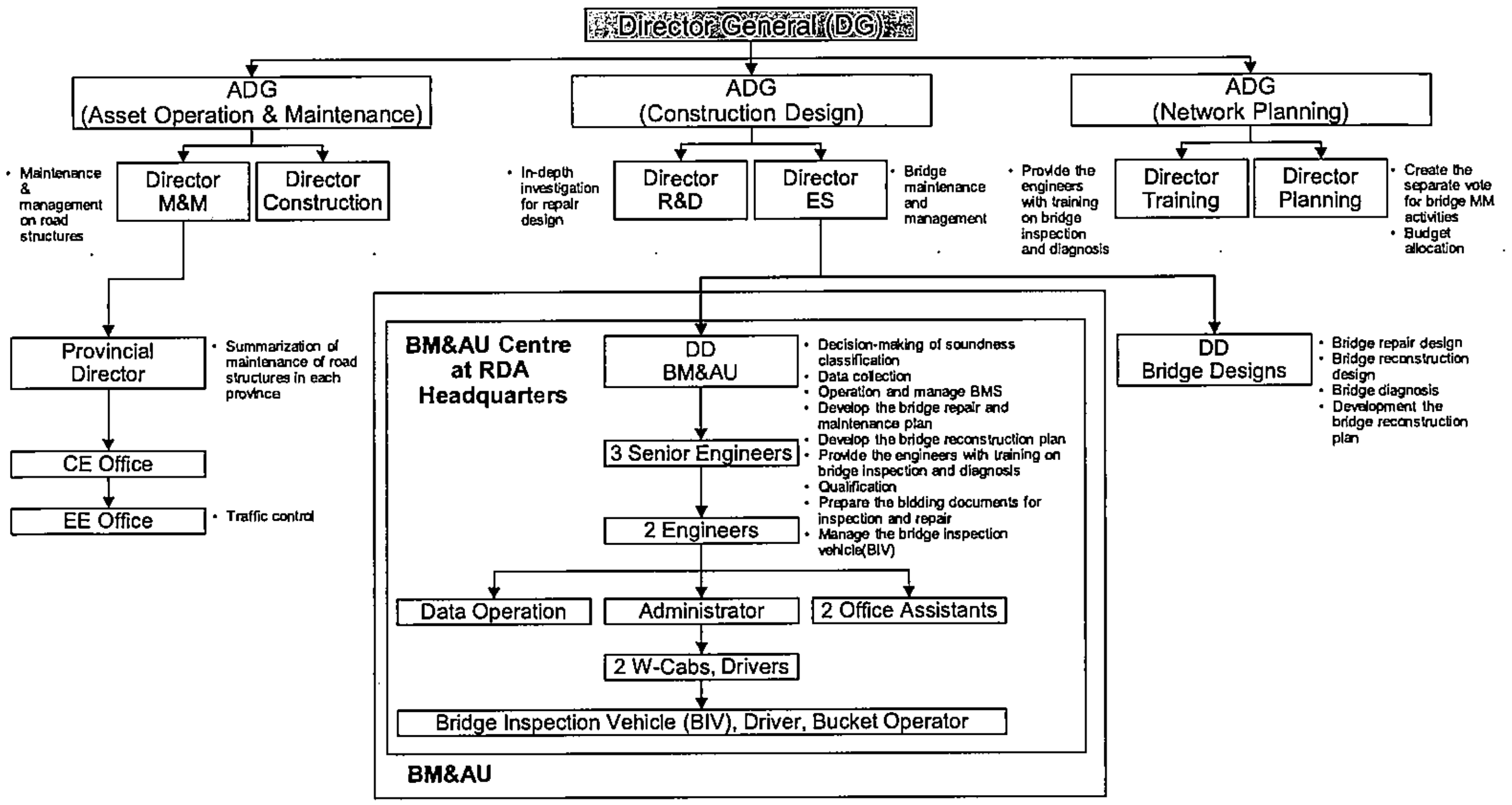
2. Roles & Responsibilities

Division (Position)		Roles and Responsibilities
BM&AU		
	Head (Deputy Director)	• Finalization of Periodic Inspection Plan • Approval of Emergency Action • Approval of Entered Data of Periodic Inspection, Initial Inspection • Final Draft of Soundness Classification (Bridge Diagnosis) • Formulation of Bridge Repair & Maintenance Scenario, Budget Plan, and Bridge Repair & Maintenance Plan • Formulation of Bridge Reconstruction Scenario and Budget Plan • Finalization of Ex-Post Evaluation
	Senior Engineer	• Review of Periodic Inspection Plan (Nationwide) • Decision of Emergency Action • Bridge Diagnosis • Visual Inspection (as needed) • Confirmation of Draft of Bridge Repair & Maintenance Scenario, Budget Plan, and of Bridge Repair & Maintenance Plan • Confirmation of Draft of Bridge Reconstruction Scenario and Budget Plan • Confirmation of Ex-Post Evaluation
	Engineer	• Arrangement of Bridge Inspection Vehicle (BIV) • Assist DD BM&AU in the following process: - Development of Periodic Inspection Plan (Nationwide) - Development of Final Draft of Soundness Classification - Development of Draft of Bridge Repair & Maintenance Scenario, Budget Plan, and Bridge Repair & Maintenance Plan - Development of Draft of Bridge Reconstruction Scenario and Budget Plan - Development of Ex-Post Evaluation

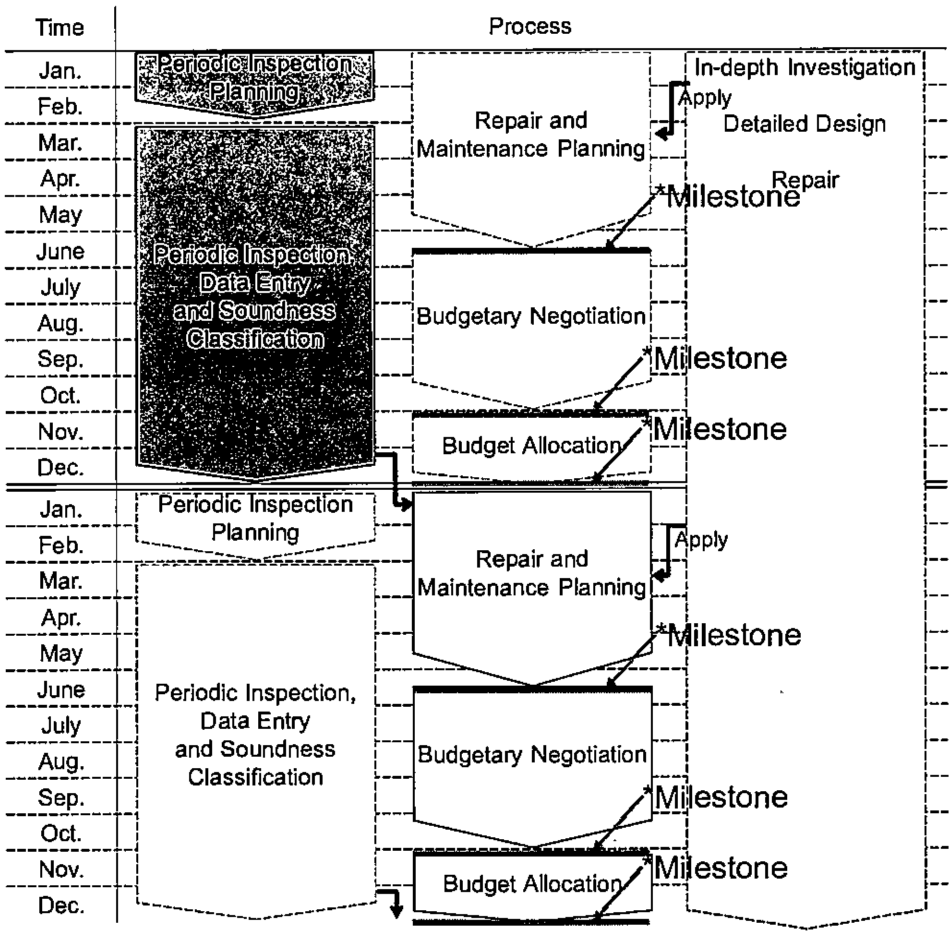
2. Roles & Responsibilities

Division (Position)		Roles and Responsibilities
BM&AU		
	Data Operation	• System Operation
	BM&AU, Engineer at PD Offices	• Implementation of Emergency Action • Visual Inspection of Periodic inspection and Initial Inspection • Data Entry of Periodic Inspection, Initial Inspection and Repair Record • Check Soundness Classification and Bridge Condition • Development of Periodic Inspection Plan (for Each Province)
Provincial Director		• Assist BM&AU engineer
EE Offices		• Planning and Implementation of Traffic Control during Periodic Inspection • Implementation of Emergency Action • Visual Inspection with BM&AU, Engineer at PD Offices • Development of Tender Document • Supervisor of Bridge Repair Work / Reconstruction (as needed) • Implementation of Routine Maintenance of Bridges

3. Institutional Framework



4. Process Schedule



- Periodic Inspection
  - Planning of periodic inspection in the beginning of fiscal year
  - Periodic inspection by the end of fiscal
- Budget allocation
  - Developing of Repair & Maintenance plan based on results of periodic inspection
  - Budget negotiation by Budget allocation
- In case that damage in need of immediate and major repair is detected by inspection
  - Implementation the countermeasure within fiscal budget

  or
  - Other budget plan for the countermeasure should be developed

1st Workshop for Output1&2

Agenda

24th Aug.2016

Time	Topic
13:30 – 13:35	Opening Address Mr. Hideaki TAKAURA Team Leader / JICA Project Team
13:35 – 13:50	Flow of Bridge Management Mr. Kazuya URANO Deputy Team Leader / JICA Project Team ● Flow of the entire bridge management ● What to do for individual bridge ● What to do for bridge groups under management
13:50 – 14:10	Policy and Strategy on Bridge Management in Japan Mr. Takaoki ICHIOKA Asset Management 1 / JICA Project Team ● Background of bridge management policy and strategy in Japan
14:10 – 14:30	Efforts on Bridge Management at a Local Government Office (Nagasaki Prefecture) within Limited Human Resources & Budget Mr. Takaoki ICHIOKA Asset Management 1 / JICA Project Team ● Unique efforts at Nagasaki Prefecture
14:30 – 14:40	What to Do for the 2nd Planning Committee Meeting Mr. Kazuya URANO Deputy Team Leader / JICA Project Team ● What Working Group (both Managing & Engineering) members are expected to do
14:40 – 15:00	Discussion
15:00 – 15:20	Tea Break
15:20 – 15:50	Awareness Survey for Bridge Soundness and Importance of Bridge Mr. Toshiki KASAI Asset Management 2 / JICA Project Team ● Why awareness surveys are conducted. ● Results of awareness survey ● What to do after the awareness surveys
15:50 – 16:00	Discussion
16:00 – 16:05	Closing Remarks Mr. Hideaki TAKAURA Team Leader / JICA Project Team

Flow of Bridge Management

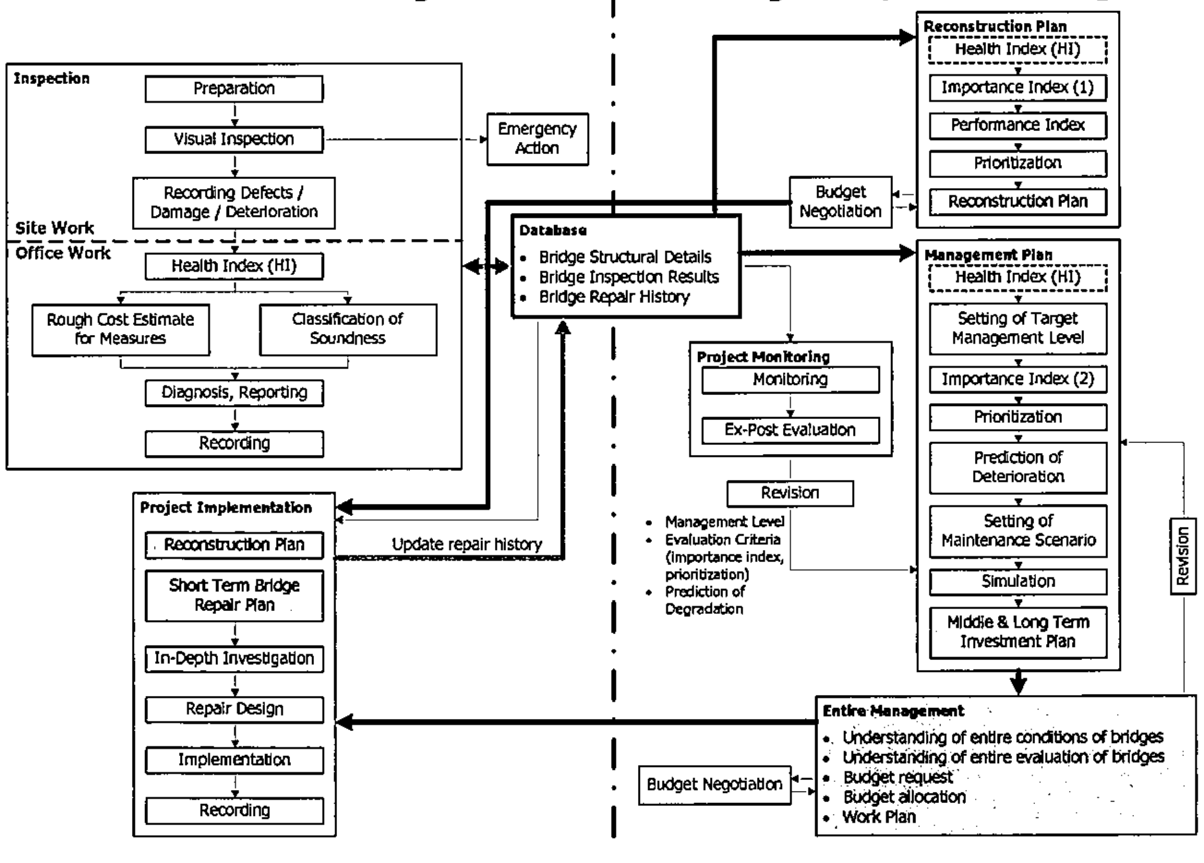
- Entire Image of Bridge Management -

THE PROJECT
FOR CAPACITY DEVELOPMENT
ON BRIDGE MANAGEMENT

Kazuya URANO

Flow of Bridge Management

For Individual Bridge | **For Bridge Groups Under Management**



2

What to Do (1)

Bridge Inspection

- Bridge inspection
- When serious cases are found, emergency actions should be taken.
  → Report to the relevant personnel for closure to traffic, load limitation, speed limitation, emergency responses.
- Record the defects, damage and deterioration.
- Quantification of bridge soundness (health index: HI).
- Rough cost estimates for measures.
- Bridge diagnosis.
- Reporting

Bridge Database

3

What to Do (2)

Middle & Long Term Investment Plan (Repair, Strengthening) for All Bridges

- Health Index, already determined.
- Setting the target management level for all bridges under the management of RDA. → theoretical solution.
- Determine the importance index.
- Prioritize the bridges from the health index and importance index.
- Predict the future progress of deterioration.
- Setting the options of maintenance scenario to alleviate the concentration of initial investment.
  → Grouping of all bridges into several categories.
  →Set the target health index for each category
  →HI = 60 (preventive), 40 (reactive), etc.

What to Do (2)

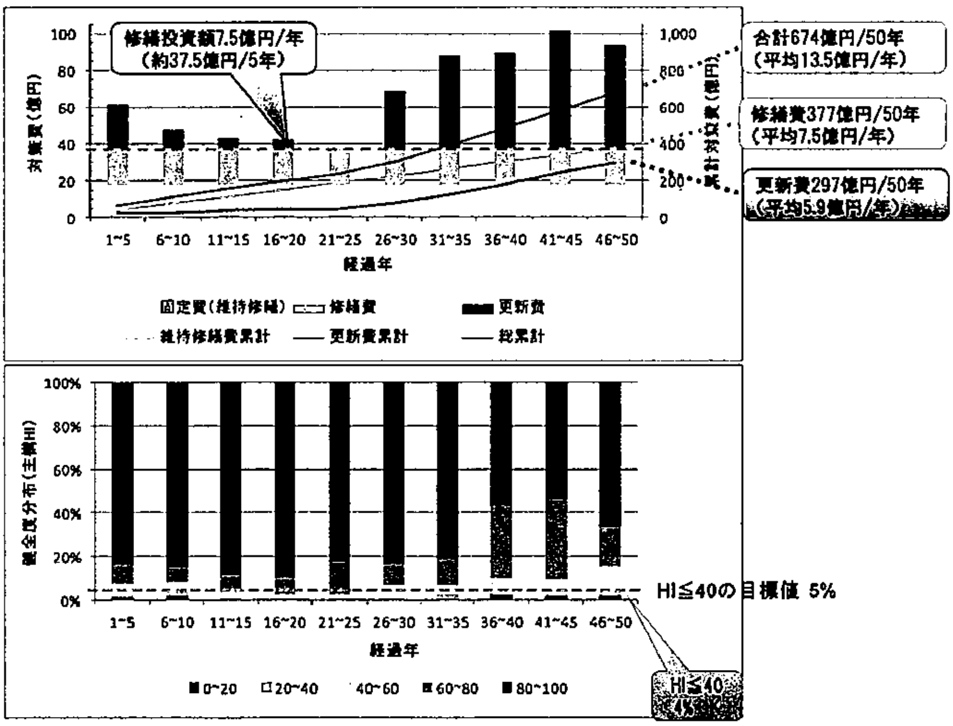
Middle & Long Term Investment Plan (Repair, Strengthening) for All Bridges

- Do the simulation of LCCs and bridge conditions under several budget options.
- Develop the middle & long term investment plan under the budget constraint.

Entire Management

What to Do (2)

Middle & Long Term Investment Plan (Repair, Strengthening) for All Bridges



6

What to Do (3)

Entire Management for Bridges

- Understanding the conditions of all the bridges under management.
- Understanding the evaluation of all the bridges (HI) under management.
- Prepare the budget request for middle / long term.
- (Budget negotiation with the Treasury)
- Budget allocation.

Short Term Bridge Repair Plan

7

What to Do (4)

Short Term Bridge Repair Plan Development for Individual Bridge (3 to 5 Years)

- Within the allocated annual budget for short term, select the bridges in the order of priority for major / minor repairs.
- Within the allocated annual budget, develop the bridge inspection / diagnosis plan.
- Within the allocated annual budget, develop the bridge maintenance plan.
- Summarize as a short term bridge repair plan.
- Plan should be reviewed and revised annually.

Plan (Project) Implementation

8

What to Do (5)

Plan / Project Implementation

- As needed, implement the in-depth (detailed) investigations for major / minor repair designs.
- Implement repair designs.
- Implement the repair works using direct labors or outsourcing.
- Record the repair work details (repair history).

Bridge Database

9

What to Do (6)

Database

- All the activities / results should be registered in the database.

  →Bridge structural details (inventory)

  →Bridge inspection results

  →Bridge repair records

  →Bridge reconstruction records

10

What to Do (7)

Bridge Reconstruction Plan for Existing Non-Conformance Bridges

- For existing non-conformance bridges, determine the importance of a bridge (importance index: II).
- Determine the performance index: PI, in terms of narrow width for traffic, insufficient water opening (flooded during rainy season), insufficient load carrying capacity, etc.
- Prioritize the bridges from the health index, importance index and performance index.
- Develop the reconstruction plan under the budget constraints.
- Budget negotiation (foreign donor fund?).
- Implement bridge reconstruction.

11

What to Do (8)

Project Monitoring

- All the projects are in progress as scheduled or not.
- Verify how the conditions (distribution of health index: HI) of all the bridges under the management of RDA are improved after the project implementation.
  →If the conditions are not improved, revised the deterioration curve, management level, or management plan.
  →Need more budget?

Management Plan

Bridge Management Strategy / Plan (Output 1) & Institutional Framework (Output 2) ** Planning Committee Activities **

THE PROJECT
FOR CAPACITY DEVELOPMENT
ON BRIDGE MANAGEMENT

Kazuya URANO

Activities at Planning Committee (PC) Meeting

Briefing

- Outlines of Bridge Management Strategy
- Directions to Future Bridge Management in Sri Lanka
- Elemental Technologies on Bridge Management

Themes to be Discussed

- Development of Short Term Bridge Repair Plan
- Institutional Framework
- Bridge Management Strategy

Reference

- Further Bridge Management Image

Outlines of Bridge Management Strategy

- Bridge management strategy should be developed based on the short-term bridge repair plan and middle / long term investment plan.

Bridge Management Strategy

Short Term Bridge Repair Plan

- It is the plan to repair / strengthen / reconstruct the bridges under management within the limited budget.
- It is to assess the current condition of individual bridge, and to plan the specific measures to be taken, timing and priority for bridges.

Plan of Action for Bridge Management

- **Plan of action** to efficiently ensure the soundness and safety of bridges within limited budget.

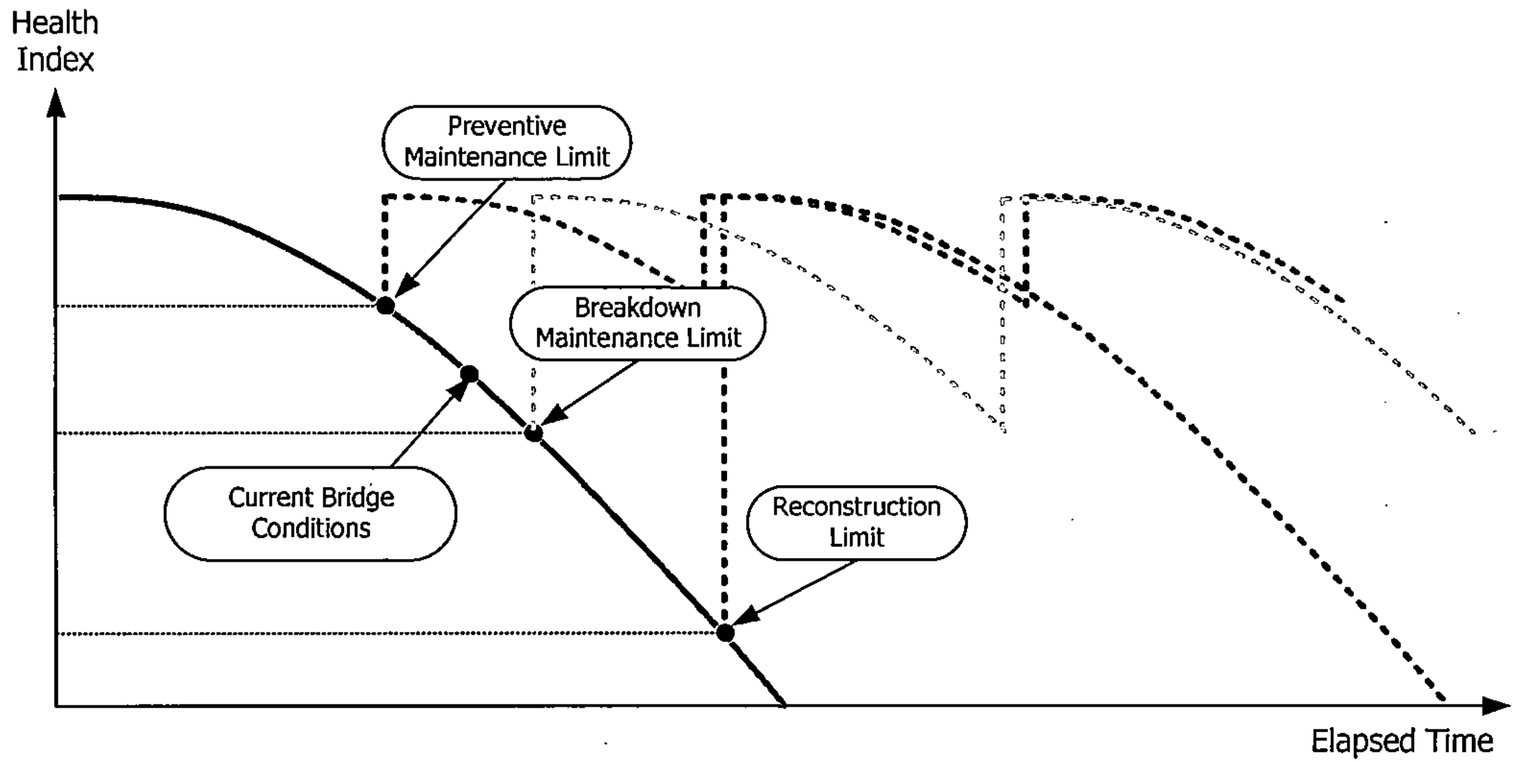
Middle / Long Term Investment Plan

- It is the investment plan for maintenance / management of bridges under management.
- It is to estimate the future necessary investment and trend of bridge conditions, and to plan the budget increase / decrease, budget allocation to provinces, directions to future bridge management.

Plan of Action for Financial Management

- **Plan of action** to optimize the necessary costs of bridge maintenance under specific bridge management level.

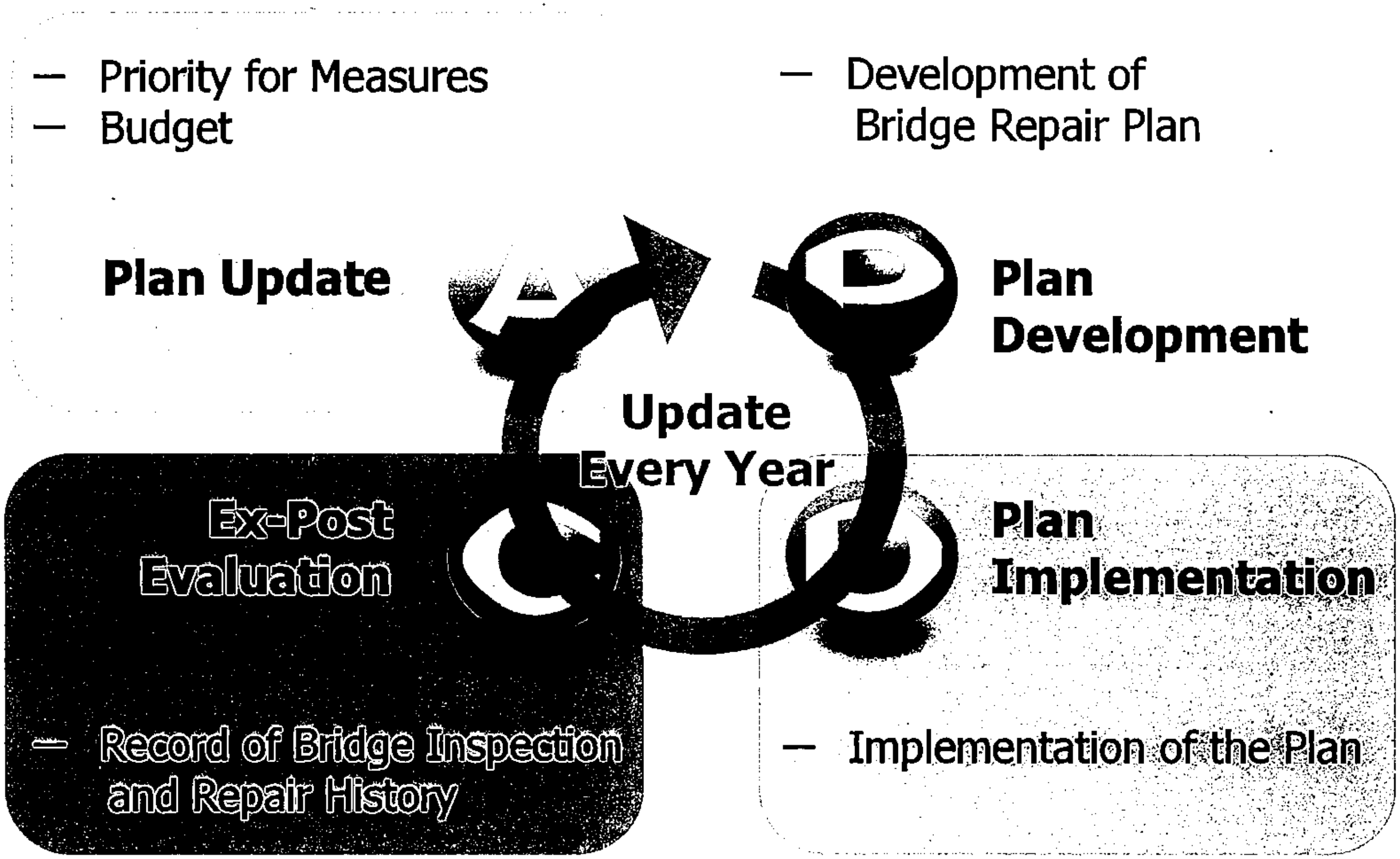
- Bridge management / maintenance costs:
  Preventive < Reactive (Breakdown) < Reconstruction
- Cyclic preventive maintenance is preferred (future target).
- What you should do is to recover the damaged / deteriorated bridges to the original conditions, if the current bridge soundness (health index) is lower than preventive maintenance limit.



Directions to Future Bridge Management in Sri Lanka

- In future, you should go towards the preventive maintenance; however, because you still have many seriously deteriorated bridges, **you should work well-balanced for major repairs of seriously damaged / deteriorated bridges, for minor repairs and for daily inspection and maintenance works.**
- In this Project, it is to develop the **Short Term Bridge Repair Plan** (middle / long term investment plan NOT developed).
  - → Inspect bridges and record the results accurately and fully.
  - → From the results, quantify the soundness of each bridge member as well as soundness of entire bridge (health index).
  - → Quantify the importance of bridge (importance factor).
  - → Quantify the order of relative priority of bridges for taking measures (prioritization).
  - → Simulate the bridge maintenance costs for the coming 5 years, for example, for several options of bridge management level, and study the feasible option.
  - → Develop the short term bridge repair plan.

- PDCA for Short Term Bridge Repair Plan



Elemental Technologies on Bridge Management

Elemental technologies on bridge management are as follows:

- Quantification of bridge inspection results (soundness): **Health Index (HI)**
- Quantification of importance of bridge: **Importance Factor**
- Quantification of the order of relative priority of bridges for taking measures: **Prioritization**
- Study of the **Bridge Management Level**
- Development of **Short Term Bridge Repair Plan**

As a Road Administrator, RDA needs to well understand these elemental technologies.

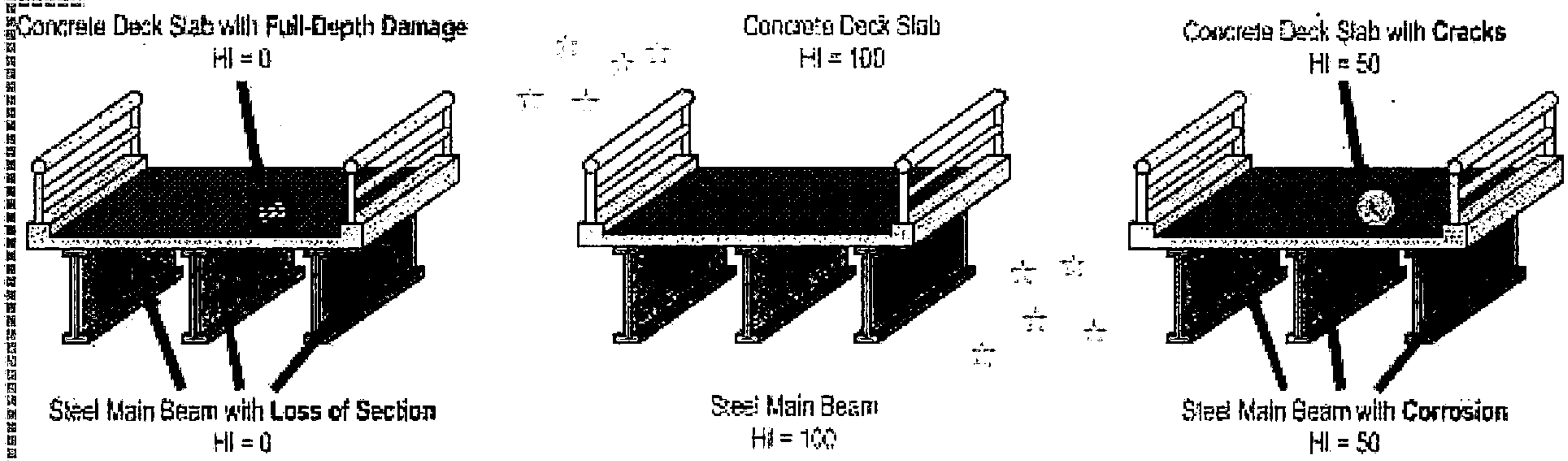
(1) Quantification of Bridge Inspection Results : Health Index (HI)

Condition of each bridge member and entire bridge are quantified based on the degree / extent of defects / damage / deterioration and effects to the bridge functions

HI =100 → Without any defects / damage, bridge member exhibits its functions sufficiently.

HI = 0 → With degradation of load carrying capacity and durability, bridge member lost its functions

→ State of HI =0 should be defined for each member



(2) Quantification of Bridge Conditions (Evaluation Criteria)

For example, evaluation criteria of concrete bridge superstructure.

Level 1	Level 2	Level 3	Level 4
Bridge Structure (Concrete)	Superstructure	Main Girder	Spall / Exposed Steel
			Cracks
			Damage on Anchorage
		Deck Slab	Spall / Exposed Steel
			Cracks
		Diaphragm	Spall / Exposed Steel
			Cracks
	Substructure		Scour
			Spall / Exposed Steel
			Crack
			Dirt Deposition, Vegetation

(3) Quantification of Importance of Bridge (Evaluation Criteria)

For examples, evaluation criteria for importance of bridge

Level 1	Level 2	Level 3	Points of View
Effects due to Closure to Traffic	At normal times	Traffic Volume	Heavy traffic
		Traffic Conditions	Heavy vehicles, bus route
	At disaster times	Roadside Conditions	Densely inhabited districts
		Emergency Transportation Route	Secure the transportation route at disaster times for emergency
		Detour	With or without detour
	Effects to the Public	Landscape	Nice view to the public
		Historically Valuable	Historically valuable bridges
Effects due to Collapse	Crossings		Adverse effects to roads / rails
	Utilities Attached		Gas, electric line or water pipe
Efficiency	Ease of Measures		Ease of land acquisition
	Costs of Measures		Costs for repair / reconstruction

(4) Quantification of Priority for Measures (several options)

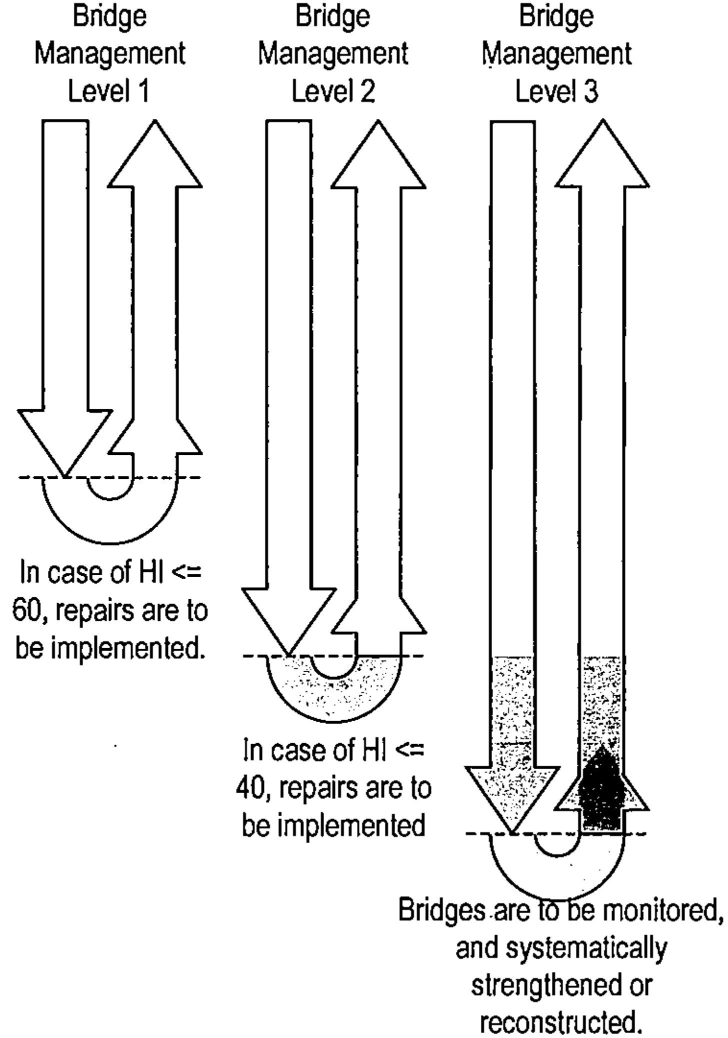
- ✓ Comprehensively determine from the health index and importance factor

$$\text{Priority} = \alpha \times \text{Health Index (HI)} + \beta \times \text{Importance Factor}$$

- ✓ Determine only from the health index
- ✓ Others

(5) Bridge Management Level (for example)

Health Index (HI)	Condition of Members
80 < HI <= 100	- Sound Conditions - No measure is required at present
60 < HI <= 80	- Slightly damaged / deteriorated - Periodical inspection is needed. - Repairs are to be implemented as needed.
40 < HI <= 60	- Defects / damage/ deterioration are identified. - Repairs are to be implemented from preventive maintenance perspective.
20 < HI <= 40	- Defects / damage/ deterioration are identified. - Repairs are to be implemented.
0 <= HI <= 20	- Considerable defects / damage / deterioration are identified. - Large scale of strengthening/ repair are to be implemented.



Bridge maintenance cost will be estimated for each level.

Development of Short Term Bridge Repair Plan

- Feasible Bridge Management Level?
  - ✓ RDA Budget on Bridge Management and Maintenance
    - → Foreign fund (reconstruction)
    - → Maintenance of Roads & Bridges (RMTF) for daily bridge maintenance works
    - → Widening & Improvement of Roads
    - → Reconstruction of Damaged / Weak Bridges for major bridge repairs, strengthening and reconstruction
    - → New budget item (vote) for minor **bridge** repair?
    - → New financial resources?
- Bridge Repair Plan for 5 Years will include:
  - ✓ Bridge inspection / diagnosis plan (target bridges, time schedule)
  - ✓ Bridge maintenance work plan (what to do, time schedule)
  - ✓ List of bridges for reconstruction (target bridges, costs)
  - ✓ List of bridges for major / minor repairs (target bridges, what to do, time schedule, costs)

Institutional Framework

- Bridge management procedures (reporting and approval process included)
- Bridge inspection system (inspection plan, implementation, confirmation)
- Bridge diagnosis and evaluation system (review and adjustment by the head office)?
- Bridge maintenance works, minor repairs, major repairs, strengthening and reconstruction, using force accounts or outsourcing?
- Tools, machinery and equipment to be procured / managed
  - ✓ Bridge inspection tools / equipment
  - ✓ Bridge maintenance work machinery / equipment
  - ✓ Machinery / equipment for minor repairs
  - ✓ Machinery / equipment for major repairs

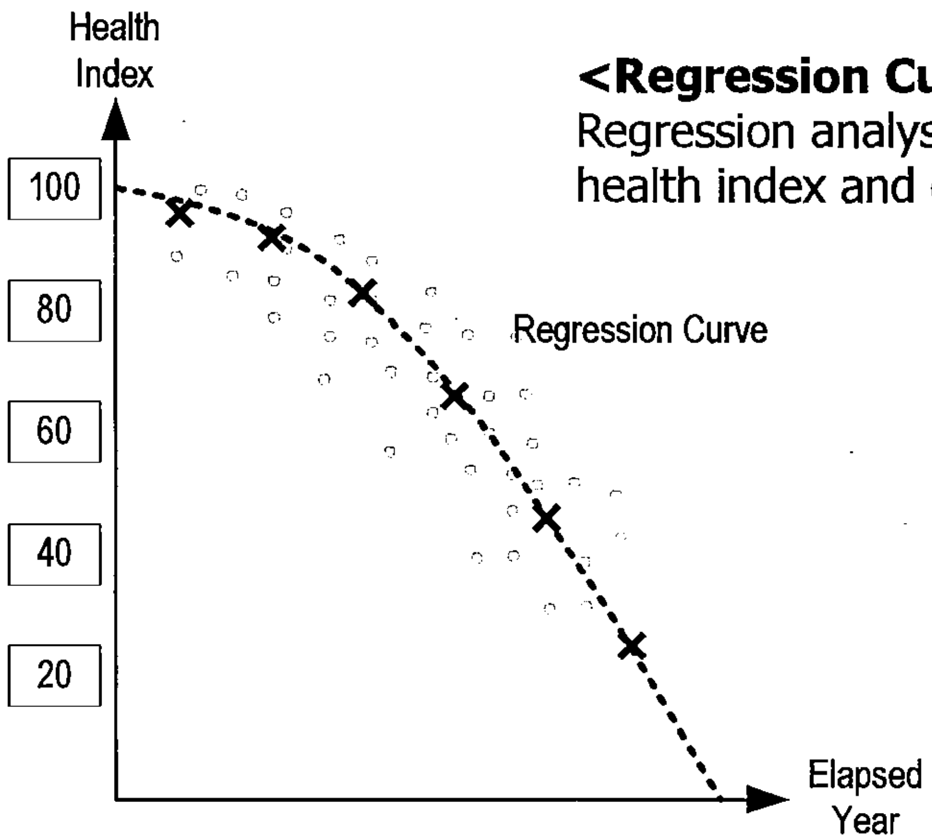
- Scale of Organization?
  - ✓ Large scale organization, using force accounts
  - ✓ Small scale organization, using outsourcing
- Necessary Human Resources?
  - ✓ Professionals in a wide variety of fields, including engineering, project management and organization operation, using force accounts
  - ✓ Professionals in the limited fields, such as project management and organization operation, using outsourcing
- Organization Structure and Allocation of Personnel?
- Roles and Responsibilities for each Division / Unit and Personnel?
- Necessary budget, including the administration costs?

Contents of Bridge Management Strategy

- Management level for bridges on national roads?
- Annual investment for bridge management?
- How many bridges are to be reconstructed annually? → reduce the number of seriously damaged / deteriorated (dangerous) bridges
- How many bridges major repairs are to be implemented annually?
- How many bridges minor repairs are to be implemented annually?
- Budget shift from the "development" to "management and maintenance".
- Human resources development and introduction of license system for professional bridge maintenance expert.

<<Reference>> Further Bridge Management Image

- When you have collected sufficient numbers of bridge inspection data,
  → Possible to predict **future deterioration** for each bridge member
  → Possible to optimize the life cycle costs (LCC) and to predict future bridge conditions (HI) (Middle / Long Term Investment Plan)



<Regression Curve for Each Member>
Regression analysis will be made from the health index and elapsed time period.

● Middle / Long Term Investment Plan (Future Bridge Conditions)

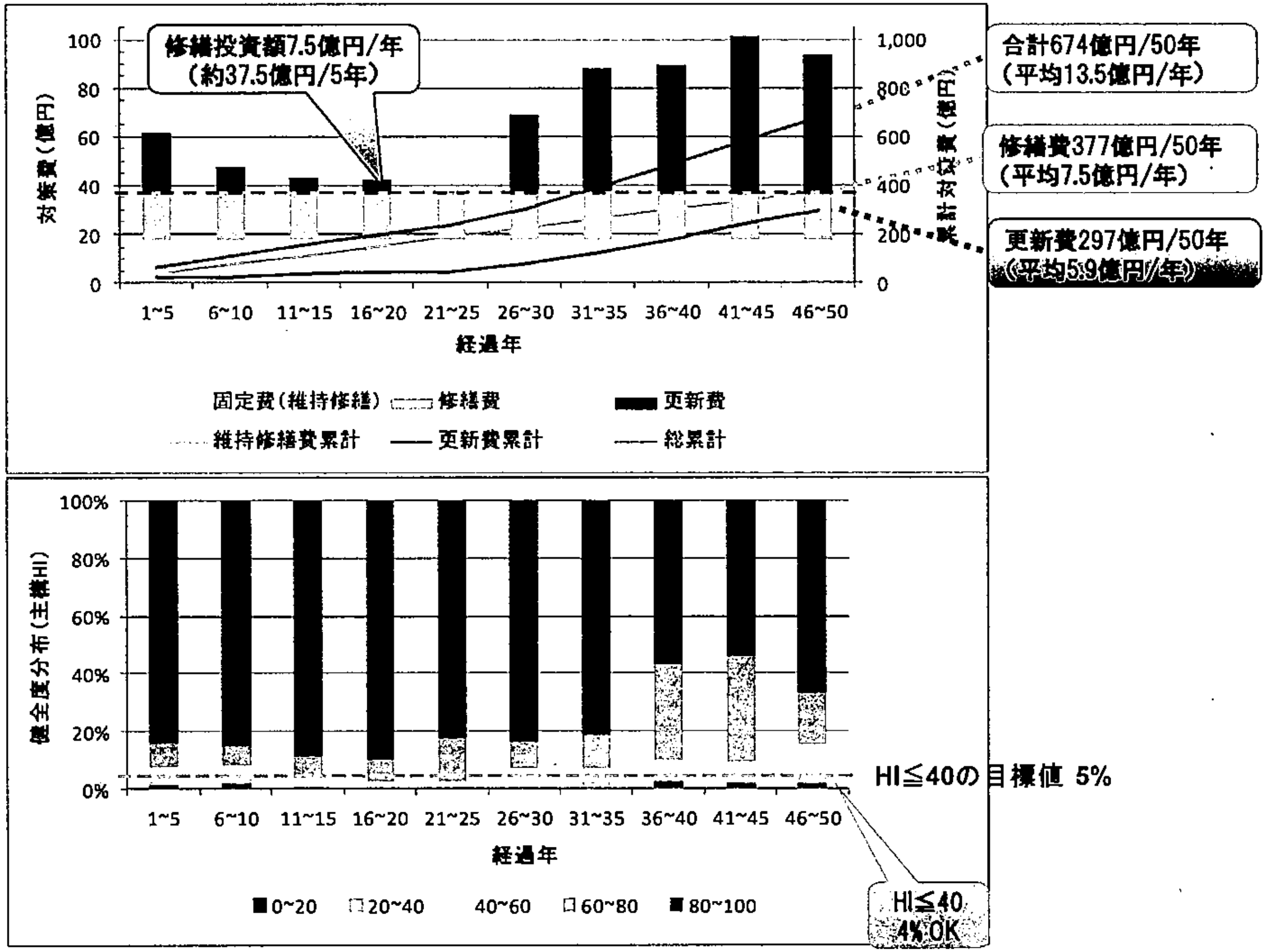


図- 4.7 管理区分を導入し計画的修実施の場合 ⇒ 最適な修繕投資額 7.5 億円/年

Tentative Schedule

PC	Themes	Time
1st PC	• Proposal on Establishment of PC • Mutual understanding of issues on current bridge management • Agreement of tentative schedule and themes	Jun. 2016
2nd PC	• Features of RDA bridges and typical defects / damage / deterioration • Current issues on bridge management and maintenance • Discussion on future image of bridge management and maintenance • Elemental technologies on bridge management	Sep. 2016
3rd PC	• Simulation of bridge management levels • Short Term Bridge Repair Plan (Micro Management)	Nov. 2016
4th PC	• Roles and responsibilities of relevant divisions / units and personnel of RDA related to bridge management	Dec. 2016
5th PC	• Discuss the contents of bridge management strategy	Jan. 2017

WS-2

2nd Workshop Agenda

October 20, 2016

Time	Theme
13:30-13:45	Issues Extracted from Baseline Surveys Mr. Hideaki TAKAURA JICA Project Team / Team Leader
13:45-14:00	Bridge Inspection and Evaluation System in Several Countries and Bridge Inspection System Provided to RDA, Sri Lanka Mr. Kazuya URANO JICA Project Team / Deputy Team Leader
14:00-14:10	Landing Points of PC Meeting / Program of Workshop and PC Meeting Mr. Hideaki TAKAURA JICA Project Team / Team Leader
14:10-14:15	Break
14:15-14:30	Bridge Management Indices and Target Bridge Management Levels in Japan Mr. Kazuya URANO JICA Project Team / Deputy Team Leader
14:30-14:45	Bridge Management Plans in Shizuoka Prefecture, Japan Mr. Kazuya URANO JICA Project Team / Deputy Team Leader
14:45-14:55	Report from RDA Working Group (WG) on September 13, 2016 Mr. B. V. D. N. Chandrasiri ADG (CD), RDA
14:55-15:05	Progress of Project Activities Mr. T. Vasanthakumar Acting DD of Bridge Design, Head of BM&AU, RDA
15:05-15:15	Issues on Institutional Framework for Bridge Management within RDA Mr. Hideaki TAKAURA JICA Project Team / Team Leader
15:15-15:30	Discussion
15:30-15:35	Closing Remarks

Analysis of Baseline Survey

JICA Project Team:
Hideaki TAKAURA

1. High Level Strategy

High Level Strategy on bridge Management is nonexistent.

Maintenance of roads are focused and maintenance of bridges are neglected.

National Road Master Plan (2007-2017)

National Road Master Plan importance of bridge maintenance will be focused

Contents of Bridge Management Strategy (draft)

- Soundness of bridge C/D reduces yy % to zz % (XX years later)
- Institutionalization of bridge inspection
- Improvement of bridge design standard
- Improvement of quality control of construction
- Introduction of education, training, qualification system.

2. Bridge Management and Maintenance Plan

- Each of the local office is preparing Repair/reconstruction Bridge lists, total plan with prioritized list is not prepared

- From which bridge should be taken measures (Prioritization) is not clear.
- Measures are not based on maintenance plan
- Amount of budget request is not reasonable

- Based on Maintenance plan, take measures for each bridge.
- Based on Management Levels, Maintenance Plan (Short term repair plan, Middle-long term invest Plan) should be established.

3. Budget for Bridge Maintenance

Budgets utilize for bridge maintenance on National Road as (i) Maintenance of Roads & Highways (RMTF), (ii) Widening and Improvement of Bridges, (iii) Reconstruction of Damaged / Weak Bridges

- Planning Division collect budget request from all the departments in RDA, submit them to Ministry of Finance through Ministry of Highway

- Minor repair of bridge is seldom implemented
- Budget request based on achievement of past year or just estimation from unit rate/ area of bridges are not reliable
- Establish a calculation system for proper repair cost based on inspection results
- Total amount and cost breakdown for bridge maintenance work is not clear.

- Establish a calculation system for proper repair cost based on inspection results.
- Establish a system to estimate bridge repair cost based on Soundness Index.
- Establish a system to sum up each repair costs to total amount for budget request.

Planning Division collect budget request from all the departments in RDA, submit them to Ministry of Finance through Ministry of Highway.

- Director of Maintenance Allocates
- (i) Maintenance of Roads & Highways (RMTF), (iii) Reconstruction of Damaged / Weak Bridges to PD's office. PD's office allocate budget to CE's office, CE's office allocates EE's office
- Implementation amount for roads and bridges are not clearly separated

➡

- Implementation rate is low, next year budget can be reduced.

➡

- Clarify budget items applicable for each maintenance work.
- Clarify implementation amount of roads and bridges.
- To improve budget implementation system to consume all Budget in a year.

4. Condition of Bridges

- Some bridges are not in sound conditions
- Inspection of bridges are not covers all. improper present inspection results.
- Initial condition of bridges are not clear.

➡

- Purpose and procedure of inspection of bridges are not clear.
- Role and responsibility of bridge maintenance work is not clear.
- Drawing and other initial information of bridges are not remains.
- Feed back from existing condition of bridges to design is not be done.
- Details of bridges should be improved & focused (water-cut kerb etc..)

➡

- Proper inspection to know the condition of bridges.
- Feedback of existing conditions and improvements to design standards.

5. Work Procedure of Bridge Maintenance

Documents regulate contents and procedure of bridge maintenance work is nonexistent.

- Contents and back ground of work is not clear.
- Role and responsibility of bridge maintenance work is not clear.
- New construction and Maintenance of road are busy, bridge maintenance is not focused.

- Clarify roles and responsibilities of work in documents
- Clarify contents and procedures of work in documents.

6. Necessary staff for work

- Inspection is not properly implemented.
- Repair work is not properly implemented

- Staff has knowledge of bridge and structures is not allocated for inspection and feedback work.
- Role and responsibility of bridge maintenance work is not clear.
- Training of staff is not properly done.

- Establishment of Special Unit for bridge maintenance – BM&AU

  Preparation of Human Development Plan.
- Proper allocation of staff of bridge maintenance in head office and local offices.

7. Necessary equipment for work

- Inspection is not properly implemented.
- Repair work is not properly implemented

➡

- Contents and back ground of work is not clear.
- Equipment for Inspection work is not prepared.
- Equipment for repair work is not prepared.

➡

- Preparation of necessary equipment for inspection work.
- Preparation of necessary equipment for repair work.

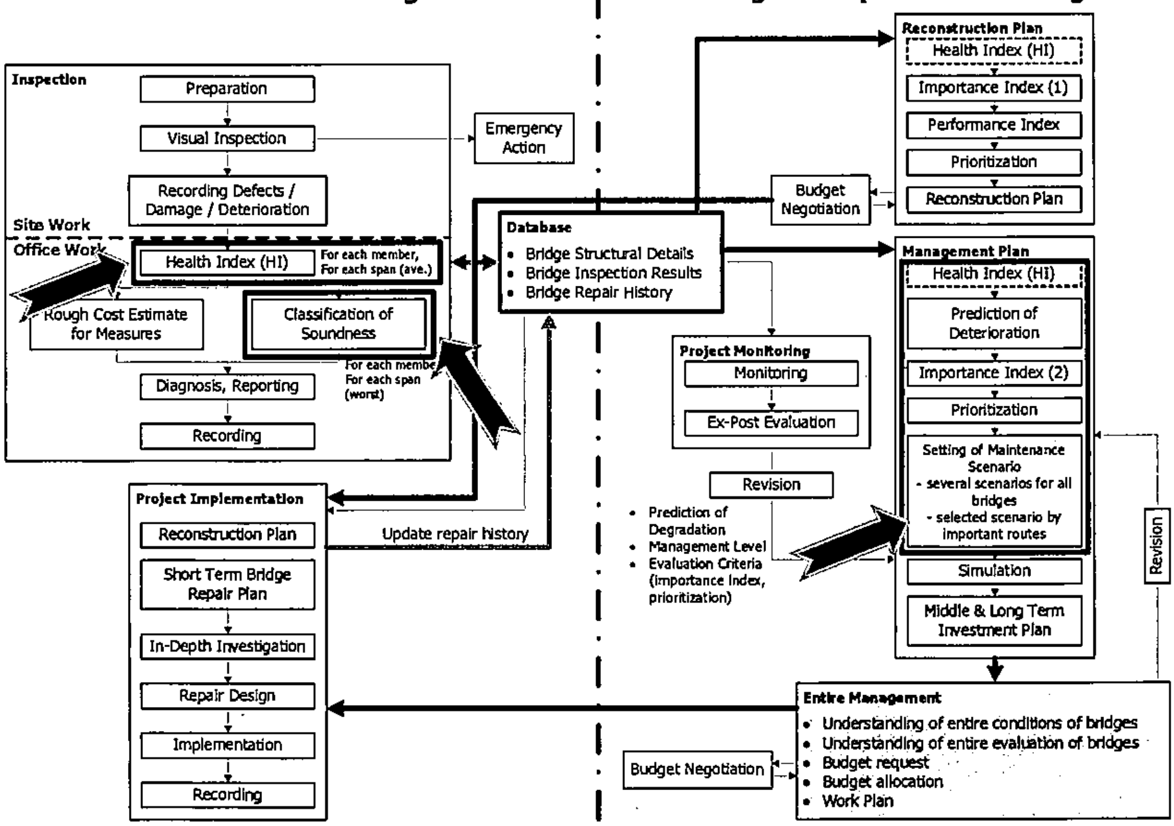
Bridge Management Indices
&
Target Bridge Management Levels
In Japan

THE PROJECT
FOR CAPACITY DEVELOPMENT
ON BRIDGE MANAGEMENT

Kazuya URANO

Today, we talk ....

For Individual Bridge | **For Bridge Groups Under Management**



1. Bridge Management Indices Used in Japan

Central Government (Ministry)

- Soundness Classifications: 9 classifications

	Descriptions
A	No damage, or slight damage which does not need repairs, etc.
B	Need repairs, etc. depending on the situations
C1	Need repairs, etc. promptly for preventive maintenance purpose
C2	Need repairs, etc. promptly for bridge structural safety
E1	Need emergency actions / responses for bridge structural safety
E2	Need emergency actions / responses for other reasons
M	Need maintenance works (small works conducted in daily activities)
S1	Need in-depth investigations to judge the need of repairs, etc.
S2	Need follow-up survey (ex. extent of crack development)

Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan

Local Governments

- Health Index, same as that proposed for RDA.

Difference between Central & Local Governments

Defects, Damage and Deterioration on Each Bridge Member
- Detect the defects, damage and deterioration at sites.
- 26 types of defects, damage and deterioration specified.
- Keep the records: each member / damage, extent thereof

(Objectively using the sample materials)

Subjectively

Health Index Calculation (Quantification)

Bridge Soundness Classifications
- Nine (9) classifications for the Ministry
- Different classifications for local governments

Central Government
- Sufficient budget
- Experienced experts

Local Government
- Insufficient budget
- Unexperienced staff

4

Calculation of Health Index (HI)

■HI is calculated based on the combination of the following three (3) components:

Evaluation of Defects, Damage & Deterioration (Damage) on Each member

$$\sum_{i = 1 \text{ to } 26} \boxed{\begin{array}{l}\textbf{Degree of Damage}\\ \textbf{5 ratings}\\ \textbf{(a, b, c, d, e)}\end{array}} \times \boxed{\begin{array}{l}\textbf{Extent of Damage}\\ \textbf{0 to 100 \%}\end{array}} \times \boxed{\begin{array}{l}\textbf{Weighting Factor}\end{array}}$$

i = type of defects, damage and deterioration: 26 types

5

Types of Defects, Damage & Deterioration Specified

Material	Type of Defects, Damage & Deterioration	
Steel	1	Corrosion
	2	Crack
	3	Loosening and missing of bolts, rivets
	4	Rupture
	5	Degradation of surface coating (painting)
Concrete	6	Crack
	7	Spalling, exposure of reinforcing steels
	8	Water leakage, free lime
	9	Depression
	11	Crack on deck slab
	12	Delamination

Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan

6

Types of Defects, Damage & Deterioration Specified

Material	Type of Defects, Damage & Deterioration	
Others	13	Unusual gap at beam ends
	14	Waving / corrugation on road surface
	15	Unusual pavement
	16	Disorder of bridge bearing
	17	Others

Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan

7

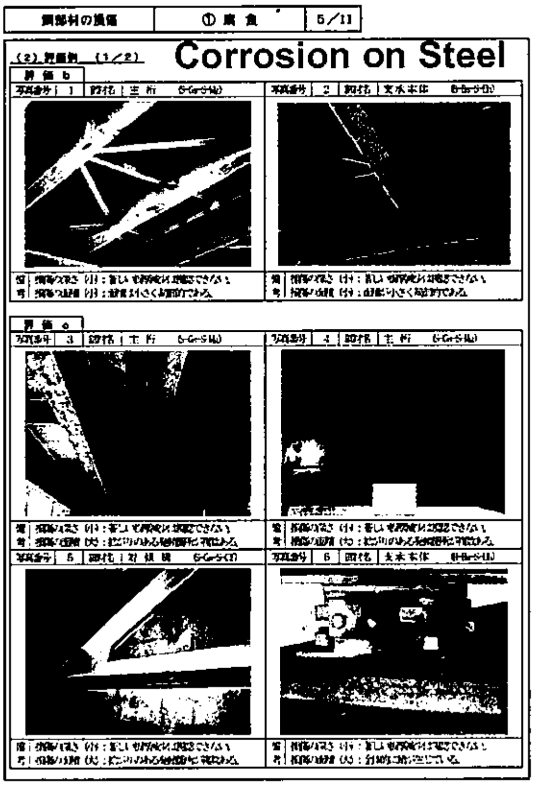
Types of Defects, Damage & Deterioration Specified

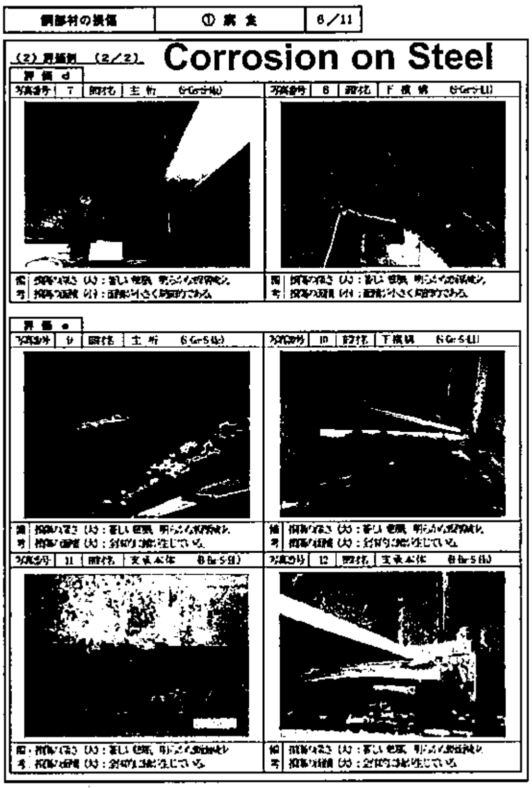
Material	Type of Defects, Damage & Deterioration	
Common	10	Damage on bridge repairs / strengthening
	18	Damage on anchorages
	19	Discoloration, deterioration
	20	Water leakage and ponding
	21	Unusual sound and vibration
	22	Unusual deflection
	23	Deformation, defect
	24	Clogging of soils
	25	Settlement, lateral movement, tilting
	26	Scouring

Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan

Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan

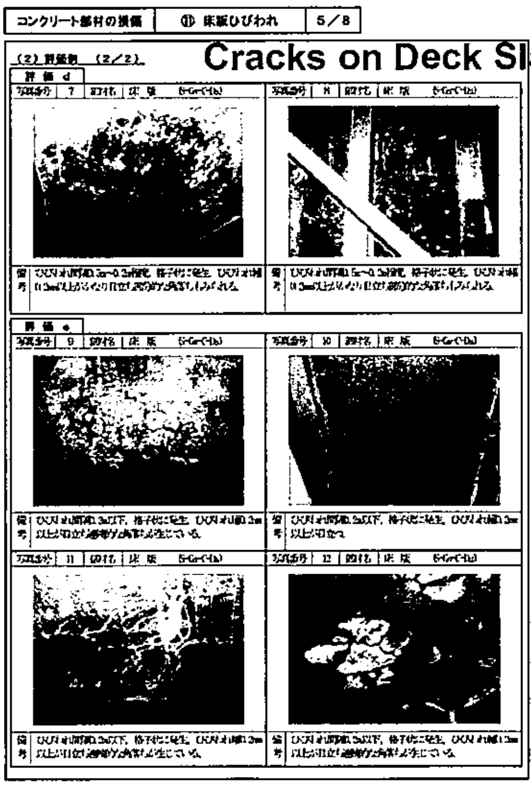
Sample Materials for Degree of Damage on Bridges (1)

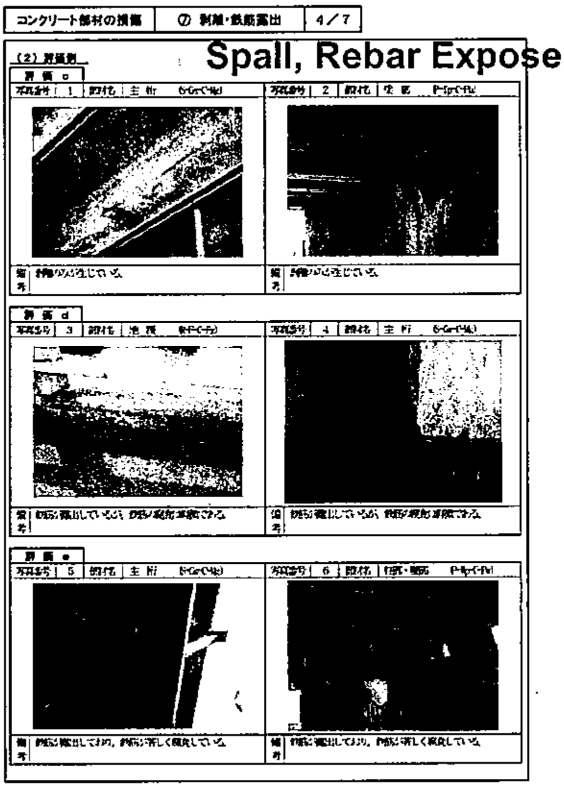




Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan

Sample Materials for Degree of Damage on Bridges (2)





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2. Target Bridge Management Level

Central Government (Ministry)

All bridge members are categorized into 9 classifications. A, B, C1, C2, E1, E2, M, S1, S2

E1/E2 Emergency Action

C1/C2 Prompt Repairs, etc.

A/B No Damage, Slight Damage

All bridge members to be taken measures immediately

All bridge members to be taken measures until next inspection

If the budget remains, preventive measures taken.

- ☐ To prevent Defect Liability, all the bridge members classified as E1/E2 and C1/C2 are to be taken measures.
- ☐ Sufficient budget should be allocated.

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Local Governments (within Limited Budget & Resources)

Calculate Health Indexes (HIs) for all bridge members.

Predict the future degradation of defects, damage and deterioration detected (develop the deterioration curve).

Prioritize all bridge members by HIs.

Set the maintenance scenarios.

Do the simulation

Select the suitable scenario for road administrator in order to manage bridges efficiently, effectively and systematically.

12

Local Governments

- Examples of Maintenance Scenarios

Target for All Bridges	Bridges by Groups
Several Scenarios for All Bridges ● HI=60 scenario ✓ All bridges → HI = 60 ● HI=50 scenario ✓ All bridges → HI = 50 ● HI=40 scenario ✓ All bridges → HI = 40	● One Target Scenario (Ex.) ✓ Group-A Bridges (important bridges in good conditions) → HI = 60 ✓ Group-B Bridges (important bridges in bad conditions, other bridges) → HI = 40 ✓ Group-C Bridges (box culverts) → HI = 20

Compared by simulation: LCC, trend in bridge soundness change

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Local Governments

- Target bridge management level will be:
  - ✓ Life cycle cost is minimal among several scenarios.
  - ✓ Bridge soundness will be drastically improved.
  - ✓ Budget level needed for the scenario is acceptable for the road administrator.
    - → HI = 60 scenario for all bridges
    - → Or, HI = 50 scenario for all bridges
    - → Or, HI = 40 scenario for all bridges
    - → Or, scenario for bridges categorized by groups?

Landing Points in PC

Contents of Guideline	Contents	Contents in WS	Landing Points in PC
1. System of Bridge Management	➢ **Flow of Bridge Management** ● Inspection Plan, Record of damages, Calculation of Soundness Indices, Estimation of Measurement Cost, Classification of Soundness ● Quantified and store in Database of Inspection results and record of repair work. ● Preparation of maintenance plan based on information from Database ➢ **Bridge maintenance plan** ● Short term Repair Plan in few years	① Flow of bridge management, an example from Japan. ② **Regarding 'Short term Repair Plan', 'Middle-long term Investment Plan', Reconstruction and renewal Plan' explain an example from Japan.**	➢ **Flow of bridge maintenance in Sri Lanka.** ➢ Latest information on bridges should store in database. ➢
2. Maintenance Target 2.1 Maintenance Indices	➢ **As Maintenance Indexes, 「Health Index: HI」 will be applied.**	③ An example from Japan ④ Explain an example of HI=0 in Japan.	➢ **Concept of Health Index in Sri Lanka : Definition of Health Index (Appearance of function of structure), Definition of HI=0.** ➢
2.2 Target Management Level	➢ **Management Level : HI will be applied.**	⑤ An example from Japan ⑥ Propose grouping of bridges in Sri Lanka.	➢ Grouping of bridges routes by routes, difference of deterioration speed, varied Management Level, purpose and necessity of bridge maintenance. ➢
3. Grasp, Evaluation of Condition of Bridges 3.1 Survey, Inspection	➢ **System of Inspection** ● Types of Inspection. ➢ Inspection Items (structural members, types of damages) ➢ Periodic inspection carry out in every 5 years. Basic method is distant view observation.	⑦ Examples of inspection from some foreign countries. (Performance Evaluation／Damage Evaluation) ⑧ Recommendation of inspection method considering condition of Sri Lanka :	➢ **Types and system of inspection of bridges in Sri Lanka** ➢ **Contents of inspection in Sri Lanka (Interval of inspection will be changed for different bridge groups. Contents of inspection records, evaluation of inspection)** ➢ :

Landing Points in PC

Contents of Guideline	Contents	Contents in WS	Landing Points in PC
3.2 Evaluation of condition of bridges	➢ **By each damage record conditions quantifiably, based on this records soundness indices will be scored. (Health Index: HI)**	⑨ An example from Japan ⑩ Propose of evaluation items and weighing coefficient in Sri Lanka.	➢ Damages of bridges→ Quantified evaluation (Record) ➢ Inspection result (Evaluation) shows as Health Index ➢ Evaluation for each damage types and set up of weighing
		:	➢ :
3.3 Classification of Soundness of Bridge (Diagnosis)	➢ **Classification of soundness is guided from Soundness Indices, A-D and E for damage for emergency, S needs detailed Survey (Structural member, type of structure, each spans and each bridge). Classification of soundness is evaluated separated from Soundness Indices.**	⑪ An example from Japan : Health Indexes and utilizing them. ⑫ Propose of Soundness in Sri Lanka	➢ **Definition of diagnosis** ➢ **Usage of Health Index and Soundness Classification in Sri Lanka.** ➢ **Health Index for structural members→Soundness Classification and estimation of standard repair cost.** ➢ **Health Index of bridges→ Selection of reconstruction bridges** ➢ **Soundness Classification→ Prioritization of repair of bridges**
		:	➢ :
3.4 Forecast Method of Future Condition	➢ Forecast of future condition, statistically process inspection result。	Comparison of varied forecasting methods	➢ Statistical analysis of inspection result. Before inspection results will be corrected study based on general life span of bridges.
		:	➢ :
4. Establishment of Maintenance Plan 4.1 Classification of bridge maintenance cost	➢ Repair costs divides into 3 categories. Depend on Health Indexes varies measurements method or amounts.	⑬ **Classification of budget : Inspection (Direct work) , Repair Cost1 (forecast deterioration) ,Repair Cost 2 (Periodic) , Repair 3 (Emergency)** ⑭ **Estimation of each costs**	➢ Classify bridge maintenance budget in RDA. ➢ Estimation of various costs for bridge maintenance

Landing Points in PC

Contents of Guideline	Contents	Contents in WS	Landing Points in PC
		:	➢ :
4.2 Economic Evaluation Method	➢ **Measurements and amount of work are varied depend on Health Indexes. Apply as measurements work standards repair method, standard amount or cost.**	⑮ Propose of Standard Repair method based on health Indexes. ⑯ Unit rates for repair work	➢ Repair method and repair cost corresponding to Health Index in Sri Lanka
		:	➢ :
4.3 Prioritization	➢ **Priority of measures are decided depend on Importance and Soundness.**	⑰ An Example from Japan, Importance Indices ⑱ Propose of Importance Index	➢ Calculation method of Importance Index in Sri Lanka ➢ Values on each evaluation items and set up of weighing
		:	➢ :
4.4 Preparation of Short term repair Plan	➢ Basically repair work is focusing each member. Priority is decided depend on Soundness of bridge and Importance (features of routes, site conditions)	⑲ Analysis of necessary budgets based on inspection results on Sample provinces and varied Management Level. ⑳ Propose of Management Level in Sri Lanka ㉑ propose of Short term repair Plan	➢ **Short term repair plan is reviewed every year based on inspection results.** ➢ **Short term repair plan in future and short term repair plan at present** ➢ **Rule of grouping of repair work in RDA. (Within same bridges, same routes, expecting repair timing is close (For example implement them together 5 years difference structural members and bridges)** ➢ **Contents of short term repair plan**
		:	:
4.5 Middle-long term maintenance Plan	➢ **Without restriction of budget, best pattern of investment and leveling of budget.**	➢ Simulation of invest amount ➢ Propose of Management Level in Sri Lanka	➢ Rule of leveling of budget in RDA (Limitation of postpone is 5 years) ➢ Budget of bridge maintenance is total amount of repair cost of each bridges. ● Contents of middle-long term

Landing Points in PC

Contents of Guideline	Contents	Contents in WS	Landing Points in PC
			investment
		:	:
5. Selection of reconstruction bridges 5.1 Renewal Cost	➢ **Maintenance budget and reconstruction budget are different.**	㉒ calculation of reconstruction cost	➢ **Calculation method of reconstruction cost in reconstruction plan**
		:	:
5.2 Evaluation of Soundness	➢ **Quantified evaluation of function (Function Index, Scoring)**	㉓ Evaluation items of function Index in Sri Lanka	➢ Evaluation items of function Index and weighing coefficient in RDA
		:	:
5.3 Selection of reconstruction bridges	➢ Extract reconstruction bridges by evaluation of soundness, function, Importance.	㉔ Extraction standard in Sri Lanka	➢ **Standards of extraction of reconstruction bridges in RDA**
		:	:
6. Monitoring · Post evaluation	➢ **Monitor and evaluation of Soundness Indices, changing of classification of soundness.**	㉕ Propose and discussion of concrete monitoring items and evaluation of effectiveness of bridge maintenance plan.	➢ **Concrete monitoring items and evaluation of effect of bridge maintenance plan**
		:	:
7. Policy	➢	㉖ **Policy on Bridge Maintenance Plan** - **Percentage of classification of Soundness C and D, initially 10 % to 5 % in 5 years.** - **Legislation of Bridge Inspection.** - **Education and training system**	➢ Bridge maintenance policy in RDA ➢
		:	:

Landing Points in PC

Contents of Guideline	Contents	Contents in WS	Landing Points in PC
8. Institutional Framework of Bridge maintenance	➢	㉗ **Issues on present Institutional Framework on bridge maintenance** ㉘ **Propose and discussion of Necessary Institutional Framework to realize Bridge maintenance ,management policy**	➢ **Institutional framework on bridge maintenance work in RDA** – **Procedure of bridge maintenance work** – **Classification of repair work, direct work/Contract out** – **Role and responsibility of work** – **Allocation of staff & equipment**
		:	:
9. Others	➢	㉙ Relating BMS system	➢ Reporting form, Organization, level to operates BMS system and data, data renewal

Bridge Management Plans
In
Shizuoka Prefecture, Japan

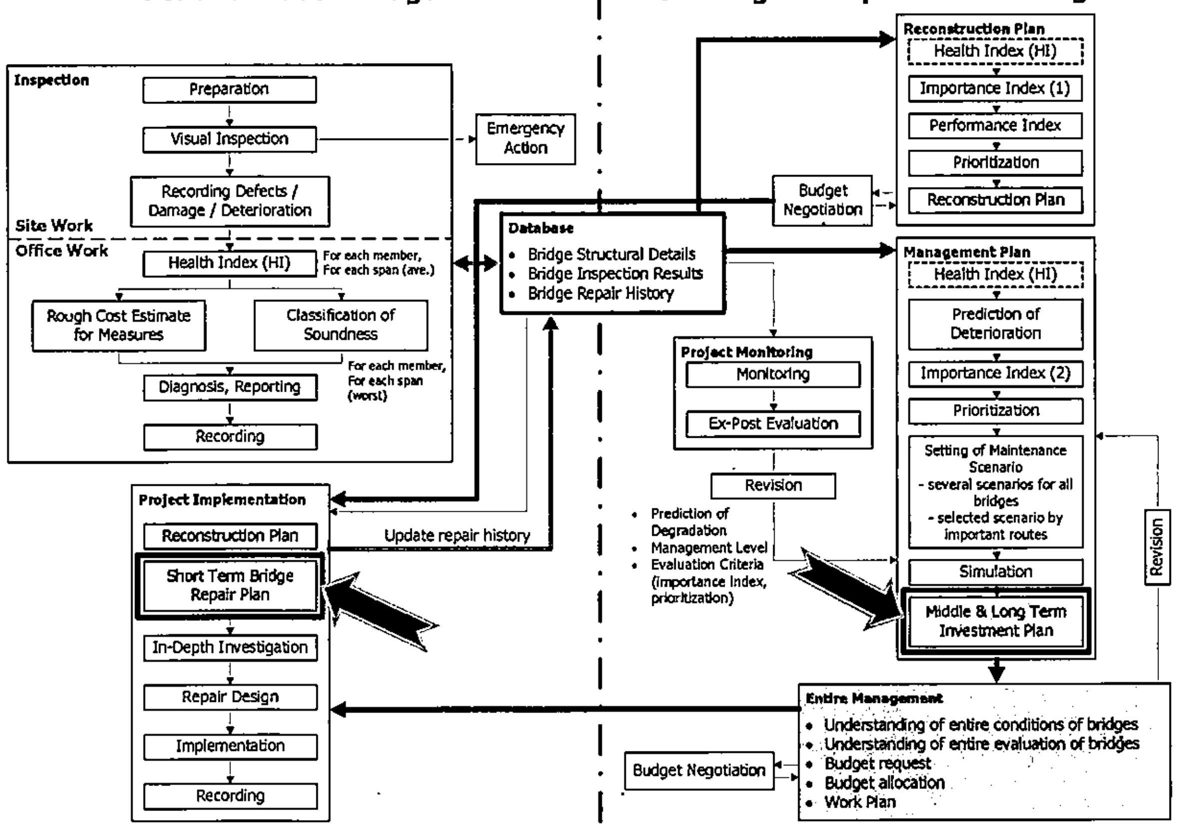
THE PROJECT
FOR CAPACITY DEVELOPMENT
ON BRIDGE MANAGEMENT

Kazuya URANO

1

Today, we talk ....

For Individual Bridge | **For Bridge Groups Under Management**



2

1. Bridge Management Plans

Middle / Long Term Investment Plan

- It is the investment plan for bridge maintenance and management.
- It is to estimate the future necessary investment and trend of bridge conditions, and to plan the budget increase / decrease, budget allocation to provinces, directions to future bridge management.

Plan of Action for Financial Management

- Optimize the necessary costs of bridge maintenance under specific bridge management level.

Short Term Bridge Repair Plan

- It is the bridge repair, strengthening and reconstruction plans under management within the limited budget.
- It is to assess the current condition of individual bridge, and to plan the specific measures to be taken, timing and priority for bridges.

Plan of Action for Bridge Management

- Ensure the soundness and safety of bridges efficiently within limited budget.

3

2. Contents of Long / Middle Term Investment Plan

1. Purpose and concept of developing the plans
   - 1-1. Purpose
   - 1-2. Concept
2. Present bridge conditions and issues in Shizuoka Prefecture
3. Needs of asset management
   - 3-1. Introduction of asset management
   - 3-2. Effects from the asset management
4. Bridge inspection
5. Efforts on extending the service life of bridges
   - 5-1. Efforts on extending the service life of bridges
   - 5-2. Plan development
     - Setting the bridge management level
     - Setting the service life
     - Development of long / middle term investment plan
     - Effects of plan development
   - 5-3. Plan implementation
     - Development of short-term bridge repair plan
     - Importance on daily works
     - Prevention of third-party effects
     - Feedback to bridge design
   - 5-4. Ex-post evaluation
   - 5-5. Review the plan
6. 3 pillars supporting the extension of service life of bridges

(1) Purpose and Concept of the Plan Development

Purpose

To implement optimum bridge maintenance and management, including the extension of service life of bridges, under the budget constraint.

Basic Concept

- Promoting the human resources development

  To improving the skills of government staff on bridge inspection (seminars and workshops, support to cities and towns)
- Sharing the information

  To collect and utilize the defects, damage and deterioration data, effective measures.
- Public relation activities

  To obtain the understanding of the importance of bridge maintenance from the local residents, through presenting the current bridge conditions and advantages of implementing the plan.

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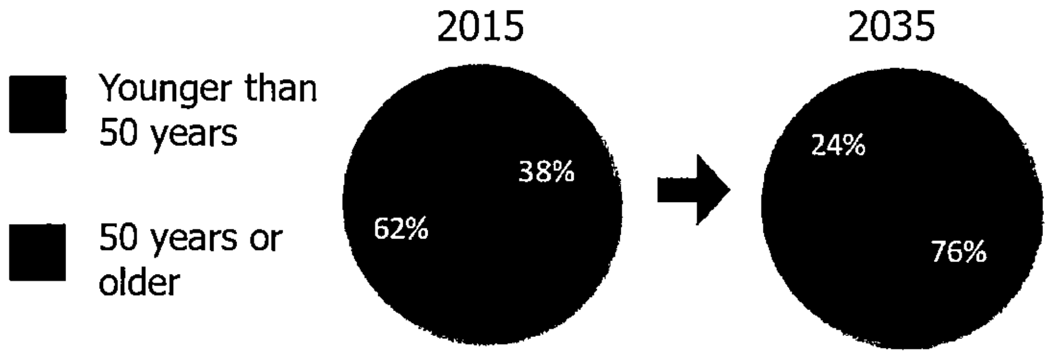
(2) Present Bridge Conditions & Issues in Shizuoka Pref.

Bridges under the Management

- Number of bridges: approximately 3,300
- Bridge ages:



Source: Long / Middle Term Bridge Management Plan 2016, Shizuoka Prefecture

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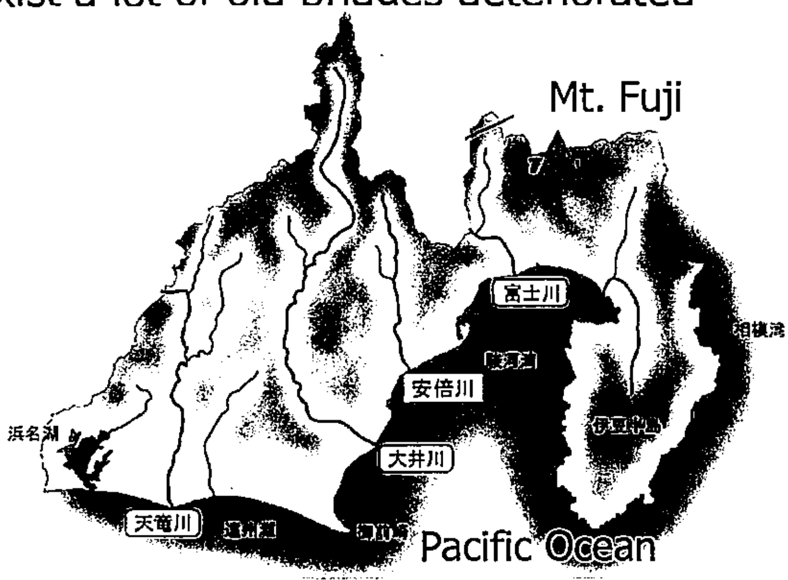
Source: Long / Middle Term Bridge Management Plan 2016, Shizuoka Prefecture

- Issues on bridges in Shizuoka
  - ✓ Severe environments (salt damage, cold regions)
  - ✓ Large river crossing (long span bridge)
  - ✓ Increased maintenance cost under limited budget
  - ✓ There exist a lot of old bridges deteriorated



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(3) Needs of Asset Management

Introduce the Asset Management Techniques

- To consider the bridges as "assets".
- In order to maximize the values of assets (efficient and effective management), the following will be implemented:
  - ✓ Understand the present bridge conditions by periodical inspection.
  - ✓ Predict the future degradation of bridges by objectively recorded data and analysis.
  - ✓ Prioritize the bridges.
  - ✓ Conduct appropriate measures systematically

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Expected Effects from Asset Management

- Ensure the safety of road transport and reduce the social / economic losses
- Reduce the total costs (repair, reconstruction, etc.)
- Ensure the environmental friendliness (by reducing the amount of industrial waste disposal)

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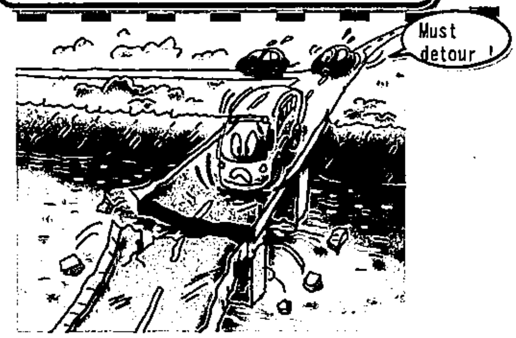
When the bridge is broken down, children canot go to school.

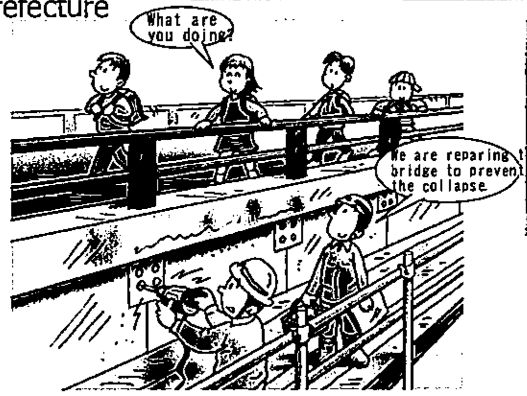
When the bridge is broken down, freight tra· c should detour.

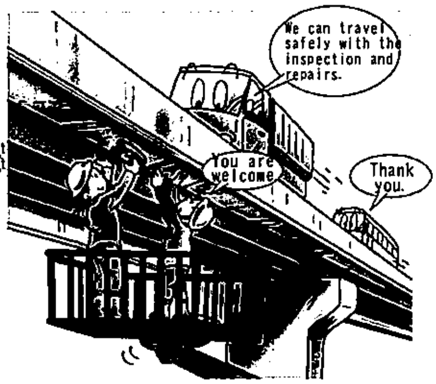


Source: Long / Middle Term Bridge Management Plan 2016, Shizuoka Prefecture

Periodical inspection and early measures are to be conducted for safety and security.

Social & Economic Losses





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Source: Long / Middle Term Bridge Management Plan 2016, Shizuoka Prefecture

(4) Bridge Inspection

Bridge Inspection System

- Bridge inspection system is specified.
- Bridge inspection is mandatory.
- Frequency of periodical inspection is specified: every 5 years.

Bridge Inspection
→ Routine Inspection (Patrol)
→ Periodical Inspection
→ Specific Inspection
→ Emergency Inspection

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(5) Efforts on Extending the Service Life of Bridges

Efforts on Extending the Service Life of Bridges

- Define the plans:

Plan	Purpose	Contents
Long / Middle Term Investment Plan	• Ensure the safety of road network in the long run. • Levelling of concentrated repair / strengthening costs of deteriorated bridges.	• Setting the management scenario of bridges based on the importance and features. • Develop the investment plan for 50 years. • Importance of daily maintenance works (cleaning, minor repairs)
Short Term Bridge Repair Plan	• Materialize the long / middle term investment plan for the coming 10 years.	• Determine the concrete timings / details of inspection and repairs, reconstruction for 10 years.

Source: Long / Middle Term Bridge Management Plan 2016, Shizuoka Prefecture

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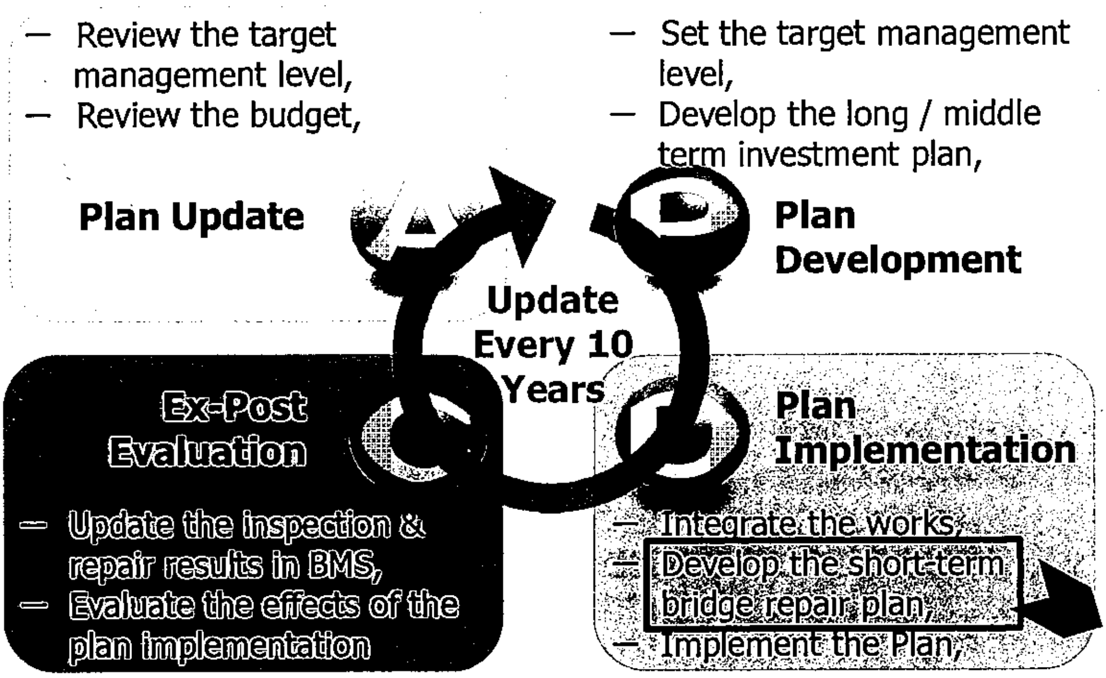
Source: Long / Middle Term Bridge Management Plan 2016, Shizuoka Prefecture

- Define the PDCA Cycle for Long / Middle Term Investment Plan:



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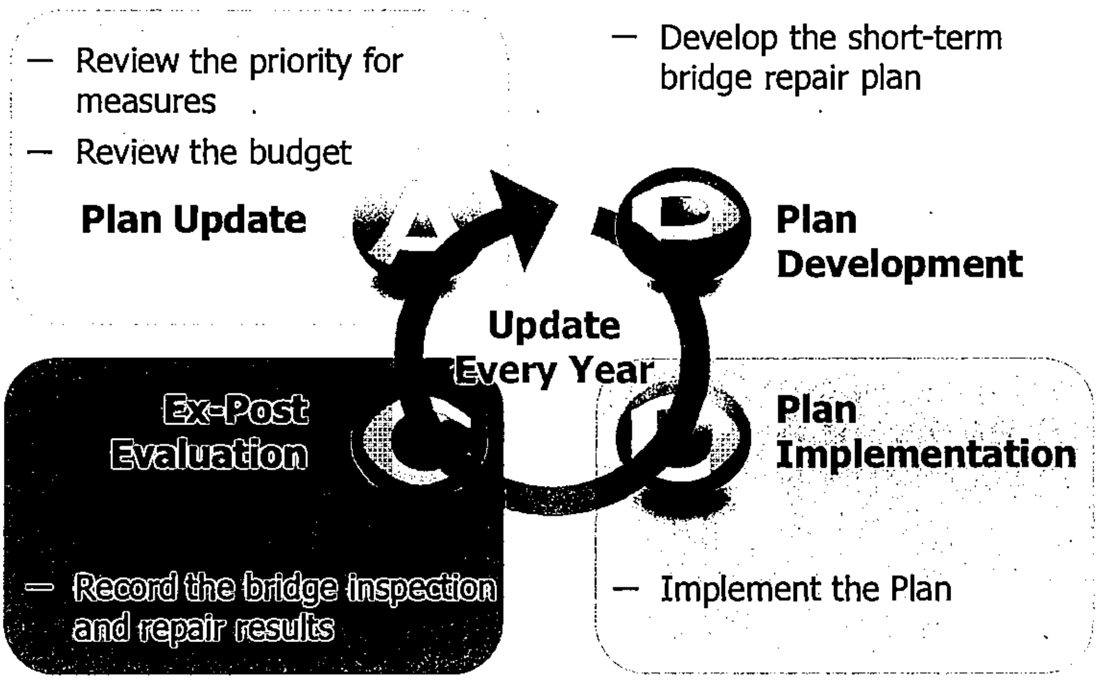
Source: Long / Middle Term Bridge Management Plan 2016, Shizuoka Prefecture

- Define the PDCA Cycle for Short Term Bridge Repair Plan:



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(6) Plan Development

Target Management Level Options

- Comparison made: HI = 80, 70, 60, 50, 40, 30, 20
  By groups (Important Bridges (L > 15m): HI=60,
  Box Culvert: HI = 20, Other Bridges: HI = 40)
- (In Shizuoka Prefecture, HI = 60 was selected.)

Setting of Design Service Life

- In order to calculate life cycle costs, design service life should be assumed.
- **120 years** in Shizuoka Prefecture.
- After the design service life, the bridge is considered to be replaced (reconstructed) (no more repair / strengthening).

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Source: Long / Middle Term Bridge Management Plan 2016, Shizuoka Prefecture

Develop Long / Middle Term Investment Plan

- Maintenance costs are classified:

Classification	Details	Target Members
Inspection	• Expenses for periodical inspection (every 5 years)	• All the members
Repair (1)	• Expenses for repairs, based on the prediction of degradation	• Main beams • Deck slab • Substructures
Repair (2)	• Expenses which are needed for periodical repairs	• Bridge bearing • Bridge expansion joint • Pavement
Repair (3)	• Expenses which are needed for accidental / unexpected repairs	• All the members

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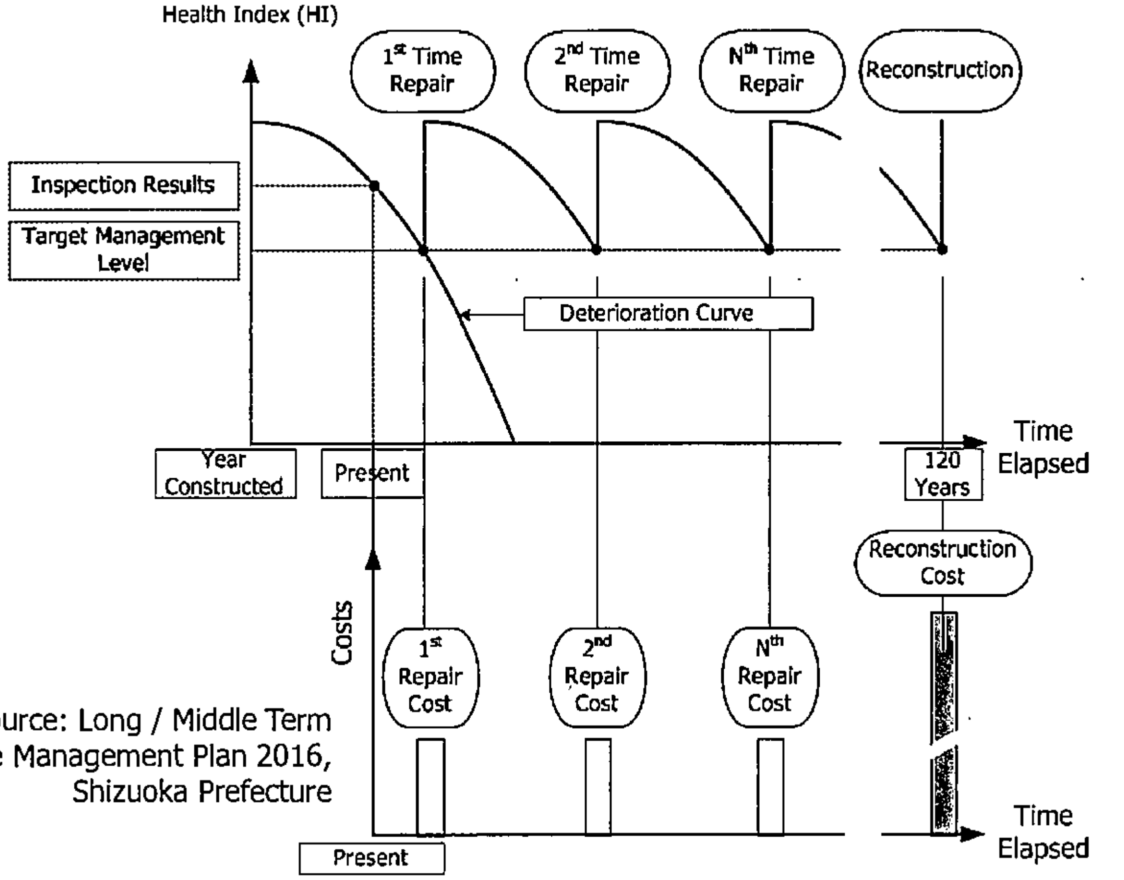
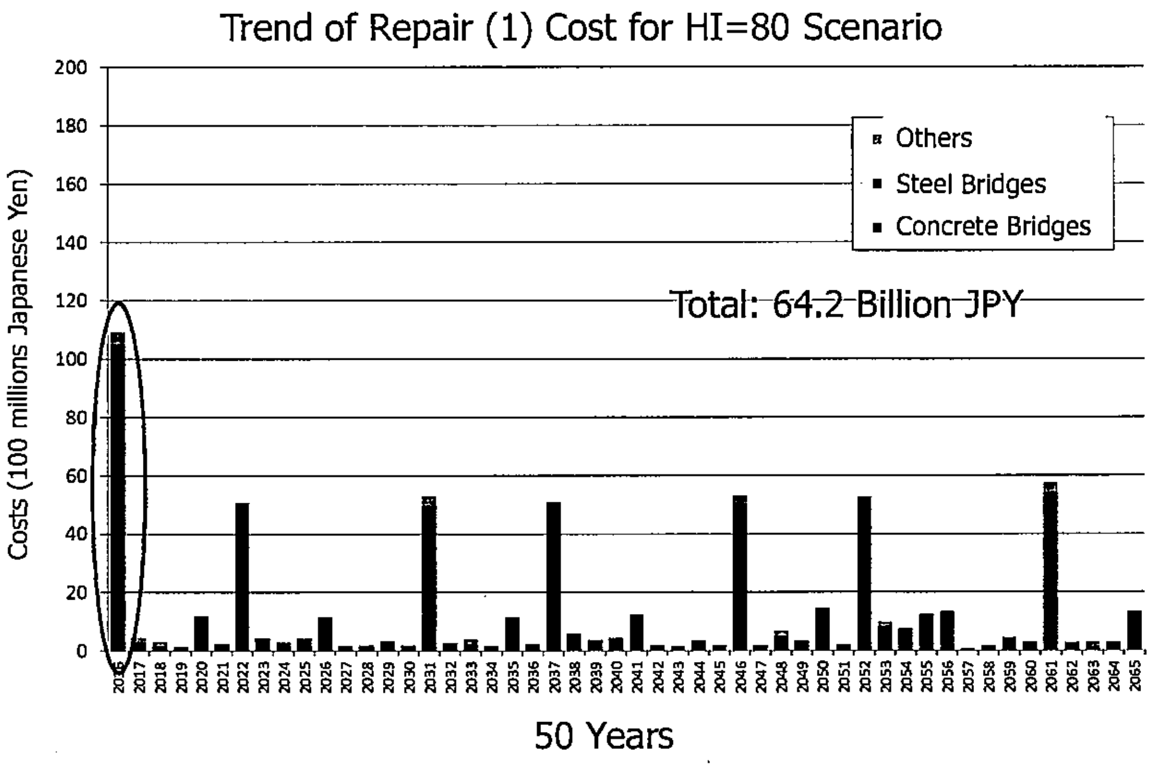
- Develop the degradation curve for each member.
- Timings for repair works, depending on the target management level.

Image of Repair (1) Cost: from the prediction of damage

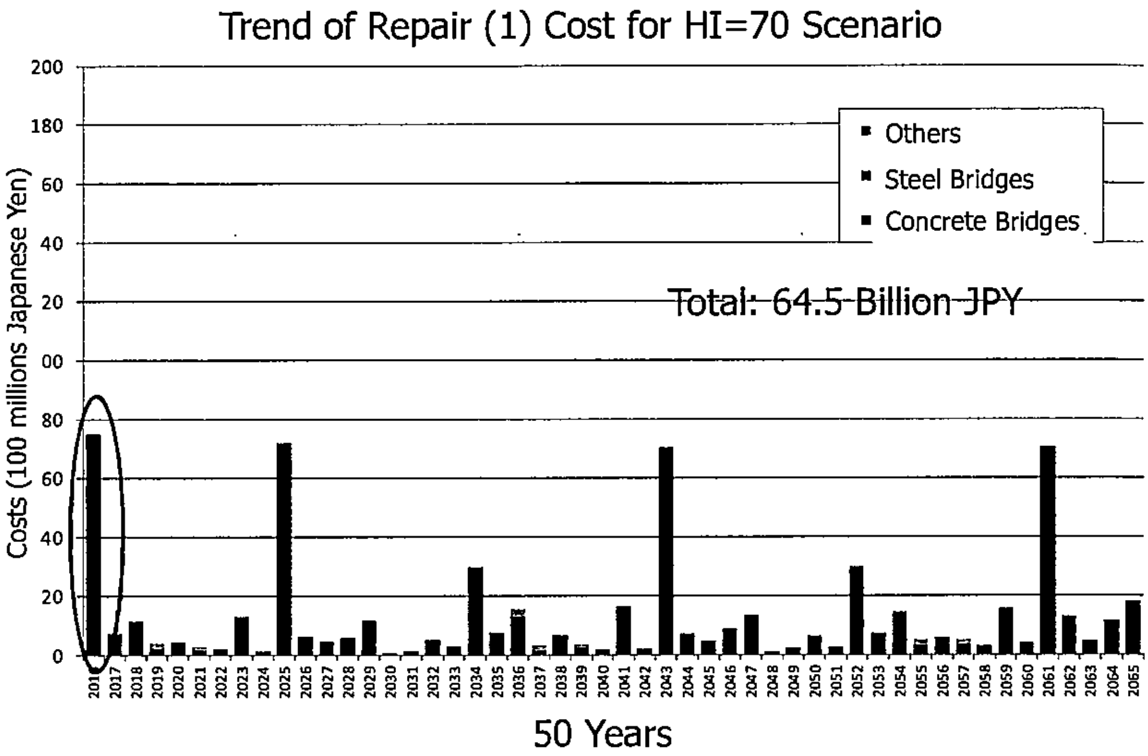


Source: Long / Middle Term Bridge Management Plan 2016, Shizuoka Prefecture

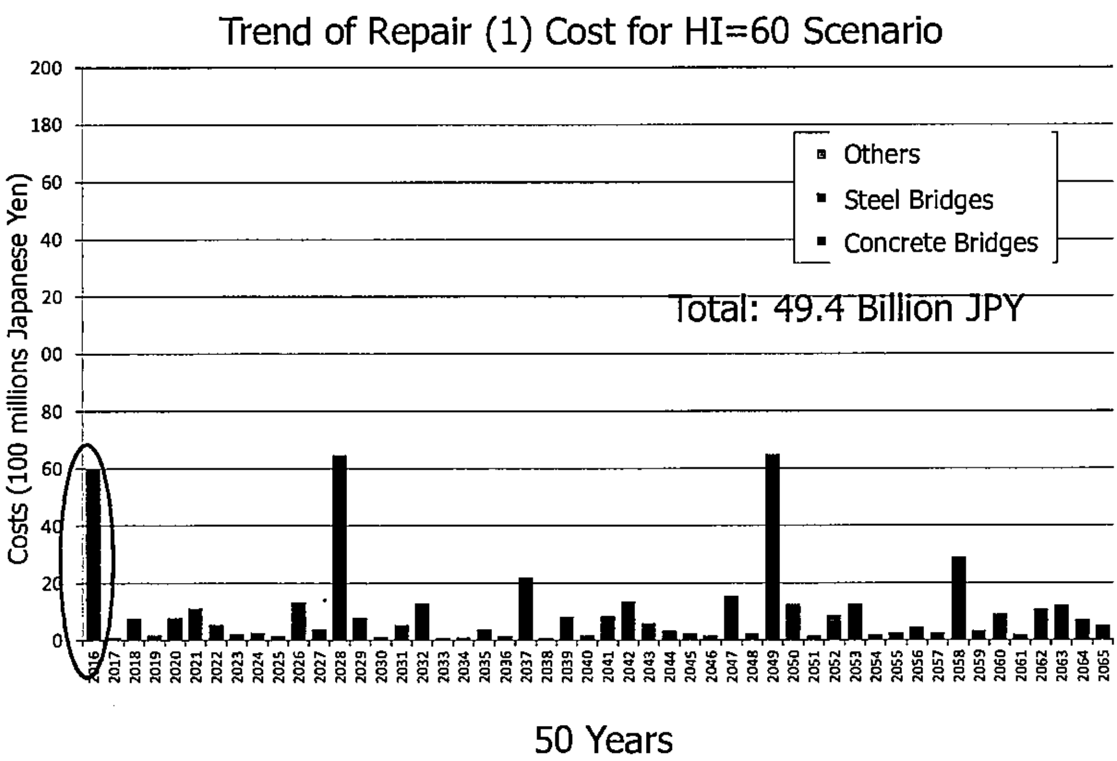
Source: Long / Middle Term Bridge Management Plan 2016, Shizuoka Prefecture



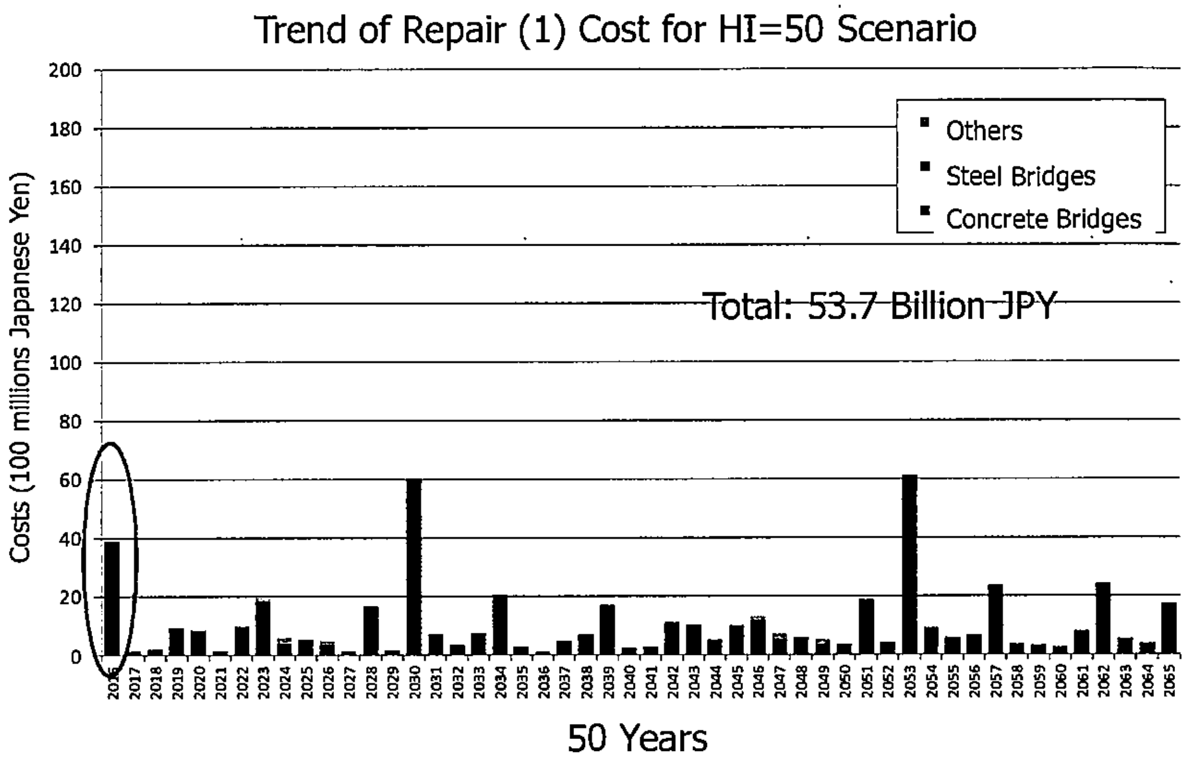
Source: Long / Middle Term Bridge Management Plan 2016,
Shizuoka Prefecture



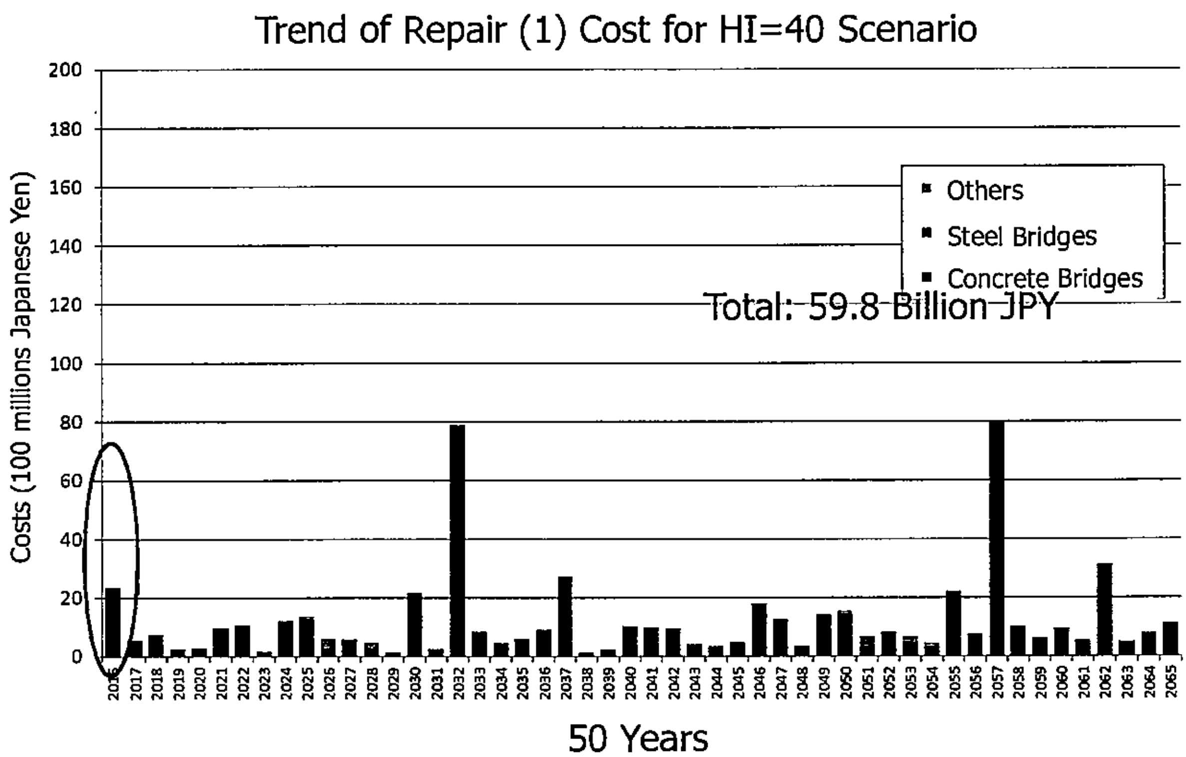
Source: Long / Middle Term Bridge Management Plan 2016,
Shizuoka Prefecture



Source: Long / Middle Term Bridge Management Plan 2016, Shizuoka Prefecture



Source: Long / Middle Term Bridge Management Plan 2016, Shizuoka Prefecture



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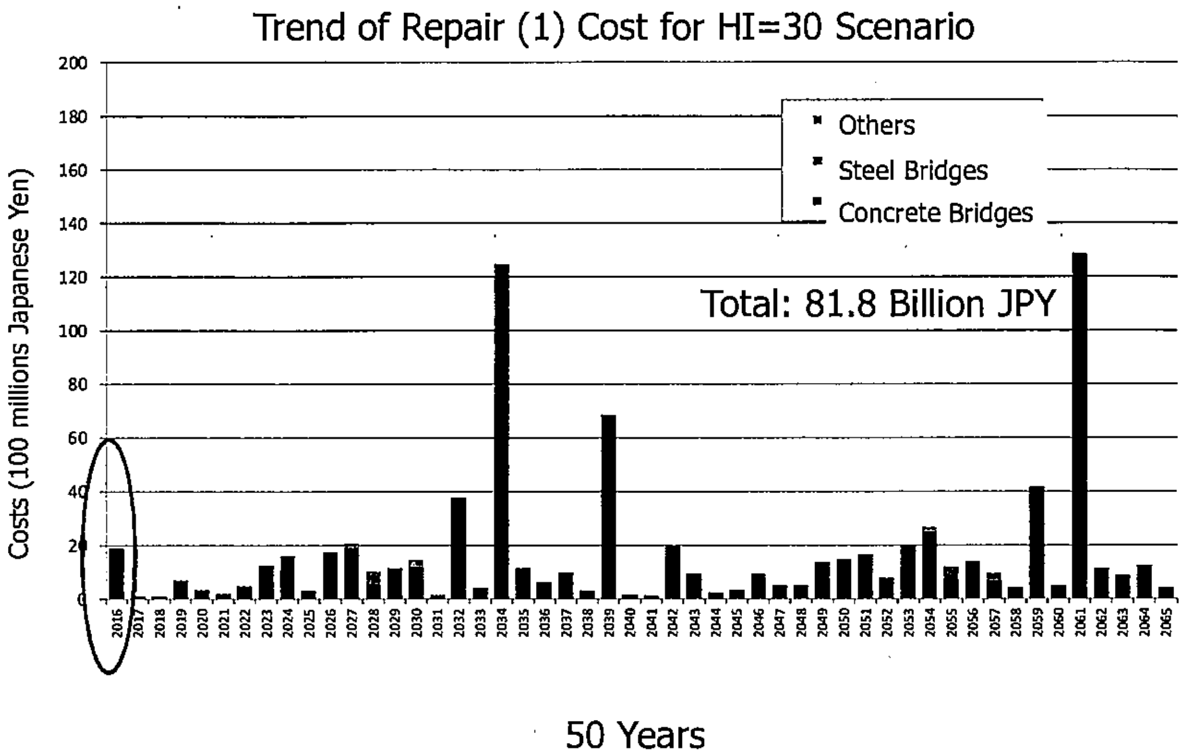
Source: Long / Middle Term Bridge Management Plan 2016,
Shizuoka Prefecture



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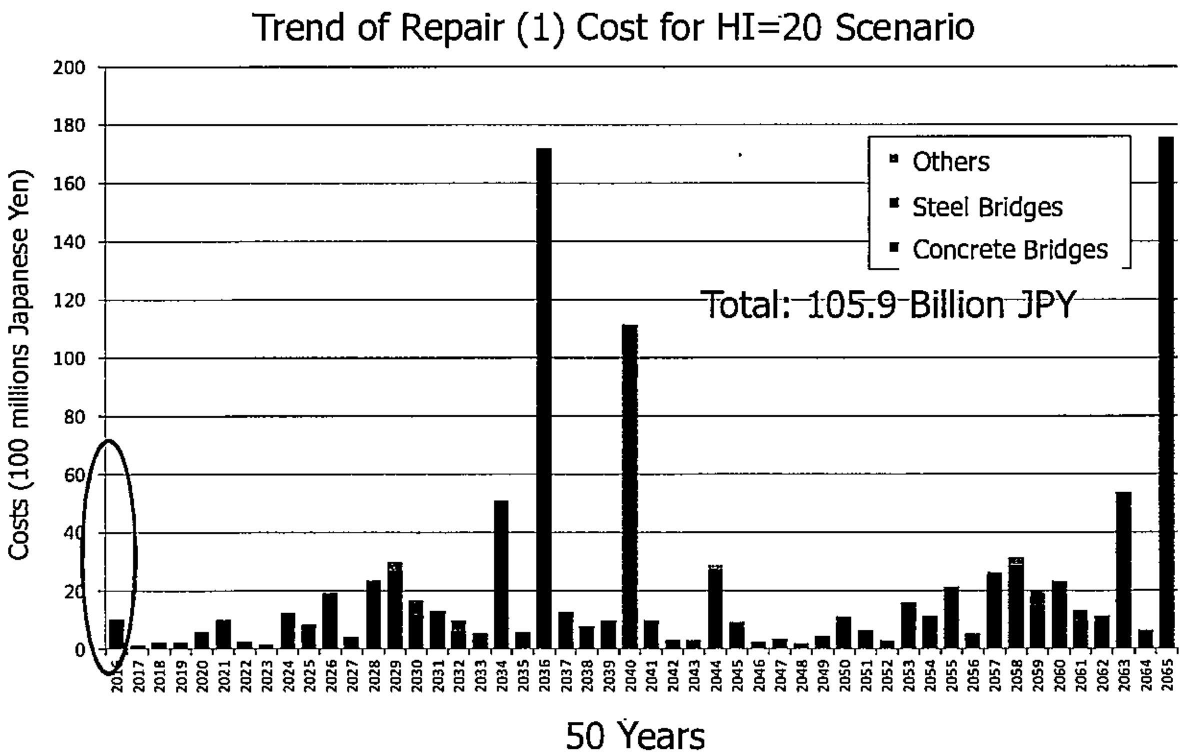
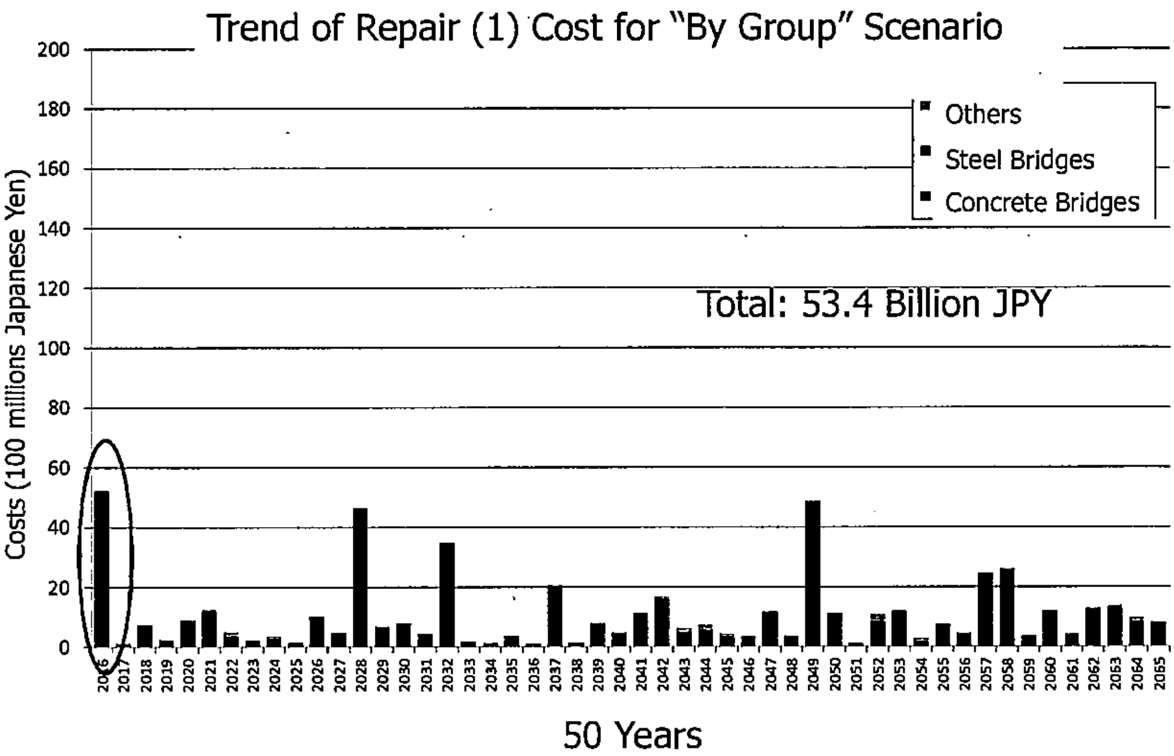
Source: Long / Middle Term Bridge Management Plan 2016,
Shizuoka Prefecture



Source: Long / Middle Term Bridge Management Plan 2016, Shizuoka Prefecture

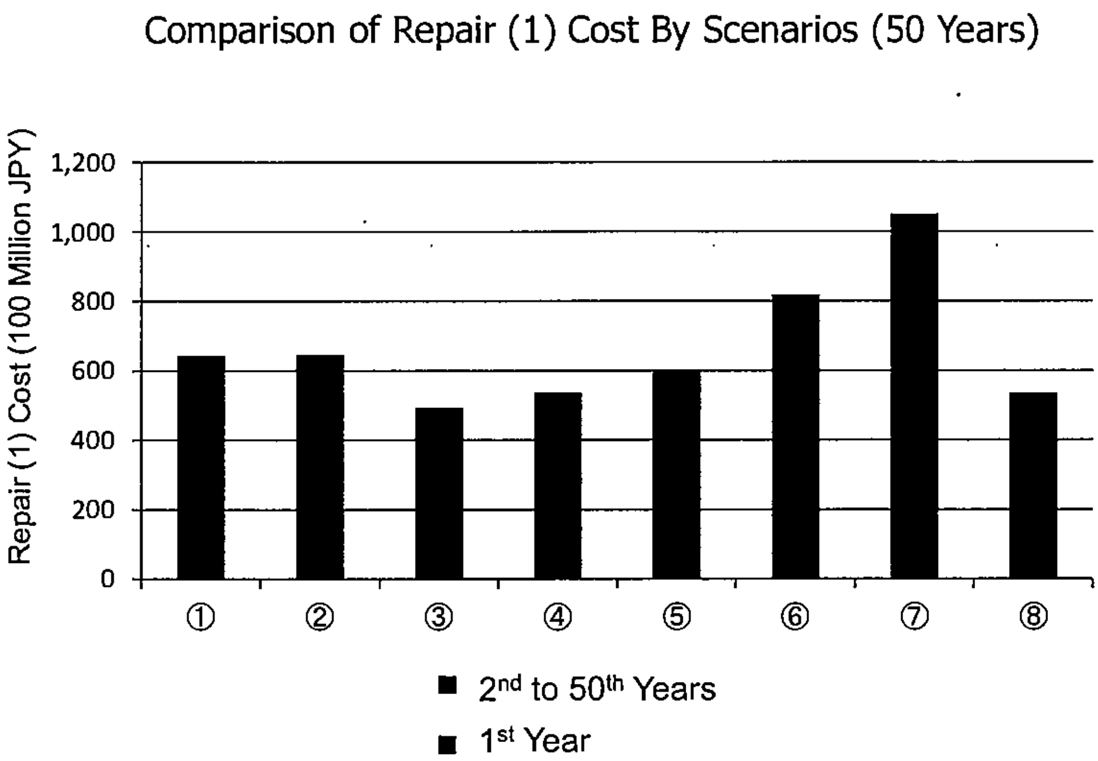


Source: Long / Middle Term Bridge Management Plan 2016, Shizuoka Prefecture

Comparison of Repair (1) Cost By Scenarios (50 Years)

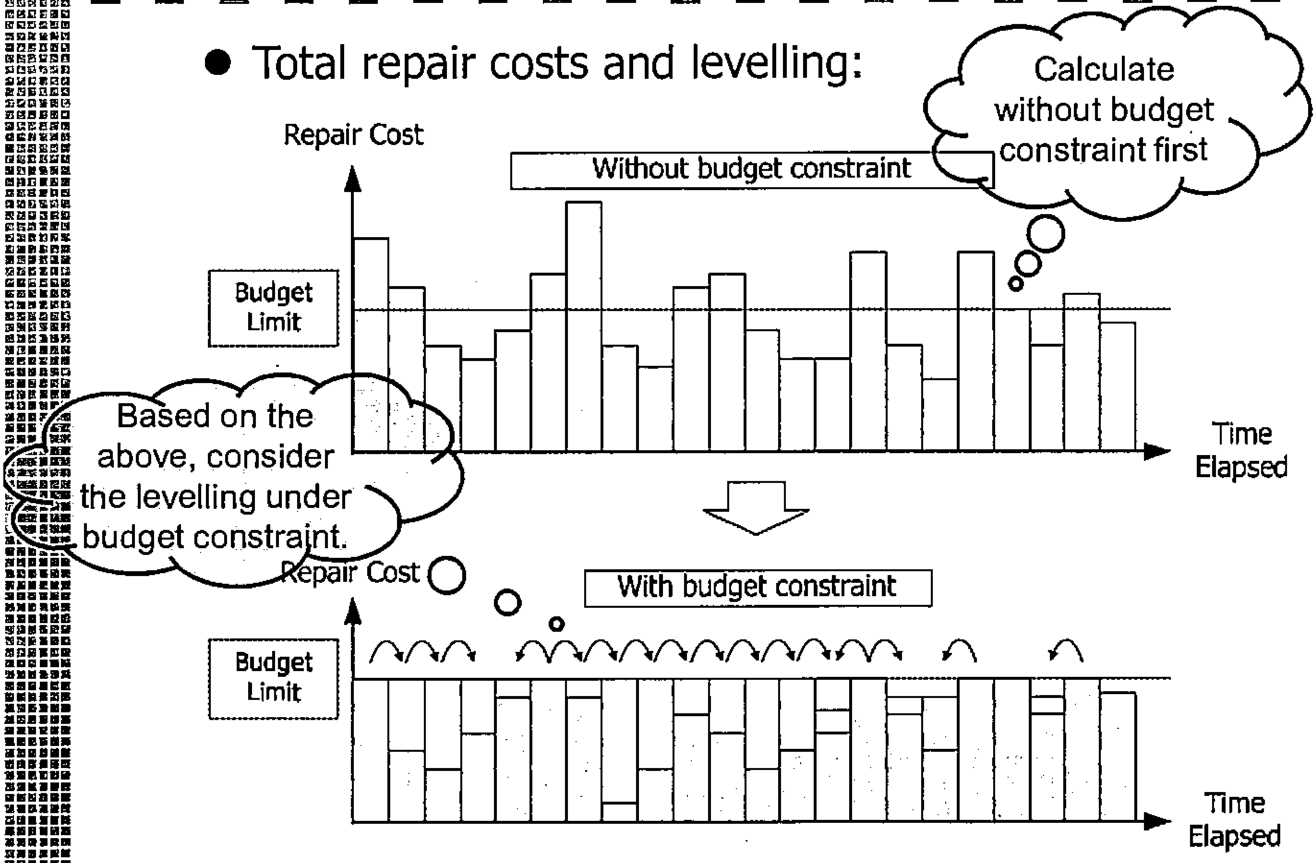
Scenario	Investment First Year (Billion JPY)	Investment Second Year to 50th Year (Billion JPY)	Total Investment (Billion JPY)
HI=80	10.91	53.31	64.22
HI=70	7.52	57.00	64.52
HI=60	6.01	43.41	49.42
HI=50	3.91	49.74	53.66
HI=40	2.36	57.45	59.81
HI=30	1.91	79.90	81.81
HI=20	1.02	104.01	105.03
By Group	5.22	48.21	53.43

Source: Long / Middle Term Bridge Management Plan 2016,
Shizuoka Prefecture



Source: Long / Middle Term Bridge Management Plan 2016,
Shizuoka Prefecture

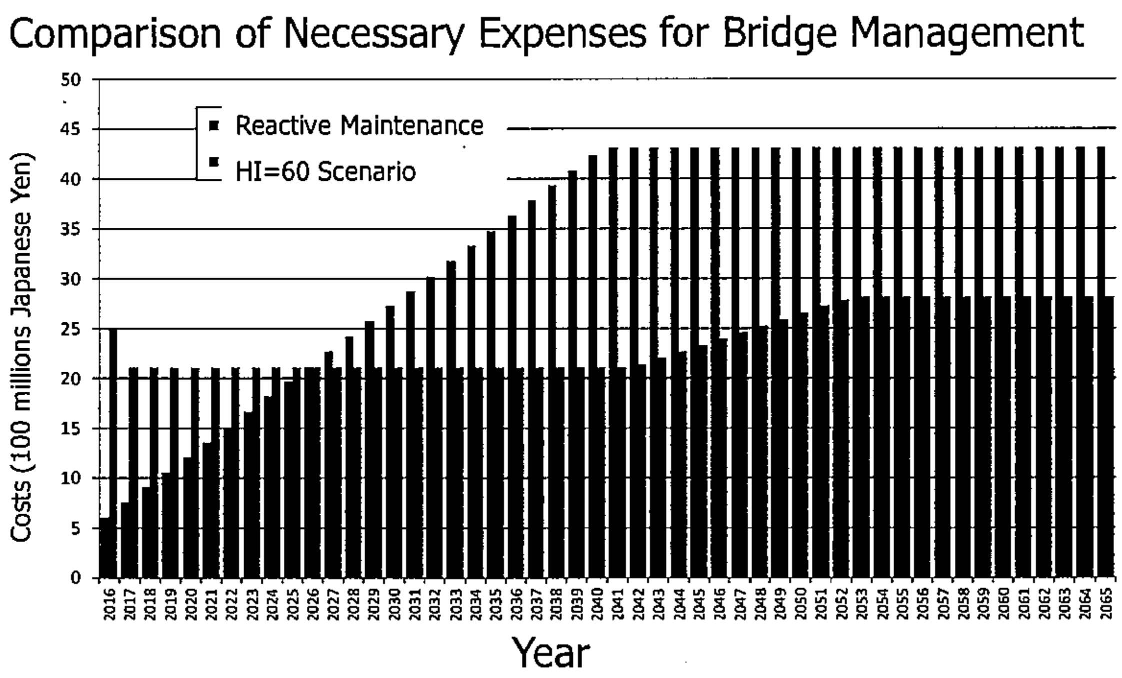
- Total repair costs and levelling:



Effects of Plan Development

- Verify the effects of plan development: compare the reactive maintenance scenario and optimum management level (HI=60 in Shizuoka Pref.)

Source: Long / Middle Term Bridge Management Plan 2016, Shizuoka Prefecture



In Shizuoka, number of bridges seriously damaged will gradually increase. Without any measures taken, such bridges need reconstruction (blue color). With proper and timely measures taken, reconstruction cost will be replaced by repair costs (red color).

Review every year

(7) Plan Implementation

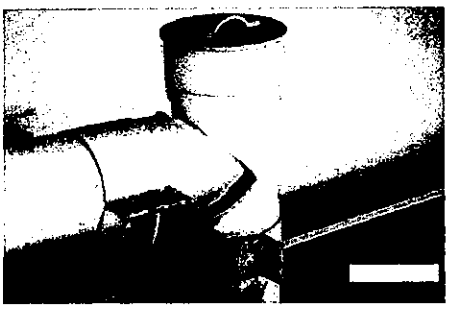
Develop the short-term bridge repair plan

- Include the firm timings and details of bridge inspection, repair and reconstruction for 10 years.
- Select the target bridges:
  - ✓ Bridge members for the coming 10 years from the long / middle term investment plan
  - ✓ Bridge members classified as C / D from the latest inspection records
  - ✓ Prioritize all the above bridge members.
- Integrate the repair works:
  - ✓ Use the scaffolding (cost saving)
  - ✓ Within a bridge, other bridge members or spans which are planned to implement within 5 years.

Source: Long / Middle Term Bridge Management Plan 2016, Shizuoka Prefecture

Importance on daily maintenance works

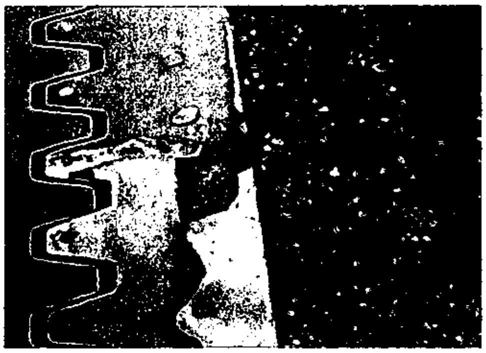
- Defects, damage and deterioration should be taken appropriate measures as early as they are detected.
- As much as possible, cleaning and minor repairs should be conducted within daily maintenance works (patrolling).

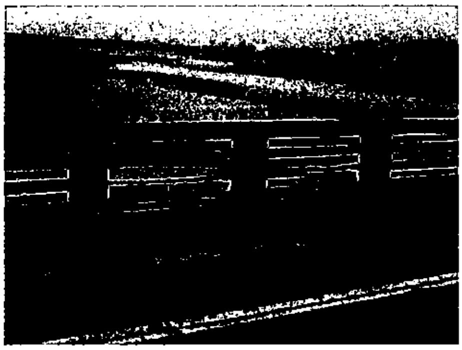


Source: Long / Middle Term Bridge Management Plan 2016, Shizuoka Prefecture

Prevention of third-party effects

- Emergency actions should be implemented to prevent third-party effects.
  - ✓ Falling off the vehicle / pedestrians from the bridge due to collapse of parapet / guard fence.
  - ✓ Flat tire due to damage of bridge expansion joint.





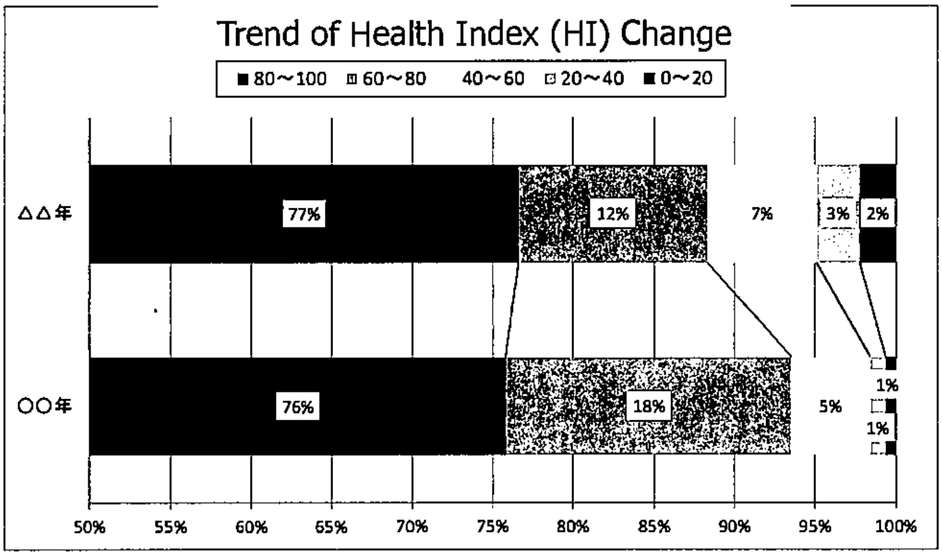
Feedback to bridge design

- From the bridge maintenance works, all the findings and knowledge are to be incorporated into bridge design:
  - ✓ Provide trough at bridge expansion joint to prevent damage on bridge bearings, substructure and beam ends.
  - ✓ Provide kerbs at both ends of bridge width to prevent damage on bridge beam due to water.
  - ✓ Provide waterproofing on bridge deck.

Source: Long / Middle Term Bridge Management Plan 2016, Shizuoka Prefecture

(8) Ex-Post Evaluation

- Upload the inspection and repair results periodically into the BMS.
- Understand the bridge conditions (improved, no change, or worsened)



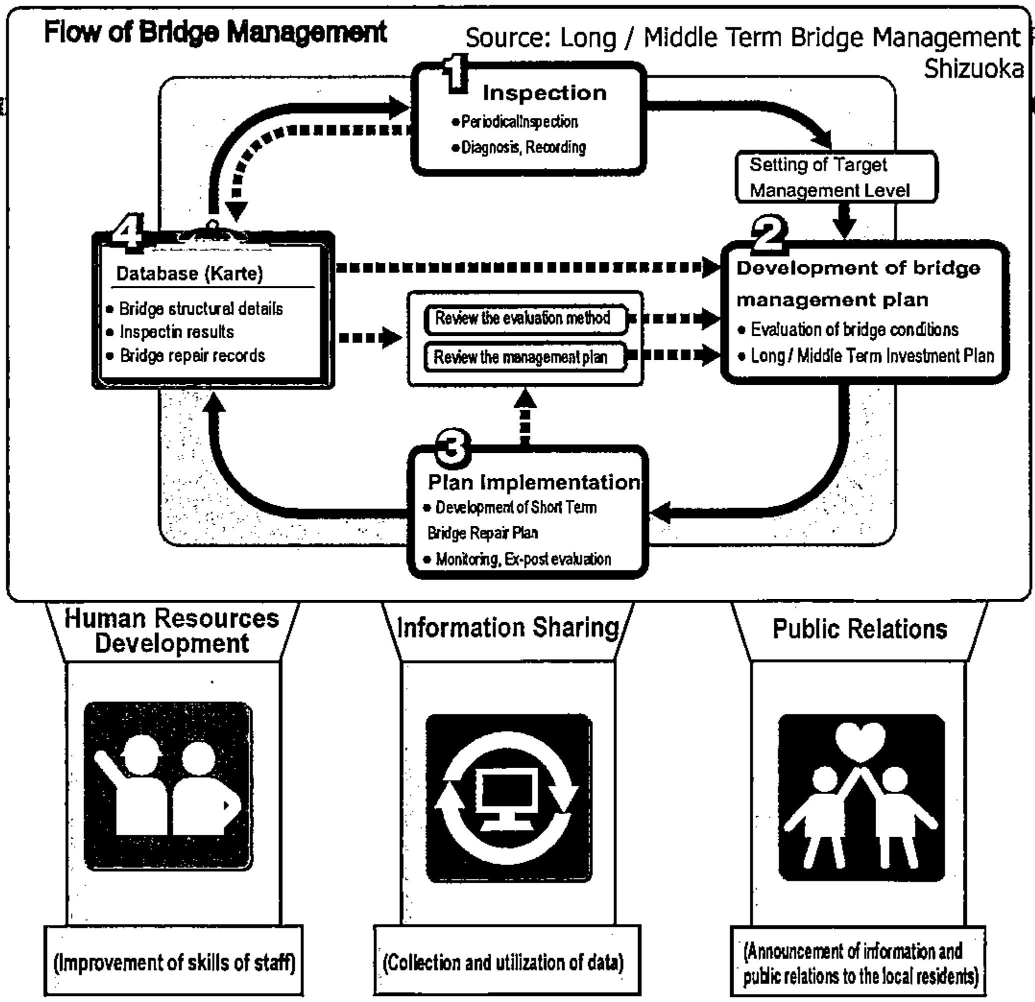
(9) Review the Plan

- After the inspection and repair data are collected through plan implementation (every 10 years), long / middle term investment plan will be reviewed on the following:
  - ✓ Methods of inspection and investigation (frequency, inspection items, etc.)
  - ✓ Evaluation criteria and weighting factors for health index calculation
  - ✓ Degradation curve
  - ✓ Selection of proper bridge repair methods
  - ✓ Design service life
  - ✓ Evaluation criteria and weighting factors for importance index

(10)3 Pillars Supporting the Extension of Service Life

- In order to promote extending the bridge service life, Shizuoka Prefecture established 3 pillars:

Source: Long / Middle Term Bridge Management Plan 2016, Shizuoka Prefecture



Institutional Framework of Bridge Maintenance in RDA

Hideaki TAKAURA
JICA Project Team

Institutional Framework for Bridge Management

Relating Division	**Planning D.**	**Eng. Services D.**	**MM & D.**	**RBC Unit**	**Construction**
Basic Function	Budgeting	Bridge Design & Technical Support	Maintenance Roads, Bridges and Offices in 9 Provinces	Maintenance of Steel Bridges	New Construction
Special Unit for bridge Maintenance		**BM&AU HO**		**BM&AU Provincial Office**	
Issues to be discussed	**Role and responsibility of relating divisions, BM&AU HO and BM&AU Provincial Office**				
	Planning for bridge Management	What kind of plan is needed? How to monitor the plan and how?			
	Budgeting	Who will decide the measures of bridges? How to estimate necessary budget for bridge maintenance?			
	Inspection	Who is in charge? Who and how to monitor the results?			
	Diagnosis	Who is in charge?			
	Reporting of inspection/diagnosis result	Whom to report and how to utilize them?			
	Human resources	Who and how to train engineers in charge?			
	Daily Maintenance of bridge	Who is in charge?			
	Equipment	What kind of equipment is needed and how to purchase?			
	Minor & Major Repair	How to decide and implement?			
	Maintenance of BMS	Who and how to maintain the system?			

3rd Workshop Agenda

November 25, 2016

Time	Contents	Presenter
09:00 – 09:05	Project Concept Based on Baseline Analysis	Mr. H. Takaura
09:05 – 09:20	Definition of Health Index (HI) & Its Usage	Mr. K. Urano
09:20 – 09:30	Target Management Standards ● Explanation of HI=0	Mr. D. Hajima
09:30 – 09:50	Evaluation of Conditions of Bridges ● Examples of Evaluation Criteria, Weighting Factors and Calculation of Health Index (HI) in Japan ● Examples of Soundness Classification based on HI in Japan ● Use of HI in Japan	Mr. K. Urano (Mr. T. Kasai)
09:50 – 10:10	Discussion	
10:10 – 10:20	Break	
10:20 – 10:35	Cost Estimate of Bridge Repairs in BMS (Part of Establishment of Bridge Management Plan) ● Classification of Bridge Maintenance Costs ● Quantity of Damage based on Health Index ● Standard Repair Methods based on Health Index ● Unit Rates of Repair Works	Mr. A. Kagami
10:35 – 10:55	Prioritization (Evaluation items , Weighting Factors) ● Importance Index, An Example from Japan ● Propose of Importance Index in Sri Lanka	Mr. T. Ichioka
10:55 – 11:00	Report from WG held on Nov. 9, 2016	Mr. Vasanthakumar
11:00 – 11:20	Discussion	
11:20 – 11:30	Closing Remarks	Mr. B. V. D. N. Chandrasiri

Analysis of Baseline Survey

1. High Level Policy

High Level policy of bridge Maintenence is nonexistent
Maintenance of roads and bridges is neglected and some deteriorated Bridges are still remaining

→ PC meeting for the Project to establish Bridge Management Policy

2. Bridge Maintenance Plan

RDA does not possess through Bridge Maintenence Plan
Procedure of Maintenance and repair work is not clear

→ Actual work procedure based on Maintenance Plan

3. Institutional Framework of Bridge Maintenance in RDA

Role and responsibility of Bridge Maintenance in relevant departments is not clear
Proper allocation of staff for inspection and feedback from Inspection

→ Role and responsibility of relevant departments should be clarified
→ Establishment of BM&AU

4. Budget

Necessary budget for Bridge Maintenance, Actual Cost for Maintenance Work is not clear
Budget items are not fit for the Bridge Maintenance

→ Budget request based on actual inspection results

5. Capacity Improvement of Staff for Bridge Maintenance in RDA

Bridge Maintenance Engineers are not trained properly

→ Proper Human Development Plan (Staff training for Bridge maintenance)

Project Concept

1. **Establishment of Bridge Management Cycle**
   - Policy
   - Establish role and responsibility in RDA for Bridge Maintenance

   ⬇

   - Preparation of manual
   - Preparation of BMS
   - OJT for RDA Staff
2. **Sustainable Bridge Maintenance**
   - Efficient Bridge Maintenance Work core unit, BM&AU
   - Visual and convenient Manual
   - Site work and input of inspection data
   - Sustainable and Usable BMS System
   - Human Development Plan considering sustainability

Project Concept Based on Baseline Analysis

Definition of Health Index (HI)
&
Its Usage

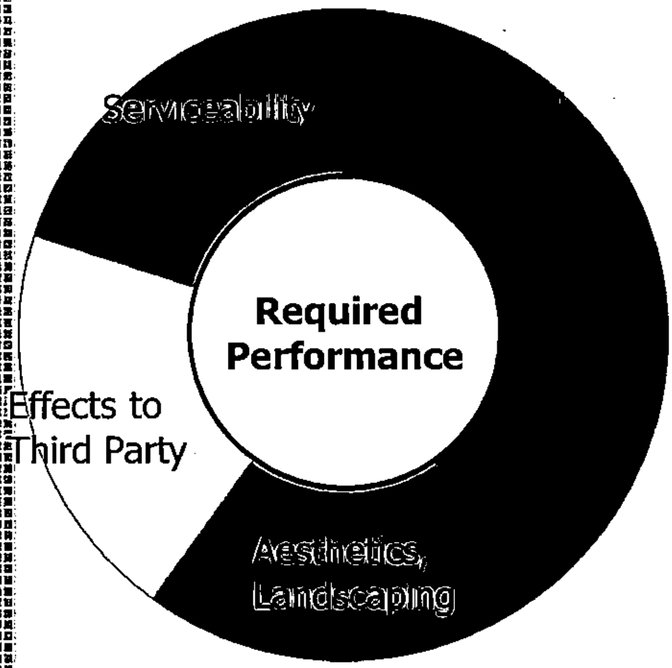
THE PROJECT
FOR CAPACITY DEVELOPMENT
ON BRIDGE MANAGEMENT

Kazuya URANO

1

1. Before we talk "HI", what is "soundness"?

Soundness: Conditions of a bridge member, a span or an entire bridge from the perspective of performances / functions required.



Performance	Description
Structural Safety	• Load carrying capacity, resistance against sliding, rotation and settlement
Serviceability	• Ride quality, walking comfort, waterproofing, stiffness (against excessive deflection)
Durability	• Resistance against aging (materials)
Effects to Third Party	• Noise / vibration • Falling off cover concrete, bolt, etc.
Aesthetics, Landscaping	• Aesthetics, landscaping

2

Required functions are:

Bridge Member		Functions Required
Super-structure	Deck slab	● Directly support the vehicle / pedestrian loads
	Main beam	● Support the loads on deck slab and deliver to bridge bearing.
	Cross beam	● Connect adjacent main beams and distribute.
	Lateral bracing	● Resist against lateral loads, such as wind.
Sub-structure	Body	● Deliver the loads from the superstructure to foundation.
	Foundation	● Deliver the loads from substructure body to the ground.
Miscellaneous	Bridge bearing	● Securely support all vertical / horizontal loads on superstructure and deliver to substructure. ● Work properly against horizontal movement and rotation to ensure road surface continuity.
	Expansion joint	● Ensure the road surface smoothness.
	Drainage	● Discharge the water from road surface for safety.
	Pavement	● Protect deck slab from vehicle loads, impacts and weathering. ● Ensure safe and comfort travelling of vehicles.

3

2. What is "health index (HI)" ?

Do you remember on the 2nd workshop?

Defects, Damage and Deterioration on Each Bridge Member
- **Detect the defects, damage and deterioration at sites.**
- **26 types of defects, damage and deterioration specified.**
- **Keep the records: each member / damage, extent thereof**

(Objectively recorded with the use of sample materials)

Subjectively

Health Index Calculation (Quantification)

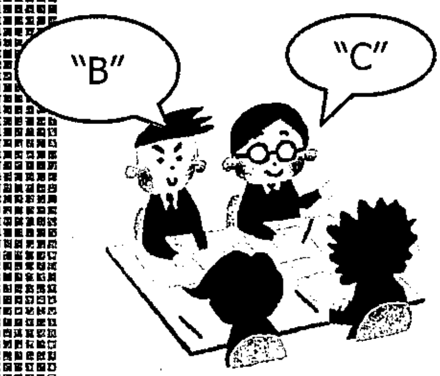
Bridge Soundness Classifications
- **Nine (9) classifications for the Ministry**
- **Different classifications for local governments**

Central Government
- Sufficient budget
- Experienced experts

Local Government
- Insufficient budget
- Unexperienced staff

4

Health Index: In order to <u>reduce the variations of evaluation results from person to person</u>, degree of required performance(s) / function(s) exhibited (soundness) is quantified for each member.



- Minimum level of required performance for a bridge member → **HI = 0**
- Performance of a bridge member owned at opening to traffic (new) → **HI = 100**
- **"HI"** is decreased with time (elapsed time after opening to traffic).

5

Image of Degradation of Performance As a Bridge

Performance	Need any restrictions	Minimum performances required (design)	Performances owned at opening to traffic (new)
		HI = 0	HI = 100
Speed	Speed limit (20 km/h)	60 km/h	80 km/h
Load carrying capacity	Load limit (10 ton)	20 ton	25 ton

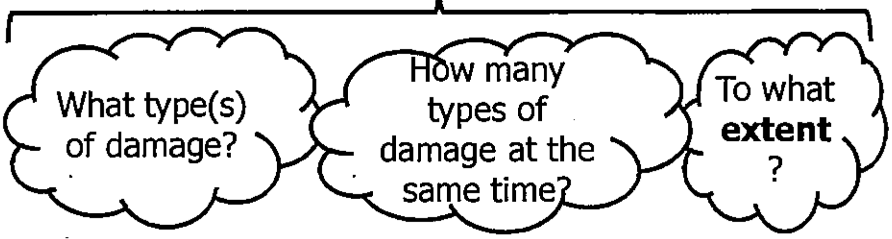
Allowance

A bridge member / bridge loses its function(s)!

Decreased with time

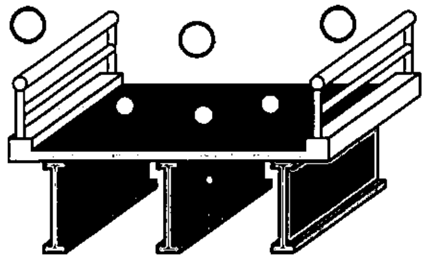
Proposed HI:

Objectively Recorded Condition Data / Information



Degree of Required Performance(s) & Functions(s) Exhibited

Interrelated



- Identify the bridge member conditions which cannot exhibit the minimum required design performance.
- Define the type(s) and **extent** of damage for **each bridge member** which need any restrictions

HI = 0

3. How to use health index (HI)?

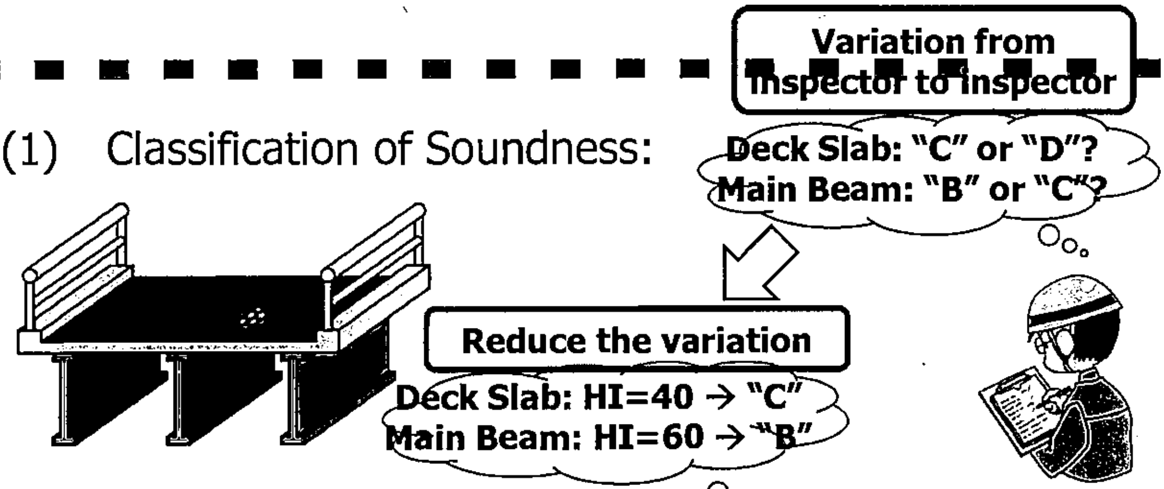
Health Index (HI):

- Index to quantify the conditions of a bridge member / a span / an entire bridge to reduce the variations of evaluation results from person to person.

Why don't we use "HI" for bridge management?

- Soundness classification (diagnosis).
- Development of future degradation curve of bridge members.
- Standard repair cost for management (for a group of bridges, not for individual bridge).

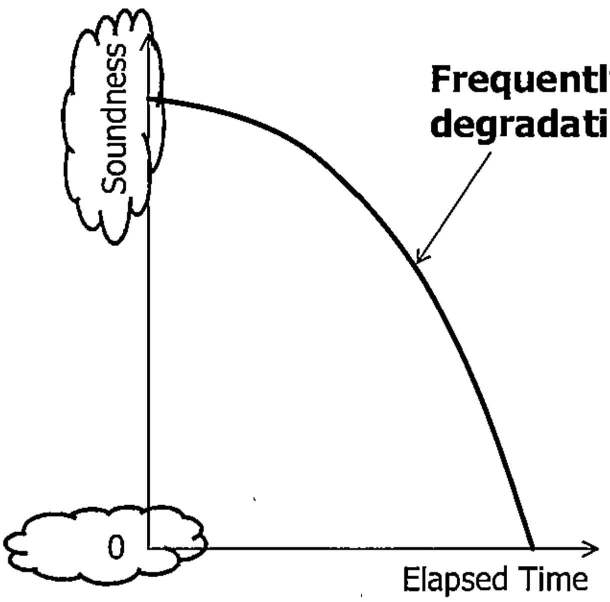
(1) Classification of Soundness:



HI (Reference)	Description	Classification
100 – 75	Sound, slight damage	A
75 – 50	Need minor repairs for preventive purpose.	B
50 – 25	Need minor repairs immediately for safety and serviceability.	C
25 – 0	Need major repairs, strengthening, replacement of bridge member	D

(2) Future Degradation Curve of Bridge Member(s):

- Prediction of future degradation of bridge member conditions is essential, in order to develop the long / middle term investment plan.

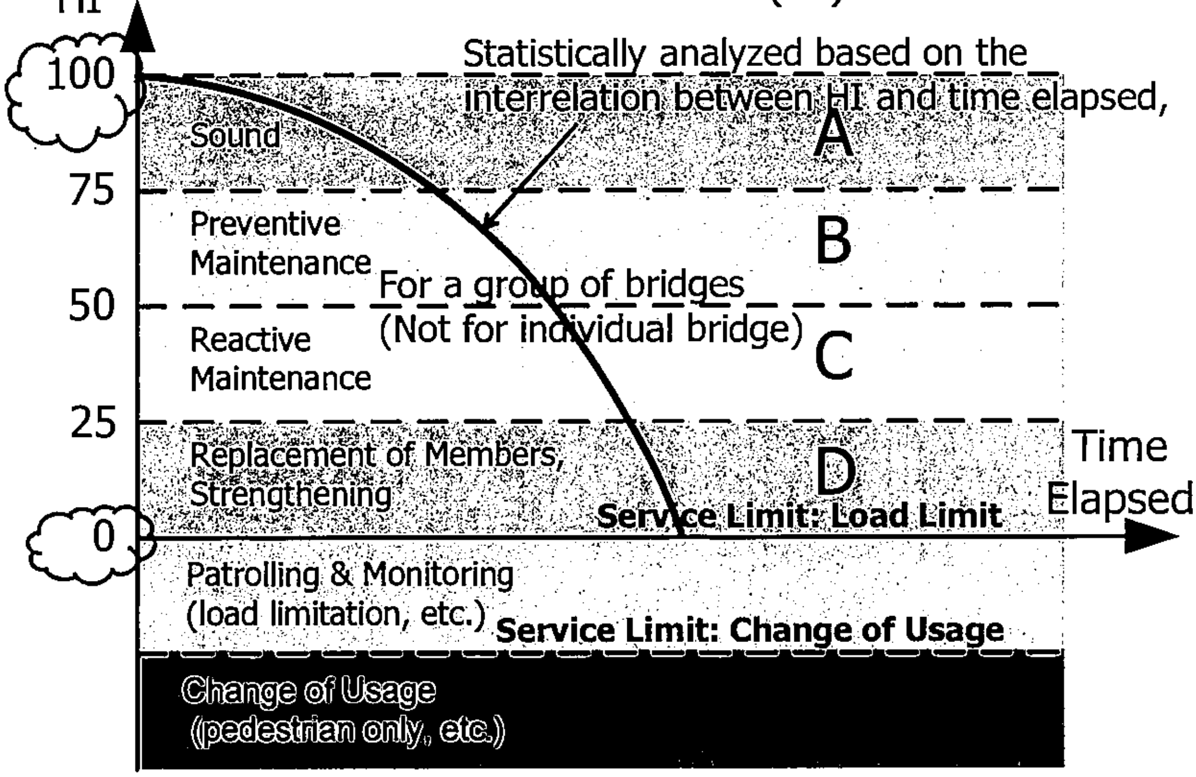


✓ Horizontal axis: time elapsed
✓ Vertical axis: soundness
→ **Not specific (abstract)**
✓ Origin: at the bottom

➡ **Conceptual Figure**

10

- With the use of health index (HI)



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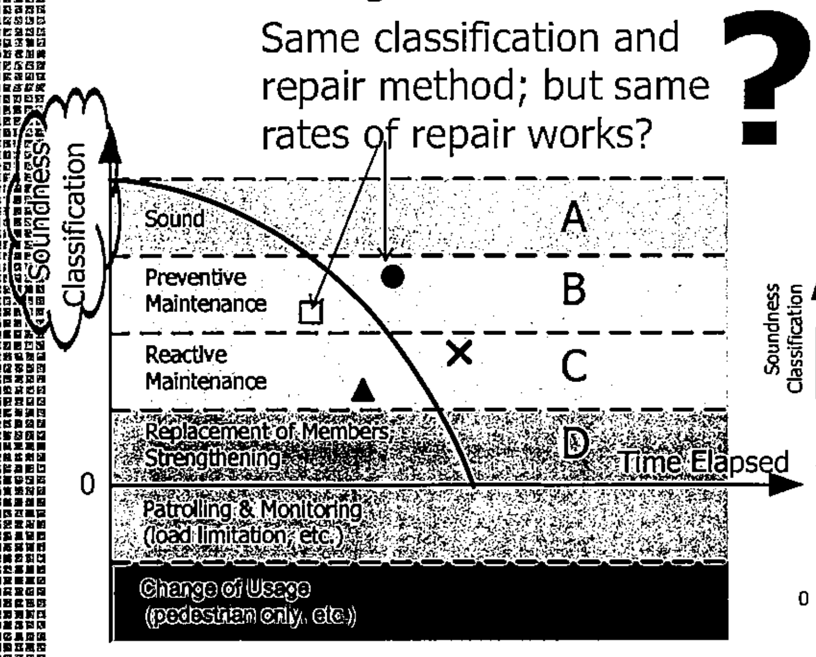
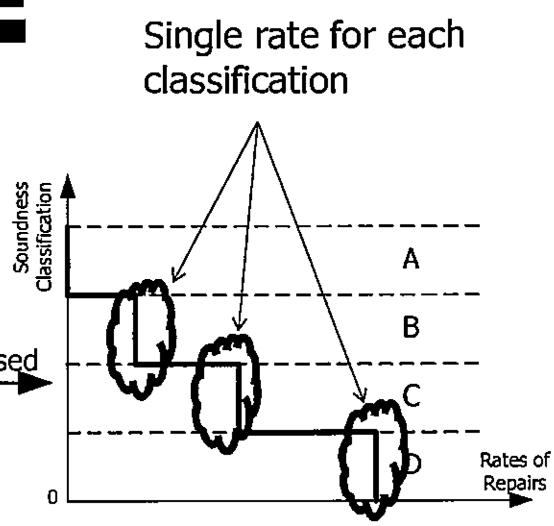
(3) Standard Repair Cost Estimate:

- With the use of soundness classification, extent of damage cannot be considered for cost estimate.





12

- With the use of health index (HI),

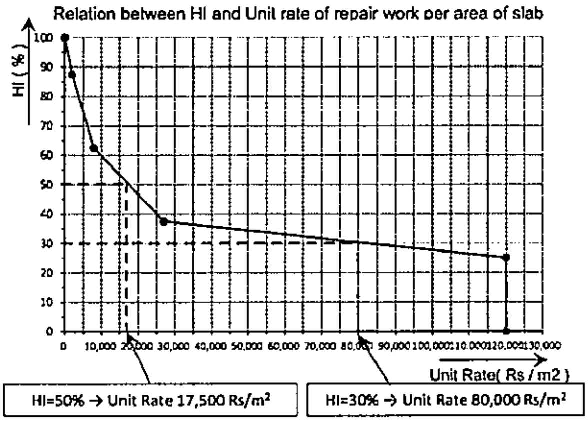
"HI" is interrelated with extent of damage.

→ Repair rates vary depending on "HI".

It is to estimate the standard repair cost for <u>a group of bridges / bridge members by "HI"</u>.

HI	Repair Method
100-75	Plastering
75-50	Injection with forms, Or mortar spray
50-25	Injection with forms, Or mortar spray
25- 0	Injection with forms, Or mortar spray Strengthening with fibre reinforced plastic

Ex. Structural Concrete Repairs

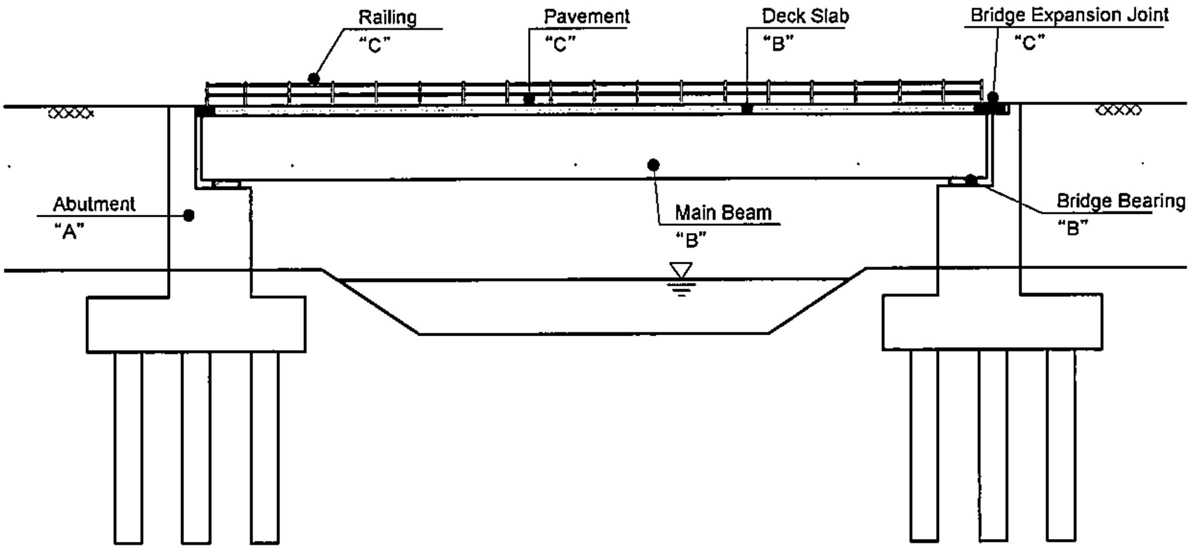


13

- Use of "HI" & "Soundness Classification"

	Member	Span / Entire Bridge
HI	**Used for Prioritization of Repairs** Evaluation Criteria X Weighting Factors	**Used for Prioritization of Bridge Reconstruction** Evaluation Criteria X Weighting Factors
Soundness Classification	**Used for Prioritization of Repairs** Classification of A Target Member	**Used for Prioritization of Repairs** **Worst Classification** among Members in A Span / Bridge

Identify the span / bridge which has seriously damaged bridge member



Worst classification among bridge members in a bridge / span → "C"

Target Management Standard

Explanation of "Health Index =0"

The Project
For Capacity Development
on Bridge Management

Daisuke Hajima

Introduction

○ To classify bridge soundness, "Health Index" is proposed.

○ **HI=100** : Performance of a bridge member owned at opening to traffic (new)

○ **HI=0** : Minimum level of required performance for a bridge member

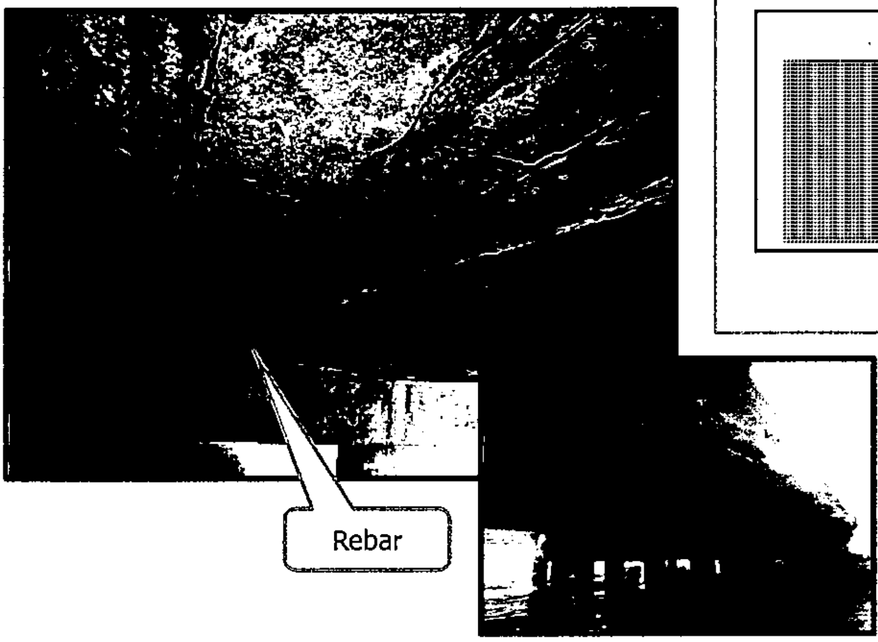
○ Therefore, HI=0" needs traffic regulation.
※ Traffic Regulation = Load Limits, Lane Regulation, Closed and so on

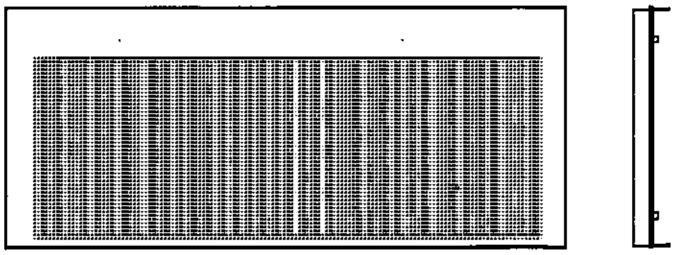
Typical examples of "HI=0" are shown on the following pages

Imagination of the Situation of Traffic Regulation

• Concrete Bridge

Delamination of the concrete occurs with a widespread deck slab soffit.
⇒ In addition, in an about the same range, the exposure of the reinforcing rod occurs.





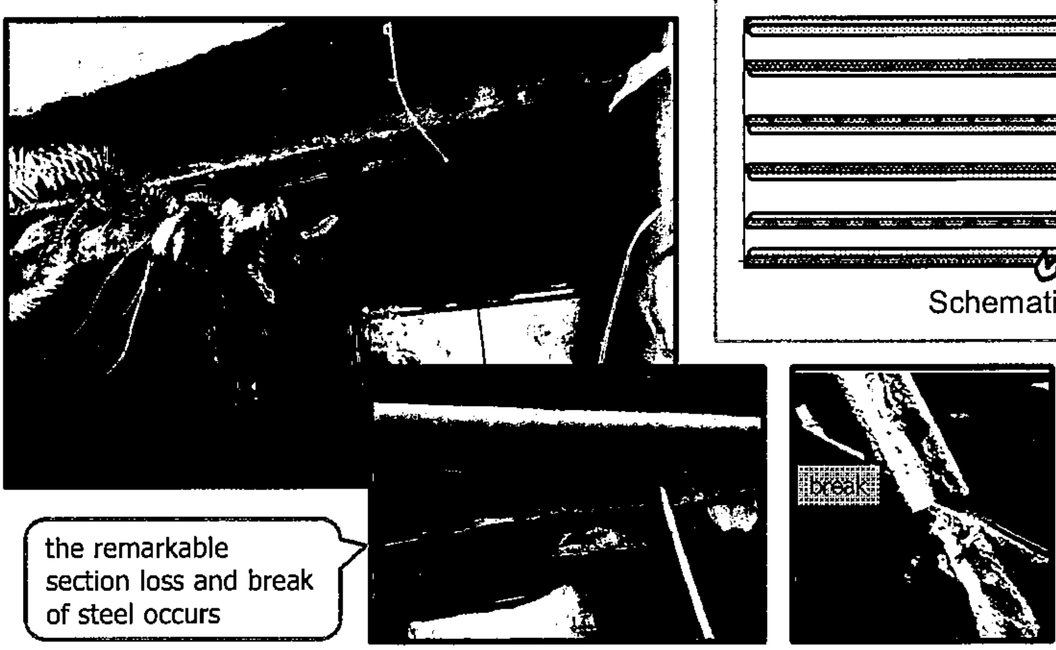
Schematic view

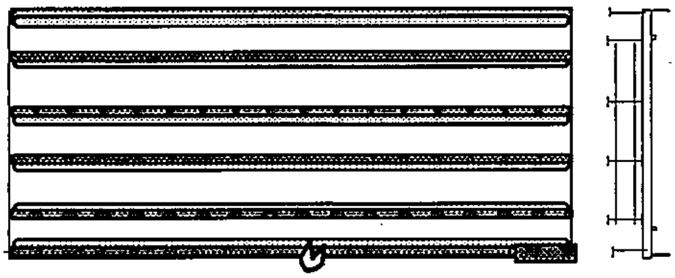
: Exposed-rebar

Imagination of the Situation of Traffic Regulation

• Steel Bridge

Steel corrosion in most of flanges and webs of beams.
⇒ When progress of the corrosion is fast, the remarkable section loss and break of steel occur.





Schematic view

: Corrosion
: Mud deposition
: Vegetation

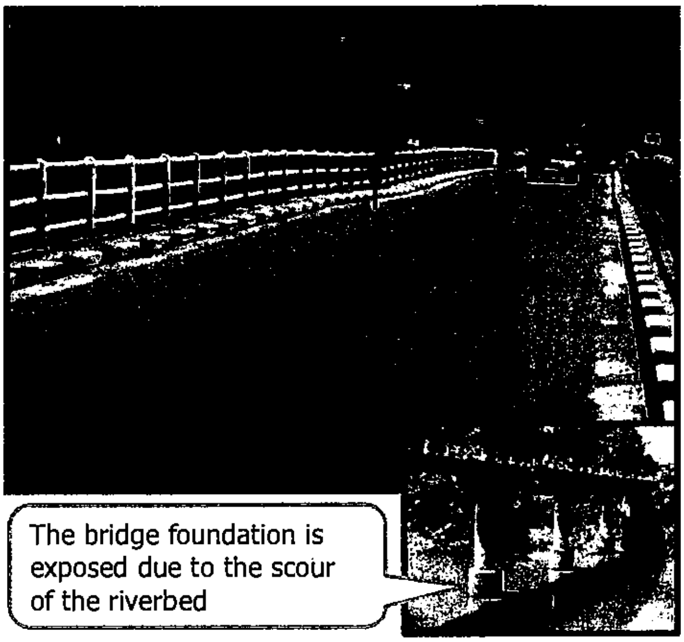
Imagination of the Situation of Traffic Regulation

• Arch bridge

The deformation of the crown part on the arch line
← Movement of the foundation

• Others

Surface settlement
← Settlement of bridge pier
← Riverbed scour



Evaluation of Conditions of Bridge

Calculation of Health Index (HI) in Japan
Soundness Classification based on HI in Japan
Use of HI and Soundness Classification in Japan

**THE PROJECT
FOR CAPACITY DEVELOPMENT
ON BRIDGE MANAGEMENT**

Kazuya Urano
Toshiki Kasai

1

(1) Examples of Evaluation Criteria, Weighting Factors and Calculation of Health Index (HI) in Japan

HI for a bridge member:

HI = 100 – Σ (Evaluation Point x Correlation Factor)

- **Evaluation Point (Deduction Point):**
  Point for each evaluation criteria (type of defects, damage and deterioration for HI) in consideration of **extent** to entire bridge member (0 to 100)
- **Correlation Factor:**
  Effect of each evaluation criteria (each type of damage) to the soundness of a bridge member (0 to 1.00)

HI for a bridge component / span / bridge:

HI = 100 – Σ (Evaluation Point x Weighting Factor)

2

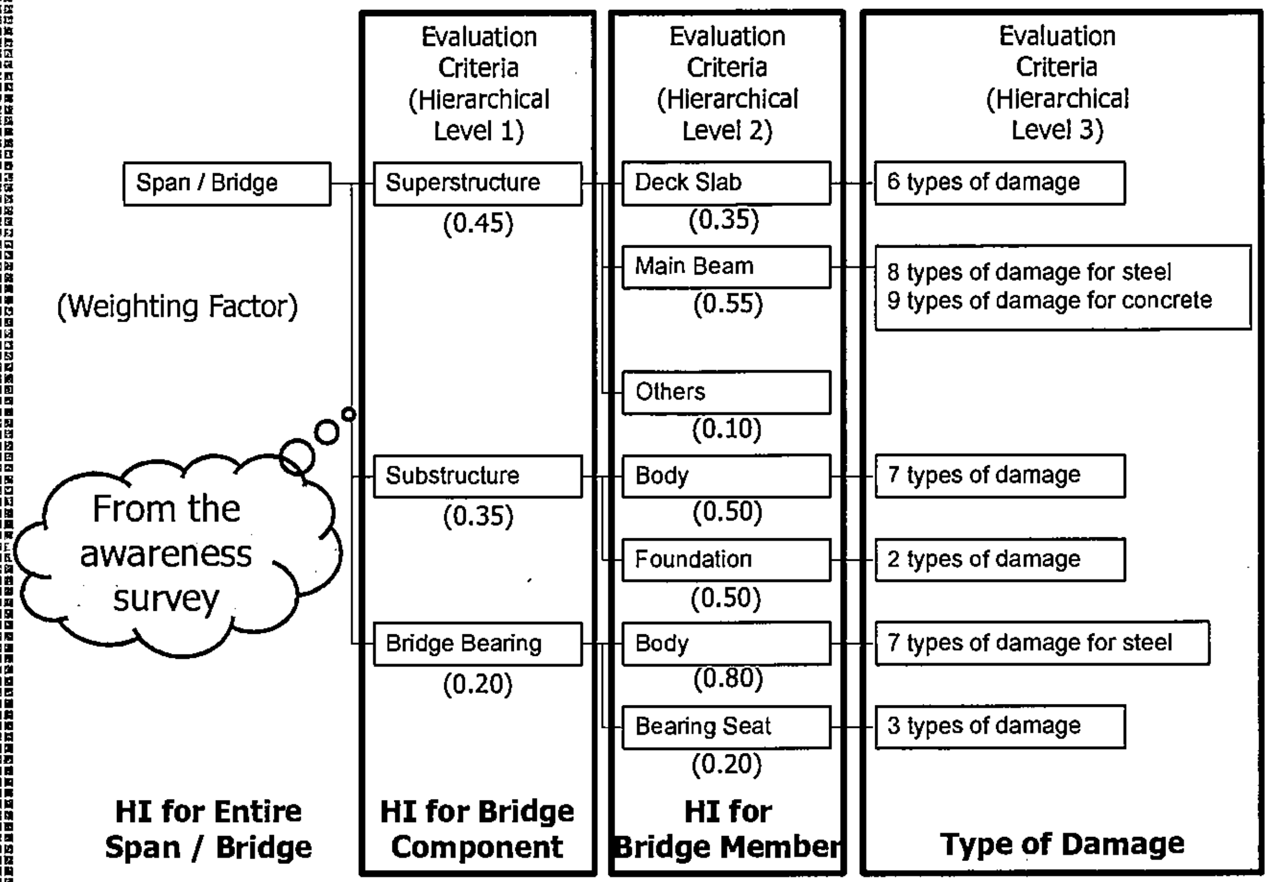
◆ Examples in Shizuoka Prefecture

1) Types of Defects, Damage and Deterioration → 26 types

Material		Damage Type	Material		Damage Type
Steel	01	Corrosion	Others	13	Unusual gap at beam ends
	02	Fatigue Crack		14	Waving & corrugation on road surface
	03	Loosening of Anchor Bolts		15	Unusual Pavement
	04	Rupture		16	Disorder of bridge bearing
	05	Paint Degradation		17	Others
Concrete	06	Crack	Common	18	Damage on Anchorage
	07	Spall / Dela / Ex-Rebar		19	Discoloration
	08	Water Leakage / Free Lime		20	Water Leakage / Ponding
	09	Depression		21	Unusual Sound / Vibration
	10	Damage on bridge repairs / strengthening		22	Unusual Deflection
	11	Crack on Deck Slab		23	Deformation, defects
	12	Delamination		24	Clogging of soils
				25	Settlement / Lateral Movement / Tilting
				26	Scour

3

2) Setting of Weighting Factor for Each Evaluation Criteria



4

●Member

(1) Superstructure

	Deck Slab — Concrete					
	Spall / Dela / Ex-Rebar	Water Leakage / Free Lime	Depression	Damage on Repairs / Strengthening	Crack of Deck Slab	Unusual Anchorage
Weighting Factors	0.150	0.050	0.400	0.100	0.100	0.200

1.00 in total

	Main Beam — Steel							
	Corrosion	Fatigue Crack	Loosening of Anchor Bolts	Rupture	Paint Degradation	Unusual gap at beam ends	Unusual Sound / Vibration	Unusual Deflection
Weighting Factors	0.050	0.150	0.100	0.350	0.050	0.050	0.100	0.150

1.00 in total

	Main Beam — Concrete								
	Crack	Spall / Dela / Ex-Rebar	Water Leakage / Free Lime	Damage on Repairs / Strengthening	Delamination	Unusual gap at beam ends	Unusual Anchorage	Unusual Sound / Vibration	Unusual Deflection
Weighting Factors	0.050	0.100	0.050	0.100	0.050	0.050	0.200	0.150	0.250

1.00 in total

5

(2) Substructure

	Body — Concrete						
	Crack	Spall / Dela / Ex-Rebar	Water Leakage / Free Lime	Damage on Repairs / Strengthening	Delamination	Unusual Anchor	Water Leakage / Ponding
Weighting Factors	0.100	0.250	0.100	0.150	0.100	0.250	0.050

1.00 in total

	Foundation	
	Settlement / Lateral Movement / Tilting	Scour
Weighting Factors	0.800	0.200

1.00 in total

(3) Bearing

	Body — Steel						
	Corrosion	Fatigue Creck	Loosening of Anchor Bolts	Rupture	Disorder of bridge bearing	Mud Deposition	Settlement / Lateral Movement / Tilting
Weighting Factors	0.050	0.100	0.100	0.300	0.150	0.050	0.250

1.00 in total

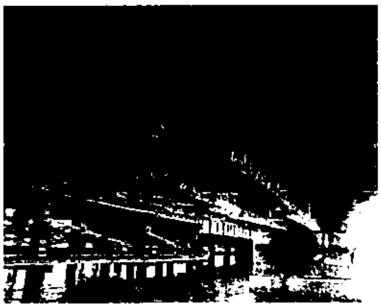
	Bearing Seat — Concrete		
	Disorder of bridge bearing	Discoloration	Mud Depositin
Weighting Factors	0.200	0.200	0.600

1.00 in total

6

3) Assume the Conditions of HI=0

【Example: Main Beam - PSC Bridge】→ Several "HI = 0" Conditions

Case-1	Case-2	Case-3
Concrete **cracks** occur in the entire bridge beam, together with **spalling of cover concrete** and **exposure of reinforcing steels.** (2 types at same time)	A prestressed concrete member has cracks and scaling / spalling at its anchorage **(damage on anchorages)**, resulted in the loss of prestressing force. (1 type at same time)	**Unusual sound / vibration and unusual deflection** are detected at the same time. (2 types at same time)
		Unusual sound / vibration and deflection will occur, resulting from the defects, damage and deterioration of a bridge member

7

4) Setting of Correlation Factors

Weighting Factor:

To express the degree of effect to the soundness for all types of defects, damage and deterioration (evaluation criteria) possibly occurred on target bridge member.

→ All the types of damage should occur at same time.

→ Summation of weighting factor for each evaluation criteria should be 1.00.

It should be considered that NOT ALL the types of defects, damage and deterioration occur on a bridge member at the same time.

→ Define the **Correlation Factor**.

→ For each bridge member, assume the possible "HI=0" damage conditions:

- ✓ **Types** of defects, damage and deterioration
- ✓ **Extent** of defects, damage and deterioration

8

All the types of damage	⇨	"HI=0" Conditions	⇨	**All** the types of damage should result in deduction point of 100 → **Weighting Factor**
One or few types of damage	⇨		⇨	One or few types of damage should result in deduction point of 100 → Correlation Factor

9

Convert to "Correlation Factors" from "Weighting Factors" at Lowest Hierarchical Level

Damage to Entire Main Beam → Deduction Point = 100

The total is 100. →"HI=0"

		Damage Type (Evaluation Criteria)	Weighting Factors	Deduction Point	Correlation Factor & Deduction Point					
					Case-1		Case-2		Case-3	
					Correlation Factor	Deduction Point	Correlation Factor	Deduction Point	Correlation Factor	Deduction Point
Case-1	06	Crack	0.05		0.333	33.3	0.250	25.0	0.125	12.5
	07	Spall / Dela / Ex-Rebar	0.10		0.667	66.7	0.500	50.0	0.250	25.0
	08	Water Leakage / Free Lime	0.05		0.333	33.3	0.250	25.0	0.125	12.5
	10	Damage on Repairs / Strengthening	0.10		0.667	66.7	0.500	50.0	0.250	25.0
	12	Delamination	0.05		0.333	33.3	0.250	25.0	0.125	12.5
	13	Unusual gap at beam ends	0.05	0~100	0.333	33.3	0.250	25.0	0.125	12.5
Case-2	18	Unusual Anchorage	0.20		1.333	133.3	1.000	100.0	0.500	50.0
	19	Discoloration	0.00		0.000	0.0	0.000	[illegible]	0.000	0.0
Case-3	21	Unusual Sound / Vibration	0.15		1.000	100.0	0.750	75.0	0.375	37.5
	22	Unusual Deflection	0.25		1.667	166.7	1.250	125.0	0.625	62.5
	23	Deformation, defect	[illegible]		[illegible]	0.0	[illegible]	0.0	[illegible]	0.0
		Total	1.00		6.667	666.7	5.000	500.0	2.500	250.0

Adopted

The total is 100. →"HI=0"

Summation of weighting factor for each evaluation criteria should be 1.00.

Summation of correlation factor will be 1.00 or greater.

◆ Correlation Factors in Shizuoka Prefecture, Japan (1-1)

Hierarchical Level 1		Hierarchical Level 2		Hierarchical Level 3								
	Weighting Factors	Member	Weighting Factors	Damage Type		Weighting Factors	Correlation Factor	Damage Grade & Deduction Point				
								A 0	B 25	C 50	D 75	E 100
Superstructure	0.45	Deck Slab	0.35	07	Spall / Dela / Ex-Rebar	0.15	0.38	◎	–	◎	–	◎
				08	Water Leakage / Free Lime	0.05	0.13	◎	–	◎	–	◎
				09	Depression	0.40	1.00	◎	–	–	–	◎
				10	Damage on Repairs / Strengthening	0.10	0.25	◎	–	◎	–	◎
				11	Crack of Deck Slab	0.10	0.25	◎	◎	◎	◎	◎
				12	Delamination	0.00	0.00	◎	–	–	–	◎
				18	Unusual Anchorage	0.20	0.50	◎	–	◎	–	◎
				19	Discoloration	0.00	0.00	◎	–	–	–	◎
		Main Beam	0.55	06	Crack	0.05	0.33	◎	◎	◎	◎	◎
				07	Spall / Dela / Ex-Rebar	0.10	0.67	◎	–	◎	–	◎
				08	Water Leakage / Free Lime	0.05	0.33	◎	–	◎	–	◎
				10	Damage on Repairs / Strengthening	0.10	0.67	◎	–	◎	–	◎
				12	Delamination	0.05	0.33	◎	–	–	–	◎
				13	Unusual gap at beam ends	0.05	0.33	◎	–	◎	–	◎
				18	Unusual Anchorage	0.20	1.33	◎	–	◎	–	◎
				19	Discoloration	0.00	0.00	◎	–	–	–	◎
				21	Unusual Sound / Vibration	0.10	0.67	◎	–	–	–	◎
				22	Unusual Deflection	0.15	1.00	◎	–	–	–	◎
				23	Deformation, defect	0.00	0.00	◎	–	◎	–	◎
		Others	0.1	06	Crack	0.05	0.25	◎	◎	◎	◎	◎
				07	Spall / Dela / Ex-Rebar	0.15	0.75	◎	–	◎	–	◎
				08	Water Leakage / Free Lime	0.10	0.50	◎	–	◎	–	◎
				10	Damage on Repairs / Strengthening	0.10	0.50	◎	–	◎	–	◎
				12	Delamination	0.10	0.50	◎	–	–	–	◎
				18	Unusual Anchorage	0.30	1.50	◎	–	◎	–	◎
				19	Discoloration	0.00	0.00	◎	–	–	–	◎
				21	Unusual Sound / Vibration	0.20	1.00	◎	–	–	–	◎
				23	Deformation, defect	0.00	0.00	◎	–	◎	–	◎

◆ Correlation Factors in Shizuoka Prefecture, Japan (1-2)

Hierarchical Level 1		Hierarchical Level 2		Hierarchical Level 3								
	Weighting Factors	Member	Weighting Factors	Damage Type		Weighting Factors	Correlation Factor	Damage Grade & Deduction Point				
								A 0	B 25	C 50	D 75	E 100
Substructure	0.35	Body	0.5	06	Crack	0.10	0.29	◎	◎	◎	◎	◎
				07	Spall / Dela / Ex-Rebar	0.25	0.71	◎	–	◎	–	◎
				08	Water Leakage / Free Lime	0.10	0.29	◎	–	◎	–	◎
				10	Damage on Repairs / Strengthening	0.15	0.43	◎	–	◎	–	◎
				12	Delamination	0.10	0.29	◎	–	–	–	◎
				18	Unusual Anchorage	0.25	0.71	◎	–	◎	–	◎
				19	Discoloration	0.00	0.00	◎	–	–	–	◎
				20	Water Leakage / Ponding	0.05	0.14	◎	–	–	–	◎
				23	Deformation, defect	0.00	0.00	◎	–	◎	–	◎
		Foundation	0.5	25	Settlement / Lateral Movement / Tilting	0.80	1.00	◎	–	–	–	◎
				26	Scour	0.20	0.25	◎	–	◎	–	◎
Bearing	0.2	Body	0.8	01	Corrosion	0.05	0.50	◎	◎	◎	◎	◎
				02	Fatigue Crack	0.10	1.00	◎	–	◎	–	◎
				03	Loosening of Anchor Bolts	0.10	1.00	◎	–	◎	–	◎
				04	Rupture	0.30	3.00	◎	–	–	–	◎
				05	Paint Degradation	0.00	0.00	◎	–	◎	–	◎
				16	Disorder of bridge bearing	0.15	1.50	◎	–	◎	–	◎
				20	Water Leakage / Ponding	0.00	0.00	◎	–	–	–	◎
				23	Deformation, defect	0.00	0.00	◎	–	◎	–	◎
				24	Clogging of soils	0.05	0.50	◎	–	–	–	◎
				25	Settlement / Lateral Movement / Tilting	0.25	2.50	◎	–	–	–	◎
		Bearing Bed	0.2	06	Crack	0.20	0.33	◎	◎	◎	◎	◎
				12	Delamination	0.20	0.33	◎	–	–	–	◎
				23	Deformation, defect	0.60	1.00	◎	–	◎	–	◎

◆ Correlation Factors in Shizuoka Prefecture, Japan (2-1)

(1) Superstructure

Deck Slab – Concrete

Damage Type		Weighting Factors	Correlation Factor	Damage Grade & Deduction Point				
				A 0	B 25	C 50	D 75	E 100
07	Spall / Dela / Ex-Rebar	0.15	0.38	◎	–	◎	–	◎
08	Water Leakage / Free Lime	0.05	0.13	◎	–	◎	–	◎
09	Depression	0.40	1.00	◎	–	–	–	◎
10	Damage on Repairs / Strengthening	0.10	0.25	◎	–	◎	–	◎
11	Crack of Deck Slab	0.10	0.25	◎	◎	◎	◎	◎
12	Delamination	0.00	0.00	◎	–	–	–	◎
18	Unusual Anchorage	0.20	0.50	◎	–	◎	–	◎
19	Discoloration	0.00	0.00	◎	–	–	–	◎

We set up the correction coefficient so that the point evaluating damage when "Depression" arises might be set to 100.

Main Beam – Steel

Damage Type		Weighting Factors	Correlation Factor	Damage Grade & Deduction Point				
				A 0	B 25	C 50	D 75	E 100
01	Corrosion	0.05	0.33	◎	◎	◎	◎	◎
02	Fatigue Crack	0.15	1.00	◎	–	◎	–	◎
03	Loosening of Anchor Bolts	0.10	0.67	◎	–	◎	–	◎
04	Rupture	0.35	1.00	◎	–	–	–	◎
05	Paint Degradation	0.05	0.33	◎	–	◎	–	◎
13	Unusual Space	0.05	0.33	◎	–	◎	–	◎
21	Unusual Sound / Vibration	0.10	0.67	◎	–	–	–	◎
22	Unusual Deflection	0.15	1.00	◎	–	–	–	◎
23	Deformation, defect	0.00	0.00	◎	–	◎	–	◎

We set up the correction coefficient so that the point evaluating damage when "Fatigue Crack" arises might be set to 100.

◆ Correlation Factors in Shizuoka Prefecture, Japan (2-2)

Main Beam – Concrete

Damage Type		Weighting Factors	Correlation Factor	Damage Grade & Deduction Point				
				A 0	B 25	C 50	D 75	E 100
06	Crack	0.05	0.33	◎	◎	◎	◎	◎
07	Spall / Dela / Ex-Rebar	0.10	0.67	◎	–	◎	–	◎
08	Water Leakage / Freelime	0.05	0.33	◎	–	◎	–	◎
10	Damage on Repairs / Strengthening	0.10	0.67	◎	–	◎	–	◎
12	Delamination	0.05	0.33	◎	–	–	–	◎
13	Unusual Space	0.05	0.33	◎	–	◎	–	◎
18	Unusual Anchor	0.20	1.33	◎	–	◎	–	◎
19	Discoloration	0.00	0.00	◎	–	–	–	◎
21	Unusual Sound / Vibration	0.10	0.67	◎	–	–	–	◎
22	Unusual Deflection	0.15	1.00	◎	–	–	–	◎
23	Deformation, defect	0.00	0.00	◎	–	◎	–	◎

We set up the correction coefficient so that the point evaluating damage when "Crack & Spall / Dela / Ex-Rebar" arises might be set to 100.

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◆ Correlation Factors in Shizuoka Prefecture, Japan (2-3)

(2) Substructure

Body — Concrete

	Damage Type	Weighting Factors	Correlation Factor	Damage Grade & Deduction Point				
				A 0	B 25	C 50	D 75	E 100
06	Crack	0.10	0.29	◎	◎	◎	◎	◎
07	Spall / Dela / Ex-Rebar	0.25	0.71	◎	–	◎	–	◎
08	Water Leakage / Free Lime	0.10	0.29	◎	–	◎	–	◎
10	Damage on Repairs / Strengthening	0.15	0.43	◎	–	◎	–	◎
12	Delamination	0.10	0.29	◎	–	–	–	◎
18	Unusual Anchorage	0.25	0.71	◎	–	◎	–	◎
19	Discoloration	0.00	0.00	◎	–	–	–	◎
20	Water Leakage / Ponding	0.05	0.14	◎	–	–	–	◎
23	Deformation, defect	0.00	0.00	◎	–	◎	–	◎

We set up the correction coefficient so that the point evaluating damage when "Crack & Spall / Dela / Ex-Rebar" arises might be set to 100.

Foundation — Concrete

	Damage Type	Weighting Factors	Correlation Factor	Damage Grade & Deduction Point				
				A 0	B 25	C 50	D 75	E 100
25	Settlement / Lateral Movement / Tilting	0.80	1.00	◎	–	–	–	◎
26	Scour	0.20	0.25	◎	–	◎	–	◎

We set up the correction coefficient so that the point evaluating damage when "Scour" arises might be set to 100.

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◆ Correlation Factors in Shizuoka Prefecture, Japan (2-4)

(3) Bearing

Body — Steel

	Damage Type	Weighting Factors	Correlation Factor	Damage Grade & Deduction Point				
				A 0	B 25	C 50	D 75	E 100
01	Corrosion	0.05	0.50	◎	◎	◎	◎	◎
02	Fatigue Crack	0.10	1.00	◎	–	◎	–	◎
03	Loosening of Anchor Bolts	0.10	1.00	◎	–	◎	–	◎
04	Rupture	0.30	3.00	◎	–	–	–	◎
05	Paint Degradation	0.00	0.00	◎	–	◎	–	◎
16	Disorder of bridge bearing	0.15	1.50	◎	–	◎	–	◎
20	Water Leakage / Ponding	0.00	0.00	◎	–	–	–	◎
23	Deformation, defect	0.00	0.00	◎	–	◎	–	◎
24	Clogging of soils	0.05	0.50	◎	–	–	–	◎
25	Settlement / Lateral Movement / Tilting	0.25	2.50	◎	–	–	–	◎

We set up the correction coefficient so that the point evaluating damage when "Fatigue Crack" arises might be set to 100.

Bearing Bed — Concrete

	Damage Type	Weighting Factors	Correlation Factor	Damage Grade & Deduction Point				
				A 0	B 25	C 50	D 75	E 100
06	Crack	0.20	0.33	◎	◎	◎	◎	◎
12	Delamination	0.20	0.33	◎	–	–	–	◎
23	Deformation, defect	0.60	1.00	◎	–	◎	–	◎

We set up the correction coefficient so that the point evaluating damage when "Deformation, defect" arises might be set to 100.

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(2) Examples of Soundness Classification based on HI in Japan

Soundness of each bridge member is classified based on health index (HI) as follows:
It is noted that soundness classification is determined not only by health index (HI), but by subjective of diagnosis expert (consultant).

Classification		Description	HI
I	Sound	● Bridge / bridge member functions well.	70 - 100
II	Preventive Stage	● Bridge / bridge member functions well. ● It is preferred to take necessary measures for preventive maintenance purpose.	20 - 80
III	Measures to be taken at an early stage	● Possible to give adverse effects to bridge / bridge member. ● Proper measures should be taken earlier.	0 - 40
IV	Measures to be taken Urgently	● Bridge / bridge member are not functioned well, or substantially possible to give adverse effects to bridge / bridge member. ● Necessary measures should be taken urgently.	-

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(3) Use of HI and Soundness Classification in Japan

	Member	Span / Entire Bridge
HI	**Used for Prioritization of Repairs** Evaluation Criteria X Weighting Factors	--
Soundness Classification (A, B, C, D)	**Used for Prioritization of Repairs** Classification of A Target Member	**Used for Prioritization of Repairs** **Worst** Classification among Members in A Span / Bridge

Cost Estimate of Bridge Repairs in BMS
(Part of Establishment of Bridge Management Plan)

25th November, 2016

THE PROJECT FOR CAPACITY DEVELOPMENT ON BRIDGE MANAGEMENT

Akira KAGAMI

CONTENTS

1. Classification of Bridge Maintenance Costs
2. Quantity of Damage based on Health Index
3. Standard Repair Methods based on Health Index
4. Unit Rates of Repair Works

1. Classification of Bridge Maintenance Cost

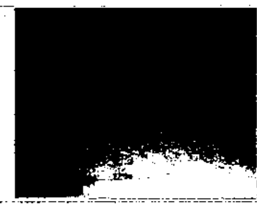
Example of classification of Cost for maintenance and how to use in BMS

Features / Details		Target Members	How to treat in BMS
• Expenses for periodical inspection • Expenses for detail inspection for repair work • Routine maintenance	(Detail) Inspection / Routine maintenance	• All the members	• Not based on HI • In case these works will be conducted by contract work, it need to estimate as reprise
• Expenses for repairs which can be observed at inspection • Deterioration progress gradually • Constructed on site	Repair (1)	• Main / Cross beams, Lateral • Deck slab • Substructures	• Estimate repair cost based on HI
• Deterioration occur suddenly due to service life • Expenses which are needed for periodical repairs or replacement • The member which can be judge only 2 status, Broken (HI=0) / Unbroken (HI=100) • Precast product	Repair (2)	• Bridge bearing • Bridge expansion joint • Pavement • Drainage	• Estimate repair cost based on HI
• Expenses which are needed for accidental / unexpected repairs (Car accident, Flood, Land slide and so on) • Damages occur accidentally	Repair (3)	• All the members	• Not based on HI • Estimate as reprise based on numerical statistics

In BMS system, quantity of repairs at each members are calculated based on HI.

2. Quantity of Damage based on Health Index

Relation between HI and degree of damages for Concrete slab

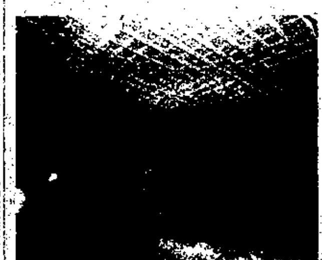
Classification (HI)	Degree of damage	Photos (Reference)
A (HI=100-75)	Delamination and exposure of reinforcing steel can be observed less than 25% on the surface of slab	
B (HI=75–50)	Delamination and exposure of reinforcing steel can be observed more than 25% on the surface of slab	
C (HI=50–25)	Delamination and exposure of reinforcing steel can be observed more than 50% on the surface of slab	
D (HI=25–0)	Delamination and exposure of reinforcing steel can be observed entire surface of slab	

In BMS system, repair method are linked with HI when calculate the cost of repair work.

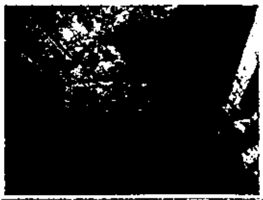
3. Standard Repair Methods based on Health Index

Repair method for concrete slab

In case, there are several options of repair method which can be applied to the same Health Index, the most expensive type of method will be selected in BMS system .

Repair method	Outline of method	Photo
	...where concrete ... This method ... no formwork. ... mm	
Injection method	This method is generally suitable for severely damaged concrete, or for largely damaged area where the reinforcing steel is exposed. This method is generally grouting the non-shrinkage mortar or concrete with setting the formwork. Degree of damage Damaged area > 10m2, Damaged depth > 30mm Rate of Health Index C - D	
Mortar spraying method	This method is generally suitable for severely damaged concrete, or for largely damaged area which is exposing the reinforcing steel. Spray gun is use to spray the mortar and concrete by compressed air rendering and profiling of vertical and overhead surfaces. Degree of damage Damaged area > 10m2, Damaged depth > 30mm Rate of Health Index C - D	

Relation between HI and repair method for Concrete slab)

Classification (HI)	Description and proper repair method	Photos (Reference)
A (HI=100-75)	No need repairs or if necessary, minor repair will be conducted. Repair method : Plastering method	
B (HI=75–50)	Need minor repairs for preventive purpose. Repair method : Plastering method	
C (HI=50–25)	Need major repairs immediately for safety and serviceability. Repair method : Injection method or Mortar spraying method	
D (HI=25–0)	Need major repairs and strengthening immediately for safety and serviceability. Repair method : Injection method or Mortar spraying method Strengthening : Continuous fiber-reinforced sheet bonding	

In BMS system, cost of repair work for each members are calculated based on HI.

4. Unit Rates of Repair Works

Setting the unit rate of repair work using in BMS for concrete slab

Assumed concrete slab's dimensions ①

Item	Unit	Dimensions	NOTE
Length of slab	m	7.0	
Width of slab	m	10.0	
Area of slab	m^2	70.0	(a)

Back date of calculation for setting the unit rate of repair work

Health Index	② Damaged area	Percentage of damage against to whole area of slab	Depth of damage	Quantity of damage	③ Unit rate for each repair / strngthening method		④ Cost of repair work (b)	⑤ Unit rate per area of slab (b / a)
A	8.8 m^2	12.5 %	0.03 m	0.3 m^3	420,000 Rs/m^3	Plastering	110,250 Rs	*2,000 Rs/m^2*
B	26.3 m^2	37.5 %	0.05 m	1.3 m^3	430,000 Rs/m^3	Plastering	564,375 Rs	*8,000 Rs/m^2*
C	43.8 m^2	62.5 %	0.10 m	4.4 m^3	430,000 Rs/m^3	Mortar spraying	1,881,250 Rs	*27,000 Rs/m^2*
D	70.0 m^2	100.0 %	0.10 m	7.0 m^3	430,000 Rs/m^3	Mortar spraying	3,010,000 Rs	43,000 Rs/m^2
	70.0 m^2	100 %			77,000 Rs/m^2	Continuous fiber-reinforced sheet bonding	5,390,000 Rs	77,000 Rs/m^2
	Sub Total						8,400,000 Rs	*120,000 Rs/m^2*

Procedure to set the unit rate of repair work in BMS

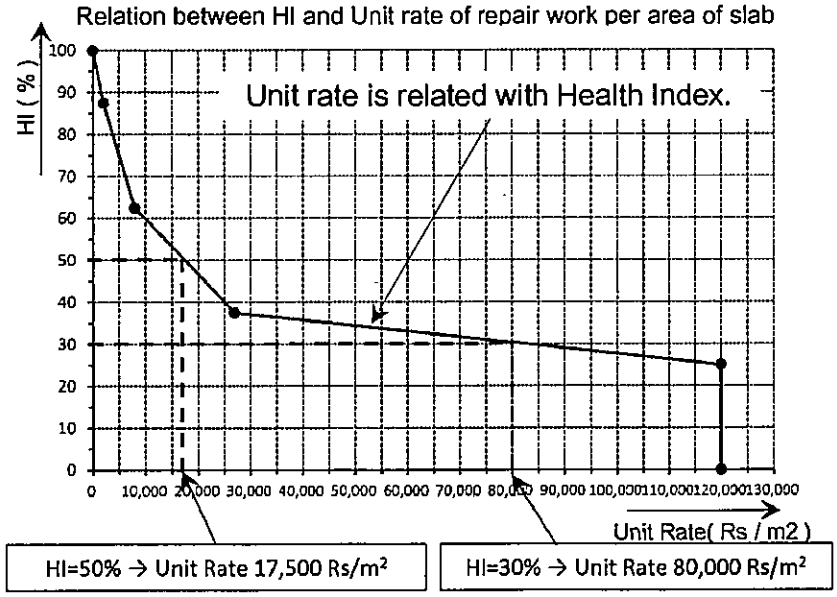
1. Assuming the dimensions of concrete slab
2. Calculating the average quantity of repair work
   ※Depth of damage is related with Health Index
3. Selecting the proper repair method based on degree of damage (= HI)
4. Calculating the cost of repair work
5. Calculating the unit cost of repair work per total area of slab
   (e.g. HI=75-50 ,Classification : B)
   564,375 Rs / 70.0 m^2 = 8,000 Rs / total area of slab

Unit cost of repair work using in BMS

Back date of calculation for setting the unit rate of repair work

Health Index	Damade area	Percentage of damade against to whole area of slab	Depth of damage	Quantity of damage	Unit rate for each repair / strngthening method		Cost of repair work (b)	Unit rate per area of slab (b / a)
A	8.8 m^2	12.5 %	0.03 m	0.3 m^3	420,000 Rs/m^3	Plastering	110,250 Rs	*2,000 Rs/m^2*
B	26.3 m^2	37.5 %	0.05 m	1.3 m^3	430,000 Rs/m^3	Mortar spraying	564,375 Rs	*8,000 Rs/m^2*
C	43.8 m^2	62.5 %	0.10 m	4.4 m^3	430,000 Rs/m^3	Mortar spraying	1,881,250 Rs	*27,000 Rs/m^2*
D	70.0 m^2	100 %	0.10 m	7.0 m^3	430,000 Rs/m^3	Mortar spraying	3,010,000 Rs	43,000 Rs/m^2
	70.0 m^2	100 %			77,000 Rs/m^2	Continuous fiber-reinforced sheet bonding	5,390,000 Rs	77,000 Rs/m^2
	Sub Total						8,400,000 Rs	*120,000 Rs/m^2*

Relation between HI and Unit rate of repair work per area of slab



Finally, unit rate for each members will be setting with the same manner.
These will be incorporate in BMS system.

Thank you for your kind attention !

Prioritization of Bridges for Repairs

- Evaluation Criteria & Weighing Factors -
- Evaluation Indicators & Points -

THE PROJECT
FOR CAPACITY DEVELOPMENT
ON BRIDGE MANAGEMENT

Kazuya URANO
Toshiki KASAI

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Contents

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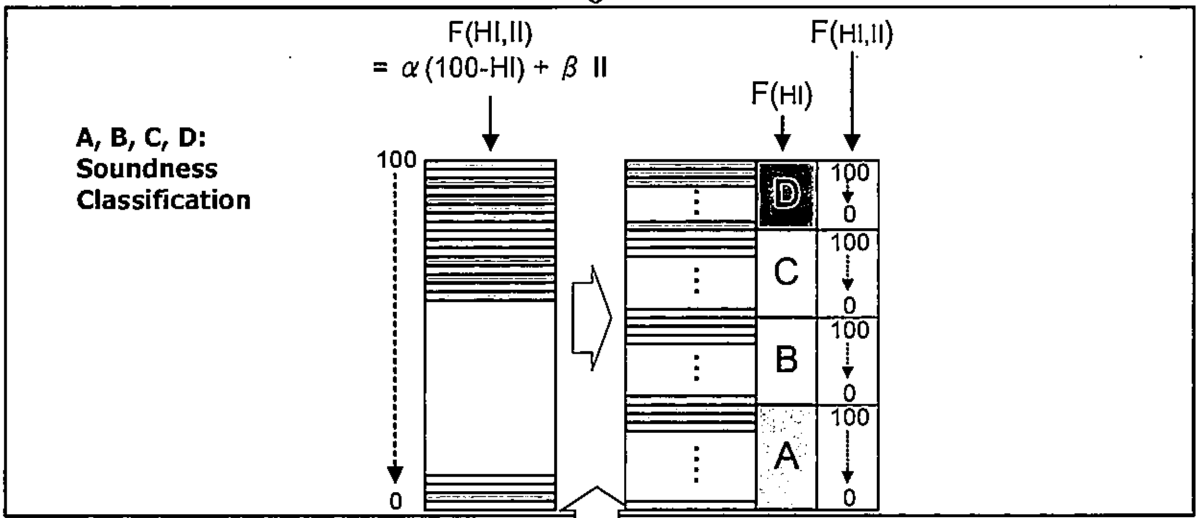
1. Prioritization of Bridges for Repair

Prioritization of Bridge Repair:

1. Bridges with lower Health Index (HI) will be prioritized.
2. However, bridges which may give large extent of obstruction due to out-of-service conditions should also be prioritized. → **Importance Index should be considered**



In order to ensure minimum safety, consideration should be given not to omit the bridges with low health indices.

3

(1) What is Health Index (HI)?

Do you remember on the 2nd workshop?

Defects, Damage and Deterioration on Each Bridge Member
- **Detect the defects, damage and deterioration at sites.**
- **26 types of defects, damage and deterioration specified.**
- **Keep the records: each member / damage, extent thereof**

(Objectively recorded with the use of sample materials)

Subjectively

Health Index Calculation (Quantification)

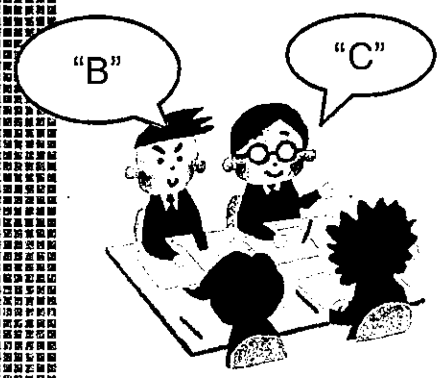
Bridge Soundness Classifications
- **Nine (9) classifications for the Ministry**
- **Different classifications for local governments**

Central Government
- Sufficient budget
- Experienced experts

Local Government
- Insufficient budget
- Unexperienced staff

4

Health Index: In order to <u>reduce the variations of evaluation results from person to person</u>, degree of required performance(s) / function(s) exhibited (soundness) is quantified for each member.



- Minimum level of required performance for a bridge member → **HI = 0**
- Performance of a bridge member owned at opening to traffic (new) → **HI = 100**
- **"HI"** is decreased with time (elapsed time after opening to traffic).

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Image of Degradation of Performance As a Bridge

Performance	Need any restrictions	Minimum performances required (design)	Performances owned at opening to traffic (new)
		HI = 0	HI = 100
Speed	Speed limit (20 km/h)	60 km/h	80 km/h
Load carrying capacity	Load limit (10 ton)	20 ton	25 ton

Allowance

A bridge member / bridge loses its function(s)!

Decreased with time

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Proposed HI: Objectively Recorded Condition Data / Information

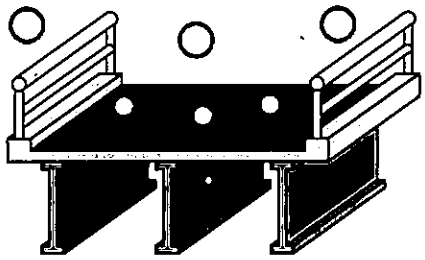
What type(s) of damage?

How many types of damage at the same time?

To what **extent**?

Degree of Required Performance(s) & Functions(s) Exhibited

Interrelated



- Identify the bridge member conditions which cannot exhibit the minimum required design performance. → **HI = 0**
- Define the type(s) and **extent** of damage for **each bridge member** <u>which need any restrictions</u>

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(2) What is Importance Index (II)?

Index for prioritization of "bridge repairs", called **<u>"importance index"</u>**, expresses **"the extent of obstruction"** occurred due to out-of-service condition of the bridges (closure to traffic or collapsed) on the following:

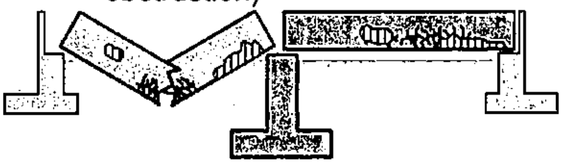
- ❑ Provide access within regional area
- ❑ Provide mobility in wide area network
- ❑ Third-party effects.

With repair works, the out-of-service condition or the above obstructions **can be avoided**.

Shall we repair the bridges promptly not to be in trouble due to out-of-service condition?

8

Images of Health Index and Importance Index

	Conditions Considered	Meaning of Index, How to Use
Health Index (HI)	< Present Condition> H.I= 100 → Full functions as with new construction H.I= 0 → Functions lost due to deterioration or damage  **[Target functions: load carrying capacity, ride quality, etc.]**	● Degree of allowance of functions / performance degraded with deterioration and damage. ➢ Criterion for judging the need of repairs ➢ Criterion for judging the need of reconstruction
Importance Index (II)	< Out-of-Service Condition > I.I = 100 → Largely affect to surrounding areas (obstruction) I.I = 0 → No effect to surrounding areas (no obstruction) 	● Extent of obstruction to surrounding areas when the bridge is out-of-service. ➢ Prioritize bridge repairs ➢ Prioritize bridge reconstruction

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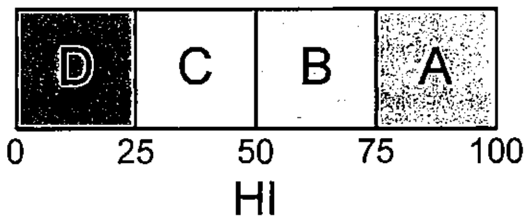
(3) Prioritization of Bridge Repairs

➢ For prioritizing the bridges for repairs, in consideration of safety, larger weighing factor is given to “Health Index (HI)” than “Importance Index (II)”.

- Priority of Bridge Repairs
  $= \alpha \times (100 - HI) + \beta \times II$,
  where, $\alpha = 0.70$, $\beta = 0.30$

Determined by BM&AU

➢ In order not to omit bridges with low HI, bridges categorized as HI Classification “D” should be repaired first, followed by “C”, “B” and “A”.



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2. Setting of Importance Index (II)

(1) Evaluation Criteria & Weighing Factors

- Extracted the **evaluation criteria** on July 22, 2016 for the importance of bridges, with the attendance of some managing and engineering members of Working Group.
- Awareness survey was conducted to set up the weighing factors for each evaluation criterion.

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Summary of Evaluation Criteria & Weighing Factors

Hierarchical Level 1		Hierarchical Level 2	
Evaluation Criteria	**Weighing Factor**	**Evaluation Criteria**	**Weighing Factor**
Importance to Providing Access within Regional Area (regional living function and economic activities)	0.32	Densely inhabited districts (DID)	0.19
		Connectivity to important facilities	0.26
		Difficulty in restoration	0.30
		Isolated villages / towns	0.25
Importance to Providing Mobility in Wide Area Network	0.27	Traffic characteristics	0.28
		Detour	0.33
		Specific important route	0.39
Third-Party	0.41	Crossing	0.50
		Utilities attached	0.28
		Disturbance to water flow at flood times	0.22

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(2) Evaluation Indicators & Points

For each evaluation criterion on 2nd hierarchical level, evaluation indicators and points should be set up.

1) Densely inhabited districts
2) Connectivity to important facilities
3) Difficulty in restoration
4) Isolated villages / towns
5) Traffic characteristics
6) Detour
7) Specific important route
8) Crossings
9) Utilities attached
10) Disturbance to water flow at flood times

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For each evaluation indicators developed, evaluation points should be given.

- ❑ Absolute points are not important.
- ❑ Evaluation points should be developed for comparison among bridges (relative points are important).

  → Highest importance is given "Point = 100"
  → Lowest importance is given "Point = 0"
  → In-between is given "Uniformly distributed point"
  → "Subjectivity" is incorporated by weighing factors.

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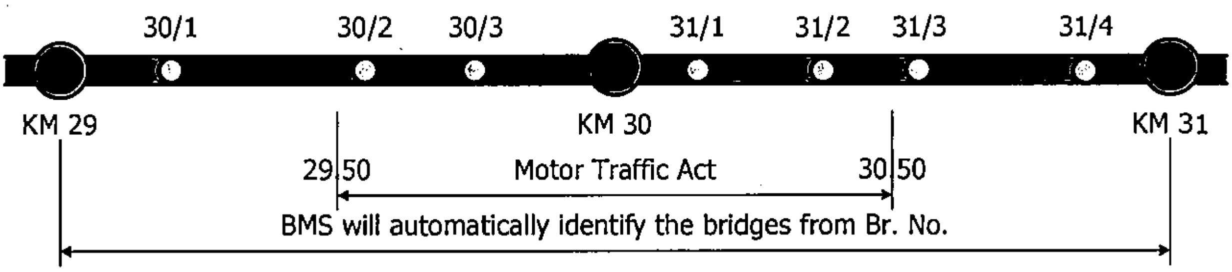
1) Densely inhabited districts (DID)

Provide access for daily living function and economic activities in the regions.

→ to be judged whether bridges within DID or outside DID

According to “Description of Built-Up Areas along the Roads or Sections of Roads to Which A Speed Limits are Applicable” in Motor Traffic Act, it should be determined as follows:

Sr. No.	Route No.	Name of Road	Township	Section (km)		
				From	To	Section Length
8	A001	Colombo - Kandy	Yakkala	29.50	30.50	1.00



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Evaluation Group & Point

Group	Evaluation Point
Apply (within built-up areas)	100
Not Apply (outside built-up areas)	0

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2) Connectivity to important facilities

It should be judged by the Executive Engineer's Office, which may know the local conditions.

→ Provide access to important facilities such as markets, religious facility, bank, school, water, industrial areas, etc.

Determined by Planning Division

Evaluation Group & Point

Group	Description	Evaluation Point
3	Extremely important facilities: airports, seaports, major bus terminals, major train stations, government hospitals	100
2	Important facilities: national school, tourism attraction, agricultural attraction, industrial attraction, bases for religious activity, national shrine, bus station, train station	50
1	No connectivity	0

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3) Difficulty in restoration

Judged by Executive Engineer's Office

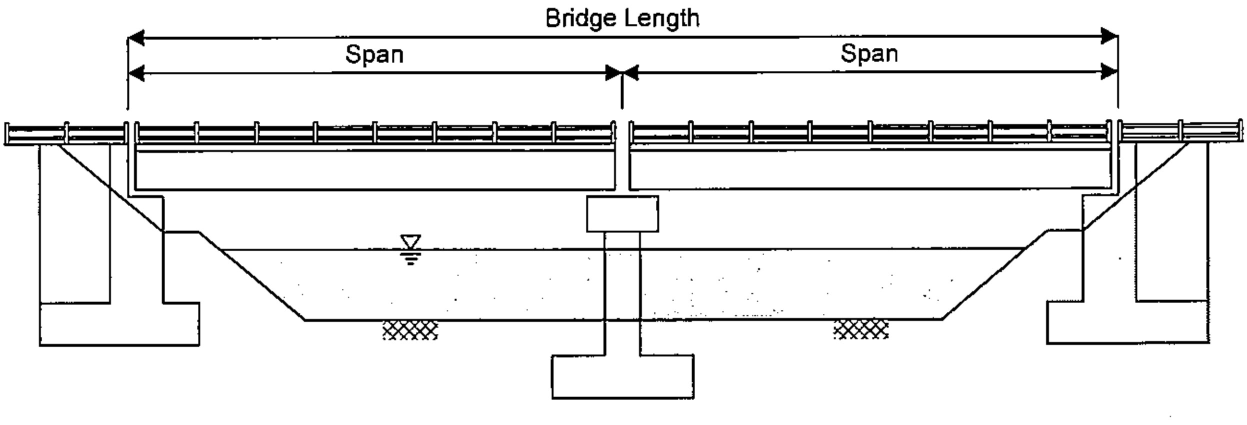
It will be judged from the following:

✓ Availability of space for temporary bridge by the side of existing bridge (within ROW, outside ROW)

✓ Span more than 25 meters (standard pretension beam ≤ 25.0)

✓ Bridges over the deep river with piers (need cofferdam in water)

✓ Bridge length more than 50 meters



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Evaluation Group & Point

Group		Evaluation Point
Space for temporary bridge	Yes, within ROW	0
	Yes, outside ROW	50
	No	100
Span	25 meters or less	0
	More than 25 meters	100
Bridge piers in water in need of cofferdam	No cofferdam needed, No river crossing	0
	Cofferdam needed	100
Bridge length	50 meters or less	0
	More than 50 meters	100

Evaluation point for "difficulty in restoration" should take the maximum point among the above sub-criteria.

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4) Isolated villages / towns

It is judged by the Executive Engineer's Office whether there are any isolated villages / towns which cannot be accessed if the target bridge is impassable.

- ✓ Applied (access to isolated villages / towns)
- ✓ Not Applied

Evaluation Group & Point

Group	Evaluation Point
Applied	100
Not Applied	0

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5) Traffic characteristics

It is judged by the traffic volume and categorized into five groups with evaluation point:

Evaluation Group & Point

Group	Traffic Volume	Evaluation Point
5	50,000 or more	100
4	20,000 – 49,999	75
3	5,000 – 19,000	50
2	500 – 4,999	25
1	0 – 499	0

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6) Detour

It is to judge the difficulty in providing the mobility in wide area network even when the bridge is impassable.

Detour should be on A, B, C and D class roads (not only on A and B class roads).

It is difficult to measure the length of detour; therefore, it is decided to judge by the additional time needed when the detour is used. Additional time should be determined by Executive Engineer's Office.

Evaluation Group & Point

Group	Additional Time Needed	Evaluation Point
3	60 minutes or more	100
2	30 – 59 minutes	50
1	0 – 29 minutes	0

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7) Specific important route

It is to judge whether the target bridge is on strategically important route or not in wide area network.

Strategically important route should be determined by the Planning Division.

→ Not yet finalized.

- ✓ Applied
- ✓ Not Applied

Evaluation Group & Point

Group	Evaluation Point
Applied	100
Not Applied	0

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8) Crossings

It considers the following crossings.

- ✓ Railway
- ✓ Expressway
- ✓ Road (traffic volume on PCU basis: 20,000 or more)
- ✓ Road (traffic volume on PCU basis: 500 – 19,999)
- ✓ Road (traffic volume on PCU basis: 499 or less)
- ✓ River
- ✓ None

For roads, it is considered that the extent of obstruction differs depending on the traffic volume. Therefore, road is categorized into 3 cases.

Evaluation Group & Point

Group		Evaluation Point
Railway		100
Expressway		100
Road	20,000 or more	100
	500 – 19,999	50
	499 or less	0
River		0
None		0

For river crossing, the effects to the surrounding areas are considered in "Disturbance to Water Flow at Flood Times".

When several crossings are selected, the maximum point should be taken as a representative point.

Ex) railway and road (500 – 19,999) → 100 or 50 → 100

9) Utilities attached

It considers the following utilities commonly attached to the bridge.

- ✓ Telecommunication cable (optic)
- ✓ Telecommunication cable (metal)
- ✓ Power cable
- ✓ Water supply / sewage pipes
- ✓ Oil pipeline

In the discussion, the idea was raised that importance of the utility differs depending on the diameter / size (large diameter for main line, small diameter for distribution line). However, it is considered that the utility with large diameter be supported by separate structure.

→ No sub-category is given by diameter.

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Evaluation Group & Point

Group	Evaluation Point
3 or more types of utilities attached	100
2 types of utilities attached	66
Single type of utility attached	33
None	0

When the bridge is collapsed, utilities attached to the bridge will not be available for residents' livelihood (water, power, electricity, telecommunication)

All utilities are essential to residents' livelihood, and are considered equally important.

When several utilities are attached, the said bridge more important than that with one utility or nothing.

Sub-criteria are set up depending on the number of utilities attached.

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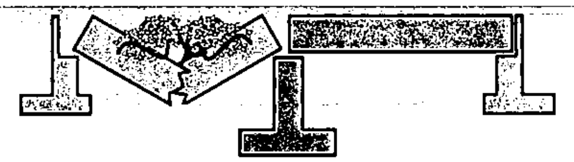
10) Disturbance to water flow at flood times

It is to consider the effects to surrounding areas when the water opening is reduced due to bridge collapse.

Importance Index (II)

- When the bridge is collapsed,
  - A) Possible to allow increased water level and overflow with reduced water opening.
  - B) Possible to wash away the abutment or pier by erosion at riverbank behind abutment or scour at pier.



Collapsed Situation

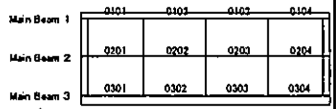
It is to propose that the number of span be the indicator to consider the above effects as follows:

Group	Number of Span	Evaluation Point
3	Single span	100
2	2 spans	50
1	3 or more spans, no crossing the river	0

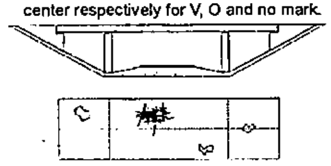
Outlines of Bridge Inspection System in Various Countries

Country	Scope of Application	Type of Bridge Inspection	Frequency of Bridge Inspection	Method of Bridge Inspection	Periodic Bridge Inspection Organization	Bridge Inspection Items and Evaluation	Remarks
U.S.A.	• All bridges on public roads in the country, which has 20 feet or greater length.	• Routine inspection regulated by Federal Government. • In case of non-compliance (inspection is not properly conducted), subsidy from the Federal Government is suspended.	• Once or more times per two years. • For bridges in sound conditions, inspection frequency can be every four (4) years with the permission from FHWA.	• Visual inspection from the bridge surface, ground or boat. • Use the inspection platform if available. • In-depth inspection with close visual inspection will be implemented at a longer time interval than routine inspection.	• Bridge inspection team in the state or local government will conduct the inspection. • Inspection team comprises 1 to 4 members (2 members as usual). • State road bridges will be inspected by the government staff. Local government road bridges will be inspected by private subcontractors.	• Approximately 140 standard structural elements, classified by materials and structural types, are evaluated on their structural conditions qualitatively and quantitatively, and categorized into 3 to 5 groups. All these results are classified into ten (10) structural evaluation ratings and recorded in National Bridge Inventory (NBI) by deck slab, superstructure, substructure, etc. (Many states use this way.) • The rating definitions are: 9 - Condition and/or existence unknown. 8 - Not applicable. 7 - New condition. No deterioration. 6 - Used to shade between ratings of 5 and 7. 5 - Minor deterioration, but functioning as originally designed. 4 - Used to shade between ratings of 3 and 5. 3 - Serious deterioration, or not functioning as originally designed. 2 - Used to shade between ratings of 1 and 3. 1 - Totally deteriorated, or in failed condition. • Each bridge is evaluated on its load carrying capacity whether the capacity is below the legally designated maximum loading. If the capacity is not sufficient, such bridge should be registered.	
U. K.	• All the bridges on arterial roads, which has 3 meters or greater length	• General Inspection	• Inspection interval shall not exceed two (2) years.	• Visual inspection from the ground (any invisible bridge portions will be inspected by close visual inspection conducted every 6 years)	• All the inspections are implemented by management agencies (local authorities, government-owned corporations, consultants).	• Evaluation will be made on two (2) categories: structural stability (ex. load carrying capacity, etc.) and structural conditions (5 ratings). • Presently, the evaluation has been conducted within the schemes of Fifteen-Year Bridge Strengthening Plan. • In near future, "Whole Life Evaluation" will be introduced. Presently, trial whole life evaluation has been conducted with identification of current structural conditions at the times of inspection and prediction of deterioration.	
		• Principal Inspection	• Inspection interval shall not exceed six (6) years. • Exceptionally, inspection interval will be ten (10) years.	• Close visual inspection	• All the inspections are implemented by management agencies (local authorities, government-owned corporations, consultants).		
France	• All the bridges on national roads, which has 2 meters or greater length	• Annual Inspection	• Every year for bridges	• Simple inspection	• Construction work offices implement the inspection at the time of general maintenance work.	• Identify the unusual conditions and signs of apparent changes.	• In the previous version of standard, annual inspection has covered only 85% of all the target bridges due to shortage of human resources. Therefore, after the IQOA inspection is in operation, sufficient number of human resources has been secured. • Periodical in-depth inspection had been conducted every five (5) years in the past. After the IQOA inspection is in operation (every three years), time interval has been changed to six (6) years.
		• Image Diagnosis	• Every three (3) years	• Visual inspection on external appearances (no scaffolding is provided for this inspection)	• Construction work offices and Structural Division staff (CDOA) will do.	• Evaluation on structures will give one overall rating in consideration of all bridge components (superstructure, substructure, bearing, foundation, ancillary works). • Evaluation will select one rating out of five (5). In addition to this system, "S" rating will be given for emergency response in terms of safety of road users.	

Outlines of Bridge Inspection System in Various Countries

Country	Scope of Application	Type of Bridge Inspection	Frequency of Bridge Inspection	Method of Bridge Inspection	Periodic Bridge Inspection Organization	Bridge Inspection Items and Evaluation	Remarks
		• Periodical In-Depth Inspection	• Every six (6) years • For robust and sound bridges, time interval will be extended to 9 years (to be judged by Regional Development Bureau Director). Time intervals will be shortened to 3 years or 1 year.	• Compared to IQOA, more technically scrutinized inspection will be conducted.	• Structural Division staff, (CDOA), technical network personnel or the consultants will do.	• Director will determine the list of bridges in need of periodical in-depth inspection. • Evaluate the structures in accordance with the IQOA standards.	
Japan Ministry of Land, Infrastructure, Transport and Tourism (MLIT)	• All the road bridges, which has 2 meters or greater length.	• Periodical Inspection	• Initial inspection will be conducted within two (2) years after the opening to traffic. Thereafter, inspection will be conducted every five (5) years.	• Close visual inspection. • As needed, non-destructive tests such as palpation and hammering test will be used.	• Consultants will do.	• Bridge inspection to understand the extent of defects, damage and deterioration ➢ Understand the conditions of defects, damage and deterioration for each element (minimum unit of bridge member) and each type of defect, damage and deterioration (26 types). ➢ Bridge conditions recorded do not include causes of defects, damage and deterioration, prediction of degradation, and effects to the performances of an entire bridge structure (just an objective fact indicating the present condition). ➢ Classified into 5 ratings (a, b, c, d, e).	• Element of bridge members (ex. Main beams) 
					• Diagnosis will be conducted by the consultants.	• Diagnosis to judge the classification of measures to be taken. ➢ Classify the measures to be taken for each structural member and for each type of defect, damage and deterioration. ➢ Classification is based on the engineering judgement by the professionals. ➢ Comprehensive judgements for measures to be taken by road administrator, in consideration of evaluation of defects, damage and deterioration, causes thereof, prediction of degradation, effects to the performances of an entire bridge structure, and present conditions. ➢ 9 classifications (A, B, C1, C2, E1, E2, M, S1, S2)	
Japan Local Government Office of Shizuoka Prefecture	• All the road bridges which lengths are between 2 meters and 15 meters, as well as all the road bridges longer than 15 meters and in good conditions.	• Preliminary Inspection	• Once per five (5) years.	• For a representative span(s), inspect the bridges within a visible range by eyes from the ground (distant visual inspection).	• Bridge inspection team in the prefectural government offices inspects the bridges. • Inspection team comprises 2 to 3 members from the government offices or consultants.	• Target bridge members for inspection are only primary ones. Types of dafects, damage and deterioration to be checked are limited to those with high frequency of occurrence. • Extent of defects, damage and deterioration is categorized into three (3) grades (sound, slight, serious). • Based on the records of defects, damage and deterioration conditions, health index (quantification of soundness) is calculated for each member and span. Standard bridge repair costs are also calculated, corresponding to the value of health index.	• At present, with the amendment of the law in 2014, "distant visual inspection for a representative span(s)" has been changed to "close visual inspection for all spans" for Rough Inspection. • Types of bridge inspection have been renamed (Rough Inspection → Periodical Inspection A, In-Depth Inspection → Periodical Inspection B). • There has been no change on fundamental ideas of bridge inspection.

Outlines of Bridge Inspection System in Various Countries

Country	Scope of Application	Type of Bridge Inspection	Frequency of Bridge Inspection	Method of Bridge Inspection	Periodic Bridge Inspection Organization	Bridge Inspection Items and Evaluation	Remarks
	● All the road bridges longer than 15 meters and in bad conditions.	● In-Depth Inspection		● Within an arm's reach, inspect the bridges visually (close visual inspection).	● Consultants will do.	● For all the bridge members, 26 types of defect, damage and deterioration will be identified. Each defect, damage and deterioration will be categorized into five (5) grades (A to E), depending on its degree and extent. ● For each defect, damage and deterioration, its extent will be recorded in 10% increments (each element of bridge members will not be evaluated individually). ● Based on the records of defects, damage and deterioration conditions, health index (quantification of soundness) is calculated for each member and span. Standard bridge repair costs are also calculated, corresponding to the value of health index.	
Finland	–	–	–	–	–	● Each of 30 types of defects, damage and deterioration is evaluated into four (4) grades: 1 = slight, 2 = remarkable, 3 = serious, 4 = very serious ● Repair method is specified for each type of defect, damage and deterioration, and for each grade. ● As an indicator for bridge conditions, overall damage point system (VPS) is used. VPS indicates the conditions of defect, damage and deterioration, and quantities thereof, in figures. VPS can be used to understand the conditions of individual bridge or a group of bridges under the management.	● Bridge inspection manual is prepared as a specification of Bridge Management System. Therefore, all the inspection results are recorded in text format in order that these results can be registered in the management system smoothly. ● The location of defects, damage and deterioration on superstructure is indicated as follows: the digit in one's place for the order of the span; the first decimal place for the longitudinal location in which segment of a span out of 10 segments equally divided; left, right and center respectively for V, O and no mark.  1.5 V 2.4 V 2.8 O 3.4

4th Workshop Agenda

March 08, 2017

Time	Contents	Presenter
08:30 – 09:00	Registration	--
09:00 – 09:05	Welcome address	Director ES
09:05 – 09:20	Definition of Functionally Obsolete Index FOI) & Prioritization of Bridges for Reconstruction	Mr. K. Urano
09:20 – 09:35	Standard Repair Methods for Health Indices Unit Rates for Bridge Repairs	Mr. A. Kagami
09:35 – 09:50	Definition of "Health Index = 0"	Mr. T. Ichioka
09:50 – 10:10	Discussion	
10:10 – 10:20	Break	
10:20 – 10:35	Definition of Important Index (II)	Mr. T. Ichioka
10:35 – 10:55	Revised Bridge Repair Manual	Mr. H. Takaura
10:55 – 11:10	Discussion	
11:10 – 11:20	Closing Remarks	ADG CD

Prioritization of Bridges for Reconstruction

THE PROJECT
FOR CAPACITY DEVELOPMENT
ON BRIDGE MANAGEMENT

Kazuya URANO
Toshiki KASAI

Contents

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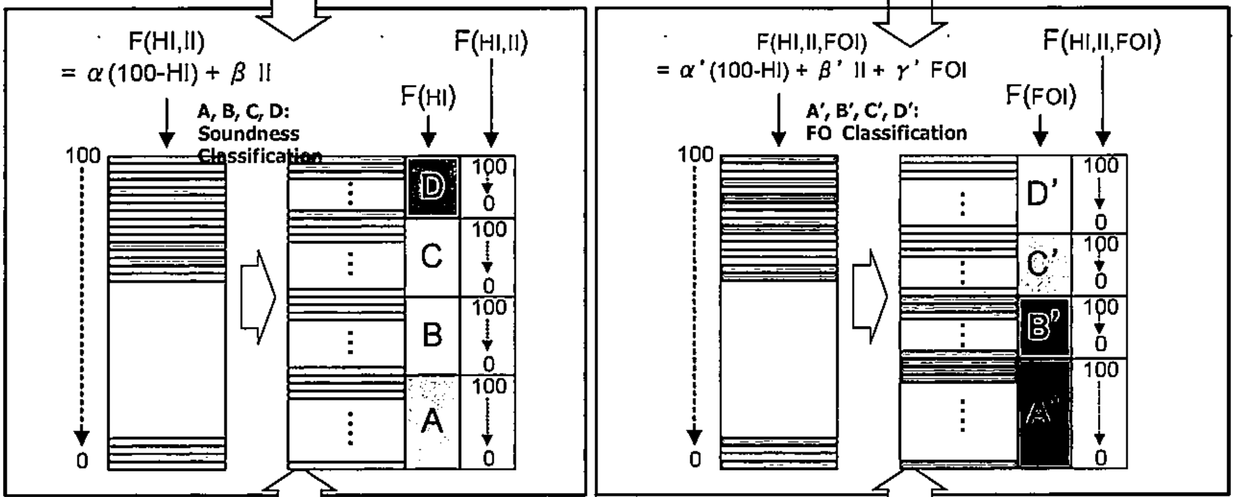
1. Prioritization of Bridges for Reconstruction

Prioritization of Bridge Repair:
1. Bridges with lower HI will be prioritized
2. However, bridges which may give large extent of obstruction due to out-of-service conditions should also be prioritized.
   → **Importance Index considered**

Prioritization of Bridge Reconstruction:
1. Functionally obsolete bridges will be prioritized.
2. However, resistant to reconstruct sound bridges → **Health Index considered.**
3. Also, bridges will high investment effect should be prioritized. → **Importance Index considered.**



In order to ensure minimum safety, consideration should be given not to omit the bridges with low health indices.

Consideration should be given not to omit the extremely functionally obsolete bridges.

3

What is Functionally Obsolete Index (FOI)?

Indices for prioritization of "bridge repairs" and "bridge reconstruction" express **"the extent of obstruction"** to surrounding areas and are considered a kind of "importance index".

Bridge Repairs	Bridge Reconstruction
Called "**Importance Index**"	Called "**Functionally Obsolete Index**"

- ☐ Express the "extent of obstruction" to surrounding areas
- ☐ Both are considered a kind of "Importance Index"

■ Focus on the effects when the bridge is out-of-service (closure to traffic, collapse, etc.)

- ✓ Importance to provide access within regional area
- ✓ Importance to provide mobility in wide area network
- ✓ Third-party effects

■ Focus on the functional obsolescence of the bridge during the service

- ✓ Structural details
- ✓ Nature of bridge
- ✓ Resistance to disaster

4

Importance Index (II)

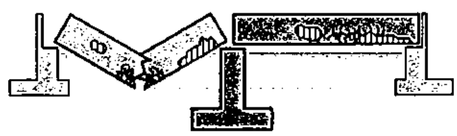
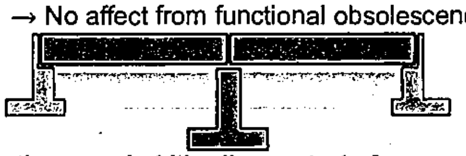
- Express the "**extent of obstruction**" occurred due to **out-of-service condition of the bridge** ("closure to traffic" or "collapse").
- With repair works, it **CAN PREVENT** closure to traffic or collapse.
  - Large effects where the bridge is on heavy traffic route.
  - Large effects where long detour is required.
  - Large effects where the bridge is on the access route to important facilities, etc.

Functionally Obsolete Index (FOI)

- Express the "**extent of obstruction**" occurred due to **functional obsolescence of the bridge.**
- With repair works, it CANNOT dissolve the functional obsolescence.
  - Generate traffic jam due to existing narrow bridge width.
  - Forced to reduce the speed or impaired the safety due to bad horizontal / vertical alignment and insufficient horizontal / vertical clearance.
  - Inundated at flood times due to low elevation of bridge surface, etc.

5

Images of Health Index, Importance Index and Functionally Obsolete Index

	Conditions Considered	Meaning of Index, How to Use
Health Index (HI)	< Present Condition> H.I= 100 → Full functions as with new construction H.I= 0 → Functions lost due to deterioration, damage  [Target functions: load carrying capacity, ride quality, etc.]	● Degree of allowance of functions / performance degraded with deterioration and damage. ➢ Criterion for judging the need of repairs ➢ Criterion for judging the need of reconstruction
Importance Index (II)	< Out-of-Service Condition > I.I = 100 → Largely affect to surrounding areas (obstruction) I.I = 0 → No affect to surrounding areas (no obstruction) 	● Extent of obstruction to surrounding areas when the bridge is out-of-service. ➢ Prioritize bridge repairs ➢ Prioritize bridge reconstruction Shall we repair the bridge promptly not to be in trouble due to out-of-service?
Functionally Obsolete Index (FOI)	< Originally Given Functions > F.O.I = 100 → Largely affect from functional obsolescence F.O.I = 0 → No affect from functional obsolescence  [Target functions: road width, alignment, etc.]	● Extent of obstruction to surrounding areas due to functional obsolescence. ➢ Prioritize bridge reconstruction Shall we promptly reconstruct the bridge because we are in trouble due to functional obsolescence?

6

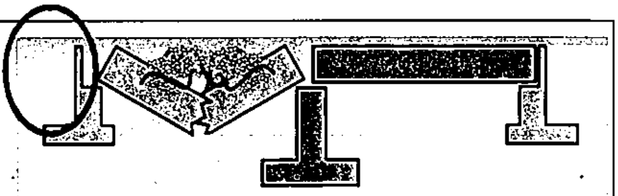
Image of Difference between "Importance Index (II)" & "Functionally Obsolete Index (FOI)"

➢ Flood times, for examples:

Importance Index (II)

●When the bridge is collapsed,

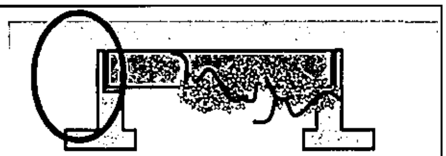
A) Possible to allow increased water level and overflow with reduced water opening.



Collapsed Situation

B) Possible to wash away the abutment or pier by erosion at riverbank behind abutment or scour at pier.

Functionally Obsolete Index (FOI)



●Even without collapse of the bridge,

A) Possible to be inundated due to low bridge surface level

B) Possible to overflow at flood times due to small water opening at bridge location

C) Possible to wash away the substructures by scouring due to fast water flow, at bridge location.

7

2. Setting of Functionally Obsolete Index (FOI)

(1) Evaluation Criteria for Prioritizing the Reconstruction

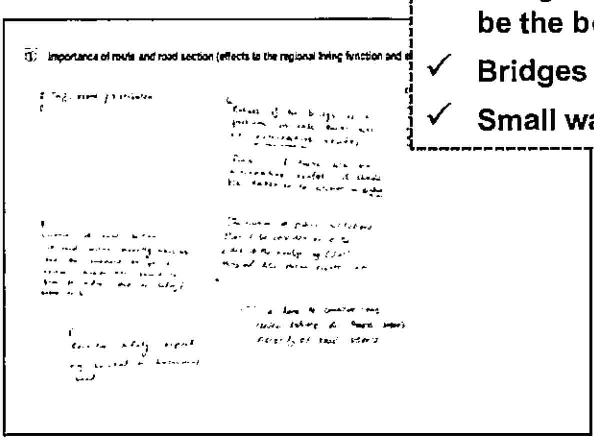
- Extracted the evaluation criteria on July 22, 2016 for the importance of bridges, with the attendance of some managing and engineering members of Working Group.
- From this, ideas on functional obsolescence of the bridges were raised.

Existing Non-Conformance Bridges

✓ **Bridges judged to be repaired is narrow and will be the bottleneck.**

✓ **Bridges in a dangerous curve.**

✓ **Small water opening.**



8

Based on the ideas on functional obsolescence of the bridge raised in the meeting, evaluation criteria were summarised as follows:

a. Structural Details (performance to ensure safety and comfortability)
   → Bridge width: number of lanes, bridge width, depend on traffic counts
   → Horizontal / vertical alignment, horizontal / vertical clearance
   → Design loading: design live loading

b. Nature of Bridge
   → Permanent or temporary

c. Resistance to Disaster (performance to ensure the use of a bridge even at disaster times)
   → Year-round mobility: level of bridge surface not inundated at disaster times, or inundated for a short period of time only and is no hindrance to critical activities for the public
   → Possibility of disaster: bridge structure, promoting the scour and overflow at flood times (disaster history)

9

(2) Weighing Factor for Each Evaluation Criterion

Number of evaluation criteria is small. Therefore, please set up the weighing factor for each criteria directly, or fill out the simple awareness survey form.

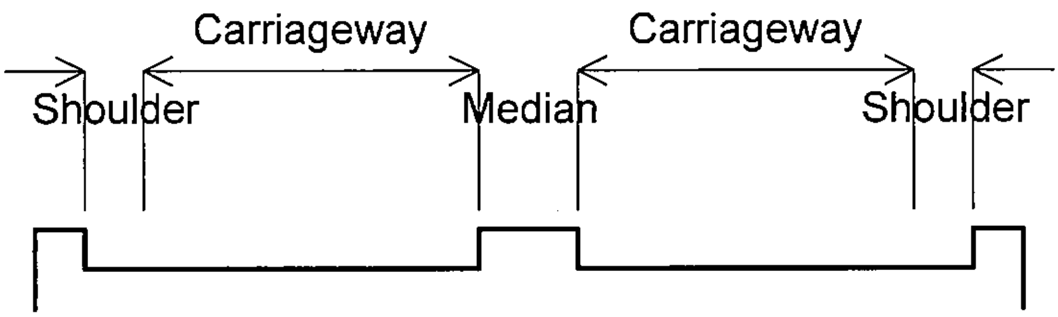
First Hierarchical Level		**Second Hierarchical Level**	
Evaluation Criteria	Weighing Factor	Evaluation Criteria	Weighing Factor
Structural Details	?	Road Width	?
		Geometry, Clearance	?
		Design Loading	?
Nature of Bridge	--	Temporary or Permanent	?
Resistance to Disaster	?	Year-Round Mobility	?
		Disaster History	?

Determined by BM&AU

(3) Evaluation Description & Points for Each Evaluation Criterion

Evaluation Criterion		Description	Point: Not Apply	Point: Apply
Structural Details	Width	➢ Required number of lane / carriageway width from the traffic counts (PCU).	0	100
	Geometry, Clearance	➢ Forced to reduce the speed due to bad horizontal / vertical alignments at approaches. ➢ Impaired the safety due to insufficient horizontal / vertical clearance (accident history)	0	100
	Design Loading	➢ Small design live loading (design loading smaller than present one).	0	100
Nature of Bridge	Permanent / Temporary	➢ "Temporary Bridge (called Bailey Bridge)" is the one, which was reconstructed after the existing bridge was collapsed / removed. ➢ UK Steel Bridges are supposed to be permanent. However, if it is easy to be dismantled, it may be considered "temporary".	0	100
Resistance to Disasters	Year-Round Mobility	➢ Inundated for a short period of time only; however, no hindrance to critical activities for the public.	0	100
	Disaster History	➢ Washed away the bridge structure and approaches at disaster times in the past. ➢ Largely damaged due to scouring in the past. ➢ Log impact / debris damage	0	100

For the bridge width:



Type of Cross Section	Traffic Volume (PCU/day)	Shoulder (m)	Carriageway	Median (m)	Required Kerb-to-Kerb Width (m)
R0	72,000 – 108,000	2 x 3.00	2 x 10.50	1.20	28.20
R1	40,000 – 72,000	2 x 3.00 (min. 2.40)	2 x 7.40	1.20	22.00 (min. 20.80)
R2	25,000 – 40,000	2 x 3.00 (min. 2.40)	2 x 7.40 (min. 7.00)	1.20	22.00 (min. 20.00)
R3	18,000 – 25,000	2 x 3.00	2 x 3.70	-	13.40
R4	300 – 18,000	2 x 2.40	2 x 3.10	-	11.00
R5	< 300	2 x 2.40	3.50	-	8.30

For Permanent / Temporary Bridges:

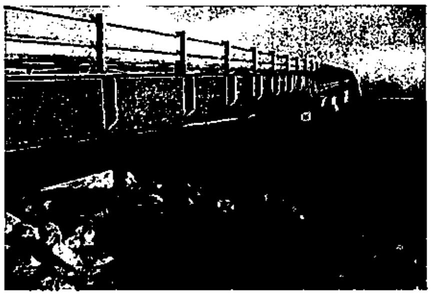
All concrete bridges would be permanent. Steel flyover at intersection would be permanent, because there was no bridge in the past.
Herewith presented are the example of steel bridges: permanent or temporary.

- Truss bridge --> permanent rivet connection

- Bailey bridge --> temporary

- Modular type --> permanent

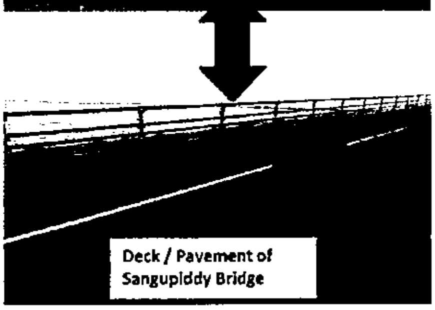
- Flyover at intersection --> permanent



- permanent (Sangupiddy Bridge)

- Bailey bridge --> temporary

How about this bridge (A014 042/02)??
- Steel I-Beam (2 beams)
- Deck plate, same as bailey bridge (not like Sangupiddy Bridge)

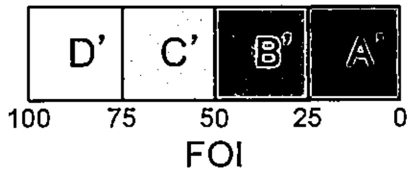


(4) Prioritization of Bridges for Reconstruction

- For prioritizing the bridges for repairs, in consideration of safety, larger weighing factor is given to "Health Index (HI)" than "Importance Index (II)".
- For bridge reconstruction, prioritization is made based on "Health Index (HI)" , "Importance Index (II)" and "Functionally Obsolete Index (FOI)".

  In consideration of "extent of obstruction" due to functional obsolescence of the bridge, larger weighing factor is given to "Functionally Obsolete Index (FOI)".

  - Priority of Reconstruction of Bridge
    $= \alpha' \times (100 - HI) + \beta' \times II + \gamma' \times FOI$,
    where, $\alpha' = ??$, $\beta' = ??$, $\gamma' = ??$
- In order not to omit extremely functionally obsolete bridges, bridges categorized as FOI Classification "D' " should be reconstructed first, followed by "C' ", "B' " and "A' ".



Standard Bridge Repair Method for Health Index
(Unit Rates for Bridge Repair)

8th March, 2017

THE PROJECT FOR CAPACITY DEVELOPMENT ON BRIDGE MANAGEMENT

Akira KAGAMI

CONTENTS

1. Procedure of setting unit price for BMS
2. Setting unit rate for BMS
   - RC-S, Box bridge – Deck Slab
   - PSC-POS, RCS-RCB – Main Beam
   - Steel Bridge – Main Beam

1.Procedure of setting unit price for BMS

1. Choose general dimension of bridge for each type
   (In BMS Unit rate should be set for each type of bridge and also for each members)
2. Setting the status of damage of each member for each type of bridge when HI=0
3. Calculate the quantity for repair work when HI=0
4. Setting the borderline of HI which repair method should be changed
5. Calculate the repair cost
   - If unit rate is mentioned in HSR → Use HSR
   - If not → Cost estimated by contractor
     or extract from Japan standard
6. Calculate the unit rate of repair work per area of slab
7. Calculate the unit rate of repair work per area of slab between the borderline by linear interpolation

2. Setting Unit Rate for BMS

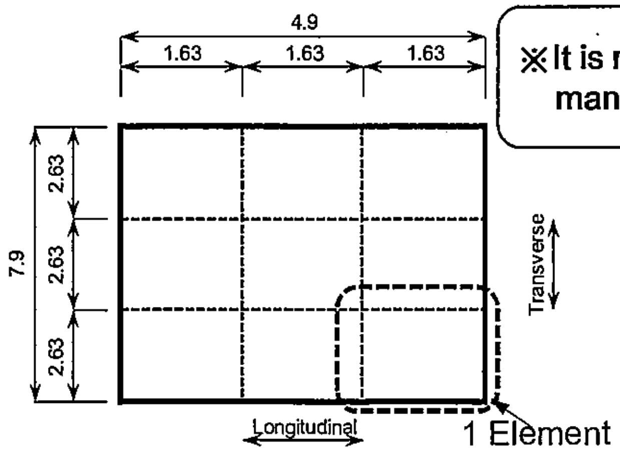
Type of bridge : RC-S,Box bridge
Member : Deck Slab

Procedure.1: Chose general dimension of bridge

Conditions

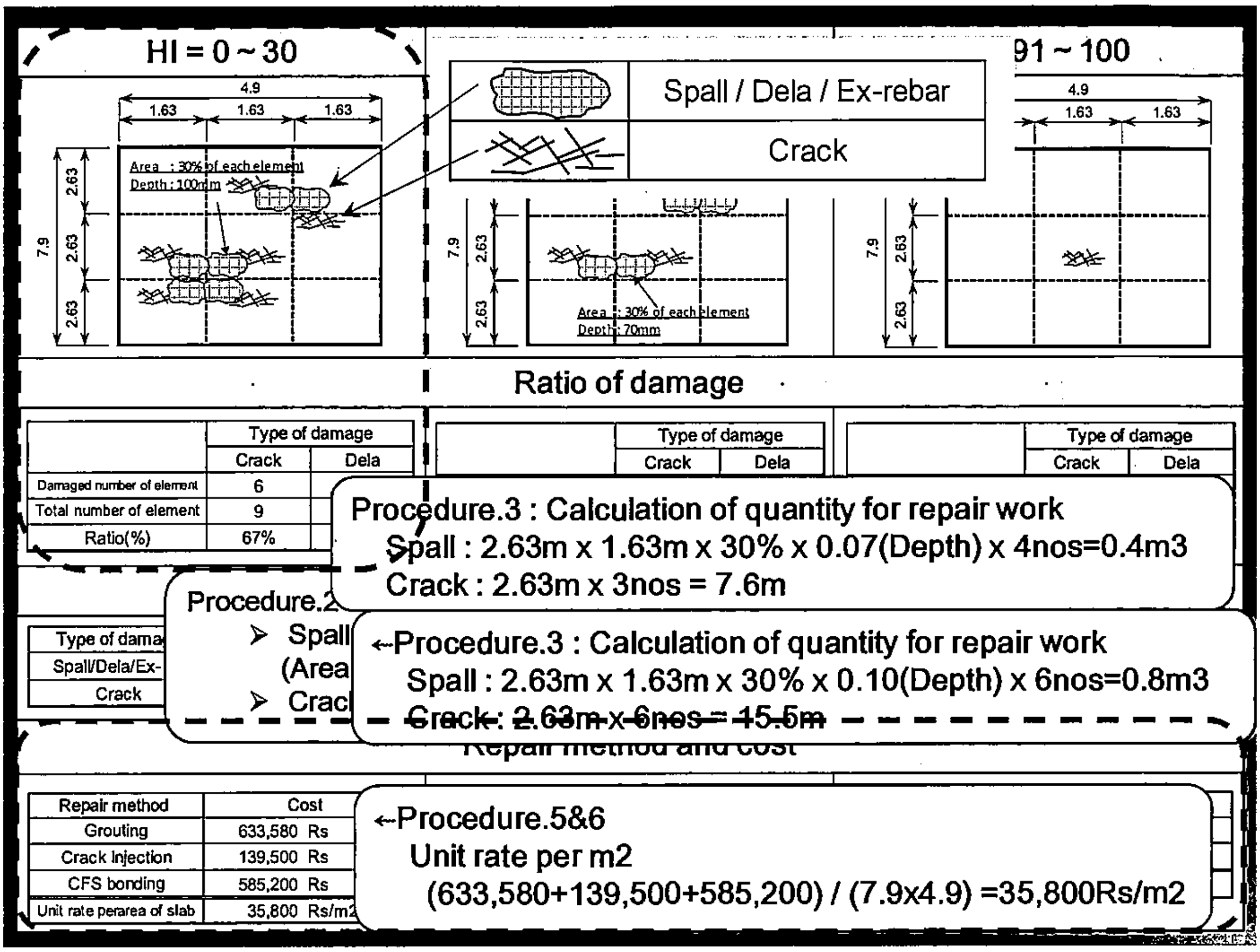
Route No	B324	Bridge No	No.10/4
Assumed dimensions of structure			
Item	Unit	Dimension	NOTE
Length of slab	m	4.9	
Width of slab	m	7.8	
Area of bridge	m^2	38.0	(a)
Damaged elemnt	m^2	25.3	

Plan view

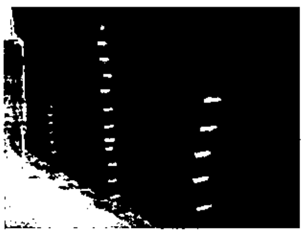


Photos

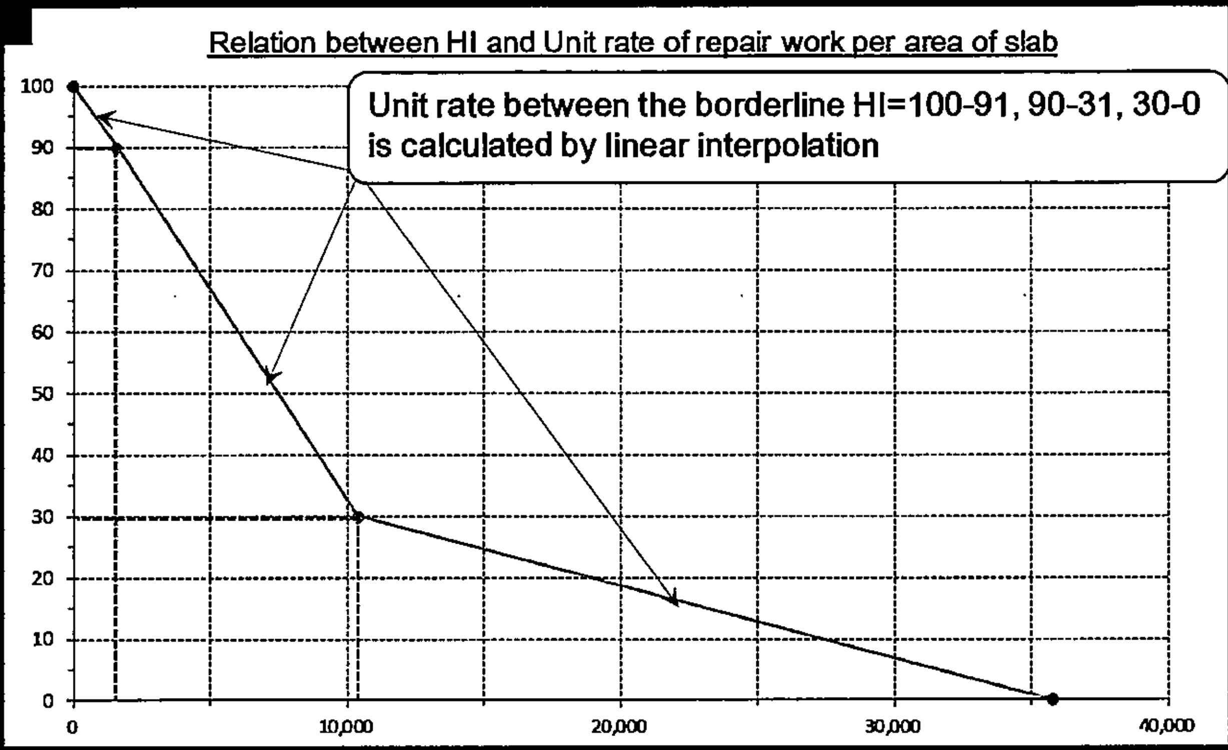
※It is mentioned in Inspection manual how to define the 1 element



Repair method for concrete structure

Repair method	Outline of method	Photo
Plastering method	This method is suitable to restore small areas where concrete is damaged with spalling, scaling and collision. This method is generally used with steel trowel and requires no formwork.	
Crack Injection method	This method is generally applied for the crack which width is from 0.2mm to 1.0mm. It can apply to concrete structures. The works include preparation of concrete surface, insertion of pipe fittings bonded with adhesion, injection of epoxy, curing and conducting performance test.	
Grouting method	This method is generally suitable for severely damaged concrete, or for largely damaged area where the reinforcing steel is exposed. This method is generally grouting the non-shrinkage mortar or concrete with setting the formwork.	

Procedure.7 : Caluculate the unit rate between the borderline



Plastring (Polymer cement mortar) RC-S Deck Slab (NO.Co-2)

Items		Unit Rate	Quantity (Duration)	Total Cost	NOTE
Equipment, Labor,Material	Plastering	423,400 Rs/m³	0.4 m³	169,360 Rs	Unit rate is estimated by contractor
	Scaffolding	9,100 Rs/m²	16.8 m²	152,880 Rs	Unit rate is based on trial construction
Total				*322,240 Rs*	

Crack Injection-RC-S Deck Slab 100-90 (NO.Co-7)

Items		Unit Rate	Quantity (Duration)	Total Cost	NOTE
Equipment, Labor,Material	Injection	9,000 Rs/m	2.6 m	23,400 Rs	Unit rate is estimated by contractor
	Scaffolding	9,100 Rs/m²	4 m²	36,400 Rs	Unit rate is based on trial construction
Total				*59,800 Rs*	

Crack Injection-RC-S Deck Slab 90 30 (NO.Co-8)

Items		Unit Rate	Quantity (Duration)	Total Cost	NOTE
Equipment, Labor,Material	Injection	9,000 Rs/m	7.8 m	70,200 Rs	Unit rate is estimated by contractor
	Scaffolding	9,100 Rs/m²	0 m²	0 Rs	Unit rate is based on trial construction
Total				*70,200 Rs*	

Crack Injection-RC-S Deck Slab 30 0 (NO.Co-9)

Items		Unit Rate	Quantity (Duration)	Total Cost	NOTE
Equipment, Labor,Material	Injection	9,000 Rs/m	15.5 m	139,500 Rs	Unit rate is estimated by contractor
	Scaffolding	9,100 Rs/m²	0 m²	0 Rs	Unit rate is based on trial construction
Total				*139,500 Rs*	

Grouting (RC-S Deck Slab) 30 0 (NO.Co-17)

Items		Unit Rate	Quantity (Duration)	Total Cost	NOTE
Equipment, Labor,Material	Grouting	362,000 Rs/m^3	0.8 m^3	289,600 Rs	Unit rate is estimated by contractor
	Scaffolding	9,100 Rs/m^2	37.8 m^2	343,980 Rs	Unit rate is based on trial construction
Total				***633,580 Rs***	

Fiber sheet bonding (RC-S Deck Slab) (NO.Co-24)

Items		Unit Rate	Quantity (Duration)	Total Cost	NOTE
Equipment, Labor,Material	Fiber sheet bonding	77,000 Rs/m^2	7.6 m^2	585,200 Rs	Unit rate is estimated by contractor 2Layer
Total				***585,200 Rs***	

Type of bridge : PSC-POS,RCS-RCB

Member : Main beam

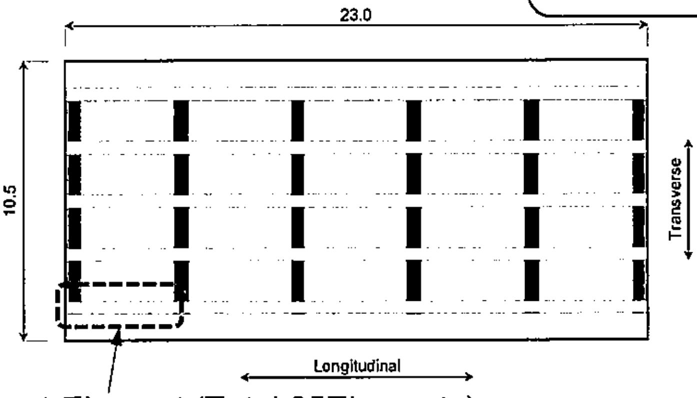
Conditions

Route No	AA026	Bridge No	No.5/1
Assumed dimensions of structure			
Item	Unit	Dimensions	NOTE
Length of slab	m	23.0	
Width of slab	m	10.5	
Area of bridge	m^2	241.5	(a)
Number of Main Beam	Nos	5	
Height of MainBeam	m	1.0	
Width of MainBeam	m	0.4	
Length of MainBeam	m	23.2	
Area of MainBeam	m^2	46.4	

Photos

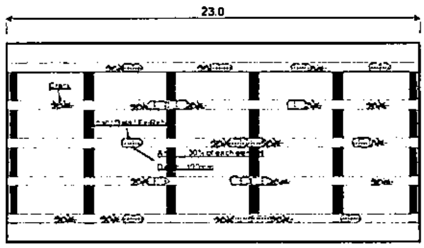
※It is mentioned in Inspection manual how to define the 1 element

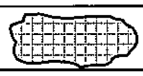
Plan view

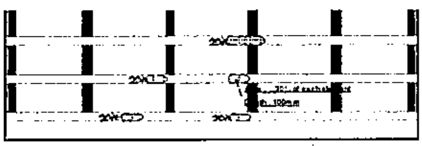


1 Element (Total 25Elements)

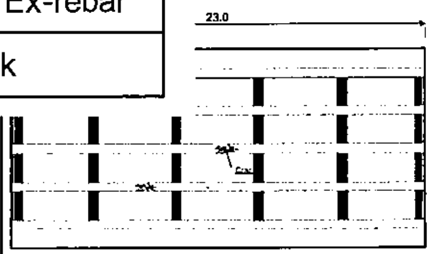
HI = 0 ~ 30



	Spall / Dela / Ex-rebar
	Crack



91 ~ 100



Ratio of damage

Calculation of qua
Spall : 4.64m x
Crack : 0.4m x

Calculation of quantity for repair work (HI=31)
Spall : 4.64m x 0.4m x 30% x 0.07(Depth) x 12nos=0.5m3
Crack : 0.4m x 2 x 10nos = 8.0m

Quantity of damage

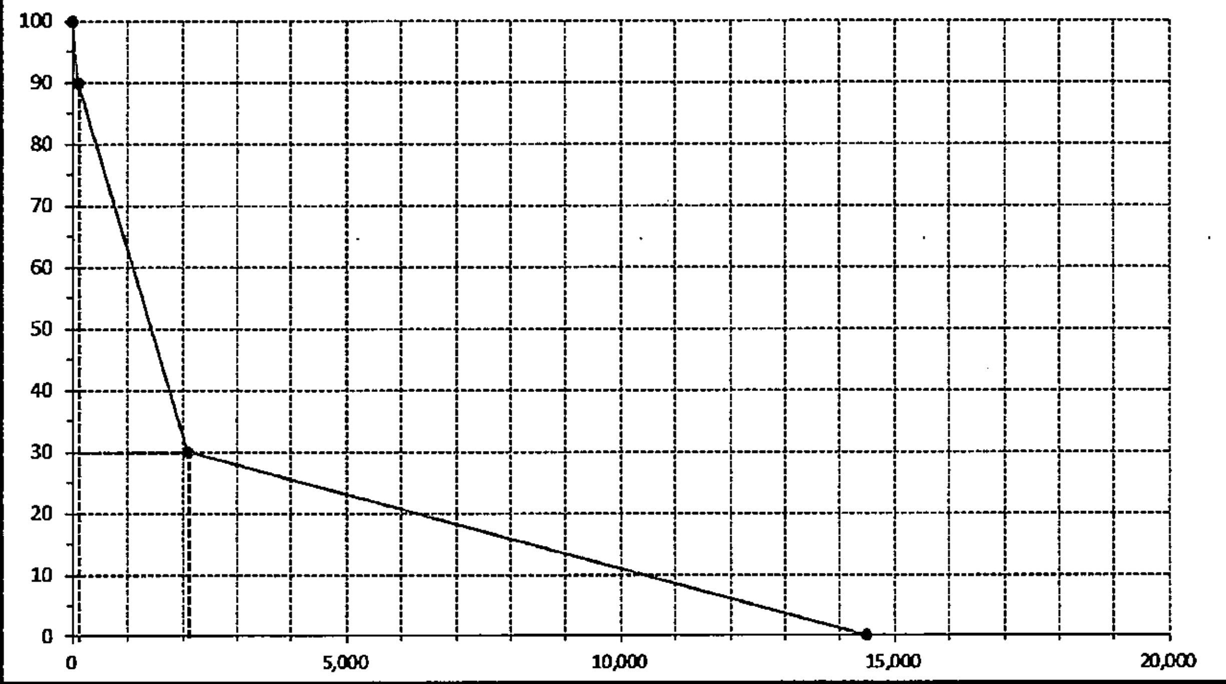
Procedure : Setting HI=0
- Spall / Dela / Ex-rebar generate at 18elements (Ratio to whole element is 72%) (Area of Spall / Dela / Ex-rebar are 30% of each element)
- Crack generate at 18elements (Ratio to whole element is 72%)

Repair method	Cost
Grouting	2,582,400 Rs
Crack Injection	129,600 Rs
CFS bonding	770,000 Rs
Unit rate perarea of slab	14,500 Rs/m^2

Repair method	Cost
Plastering (Polymer cement)	430,100 Rs
Crack Injection	72,000 Rs
Unit rate perarea of slab	2,100 Rs/m^2

Repair method	Cost
Crack Injection	14400 Rs
Unit rate perarea of slab	100 Rs/m^2

Relation between HI and Unit rate of repair work per area of slab



Plastring (Polymer cement mortar) PSC-POS,RCS-RCB Main Beam (NO.Co-3)

Items		Unit Rate	Quantity (Duration)	Total Cost	NOTE
Equipment, Labor,Material	Plastering	423,400 Rs/m^3	0.5 m^3	211,700 Rs	Unit rate is estimated by contractor
	Scaffolding	9,100 Rs/m^2	24 m^2	218,400 Rs	Unit rate is based on trial construction
Total				430,100 Rs	

Crack Injection-PSC-POS,RCS-RCB Main Beam 100 90 (NO.Co-10)

Items		Unit Rate	Quantity (Duration)	Total Cost	NOTE
Equipment, Labor,Material	Injection	9,000 Rs/m	1.6 m	14,400 Rs	Unit rate is estimated by contractor
	Scaffolding	9,100 Rs/m^2	0 m^2	0 Rs	Unit rate is based on trial construction
Total				14,400 Rs	

Crack Injection-PSC-POS,RCS-RCB Main Beam 90 30 (NO.Co-11)

Items		Unit Rate	Quantity (Duration)	Total Cost	NOTE
Equipment, Labor,Material	Injection	9,000 Rs/m	8 m	72,000 Rs	Unit rate is estimated by contractor
	Scaffolding	9,100 Rs/m^2	0 m^2	0 Rs	Unit rate is based on trial construction
Total				72,000 Rs	

Crack Injection-PSC-POS,RCS-RCB Main Beam 30 0 (NO.Co-12)

Items		Unit Rate	Quantity (Duration)	Total Cost	NOTE
Equipment, Labor,Material	Injection	9,000 Rs/m	14.4 m	129,600 Rs	Unit rate is estimated by contractor
	Scaffolding	9,100 Rs/m^2	0 m^2	0 Rs	Unit rate is based on trial construction
Total				129,600 Rs	

Grouting(PSC-POS,RCS-RCB Main Beam)	30	0			(NO.Co-19)
Items		Unit Rate	Quantity (Duration)	Total Cost	NOTE
Equipment, Labor,Material	Grouting	362,000 Rs/m^3	1 m^3	362,000 Rs	Unit rate is estimated by contractor
	Scaffolding	9,100 Rs/m^2	244 m^2	2,220,400 Rs	Unit rate is based on trial construction
Total				***2,582,400 Rs***	

Fiber sheet bonding (PSC-POS,RCS-RCB Main Beam)					(NO.Co-25)
Items		Unit Rate	Quantity (Duration)	Total Cost	NOTE
Equipment, Labor,Material	Fiber sheet bonding	77,000 Rs/m^2	10 m^2	770,000 Rs	Unit rate is estimated by contractor 2Layer
Total				***770,000 Rs***	

The other members

Diaphram	
Health Index	Repair method
91 - 100	Crack Injection
31 - 90	Crack Injection + Plastering
0 - 30	Crack Injection + Grouting

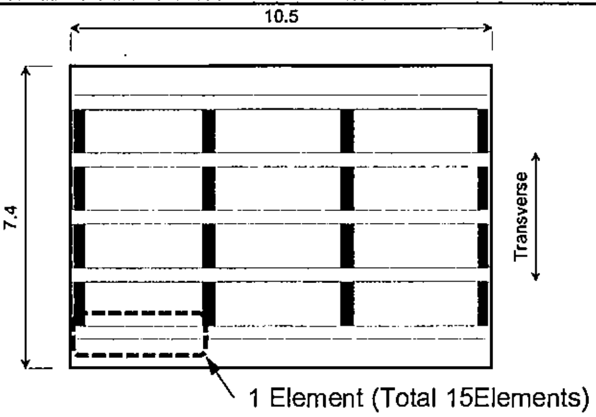
Deck Slab	
Health Index	Repair method
91 - 100	Crack Injection
61 - 90	Crack Injection + Plastering
0 – 60	Crack Injection + Grouting

Type of bridge : Steel Bridge
Member : Main beam

Conditions

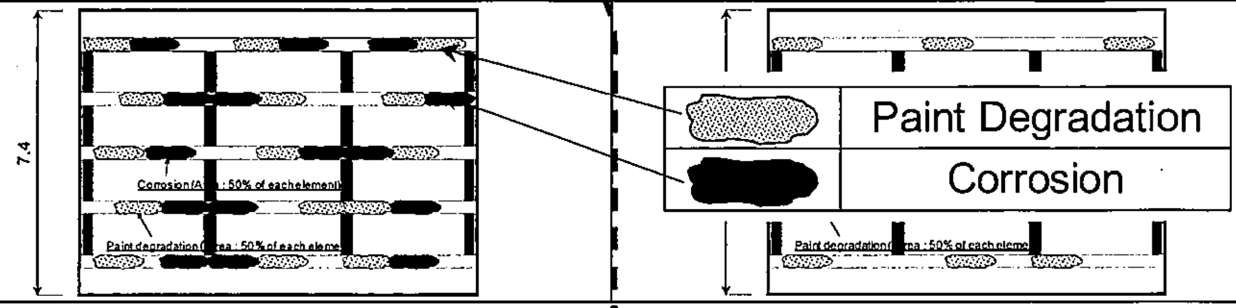
Route No	A004	Bridge No	No.31/1
Assumed dimensions of structure			
Item	Unit	Dimensions	NOTE
Length of slab	m	10.5	
Width of slab	m	7.4	
Area of bridge	m^2	77.7	(a)
Number of Main Beam	Nos	5	
Height of MainBeam	m	0.7	
Width of frange	m	0.3	
Length of MainBeam	m	10.5	
Area of MainBeam	m^2	89.25	

Plan view



Photos

HI = 0 ~ 50	HI = 51 ~ 100



Ratio of damage

Calculation of quantity for repair work (HI=0)

Calculation of quantity for repair work (HI=51)
Paint Degradation : Area of surface of girder x 50% x 1/2 =22.3m3

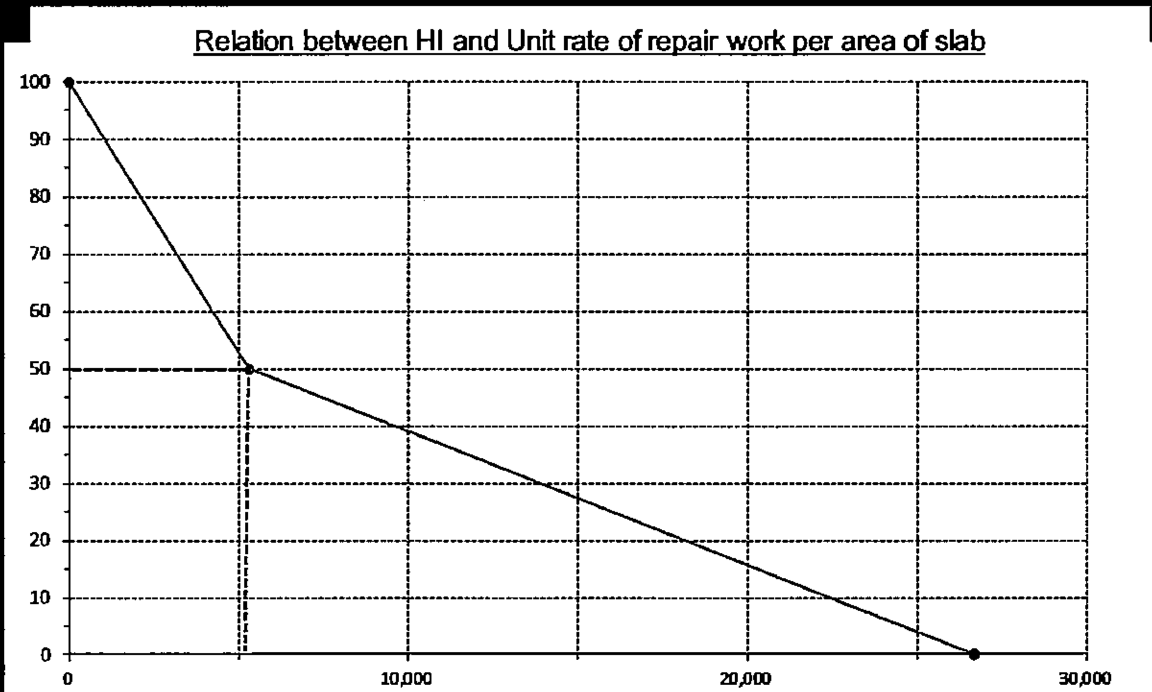
Quantity of damage

Procedure : Setting HI=0

- Paint Degradation generate at all elements (Ratio to whole element is 100%) (Area of Paint Degradation is 50% of each element)
- Corrosion generate at all elements (Ratio to whole element is 100%) (Area of corrosion is 50% of each element)

Repair method	Cost
Steel plate bonding	2,045,900 Rs
Zone painting	26,800 Rs
Unit rate perarea of slab	26,700 Rs/m^2

Repair method	Cost
Zone painting	411,500 Rs
Unit rate perarea of slab	5,300 Rs/m^2



Steel Plate Bonding (Steel Main Beam) (NO.St-1)

Items		Unit Rate	Quantity (Duration)	Total Cost	NOTE
Equipment and Labor	Welding plant	13,000 Rs/day	5 day	65,000 Rs	Unit rate is extracted from HSR(B0-105)
	Generater Electric 7-10KVA	7,200 Rs/day	20 day	144,000 Rs	Unit rate is extracted from HSR(B0-130A)
	Crane Crawler 25t	36,800 Rs/day	5 day	184,000 Rs	Unit rate is extracted from HSR
	Grinder	450 Rs/day	5 day	2,200 Rs	Unit rate is extracted from HSR(B0-105)
	Fabricating steel	1,400 Rs/day	4 day	5,600 Rs	Unit rate is extracted from HSR(ST1-131)
	Skilled labor A - 5stuff	12,800 Rs/day	20 day	256,000 Rs	Unit rate is extracted from HSR
	Surface treatment (Power tools)	2,000 Rs/m^2	44.6 m^2	89,200 Rs	Unit rate is estimated by contractor
	PAINTING WITH TWO COATS OF ENAMEL PAINT AFTER CLEANING,DERUSTING&APPLICATIO N OF ONE COAT ANTICORROSIVE PAINT	600 Rs/m^2	44.6 m^2	26,800 Rs	Unit rate is extracted from HSR(ST1-092)
	Scaffolding	9,100 Rs/m^2	77.7 m^2	707,100 Rs	Unit rate is based on trial construction
	Sub Total			***1,479,900 Rs***	
Material	Mild Steel (h=0.5,L=10.5m,n=5nos)			566,000 Rs	Unit rate is extracted from HSR(B0-411)
Total				***2,045,900 Rs***	

Zone Painting (Steel Main beam) 100 50 (NO.St-5)

Items		Unit Rate	Quantity (Duration)	Total Cost	NOTE
Equipment, Labor and Material	Surface treatment (Power tools)	2,000 Rs/m^2	22.3 m^2	44,600 Rs	Unit rate is estimated by contractor
	PAINTING WITH TWO COATS OF ENAMEL PAINT AFTER CLEANING,DERUSTING&APPLICATIO N OF ONE COAT ANTICORROSIVE PAINT	600 Rs/m^2	22.3 m^2	13,400 Rs	Unit rate is extracted from HSR(ST1-092)
	Scaffolding	9,100 Rs/m^2	38.85 m^2	353,500 Rs	Unit rate is based on trial construction
Total		***11,700 Rs/m^2***		***411,500 Rs***	

Zone Painting (Steel Main beam) 50 0 (NO.St-6)

Items		Unit Rate	Quantity (Duration)	Total Cost	NOTE
Equipment, Labor and Material	Surface treatment (Power tools)	2,000 Rs/m^2	0 m^2	0 Rs	Unit rate is estimated by contractor
	PAINTING WITH TWO COATS OF ENAMEL PAINT AFTER CLEANING,DERUSTING&APPLICATIO N OF ONE COAT ANTICORROSIVE PAINT	600 Rs/m^2	44.6 m^2	26,800 Rs	Unit rate is extracted from HSR(ST1-092)
	Scaffolding	9,100 Rs/m^2	0 m^2	0 Rs	Unit rate is based on trial construction
Total		***11,700 Rs/m^2***		***26,800 Rs***	

The other members

Cross Beam	
Health Index	Repair method
51 - 100	Zone painting and Replacement
0 - 50	Zone painting

Type of bridge : Truss Bridge

Main Beam	
Health Index	Repair method
51 - 100	Zone painting
0 - 50	Zone painting and Steel plate bonding

Cross Beam	
Health Index	Repair method
51 - 100	Zone painting
0 - 50	Zone painting and Replacement

Steel Deck Slab	
Health Index	Repair method
0 - 100	Re-Decking

Members

- Pavement
- Expansion Joint
- Bearing
- Drainage

Pavement (NO.Pa-1)

Items		Unit Rate	Quantity (Duration)	Total Cost	NOTE
Equipment, Labor,Material	Pacthing pot holes of medium depth of 20-75mm	800 Rs/m^2	29.4 m^2	23,520 Rs	Unit rate is extracted from HSR (MS-1)
Total				***23,520 Rs***	

Pavement (NO.Pa-2)

Items		Unit Rate	Quantity (Duration)	Total Cost	NOTE
Equipment, Labor,Material	Supply,lay and compact asphalt premix concrete-Bridge decks	7,500 Rs/m^2	58.9 m	441,750 Rs	Unit rate is extracted from HSR (S1-031)
Total				***441,750 Rs***	

Replacement of joint (NO.Jo-1)

Items		Unit Rate	Quantity (Duration)	Total Cost	NOTE
Equipment, Labor and Material	M.S. ANGLE IRON AND HARD RUBBER EXPANSION JOINTS AS PER DRAWING NO. T/B/107 REV.1	6,500 Rs/m	21.4 m	139,100 Rs	Unit rate is extracted from HSR(ST1-122)
Total		***6,500 Rs/m***		***139,100 Rs***	

Replacement of Bearing (NO.Be-1)

Items		Unit Rate	Quantity (Duration)	Total Cost	NOTE
Equipment, Labor and Material	SUPPLYING AND LAYING APPROVED HARD RUBBER BEARING PADS 75MM X 12MM OVER CAPPING BEAMS AND UNDER THE APPROACH SLABS	1,500 Rs/m	21.4 m	32,100 Rs	Unit rate is extracted from HSR (ST1-122)
	Hydruulic Jack	1,700 Rs/day/nos	6 nos 14 day	142,800 Rs	Unit rate is extracted from japanese standard
	Temporary support	23,200 Rs/day/nos	2 nos 14 day	649,600 Rs	Unit rate is extracted from japanese standard
	Crane Crawler 25t	36,800 Rs/day	4 day	147,200 Rs	Unit rate is extracted from HSR
	Skilled labor A - 20stuff	32,000 Rs/day	14 day	448,000 Rs	Unit rate is extracted from HSR
Total				***1,419,700 Rs***	

Replacement of drainage (NO.Dr-1)

Items		Unit Rate	Quantity (Duration)	Total Cost	NOTE
Equipment, Labor and Material	110mmφ type 250 PVC water outlet	700 Rs/m	11 m	7,700 Rs	Unit rate is extracted from HSR(ST1-148)
Total		***700 Rs/m***		***7,700 Rs***	

Thank you for your kind attention !

Revision of Bridge Inspection Manual

JICA Project Team

Hideaki TAKAURA
Kazuya URANO

Basic Ideas for Developing Bridge Inspection Manual

- Evaluate the defect, damage and deterioration (called "damage") individually.

  → Thereafter, evaluate the soundness.

  (Not directly evaluate the soundness)

- Introduce the culture of "bridge inspection" in RDA's bridge management.

  → Simplified system in order to ensure sustainability.

Points of Changes

- Previous Manual (March 18, 2016)
  - ✓ For simplification, pay attention to major damage;
    - → Overlook the minor damage
  - ✓ Record the quantities of damage;
    - → Take a lot of time for measuring the dimensions of damage (quantities)
    - → Not accurate estimated from far visually
    - → Pay less attention to see the entre bridge structure thoroughly

  It may be good to bring to the bridge repairs directly without management.

  (This is the bridge inspection for bridge repairs)

Points of Changes

- Revised Manual
  - ✓ Inspection is for management.
  - ✓ Use sufficient time to see the entire bridge structure thoroughly (not to overlook the minor damage)
  - ✓ Collect the information for management, including minor and major damage
  - ✓ With the use of information collected through bridge inspection, do the management
    - → Prioritization under the limited budget and human resources
    - → Predict the future condition of bridge (preventive maintenance purpose for the future)

  After the bridges selected, you can investigate those bridges in detail, measure the quantities, and do the repair.

1. Purpose of Bridge Inspection

- Understand the locations and extent of damage;
- Obtain the necessary information for evaluating the serviceability and soundness of target bridges;
- Estimate repair costs and prioritise the repair works.

- Detect the damage early which may affect to the safety, load carrying capacity and durability of bridges, thereafter take necessary measures;
- Collect necessary data and information for managing the bridges systematically (prioritization, predict the future conditions), in order to promote systematic and effective maintenance.

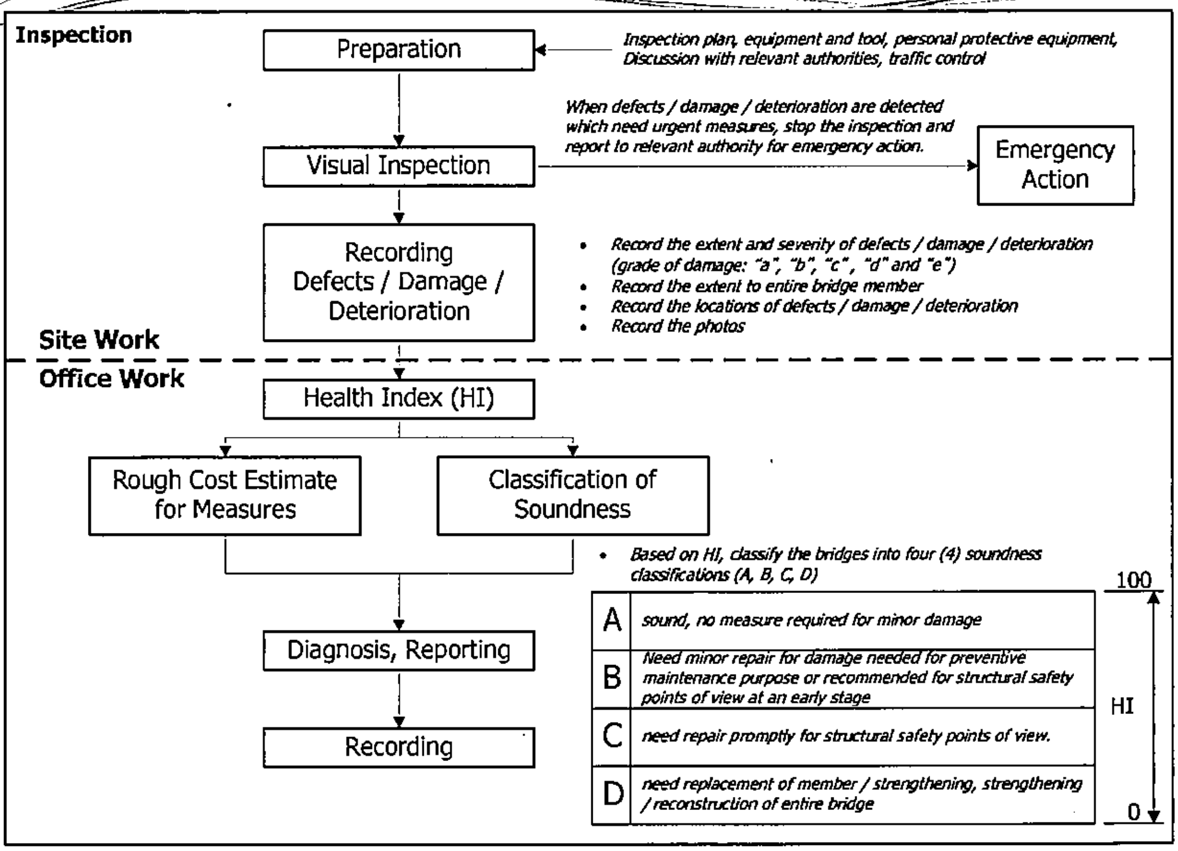
What is necessary data / information for managing the bridges systematically?

- Used for management (prioritization under the restriction of budget and human resources);
  - ✓ Objectively recorded bridge conditions with less variations from person to person
  - ✓ Not absolute value, but relative value for comparable
  - ✓ Consider not only "extent" (plan area of damage), but also "severity" (depth of damage) within an element
  - ✓ Record the "extent to entire bridge member"

2. Type of Inspection

- Routine Inspection
- Periodic Inspection ← This Manual
- Emergency Inspection
- In-depth / Detail Inspection ← Deleted
  - ✓ It is to identify the causes of damage and understand the extent of damage.
  - ✓ Based on the in-depth inspection, select the effective repair methods and areas of repairs under bridge repair plan.
  - ✓ If needed, this should be included in Bridge Repair Manual (out of the scope of Bridge Inspection Manual).

3. Flow of Periodical Bridge Inspection



4. Method of Bridge Inspection

- Visual inspection, supplemented with test hammer and pole cameras;
- Use the bridge inspection vehicle (BIV) for bridges / spans which cannot be approached;

⬇

- No change
- Added to record / select the level of bridge inspection:
  - close visual inspection
  - distant visual inspection
  - indirect inspection

5. Details of Bridge Inspection

- Types of damage:

  11 types for bridge surface, 13 types for bridge structure;
- Types of bridge structure;
- Type of target members;
- Type of damage for each bridge member;
- Introduce the concept of "element" to express the extent of damage to entire bridge member for each bridge member;
  - ✓ A bridge member is divided into several elements (type / number of element depends on the member)

6. Record of Damage on Bridges

- Divide the bridge member into elements

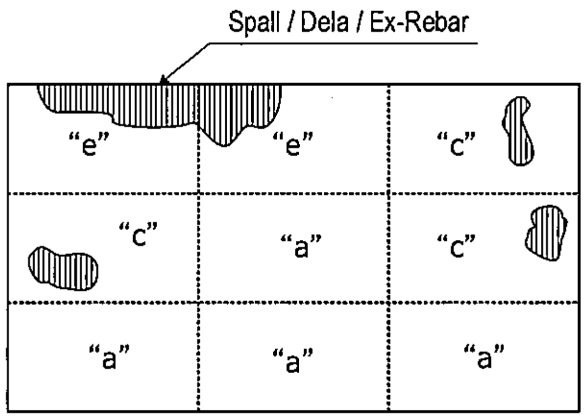
  It is because:

  ✓ To habituate seeing the entire bridge member thoroughly

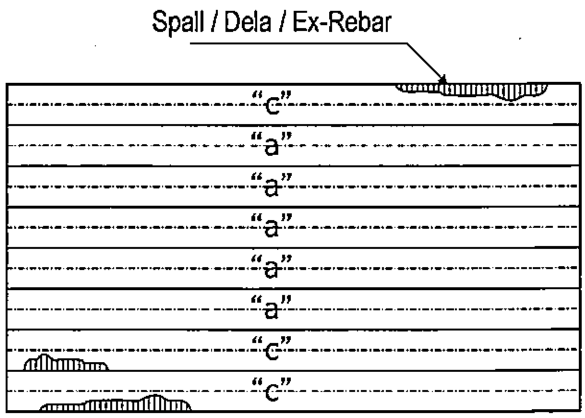
  ✓ To detect and record the damage, not only major one but also minor one ← used for management (prediction of future bridge conditions)

- Damage on "Slab" for slab bridge and box bridge:
  → **9 elements**

- Damage on slab beam for slab beam bridge:
  → **number of beams**

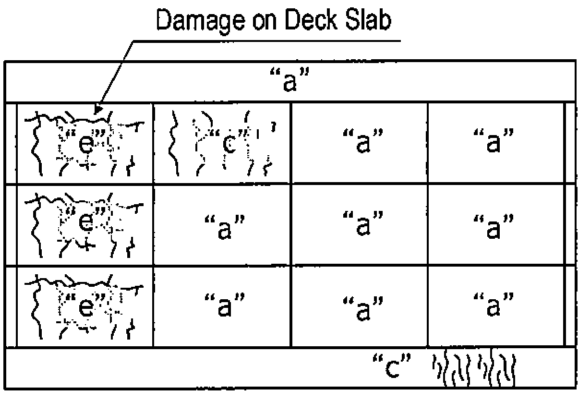


a	b	c	d	e	Σ
4	0	3	0	2	9



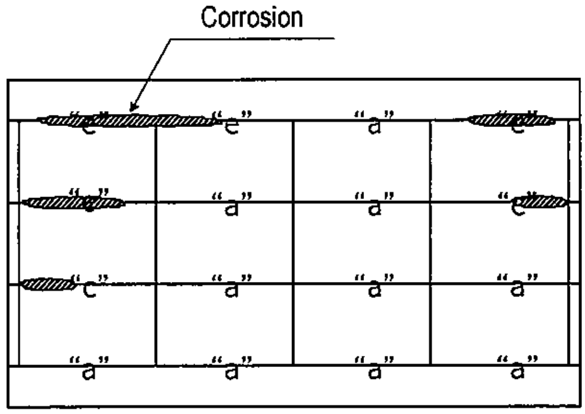
a	b	c	d	e	Σ
5	0	3	0	0	8

- Damage on deck slab for steel / concrete beam bridge:
  → **Number of areas enclosed by beam and diaphragm**



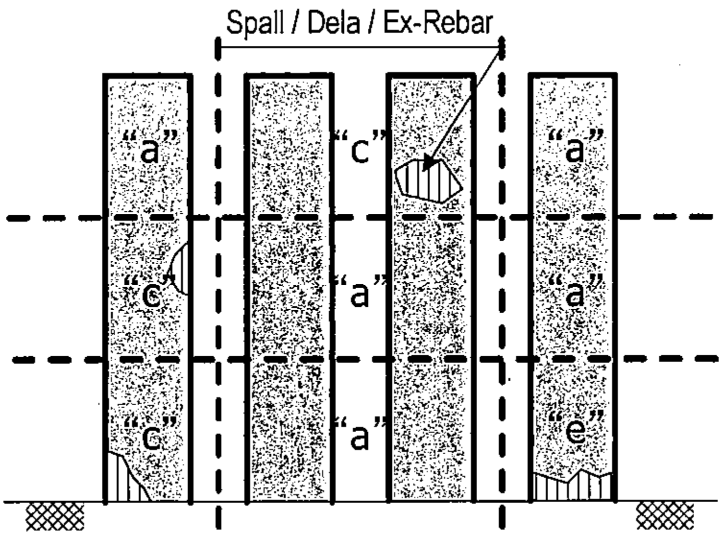
a	b	c	d	e	Σ
9	0	2	0	3	14

- Damage on main beam for steel beam bridge:
  → **number of beam elements divided by cross beam / diaphragm**

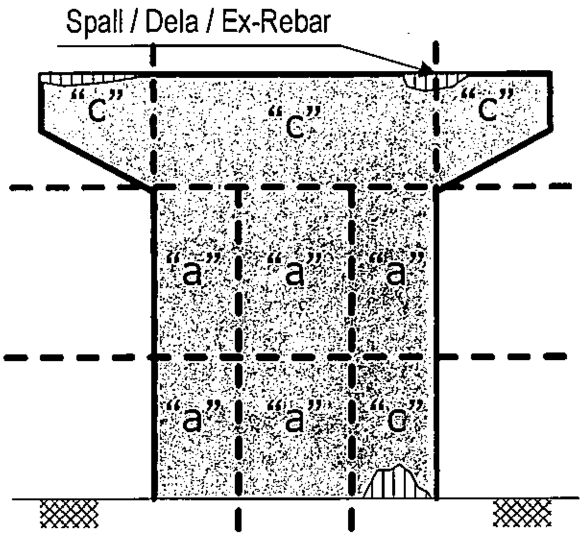


a	b	c	d	e	Σ
10	0	2	0	4	16

- Damage on pier / abutment
  → **9 elements**



a	b	c	d	e	Σ
5	0	3	0	1	9



a	b	c	d	e	Σ
5	0	4	0	0	9

- Record "extent" & "severity" of damage in an element;

a	- (Sound)	- (Sound)
b	Small	Small
c	Large	Small
d	Small	Large
e	Large	Large

- For some damage, only "a", "c" and "e", or only "a" and "e".
- **Appendix** is given so that everyone can record the damage objectively and with small variations from person to person.
- On-the-job training will be provided.

- Record the extent of damage to entire bridge member;

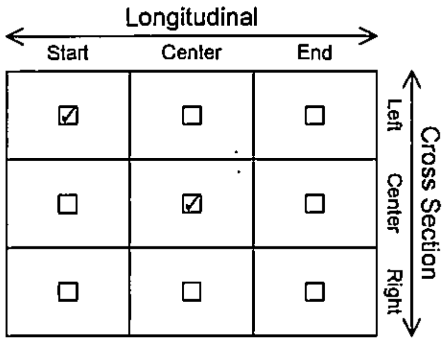
Quantity	a	b	c	d	e	Σ
Crack on Slab Bridge	5	2	1	-	1	9
Damage on Anchorage for Main Beam	9		-		2	11
Delamination on Diaphragm	12	-	-	-	-	12

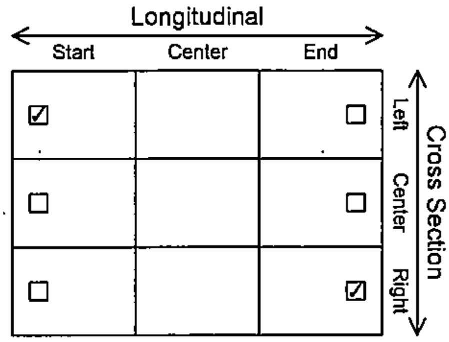
Number of element for each category

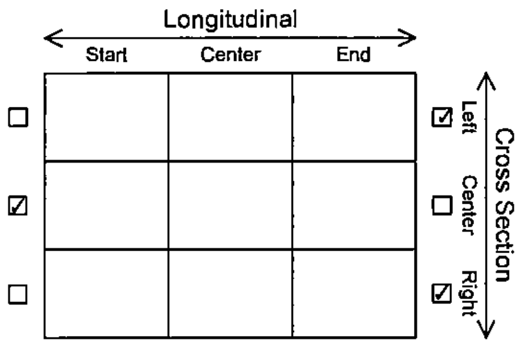
Total number of element

- Record the number of element for each category: "a", "b", "c", "d" and "e".
- Elements for each member are referred to Appendix.

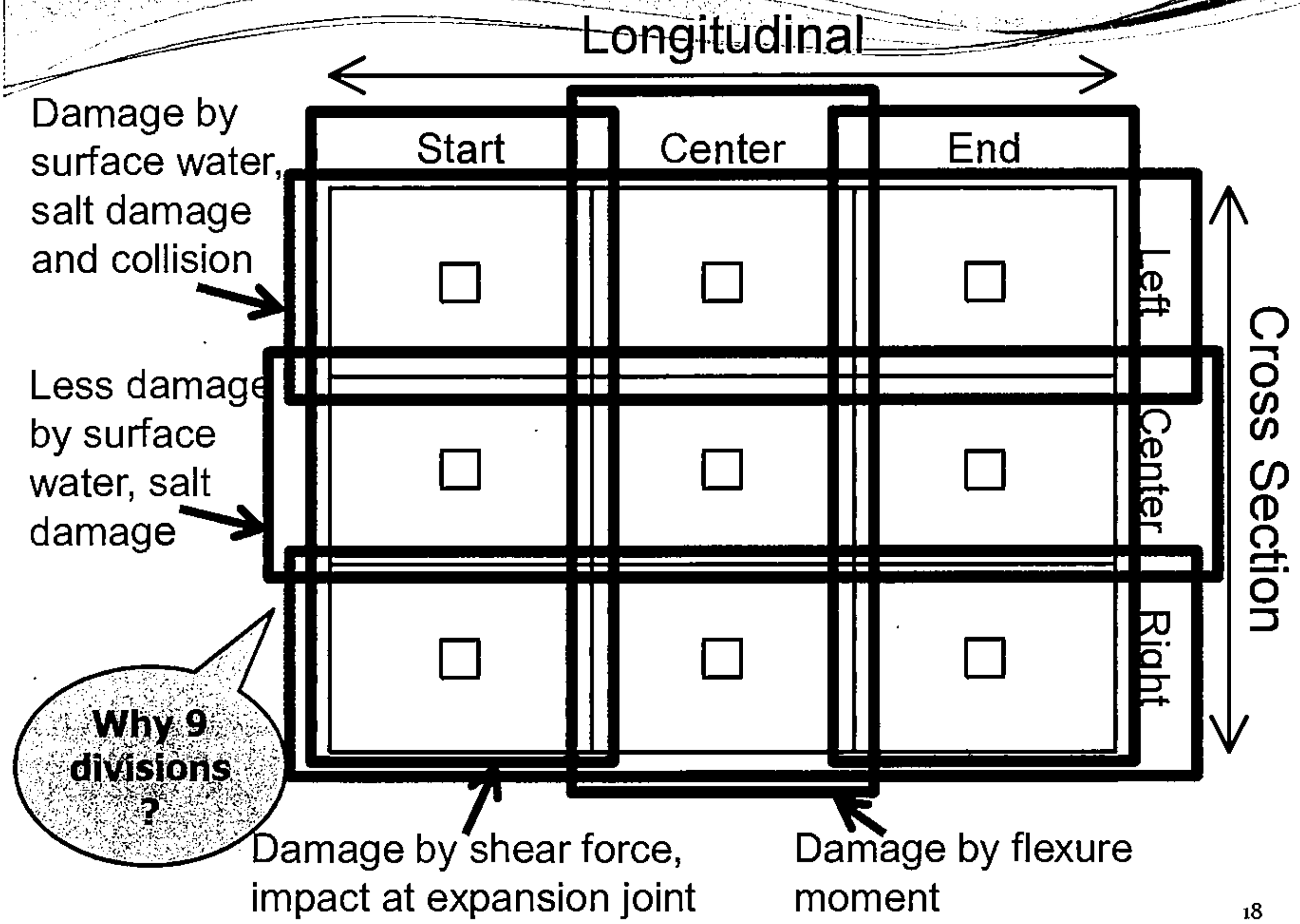
■ Record the locations of damage in **9 / 6 divides.**







- Check the element(s) "✓" where the damage with the worst category is detected.
- This is (i) to locate the damage at the next inspection, (ii) to estimate the causes, and (iii) to analyse the trend of damage.



- Scan the sketches recorded at site.
  - ✓ Sketch of the damage recorded at site is important.
  - ✓ Scan the sketch and save in the web-based database. (no need to redraw in the excel.)

7. Evaluation of Inspection Results

- Bridge conditions will be evaluated with health index (HI), logically calculated.
- Health Index (HI):
  - ✓ HI = 100 - ∑ (Evaluation Point x Weighting Factor)

    << Weighting factor => Correlation factor >>
  - ✓ Provide evaluation (deduction) point for each type of damage for each type of member.
  - ✓ Weighting factors are based on awareness survey, incorporating the ideas of RDA.
  - ✓ Define the HI=100 and HI=0 conditions.
  - ✓ Between HI=100 and HI=0, develop the mechanism to calculate the health index.

- Evaluation Point
  - ✓ Based on the extent and severity of damage, evaluation point is given uniformly.

Extent & Severity of Damage				
a	b	c	d	e
◎ 0	◎ 25	◎ 50	◎ 75	◎ 100
◎ 0		◎ 50		◎ 100
◎ 0				◎ 100

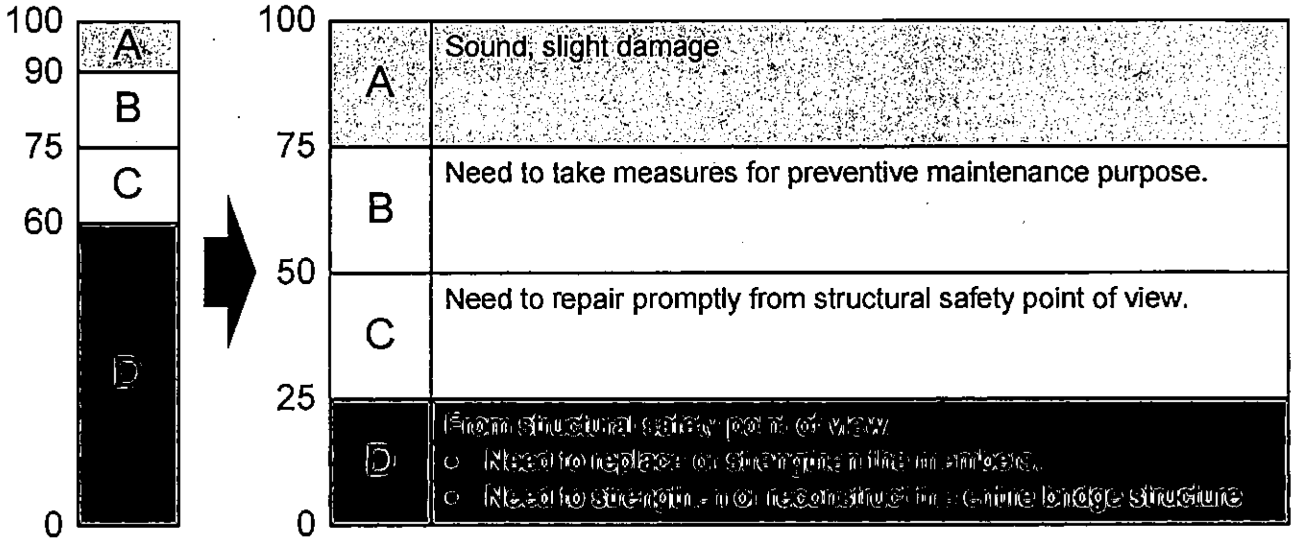
State of Progress of Damage

Sound — 25% progress — 50% progress — 75% progress — Serious

8. Bridge Soundness Classification

- Soundness classification: "A", "B", "C" and "D" based on scores given from inspection results.
  - ✓ Threshold values are changed: 90, 75, 60 → 75, 50, 25
  - ✓ Each classification has no meaning (just categorized).
  - ✓ Threshold values will be reviewed after sufficient number of inspection data are collected and analyzed for specific meaning (preventive, proactive, etc.).
- Soundness classification of "E" and "I" deleted.
  - ✓ If serious conditions in need of emergency action are found, stop the inspection and immediately report to higher divisions for actions.
  - ✓ There is no in-depth inspection for determining the soundness classification.

- Threshold values were changed.



9. Estimate of Repair Costs

- Quantities CANNOT be measured at site, because of distant visual inspection (not close visual inspection);
- Repair details (method, volume, etc.) will be varied depending on the type of damage, on extent and severity of damage in an element, and on the extent to entire bridge member;
- Difficult to estimate the cost because of so many combinations of damage type and repair method;
- Costs for budget preparation, not for tendering (cost estimate for tendering will be made separately.

- Develop the system to estimate the cost based on health index (HI) for each type of bridge member.

WS-4-2

Additional Workshop Agenda

April 24 2017

TIME	Contents	Presenter
9.00 - 9.05	Welcome address	Director ES
9.05 - 9.20	Schedule of WS and PC from April to June 2017	Mr. H. Takaura
9.20 - 9.35	Definition of Health Index HI =0	Mr. H. Takaura
9.35 - 9.55	Discussion	
9.55 – 10.10	Definition Important Index	Mr. H. Takaura
10.10 - 10.20	Discussion	
10.20 -10.25	Break	
10.25 -10.45	Institutional Framework of Bridge Maintenance	Mr. H. Takaura
10.45 -10.55	Discussion	
10.55 - 11.00	Closing Remarks	ADG CD

Prioritization of Bridges for Repairs

- Evaluation Criteria & Weighing Factors -
- Evaluation Indicators & Points -

THE PROJECT
FOR CAPACITY DEVELOPMENT
ON BRIDGE MANAGEMENT

Kazuya URANO
Toshiki KASAI

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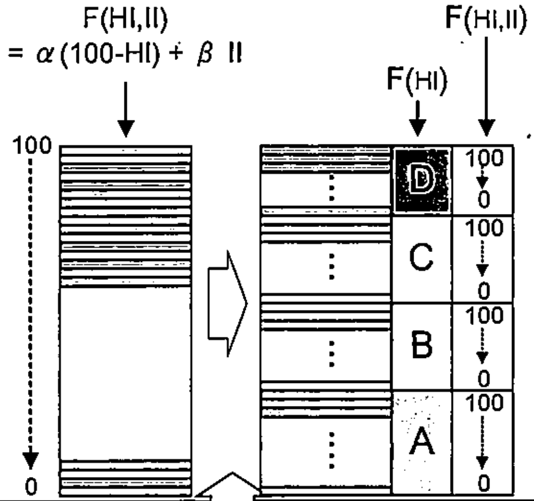
1. Prioritization of Bridges for Repair

Prioritization of Bridge Repair:

1. Bridges with lower Health Index (HI) will be prioritized.
2. However, bridges which may give large extent of obstruction due to out-of-service conditions should also be prioritized. → **Importance Index should be considered**

A, B, C, D: Soundness Classification



In order to ensure minimum safety, consideration should be given not to omit the bridges with low health indices.

3

(1) What is Health Index (HI)?

Do you remember on the 2nd workshop?

Defects, Damage and Deterioration on Each Bridge Member
- **Detect the defects, damage and deterioration at sites.**
- **26 types of defects, damage and deterioration specified.**
- **Keep the records: each member / damage, extent thereof**

(Objectively recorded with the use of sample materials)

Subjectively

Health Index Calculation (Quantification)

Bridge Soundness Classifications
- **Nine (9) classifications for the Ministry**
- **Different classifications for local governments**

Central Government
- Sufficient budget
- Experienced experts

Local Government
- Insufficient budget
- Unexperienced staff

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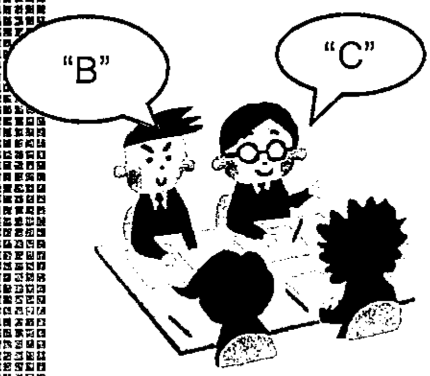
Health Index: In order to <u>reduce the variations of evaluation results from person to person</u>, degree of required performance(s) / function(s) exhibited (soundness) is quantified for each member.



- Minimum level of required performance for a bridge member → **HI = 0**
- Performance of a bridge member owned at opening to traffic (new) → **HI = 100**
- **"HI"** is decreased with time (elapsed time after opening to traffic).

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Image of Degradation of Performance As a Bridge

Performance	Need any restrictions	Minimum performances required (design)	Performances owned at opening to traffic (new)
		HI = 0	HI = 100
Speed	Speed limit (20 km/h)	60 km/h	80 km/h
Load carrying capacity	Load limit (10 ton)	20 ton	25 ton

Allowance

A bridge member / bridge loses its function(s)!

Decreased with time

6

Proposed HI: Objectively Recorded Condition Data / Information

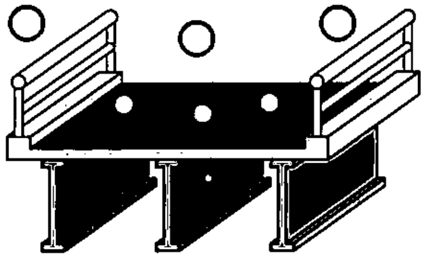
What type(s) of damage?

How many types of damage at the same time?

To what **extent**?

Degree of Required Performance(s) & Functions(s) Exhibited

Interrelated



- Identify the bridge member conditions which cannot exhibit the minimum required design performance. → **HI = 0**
- Define the type(s) and **extent** of damage for **each bridge member** <u>which need any restrictions</u>

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(2) What is Importance Index (II)?

Index for prioritization of "bridge repairs", called **<u>"importance index"</u>**, expresses **"the extent of obstruction"** occurred due to out-of-service condition of the bridges (closure to traffic or collapsed) on the following:

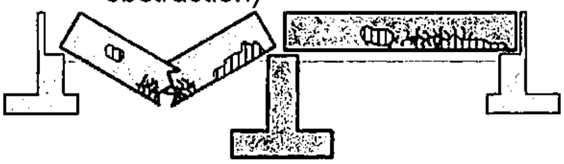
- ❑ Provide access within regional area
- ❑ Provide mobility in wide area network
- ❑ Third-party effects.

With repair works, the out-of-service condition or the above obstructions **can be avoided**.

Shall we repair the bridges promptly not to be in trouble due to out-of-service condition?

8

Images of Health Index and Importance Index

	Conditions Considered	Meaning of Index, How to Use
Health Index (HI)	< Present Condition> H.I= 100 → Full functions as with new construction H.I= 0 → Functions lost due to deterioration or damage  [Target functions: load carrying capacity, ride quality, etc.]	● Degree of allowance of functions / performance degraded with deterioration and damage. ➢ Criterion for judging the need of repairs ➢ Criterion for judging the need of reconstruction
Importance Index (II)	< Out-of-Service Condition > I.I = 100 → Largely affect to surrounding areas (obstruction) I.I = 0 → No effect to surrounding areas (no obstruction) 	● Extent of obstruction to surrounding areas when the bridge is out-of-service. ➢ Prioritize bridge repairs ➢ Prioritize bridge reconstruction

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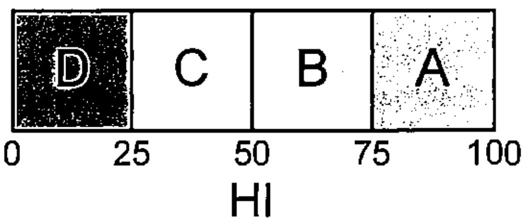
(3) Prioritization of Bridge Repairs

➢ For prioritizing the bridges for repairs, in consideration of safety, larger weighing factor is given to “Health Index (HI)” than “Importance Index (II)”.

- Priority of Bridge Repairs
  $= \alpha \times (100 - HI) + \beta \times II$,
  where, $\alpha = 0.70$, $\beta = 0.30$

Determined by BM&AU

➢ In order not to omit bridges with low HI, bridges categorized as HI Classification “D” should be repaired first, followed by “C”, “B” and “A”.



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2. Setting of Importance Index (II)

(1) Evaluation Criteria & Weighing Factors

- Extracted the **evaluation criteria** on July 22, 2016 for the importance of bridges, with the attendance of some managing and engineering members of Working Group.
- Awareness survey was conducted to set up the weighing factors for each evaluation criterion.

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Summary of Evaluation Criteria & Weighing Factors

Hierarchical Level 1		Hierarchical Level 2	
Evaluation Criteria	Weighing Factor	Evaluation Criteria	Weighing Factor
Importance to Providing Access within Regional Area (regional living function and economic activities)	0.32	Densely inhabited districts (DID)	0.19
		Connectivity to important facilities	0.26
		Difficulty in restoration	0.30
		Isolated villages / towns	0.25
Importance to Providing Mobility in Wide Area Network	0.27	Traffic characteristics	0.28
		Detour	0.33
		Specific important route	0.39
Third-Party	0.41	Crossing	0.50
		Utilities attached	0.28
		Disturbance to water flow at flood times	0.22

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(2) Evaluation Indicators & Points

For each evaluation criterion on 2nd hierarchical level, evaluation indicators and points should be set up.

1) Densely inhabited districts
2) Connectivity to important facilities
3) Difficulty in restoration
4) Isolated villages / towns
5) Traffic characteristics
6) Detour
7) Specific important route
8) Crossings
9) Utilities attached
10) Disturbance to water flow at flood times

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For each evaluation indicators developed, evaluation points should be given.

- ❑ Absolute points are not important.
- ❑ Evaluation points should be developed for comparison among bridges (relative points are important).

  → Highest importance is given “Point = 100”
  → Lowest importance is given “Point = 0”
  → In-between is given “Uniformly distributed point”
  → “Subjectivity” is incorporated by weighing factors.

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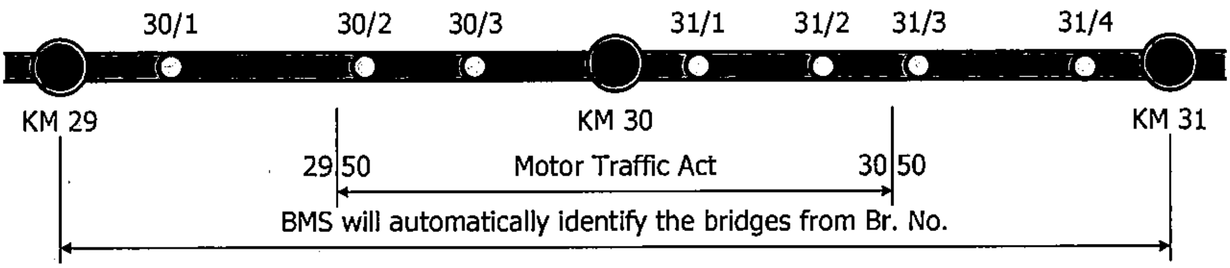
1) Densely inhabited districts (DID)

Provide access for daily living function and economic activities in the regions.

→ to be judged whether bridges within DID or outside DID

According to “Description of Built-Up Areas along the Roads or Sections of Roads to Which A Speed Limits are Applicable” in Motor Traffic Act, it should be determined as follows:

Sr. No.	Route No.	Name of Road	Township	Section (km)		
				From	To	Section Length
8	A001	Colombo - Kandy	Yakkala	29.50	30.50	1.00



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Evaluation Group & Point

Group	Evaluation Point
Apply (within built-up areas)	100
Not Apply (outside built-up areas)	0

2) Connectivity to important facilities

It should be judged by the Executive Engineer's Office, which may know the local conditions.

→ Provide access to important facilities such as markets, religious facility, bank, school, water, industrial areas, etc.

Determined by Planning Division

Evaluation Group & Point

Group	Description	Evaluation Point
3	Extremely important facilities: airports, seaports, major bus terminals, major train stations, government hospitals	100
2	Important facilities: national school, tourism attraction, agricultural attraction, industrial attraction, bases for religious activity, national shrine, bus station, train station	50
1	No connectivity	0

3) Difficulty in restoration

Judged by Executive Engineer's Office

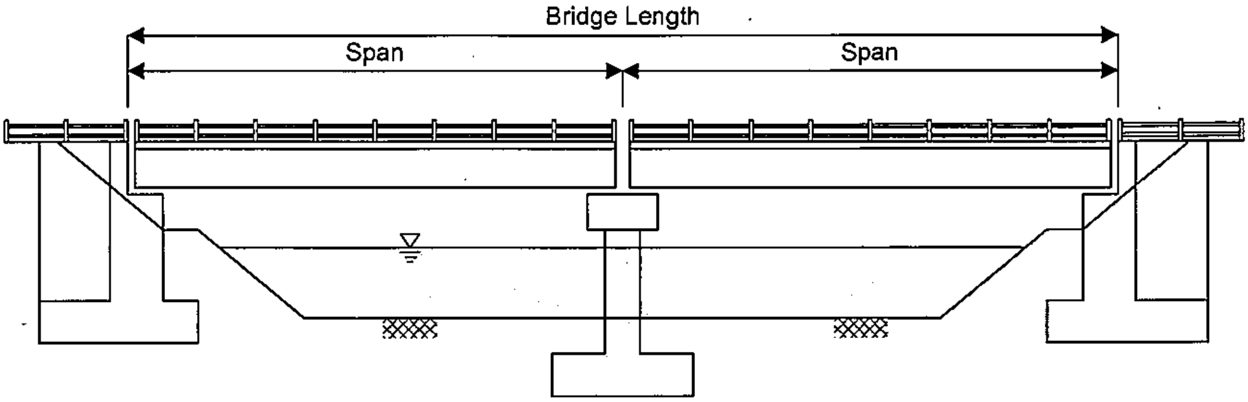
It will be judged from the following:

✓ Availability of space for temporary bridge by the side of existing bridge (within ROW, outside ROW)

✓ Span more than 25 meters (standard pretension beam ≤ 25.0)

✓ Bridges over the deep river with piers (need cofferdam in water)

✓ Bridge length more than 50 meters



Evaluation Group & Point

Group		Evaluation Point
Space for temporary bridge	Yes, within ROW	0
	Yes, outside ROW	50
	No	100
Span	25 meters or less	0
	More than 25 meters	100
Bridge piers in water in need of cofferdam	No cofferdam needed, No river crossing	0
	Cofferdam needed	100
Bridge length	50 meters or less	0
	More than 50 meters	100

Evaluation point for "difficulty in restoration" should take the maximum point among the above sub-criteria.

4) Isolated villages / towns

It is judged by the Executive Engineer's Office whether there are any isolated villages / towns which cannot be accessed if the target bridge is impassable.

- ✓ Applied (access to isolated villages / towns)
- ✓ Not Applied

Evaluation Group & Point

Group	Evaluation Point
Applied	100
Not Applied	0

5) Traffic characteristics

It is judged by the traffic volume and categorized into five groups with evaluation point:

Evaluation Group & Point

Group	Traffic Volume	Evaluation Point
5	50,000 or more	100
4	20,000 – 49,999	75
3	5,000 – 19,000	50
2	500 – 4,999	25
1	0 – 499	0

6) Detour

It is to judge the difficulty in providing the mobility in wide area network even when the bridge is impassable.

Detour should be on A, B, C and D class roads (not only on A and B class roads).

It is difficult to measure the length of detour; therefore, it is decided to judge by the additional time needed when the detour is used. Additional time should be determined by Executive Engineer's Office.

Evaluation Group & Point

Group	Additional Time Needed	Evaluation Point
3	60 minutes or more	100
2	30 – 59 minutes	50
1	0 – 29 minutes	0

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7) Specific important route

It is to judge whether the target bridge is on strategically important route or not in wide area network.

Strategically important route should be determined by the Planning Division.

→ Not yet finalized.

- ✓ Applied
- ✓ Not Applied

Evaluation Group & Point

Group	Evaluation Point
Applied	100
Not Applied	0

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8) Crossings

It considers the following crossings.

- ✓ Railway
- ✓ Expressway
- ✓ Road (traffic volume on PCU basis: 20,000 or more)
- ✓ Road (traffic volume on PCU basis: 500 – 19,999)
- ✓ Road (traffic volume on PCU basis: 499 or less)
- ✓ River
- ✓ None

For roads, it is considered that the extent of obstruction differs depending on the traffic volume. Therefore, road is categorized into 3 cases.

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Evaluation Group & Point

Group		Evaluation Point
Railway		100
Expressway		100
Road	20,000 or more	100
	500 – 19,999	50
	499 or less	0
River		0
None		0

For river crossing, the effects to the surrounding areas are considered in “Disturbance to Water Flow at Flood Times”.

When several crossings are selected, the maximum point should be taken as a representative point.

Ex) railway and road (500 – 19,999) → 100 or 50 → 100

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9) Utilities attached

It considers the following utilities commonly attached to the bridge.

- ✓ Telecommunication cable (optic)
- ✓ Telecommunication cable (metal)
- ✓ Power cable
- ✓ Water supply / sewage pipes
- ✓ Oil pipeline

In the discussion, the idea was raised that importance of the utility differs depending on the diameter / size (large diameter for main line, small diameter for distribution line). However, it is considered that the utility with large diameter be supported by separate structure.

→ No sub-category is given by diameter.

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Evaluation Group & Point

Group	Evaluation Point
3 or more types of utilities attached	100
2 types of utilities attached	66
Single type of utility attached	33
None	0

When the bridge is collapsed, utilities attached to the bridge will not be available for residents' livelihood (water, power, electricity, telecommunication)

All utilities are essential to residents' livelihood, and are considered equally important.

When several utilities are attached, the said bridge more important than that with one utility or nothing.

Sub-criteria are set up depending on the number of utilities attached.

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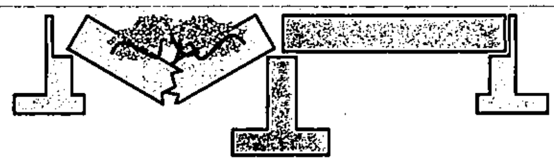
10) Disturbance to water flow at flood times

It is to consider the effects to surrounding areas when the water opening is reduced due to bridge collapse.

Importance Index (II)

- When the bridge is collapsed,
  - A) Possible to allow increased water level and overflow with reduced water opening.
  - B) Possible to wash away the abutment or pier by erosion at riverbank behind abutment or scour at pier.



Collapsed Situation

It is to propose that the number of span be the indicator to consider the above effects as follows:

Group	Number of Span	Evaluation Point
3	Single span	100
2	2 spans	50
1	3 or more spans, no crossing the river	0

Definition of "Health Index = 0"

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Toshiki KASAI

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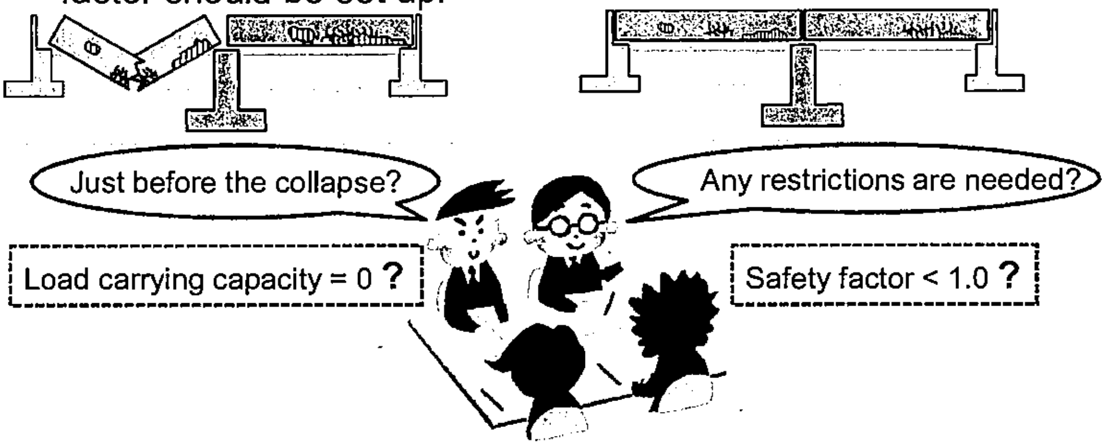
1. Why we need to define the "Health Index =0"?

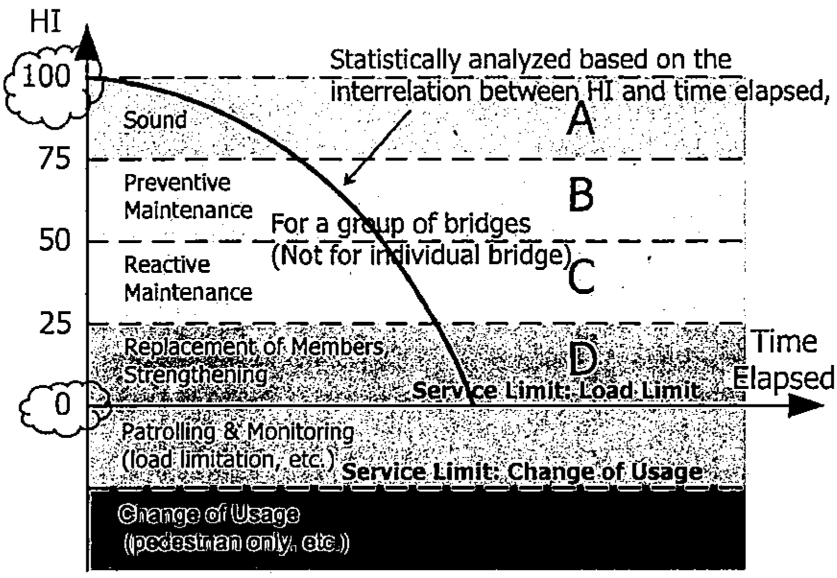
- When we talk about "HI=100", everybody can image the sound condition without any damage. However, for "HI=0", people have the different image of bridge conditions.
  - ➢ Therefore, it is needed to define the concept of "HI=0" conditions specifically.
  - ➢ It should be assumed what types of damage are on existing bridge to what extent and severity; and thereafter, correlation factor should be set up.



3

2. Definition of "Health Index = 0"

- Performance and function the bridge possesses immediately after the new construction, "HI=100" condition, will degrade with damage.
- The condition of bridge in need of any restrictions (lane control, load limit, speed limit, etc.) without exhibiting the required performance and function, will be considered "HI=0".



3. How to Set Up the "Health Index = 0" ?

- Basic Idea
  - Purpose of the bridge inspection is to understand the extent of bridge soundness.
  - Purpose of setting up the "HI=0" conditions based on the bridge inspection result is to set up the fiducial value for quantification of bridge soundness.

For example, on concrete bridge,

- In general, the bridge with crack, spalling and exposure of steel extensively distributed on entire bridge member will concurrently have large-scale loss of structural concrete and/or rupture of reinforcing steel locally.

For example, on steel bridge,

- In general, the bridge with degradation of surface coating and corrosion extensively distributed on entire bridge member will concurrently have large-scale loss of structural steel, hole and/or rupture of steel locally.

Based on the actual bridge damage situation obtained from the bridge inspection, HI=0 condition should be set up.

6

- Setting Procedure

Bridge condition in need of any restriction (lane control, load limit, speed limit, etc.) should be found from the site.

Actual bridge condition in need of any restriction

If such conditions cannot be found, **assume** any restrictions are needed to what extent the present damage further develops.

Present damage is in local area; however, such damage has extended to the bridge member entirely , it is considered needed of any restrictions.

Inspection results…

Grade of Damage

Spalling & Exposure of Steel "e" → 60 %
Cracking "e" → 60 %

Set up the correlation factor so that health index = 0

Health Index (HI):
HI = 100 - ∑ (Evaluation Point x Weighing Factor)
↓
Correlation Factor

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4. Setting of "Health Index = 0" Conditions

(1) Bridge Surface

- HI=0 conditions

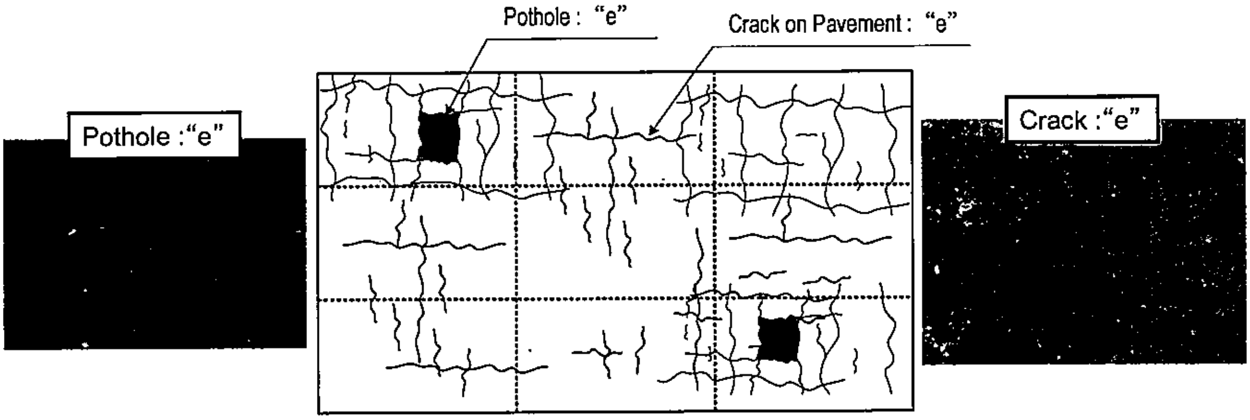
  → The bridge components / members do not exhibit the required performance / function, and are in need of any restrictions, such as lane control, load limit, speed limit, etc.

- Damage on such bridge surface components as pavement will result in the driving speed reduction of a vehicle. However, damage itself will not cause any restrictions.

  → Therefore, for bridge surface components, HI=0 should be defined when the target component loses its required function completely (same situation as "no present of such a component").

- Pavement

Pavement completely loses its function (assumed).



Description of HI=0 Condition

☐ CASE → Crack: "e" have occurred on all 9 elements.
In such a case, it is assumed that pothole: "e" has concurrently occurred on 2 elements.

Correlation factors should be set up so that HI can be 0 with this situation.

Record of Damage

Damage	Extent of Damage a (0)	b (25)	c (50)	d (75)	e (100)	Σ
Pothole	7				2	9
Crack	0				9	9
Rutting	9					9
Waving	9					9

Correlation factor should be set up so that HI can be 0 with these situations.

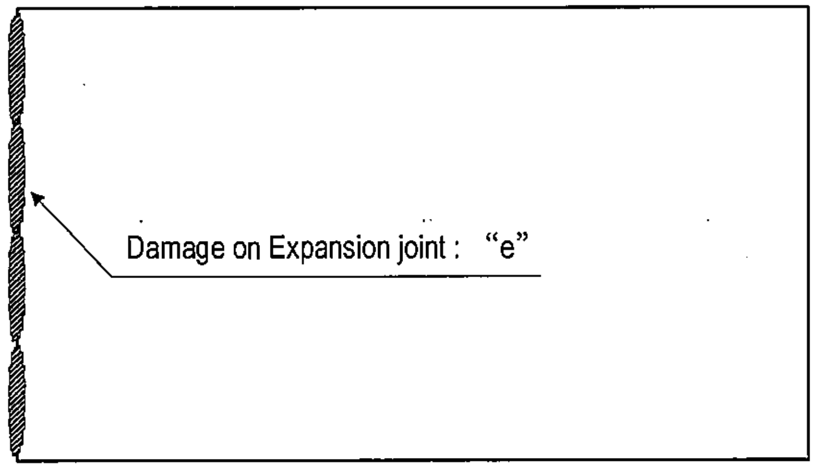
$$HI = 100 - (1.0*100*2/9+0.8*100*9/9) \fallingdotseq 0$$

Damage	Weighing Factor	Correlation Factor
Pothole	0.34	1.0
Crack on Pavement	0.26	0.8
Rutting	0.16	0.5
Waving	0.24	0.7

10

- Bridge Expansion Joint

Bridge Expansion Joint completely loses its function (assumed).



Description of HI=0 Condition

- CASE → Damage on Bridge Expansion Joint: "e" has occurred on its entire length (100%).

Correlation factors should be set up so that HI can be 0 with this situation.

11

Record of Damage

Damage	Extent of Damage					
	a (0)	b (25)	c (50)	d (75)	e (100)	Σ
Damage on Expansion joint	0				100	100
Difference in Levels	100					100

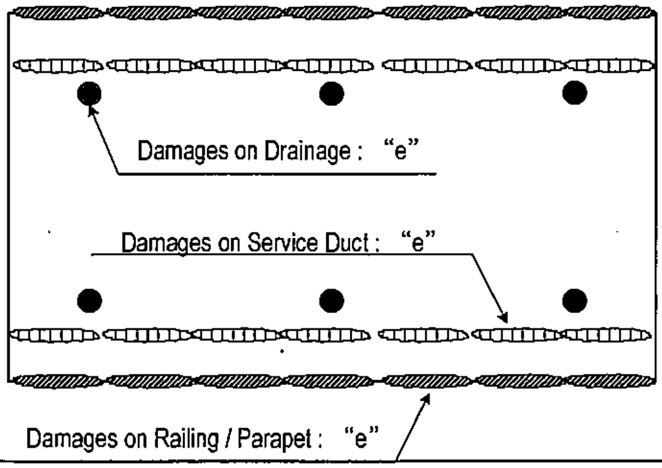
Correlation factor should be set up so that HI can be 0 with these situations.

HI = 100 - (1.0*100*100/100) ≒ 0

Damage	Weighing Factor	Correlation Factor
Damage on Expansion joint	0.59	1.0
Difference in Levels	0.41	0.7

- Accessories

Accessories lose the function thereof completely (assumed).



Description of HI=0 Condition

❑ CASE → All the accessories are considered as "one component", as they do not affect the bridge soundness largely.

Damage on drainage: "e", Damage on service duct: "e", Damage on bridge railing / parapet: "e" have occurred concurrently on its entire length (100%).

Correlation factors should be set up so that HI can be 0 with these situations.

Record of Damage

Damage	Extent of Damage					
	a (0)	b (25)	c (50)	d (75)	e (100)	Σ
Damage on Drainage	0				6	6
Damages on Service Duct	0				100	100
Damages on Railing / Parapet	0				100	100

Correlation factor should be set up so that HI can be 0 with these situations.

HI = 100 – (0.5*100*6/6+0.2*100*100/100+0.3*100*100/100)

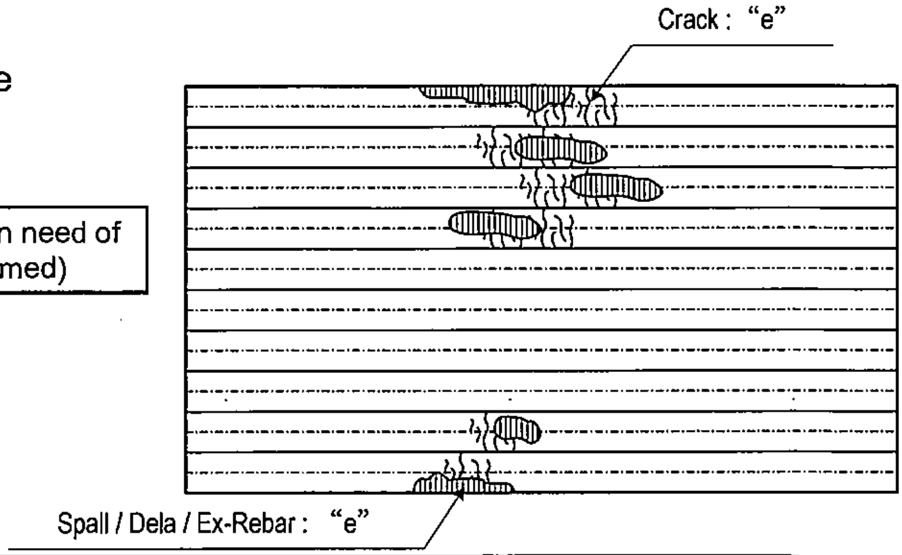
Damage	Weighing Factor	Correlation Factor
Damage on Drainage	0.45	0.5
Damages on Service Duct	0.22	0.2
Damages on Railing / Parapet	0.33	0.3

14

(2) Superstructure

- PSC-PRE

Example of damage in need of any restrictions (assumed)



Description of HI=0 Condition

☐ CASE → PSC-PRE bridges in Sri Lanka do not have such serious conditions equivalent to “HI=0”. Therefore, it is assumed that PSC PRE is as same as RC-S.

Spall / Dela / Ex-Rebar: “e” and Crack: “e” have occurred concurrently on 60% of its all elements.

In such a case, it is assumed that loss of reinforcing / prestressing steel has occurred locally.

Correlation factors should be set up so that HI can be 0 with these situations.

15

Record of Damage

Damage	Extent of Damage					
	a (0)	b (25)	c (50)	d (75)	e (100)	Σ
Spall / Dela / Ex-Rebar	4				6	10
Crack	4				6	10
Damage on Anchorage	10	–		–		10

Correlation factor should be set up so that HI can be 0 with these situations.

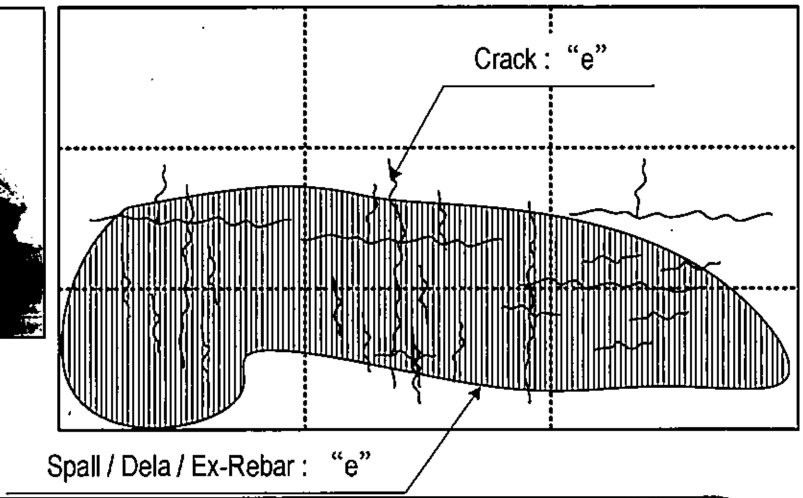
HI = 100 – (0.6*100*6/10+1.0*100*6/10)

Damage	Weighing Factor	Correlation Factor
Spall / Dela / Ex-Rebar	0.27	0.6
Crack	0.45	1.0
Damage on Anchorage	0.28	0.6

16

- RC-S

Example of damage in need of any restrictions (assumed)



Description of HI=0 Condition

❑ CASE → Spall / Dela / Ex-Rebar: "e" has occurred on 6 elements out of 9.

In such a case, it is assumed that Crack: "e" has concurrently occurred on 6 elements, though cracks are invisible due to spalling.

Also, it is assumed that loss of reinforcing steel has occurred locally.

Correlation factors should be set up so that HI can be 0 with these situations.

17

Record of Damage

Damage	Extent of Damage					
	a (0)	b (25)	c (50)	d (75)	e (100)	Σ
Spall / Dela / Ex-Rebar	3				6	9
Crack	3				6	9

Correlation factor should be set up so that HI can be 0 with these situations.

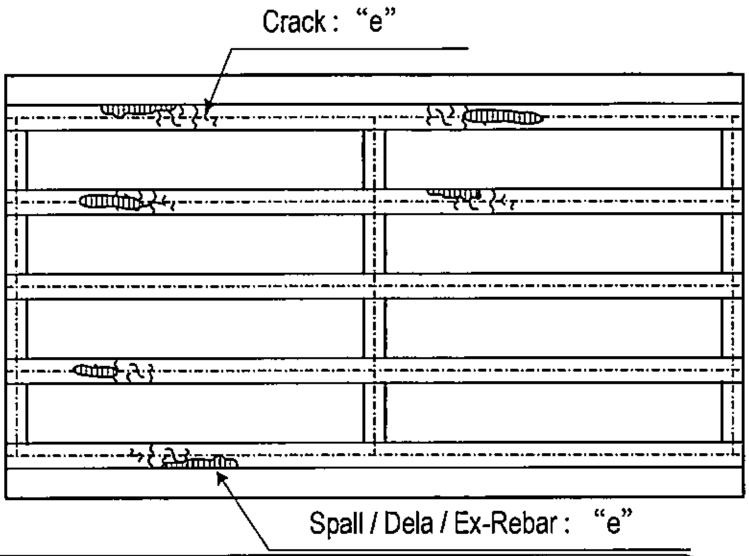
$HI = 100 - (1.0*100*6/9+0.8*100*6/9) \fallingdotseq 0$

Damage	Weighing Factor	Correlation Factor
Spall / Dela / Ex-Rebar	0.39	0.6
Crack	0.61	1.0

18

- PSC-POS,RCS-RCB

Example of damage in need of any restrictions (assumed)



Description of HI=0 Condition

❑ CASE → PSC-POS, RCS-RCB bridges in Sri Lanka do not have such serious conditions equivalent to "HI=0". Therefore, it is assumed that PSC-POS, RCS-RCB are as same as RC-S.

Spall / Dela / Ex-Rebar: "e" and Crack: "e" have occurred concurrently on 60% of its all elements.

In such a case, it is assumed that loss of reinforcing / prestressing steel has occurred locally.

Correlation factors should be set up so that HI can be 0 with these situations.

19

Record of Damage

Damage	Extent of Damage					
	a (0)	b (25)	c (50)	d (75)	e (100)	Σ
Spall / Dela / Ex-Rebar	4				6	10
Crack	4				6	10
Damage on Anchorage	10					10

Correlation factor should be set up so that HI can be 0 with these situations.

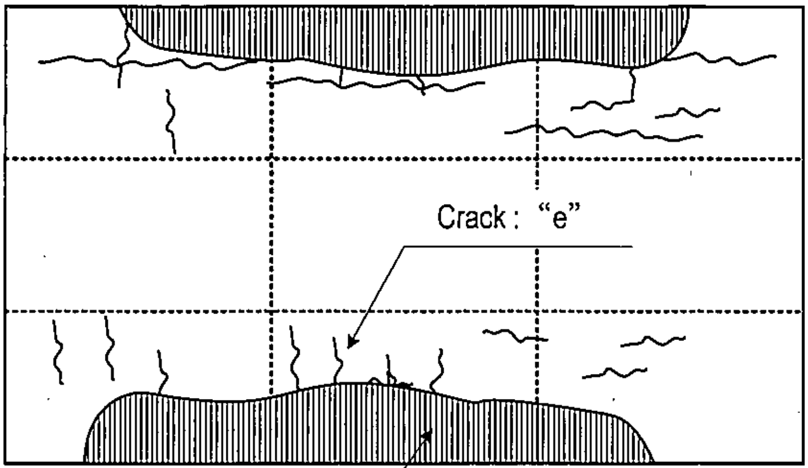
HI = 100 - (0.4*100*6/10+1.0*100*6/10) ≒ 0

Damage	Weighing Factor	Correlation Factor
Spall / Dela / Ex-Rebar	0.20	0.4
Crack	0.51	1.0
Damage on Anchorage	0.29	0.6

20

- Box Bridge

Example of damage in need of any restrictions (assumed)



Description of HI=0 Condition

❑ CASE → BOX Bridge in Sri Lanka does not have such serious conditions equivalent to "HI=0". Therefore, it is assumed that BOX Bridge is as same as RC-S.

Spall / Dela / Ex-Rebar: "e" and Crack: "e" have occurred concurrently on 6 elements out of 9.

In such a case, it is assumed that loss of reinforcing steel has occurred locally.

Correlation factors should be set up so that HI can be 0 with these situations.

21

Record of Damage

Damage	Extent of Damage					
	a (0)	b (25)	c (50)	d (75)	e (100)	Σ
Spall / Dela / Ex-Rebar	3				6	9
Crack	3				6	9

Correlation factor should be set up so that HI can be 0 with these situations.

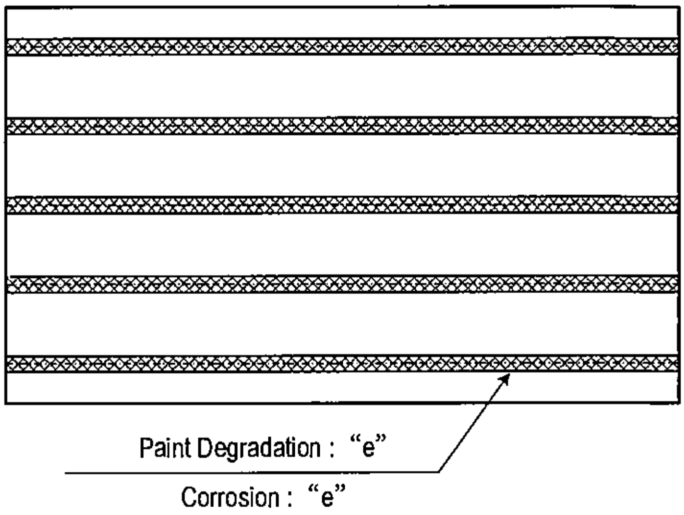
HI = 100 - (0.7*100*6/9+1.0*100*6/9) ≒ 0

Damage	Weighing Factor	Correlation Factor
Spall / Dela / Ex-Rebar	0.40	0.7
Crack	0.60	1.0

22

- Truss Bridge, Steel Bridge

Example of damage in need of damage



Description of HI=0 Condition

- CASE → Paint Degradation: "e" and Corrosion: "e" have occurred entirely (100%). In such a case, it is assumed that loss of structural steel has concurrently occurred locally.

Correlation factors should be set up so that HI can be 0 with this situation.

23

Record of Damage

Damage	Extent of Damage					
	a (0)	b (25)	c (50)	d (75)	e (100)	Σ
Paint Degradation	0				5	5
Corrosion	0				5	5
Damage (Rivet / HSFG)	5	–		–		5
Mud Deposition / Vegetation	5	–	–	–		5

Correlation factor should be set up so that HI can be 0 with this situation.

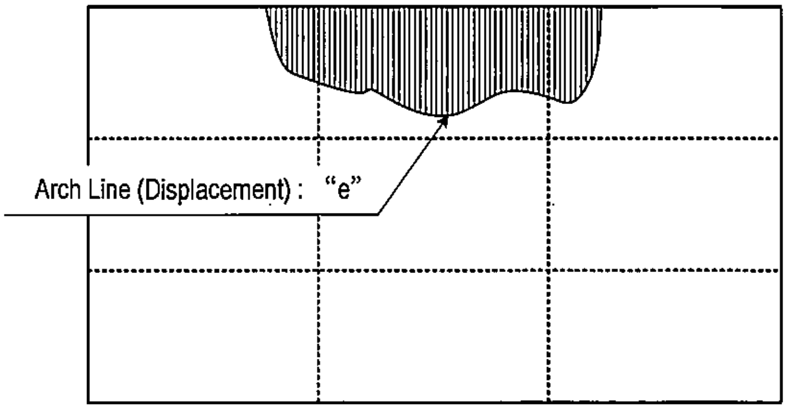
HI = 100 – (0.2*100*5/5+0.8*100*5/5)

Damage	Weighing Factor	Correlation Factor
Paint Degradation	0.09	0.2
Corrosion	0.37	0.8
Damage (Rivet / HSFG)	0.46	1.0
Mud Deposition / Vegetation	0.08	0.2

24

- Arch Bridge

Example of damage in need of damage



Description of HI=0 Condition

❑ CASE → Arch Line (Displacement) : "e" has occurred.

Correlation factors should be set up so that HI can be 0 with this situation.

25

Record of Damage

Damage	Extent of Damage					
	a (0)	b (25)	c (50)	d (75)	e (100)	Σ
Arch Line (Displacement)	0	–	–	–	1	1
Crack	9					9
Deteriorated (Loose)	9	–	–	–		9
Vegetation	9	–	–	–		9

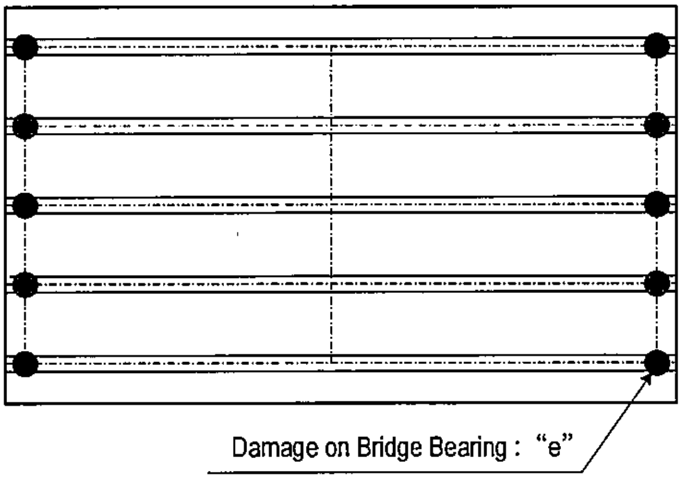
Correlation factor should be set up so that HI can be 0 with this situation.

HI = 100 - (1.0*100*1/1)

Damage	Weighing Factor	Correlation Factor
Arch Line (Displacement)	0.38	1.0
Crack	0.26	0.7
Deteriorated (Loose)	0.31	0.8
Vegetation	0.06	0.2

(3) Bridge Bearing

- When the difference in level, resulting from the damage on bridge bearing, has occurred, driving speed reduction will be needed as a result (speed limit) .
- However, due to damage on bridge bearing itself, any restrictions will not be needed.
    - Therefore, it is defined that HI=0 condition will occur when the bridge bearings (all the number, or entire length) are entirely damaged.



Record of Damage

Damage	Extent of Damage					
	a (0)	b (25)	c (50)	d (75)	e (100)	Σ
Water Leakage from Expansion Joint	10	-		-		10
Damage on Bridge Bearing	0	-		-	10	10

Correlation factor should be set up so that HI can be 0 with this situation.

HI = 100 - (1.0*100*10/10)

Damage	Weighing Factor	Correlation Factor
Water Leakage from Expansion Joint	0.23	0.3
Damage on Bridge Bearing	0.77	1.0

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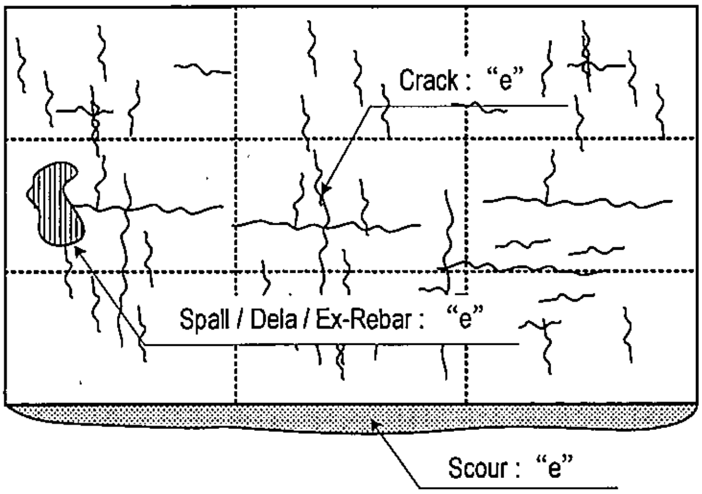
(4) Substructure

Example of damage in need of any restrictions

Scour :"e"



Description of HI=0 Condition

- ☐ CASE-1→ Scour : "e" has occurred.
- ☐ CASE-2→ Crack : "e" has occurred on all 9 elements (assumed).
  In such a case, it is assumed that Spall / Dela / Ex-Rebar : "e" has concurrently occurred on one element.

Correlation factors should be set up so that HI can be 0 with these situations.

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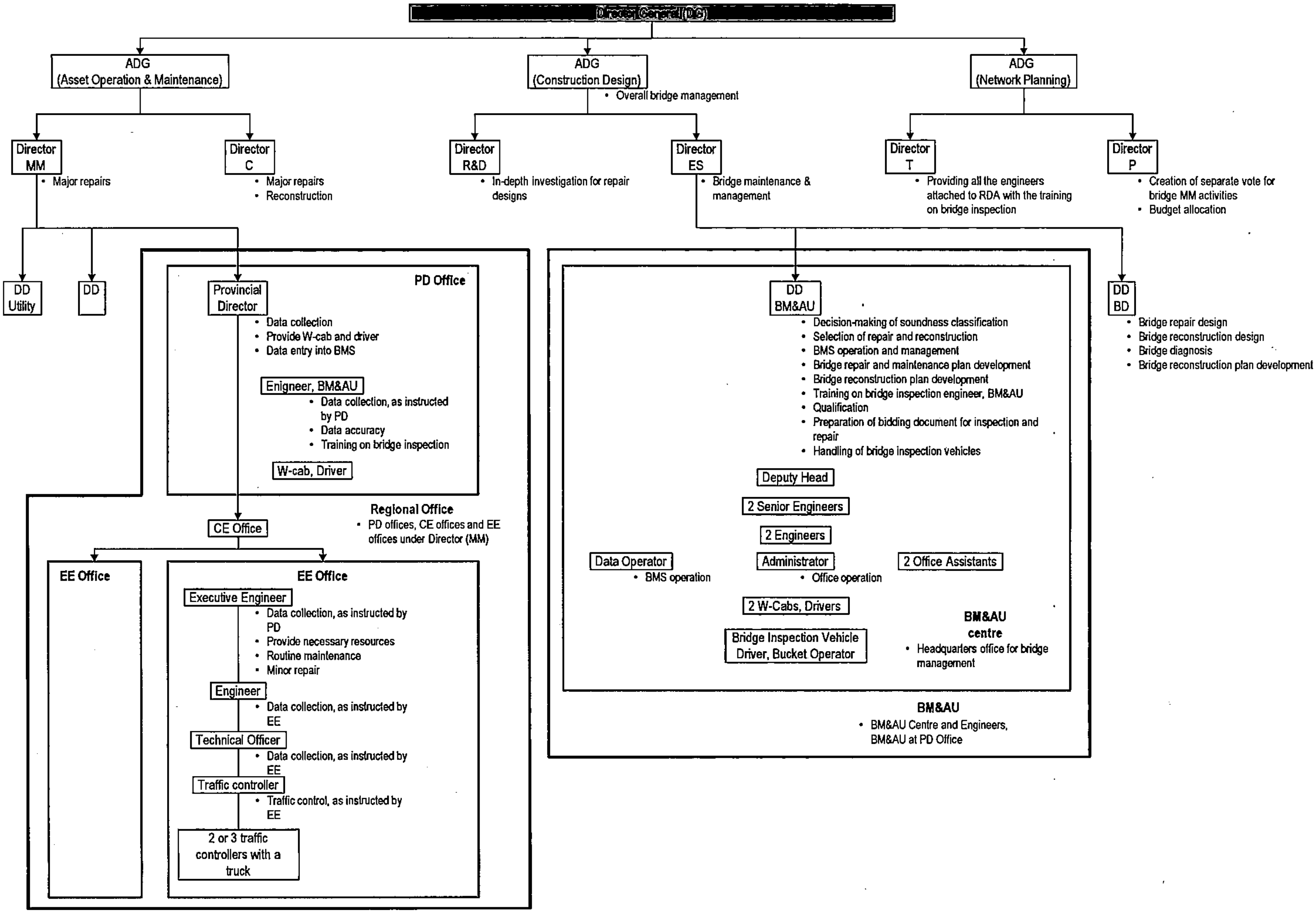
Record of Damage

	Damage	Extent of Damage					
		a (0)	b (25)	c (50)	d (75)	e (100)	Σ
CASE-1	Scour	0	–		–	1	1
CASE-2	Spall / Dela / Ex-Rebar	8				1	9
	Crack	0				9	9
	Mud Deposition / Vegetation	9	–	–	–		9

Correlation factor should be set up so that HI can be 0 with these situations.

CASE-1→HI = 100 – (1.0*100*1/1)
CASE-2→HI = 100 – (0.6*100*1/9+0.9*100*9/9)

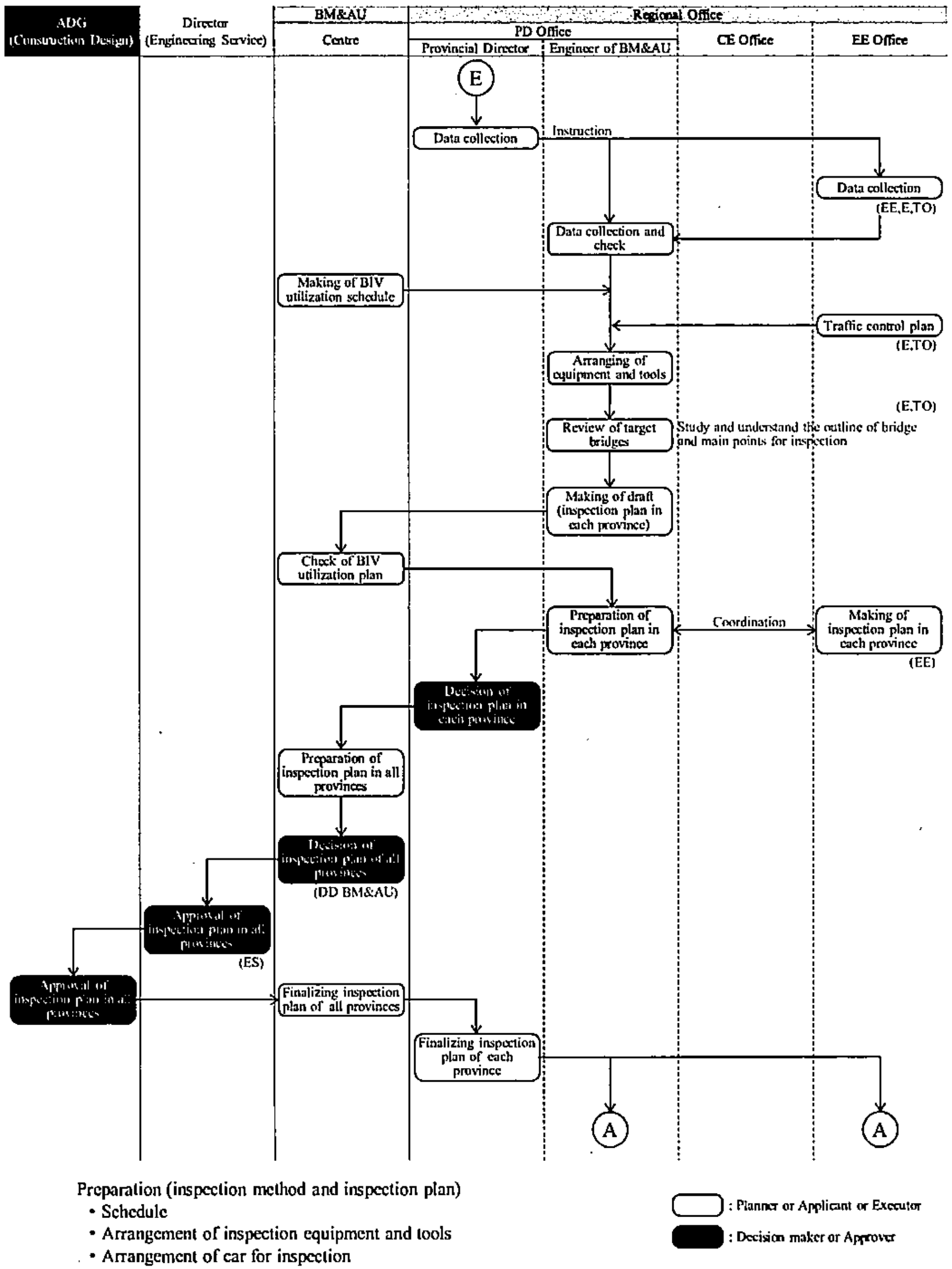
Damage	Weighing Factor	Correlation Factor
Scour	0.37	1.0
Spall / Dela / Ex-Rebar	0.24	0.6
Crack	0.34	0.9
Mud Deposition / Vegetation	0.05	0.1



Director General (DG)
ADG (Asset Operation & Maintenance)
ADG (Construction Design)
• Overall bridge management
ADG (Network Planning)
Director MM
• Major repairs
Director C
• Major repairs
• Reconstruction
Director R&D
• In-depth investigation for repair designs
Director ES
• Bridge maintenance & management
Director T
• Providing all the engineers attached to RDA with the training on bridge inspection
Director P
• Creation of separate vote for bridge MM activities
• Budget allocation
DD Utility
DD
PD Office
Provincial Director
• Data collection
• Provide W-cab and driver
• Data entry into BMS
Enigneer, BM&AU
• Data collection, as instructed by PD
• Data accuracy
• Training on bridge inspection
W-cab, Driver
Regional Office
• PD offices, CE offices and EE offices under Director (MM)
CE Office
EE Office
EE Office
Executive Engineer
• Data collection, as instructed by PD
• Provide necessary resources
• Routine maintenance
• Minor repair
Engineer
• Data collection, as instructed by EE
Technical Officer
• Data collection, as instructed by EE
Traffic controller
• Traffic control, as instructed by EE
2 or 3 traffic controllers with a truck
DD BM&AU
• Decision-making of soundness classification
• Selection of repair and reconstruction
• BMS operation and management
• Bridge repair and maintenance plan development
• Bridge reconstruction plan development
• Training on bridge inspection engineer, BM&AU
• Qualification
• Preparation of bidding document for inspection and repair
• Handling of bridge inspection vehicles
Deputy Head
2 Senior Engineers
2 Engineers
Data Operator
• BMS operation
Administrator
• Office operation
2 Office Assistants
2 W-Cabs, Drivers
Bridge Inspection Vehicle Driver, Bucket Operator
BM&AU centre
• Headquarters office for bridge management
BM&AU
• BM&AU Centre and Engineers, BM&AU at PD Office
DD BD
• Bridge repair design
• Bridge reconstruction design
• Bridge diagnosis
• Bridge reconstruction plan development

[Future]

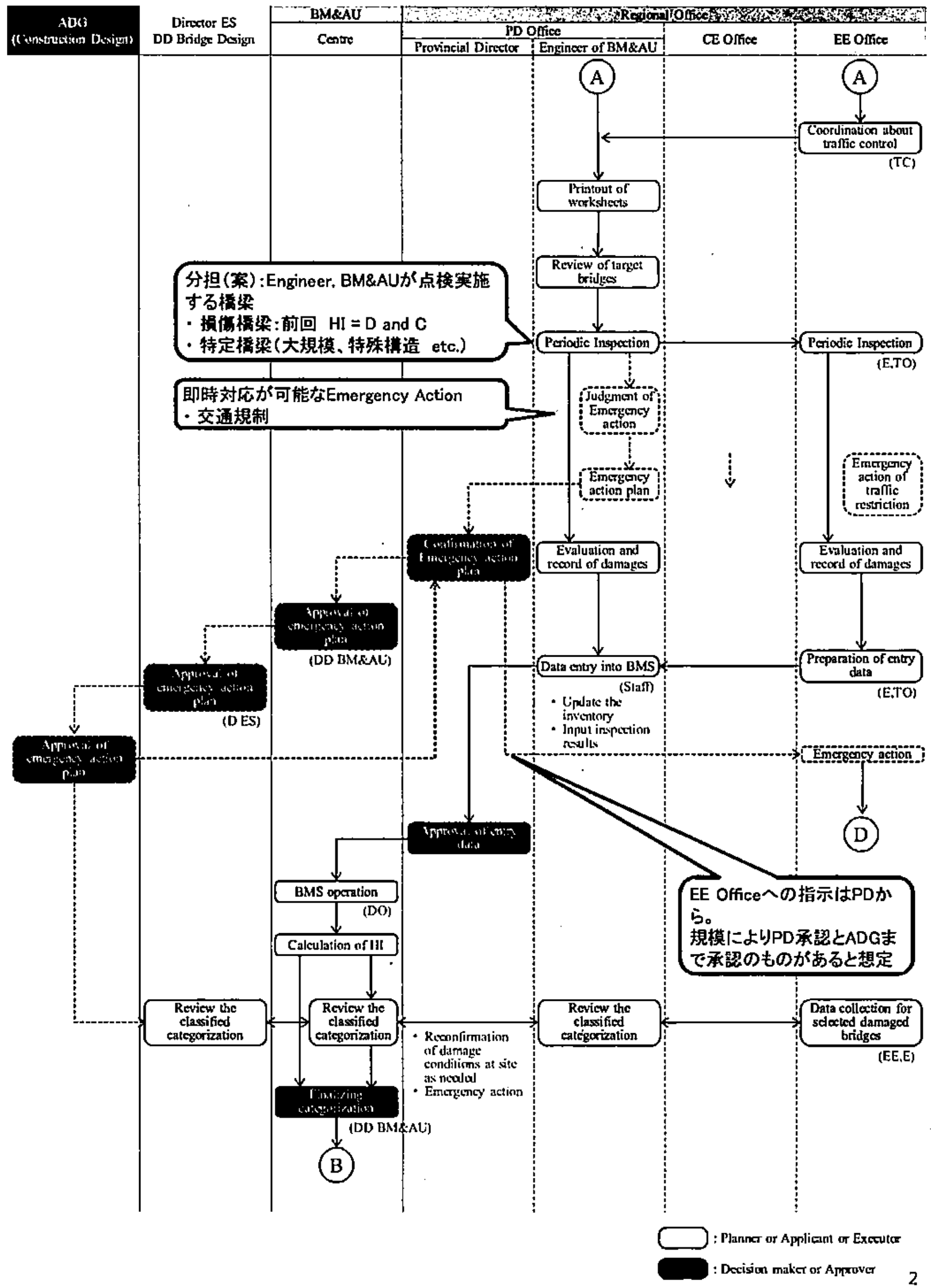
Preparation of Periodic Inspection (Making of Inspection Plan)



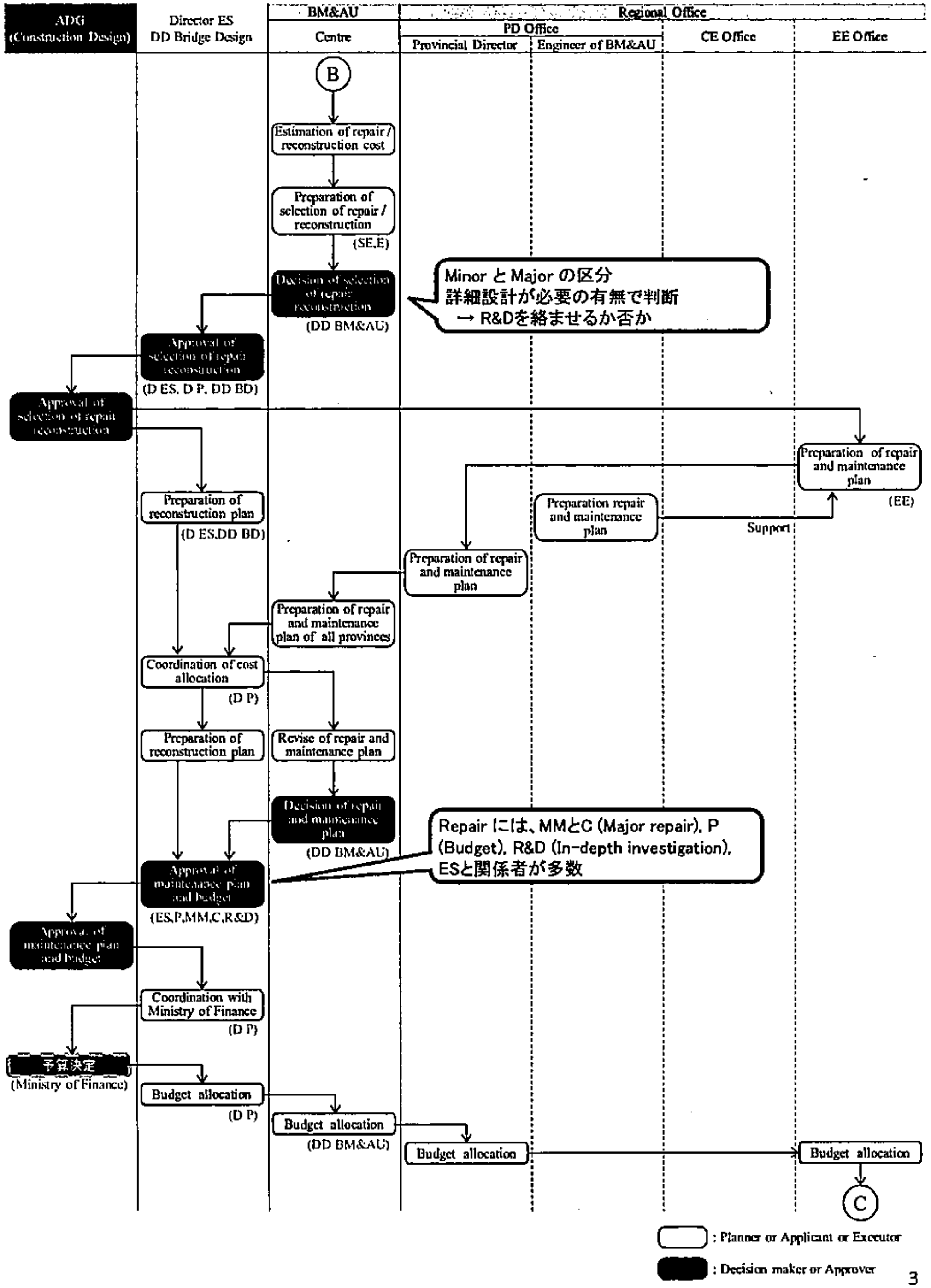
Preparation (inspection method and inspection plan)

- Schedule
- Arrangement of inspection equipment and tools
- Arrangement of car for inspection
- Arrangement of safety gears and equipment
- Arrangement of inspection vehicle.

Implementation of Periodic Inspection (Inspection and Evaluation) 点検案1：定期点検はBM&AUとEEで分担実施

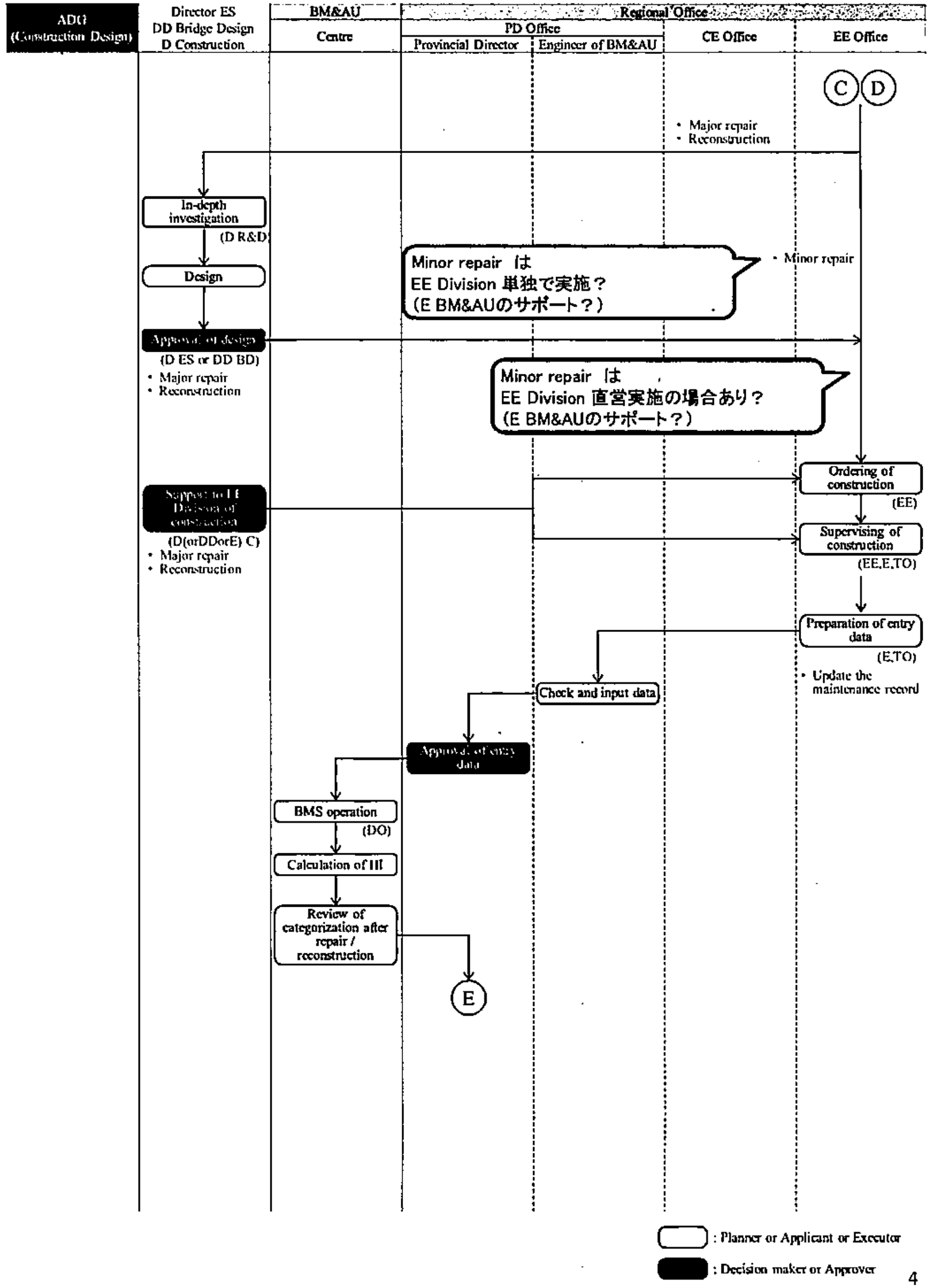


Maintenance Plan and Budget Allocation



3

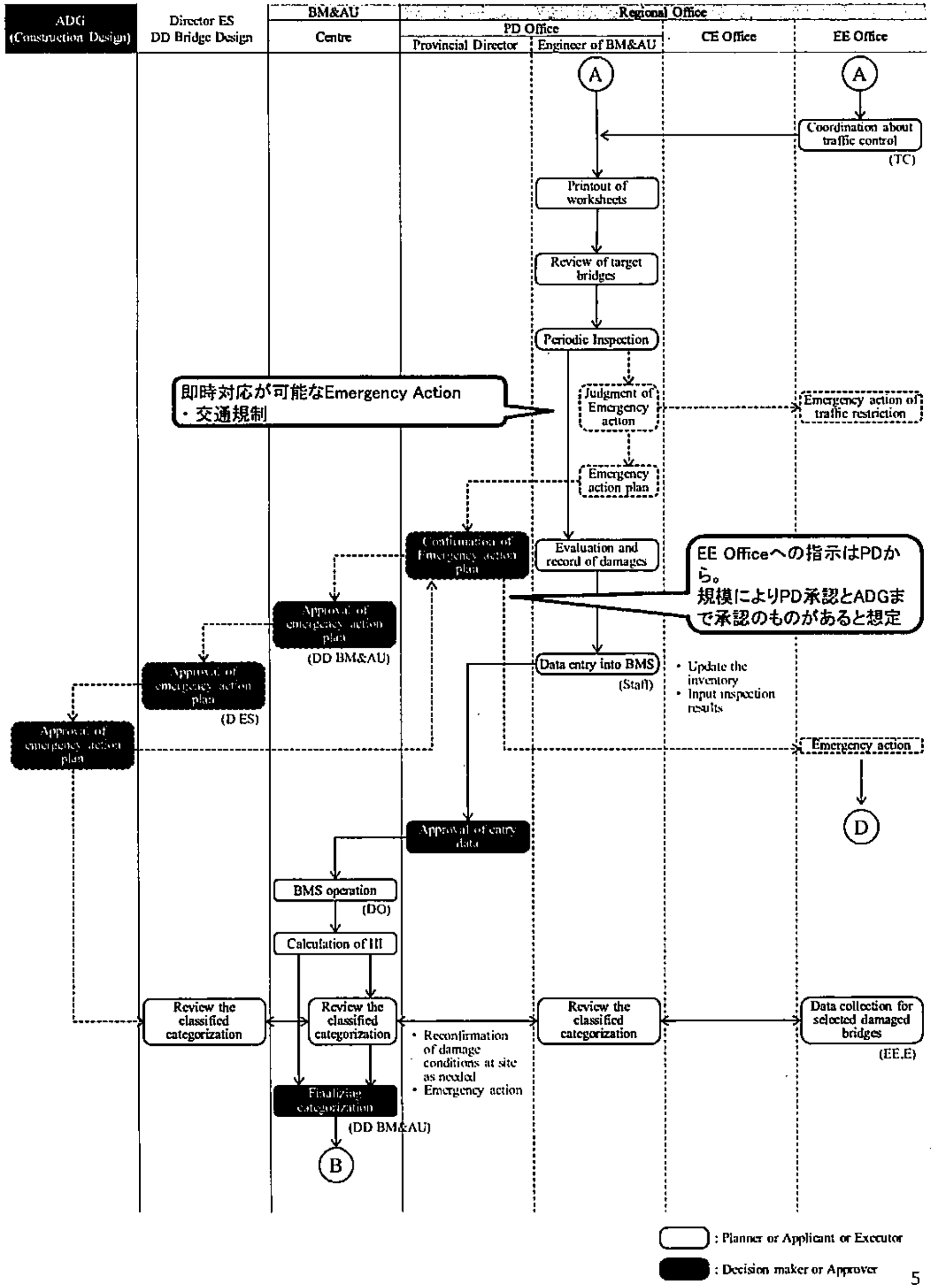
Repair and Reconstruction



4

Implementation of Periodic Inspection (Inspection and Evaluation)

点検案2:定期点検はBM&AUのみで実施



WS-5

Workshop Agenda

15th May 2017

Time	Contents	Presenter
9:00-9:05	*Welcome Address	Mr. L.S Premathilaka (Director ES)
9:05-9:25	*Calculation result of BMS by using inspection data from Sample Provinces/ Bridge Maintenance Scenario	Mr. K.Urano
9:25-9:45	*Bridge Repair & Maintenance Plan	Mr. K.Urano
9:45-10:05	Discussion	
10:05-10:15	Break	
10:15-10:35	*Institutional Framework of Bridge Maintenance Work in RDA	Mr. H.Takaura
10:35-10:55	*Next PC meeting (Strategy and Institutional Frame work)	Mr. H.Takaura
10:55-11:15	Discussion	
11:15-11:20	*Closing Remarks	Mr. B.V.D.N Chandrasiri (ADG - CD)

6

Conditions of Bridges under RDA's Management & Bridge Budget Plans (Outputs of BMS)

JICA Project Team

1

Contents

2

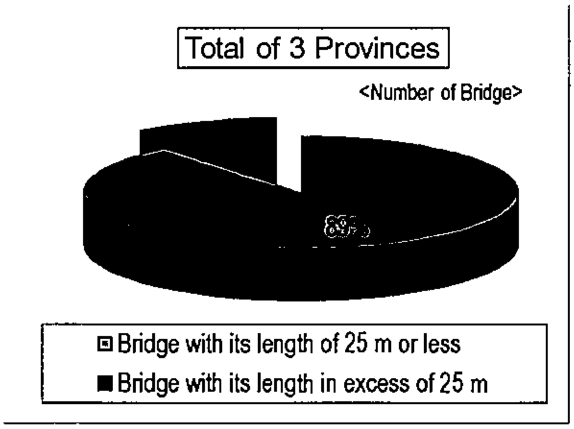
1. Target Bridges for Analysis

- Using the inspection results of bridges in 3 sample provinces, registered in BISS (Bridge Inspection Support System), various analyses were implemented.
- Total number of bridges is 1,358, of which, number of bridges with defective records is 12.
- Number of bridges used for analysis is 1,358 – 12 = 1,346 with the following breakdown.

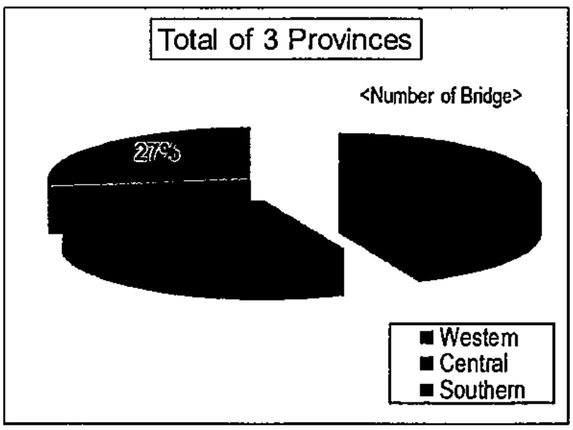
		Total of 3 Provinces	Western	Central	Southern
Bridge with its length of 25 m or less	Number of Bridge	1,202	527	349	326
	Total Length (m)	10,004	4,340	2,693	2,971
Bridge with its length in excess of 25 m	Number of Bridge	144	59	44	41
	Total Length (m)	7,516	3,403	2,229	1,885
Total	Number of Bridge	$\boxed{1,346}$	586	393	367
	Total Length (m)	17,521	7,742	4,922	4,856

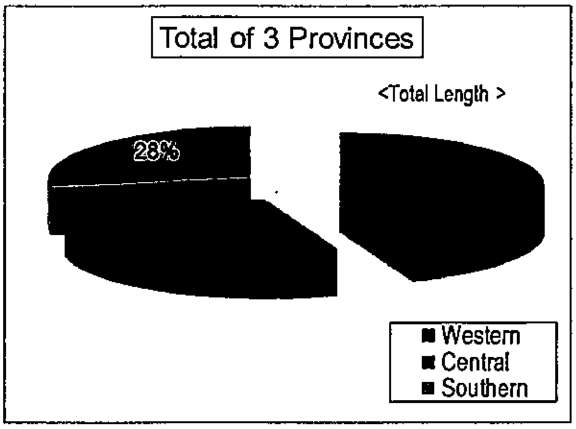
3

- Composition of Target Bridges



- 89% of the bridges in sample provinces are 25 meters or less in length.
- Number of bridges in each sample province accounts for 44%, 29% and 27% respectively for Western, Central and Southern.
- Total length of bridges in each sample province accounts for 44%, 28% and 28% respectively for Western, Central and Southern.



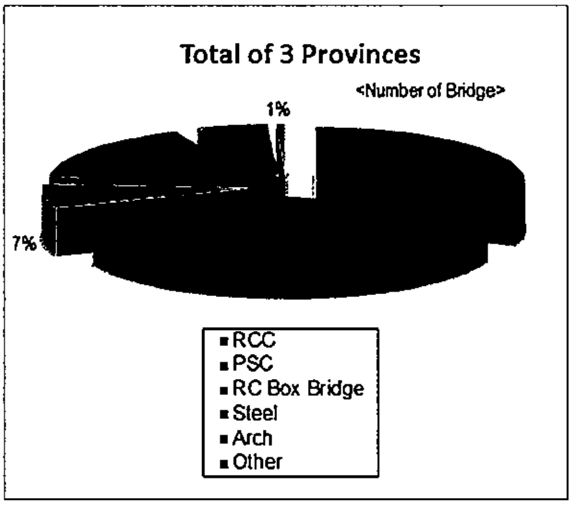


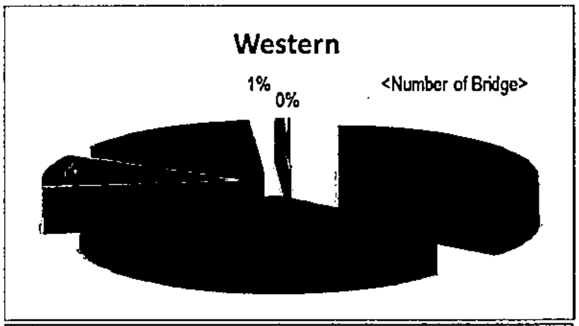
2. Summary of Bridges by Type

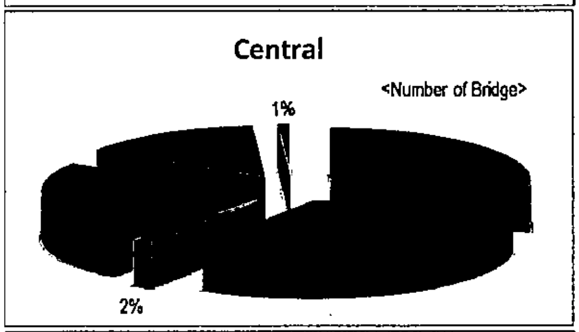
- Summary of bridges by type is given as follows.
- Concrete bridges account for 83% in number and 81% in length.

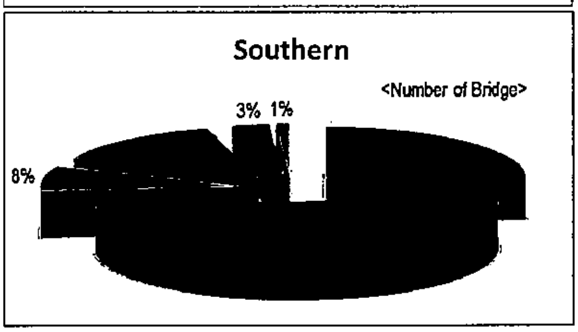
		Total of 3 Provinces	Western	Central	Southern
RCC Bridge	Number of Bridges	401	209	106	86
	Bridge Length (m)	2,723	1,352	708	663
PSC Bridge	Number of Bridges	529	218	127	184
	Bridge Length (m)	9,850	4,247	2,556	3,048
RC Box Bridge	Number of Bridges	97	61	7	29
	Bridge Length (m)	652	401	33	218
Steel Bridge	Number of Bridges	234	91	90	53
	Bridge Length (m)	3,344	1,638	1,014	693
Arch Bridge	Number of Bridges	75	5	59	11
	Bridge Length (m)	822	87	588	146
Other Bridge	Number of Bridges	10	2	4	4
	Bridge Length (m)	129	18	23	88
Total	Number of Bridges	1,346	586	393	367
	Bridge Length (m)	17,521	7,742	4,922	4,856

- Composition of Bridges by Type







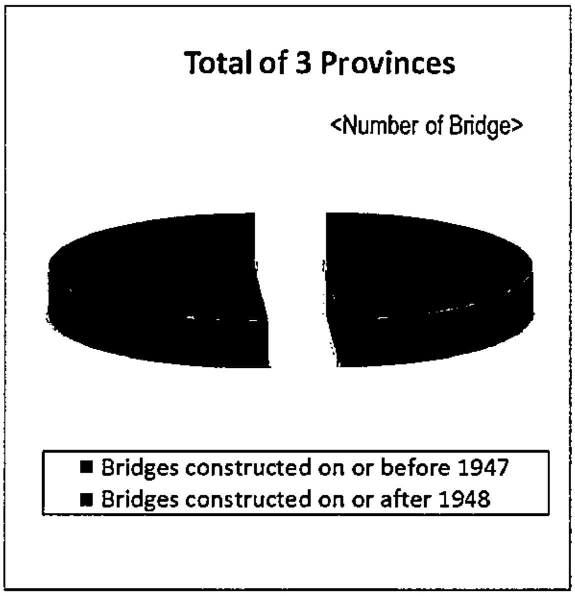


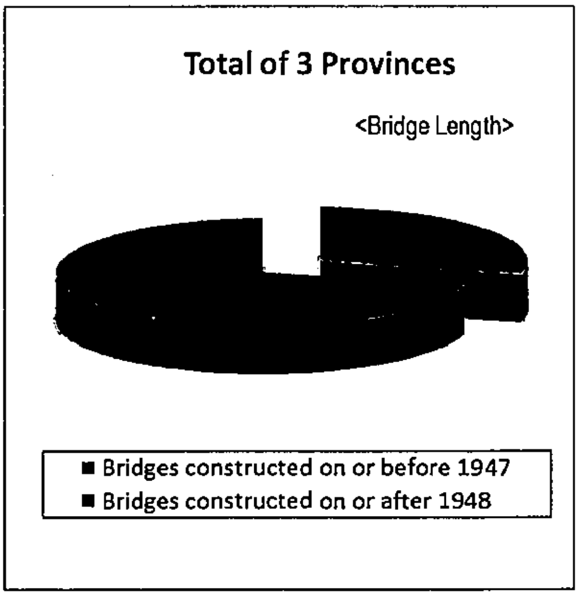
3. Summary of Bridges by Year of Construction

- Summary of bridges by year of construction is given as follows.

		Total of 3 Provinces	Western	Central	Southern
Bridges constructed on or before 1947	Number of Bridges	248	40	172	36
	Bridge Length (m)	2,165	275	1,437	453
Bridges constructed on or after 1948	Number of Bridges	259	98	43	118
	Bridge Length (m)	5,280	2,277	1,112	1,892
Total	Number of Bridges	507	138	215	154
	Bridge Length (m)	7,445	2,552	2,549	2,344
Not entered	Number of Bridges	839	448	178	213

- Composition of Bridges by Year of Construction





Comments:

Bridges constructed on or before 1947 (70 years or older) account for 49% in number and 30% in length.

4. Analysis Results focused on Bridge Soundness

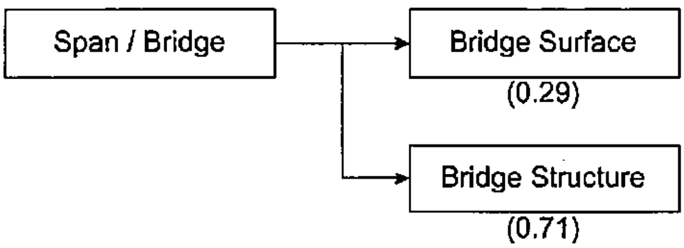
Soundness Classification by Health Index (HI)

Sound

Serious

Classification		Description	HI
A	Sound	● Bridge / bridge member functions well.	75 – 100
B	Preventive Stage	● Bridge / bridge member functions well. ● It is preferred to take necessary measures for preventive maintenance purpose.	50 – 75
C	Measures to be taken at an early stage	● Possible to give adverse effects to bridge / bridge member. ● Proper measures should be taken earlier.	25 - 50
D	Measures to be taken Urgently	● Bridge / bridge member are not functioned well, or substantially possible to give adverse effects to bridge / bridge member. ● Necessary measures should be taken urgently.	0 - 25

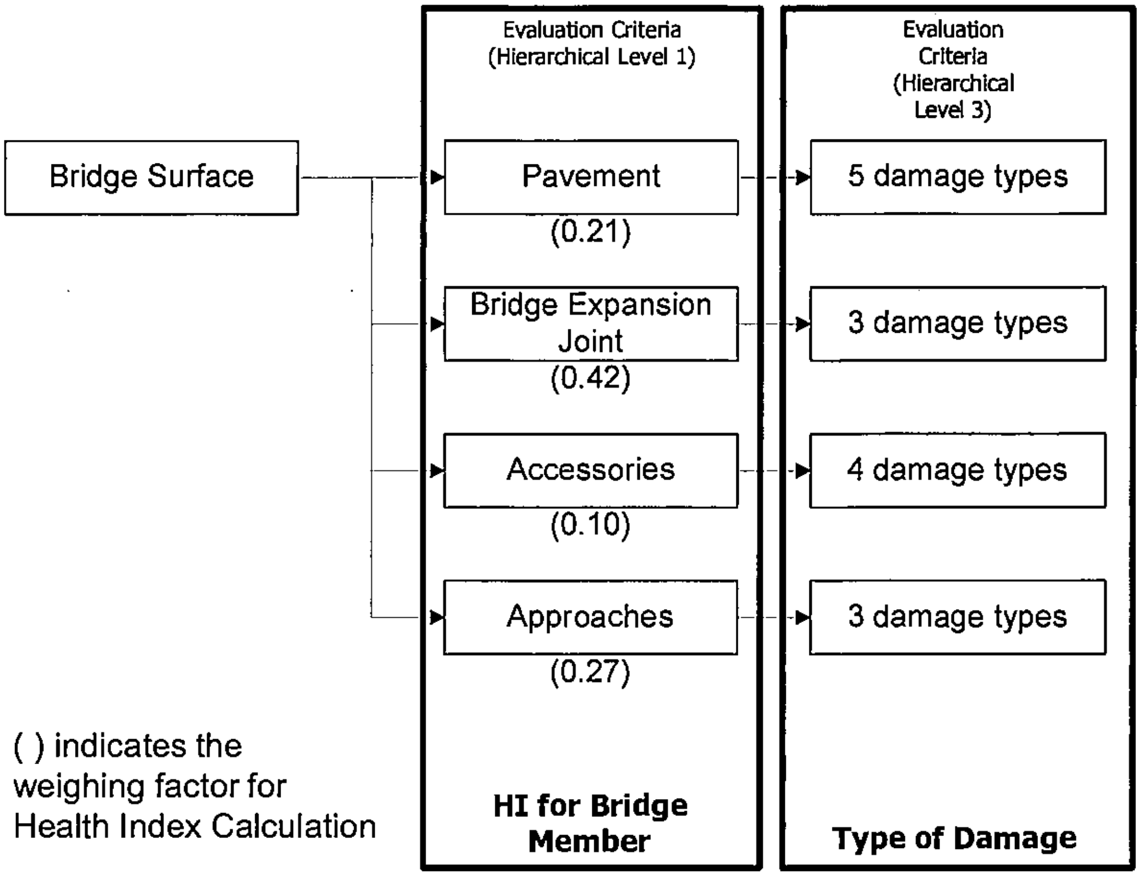
Calculation of Health Index (HI)



( ) indicates the weighing factor for Health Index Calculation

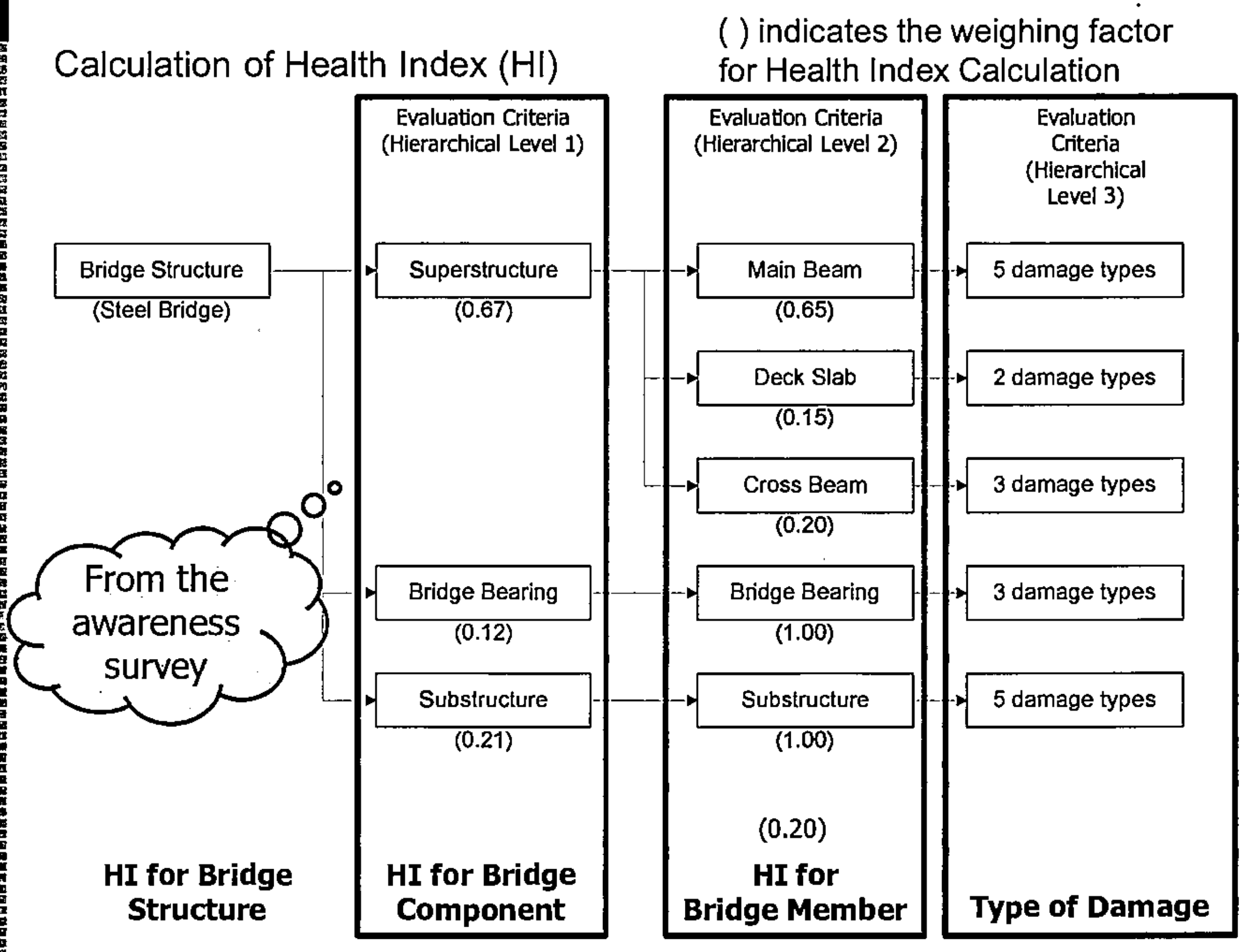
10

Calculation of Health Index (HI)



11

Calculation of Health Index (HI)



12

(1) By Region

- Summary of bridges (number of bridges) by soundness classification and region is given as follows.

Sound

Serious

	Total of 3 Provinces	Western	Central	Southern
Soundness Classification: A	771	316	225	230
Soundness Classification: B	284	141	73	70
Soundness Classification: C	127	60	33	34
Soundness Classification: D	164	69	62	33
Total	1,346	586	393	367

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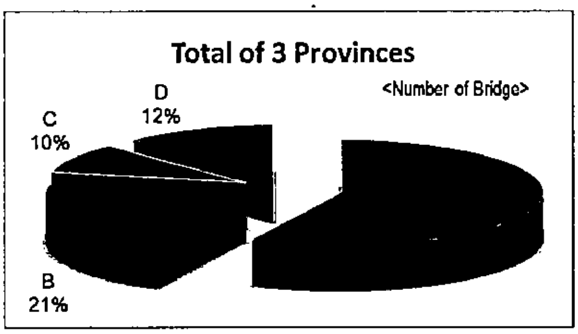
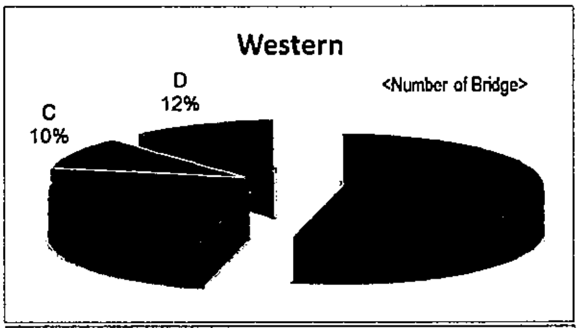
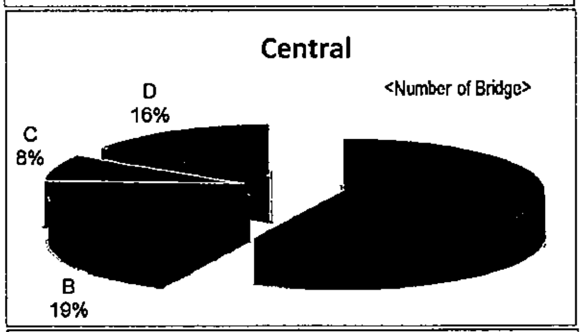
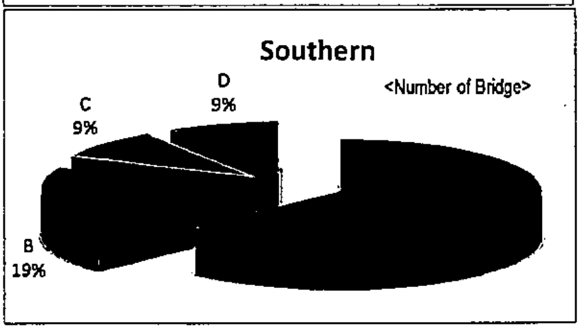
- Composition of Bridges by Soundness Classification & Region









Comments:

- ❑ About 55 – 63% of bridges are categorized as "A" (HI = 100 – 75).
- ❑ About 80% of bridges are categorized as "A" and "B" (HI = 100 – 50).

(2) By Structural Type

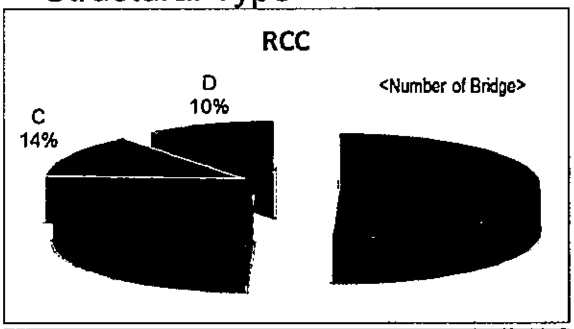
- Summary of bridges (number of bridges) by soundness classification and structural type is given as follows.

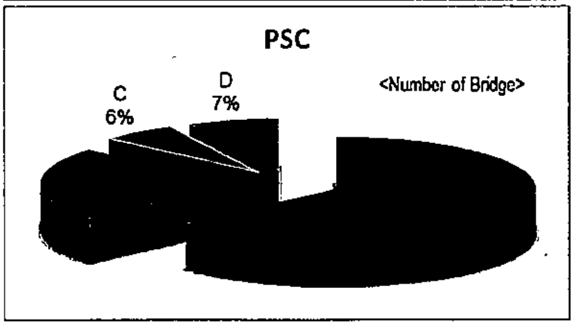
Sound

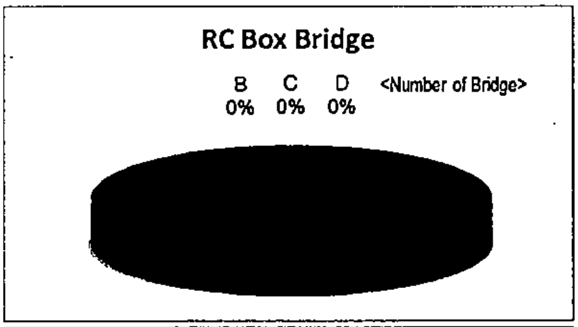
Serious

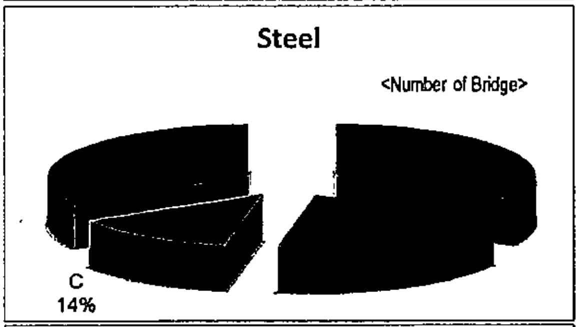
	RCC	PSC	RC Box	Steel	Arch	Other	Total
Soundness Classification: A	203	336	97	76	57	2	771
Soundness Classification: B	101	121	0	48	9	5	284
Soundness Classification: C	55	33	0	32	4	3	127
Soundness Classification: D	42	39	0	78	5	0	164
Total	401	529	97	234	75	10	1,346

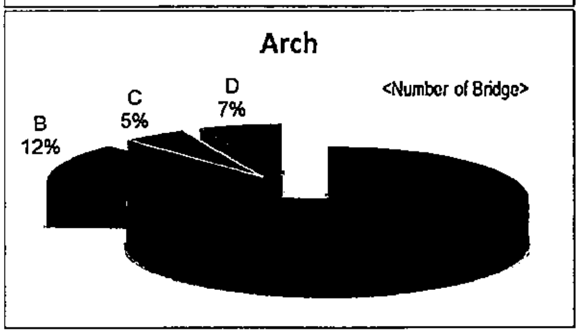
- Composition of Bridges by Soundness Classification & Structural Type











Comments:

- Box bridges are in good conditions.
- Steel bridges are relatively in deteriorated conditions.
- Arch and pre-stressed concrete bridges are relatively in good conditions.

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(3) By Bridge Member

- Summaries of bridges (number of bridges) by soundness classification and bridge member are given as follows.

Sound

Serious

	Entire Bridge	Bridge Surface	Bridge Structure
Soundness Classification: A	771	925	950
Soundness Classification: B	284	253	163
Soundness Classification: C	127	77	111
Soundness Classification: D	164	91	122
Total	1,346	1,346	1,346

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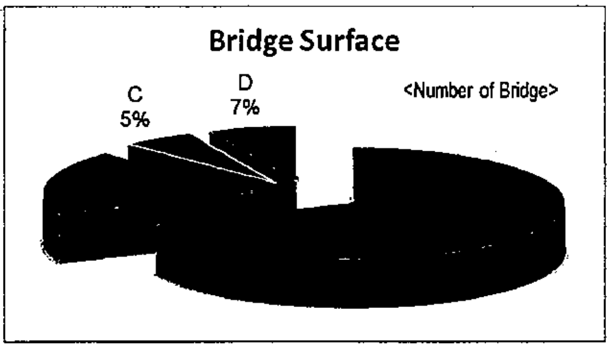
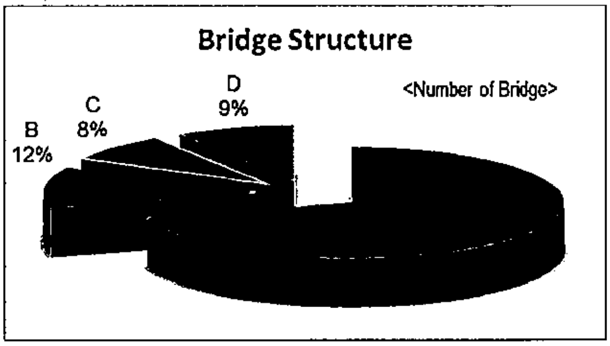
- Composition of Bridges by Soundness Classification & Bridge Member

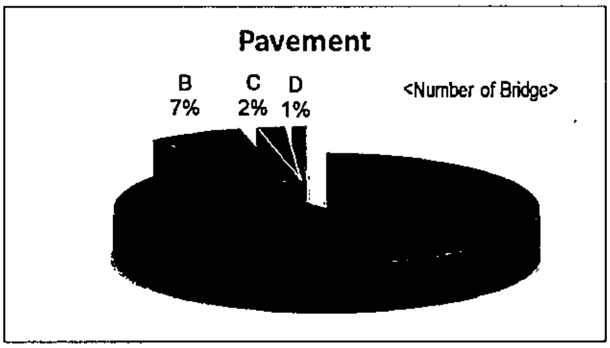


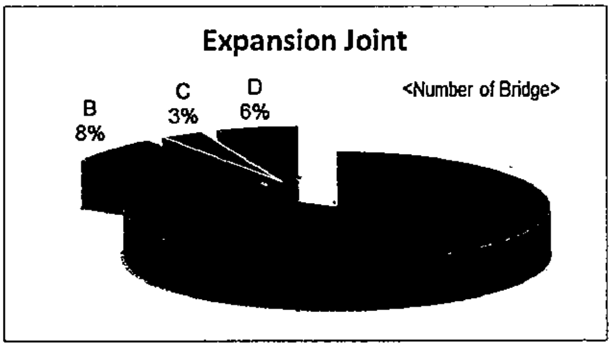


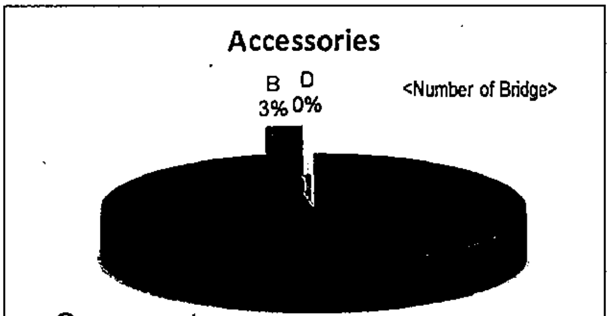
Bridge Surface

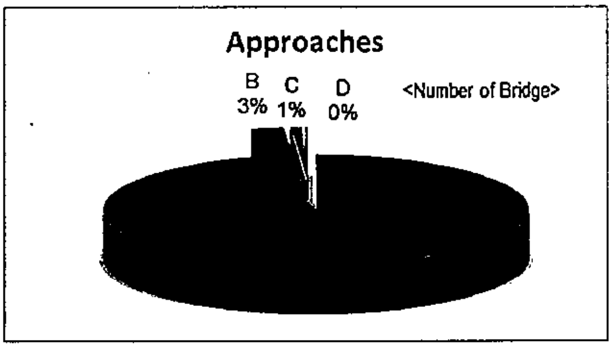
Sound ↑ ↓ Serious	Bridge Surface	Pavement	Expansion Joint	Accessories	Approaches
Soundness Classification: A	925	1,202	1,114	1,307	1,296
Soundness Classification: B	253	98	102	38	33
Soundness Classification: C	77	30	46	1	13
Soundness Classification: D	91	16	84	0	4
Total	1,346	1,346	1,346	1,346	1,346

- Composition of Bridges by Soundness Classification & Bridge Member









Comments:

Bridge surfaces are well maintained probably because the defects and damage can be easily detected and attention is paid to prevent accidents. However, bridge expansion joints are not maintained compared to other members because it may be difficult for maintenance.

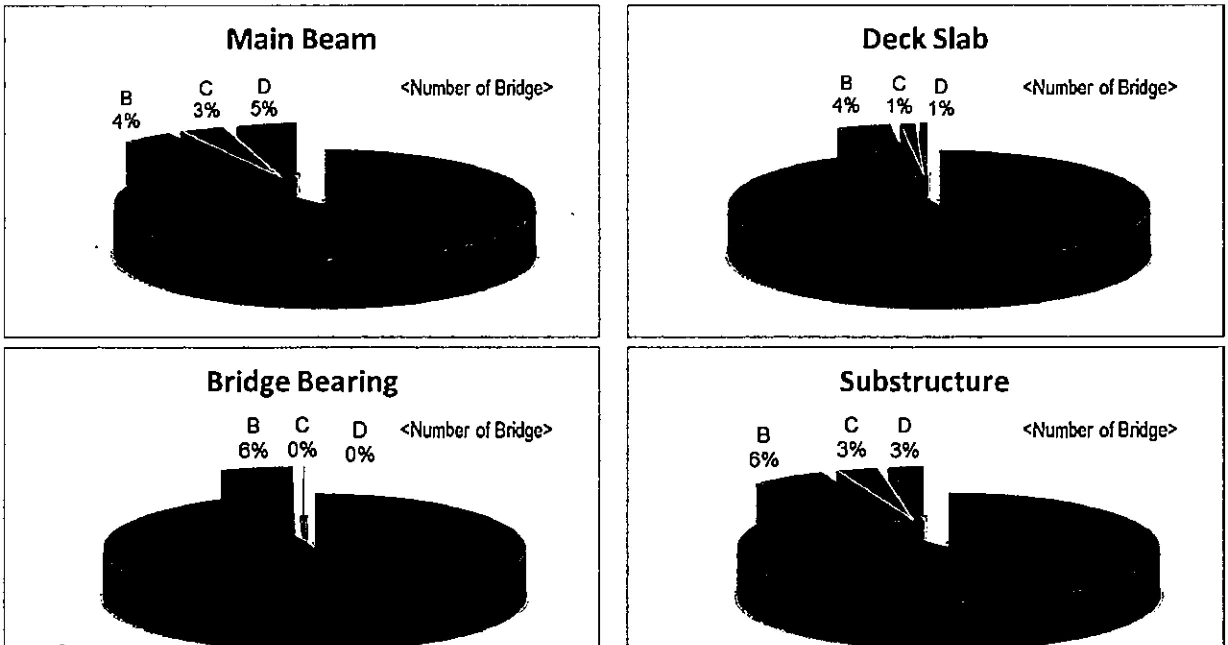
Bridge Structure

Sound

Serious

	Bridge Structure	Main Beam	Deck Slab	Bridge Bearing	Substructure
Soundness Classification: A	950	1,180	1,264	1,268	1,185
Soundness Classification: B	163	55	56	76	79
Soundness Classification: C	111	48	17	2	44
Soundness Classification: D	122	63	9	0	38
Total	1,346	1,346	1,346	1,346	1,346

- Composition of Bridges by Soundness Classification & Bridge Member



Comments:

✓ Bridge structures are relatively in good conditions because of moderate environment.

✓ Main beams are relatively deteriorated compared to other members.

✓ Deck slabs are in good conditions.

(4) By Distance to Coastline

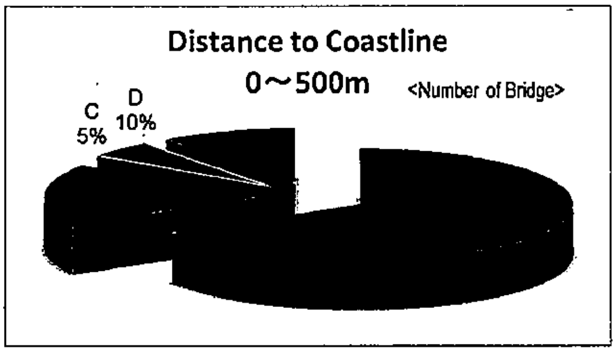
- Summary of bridges (number of bridges) by soundness classification and distance to coastline is given as follows.

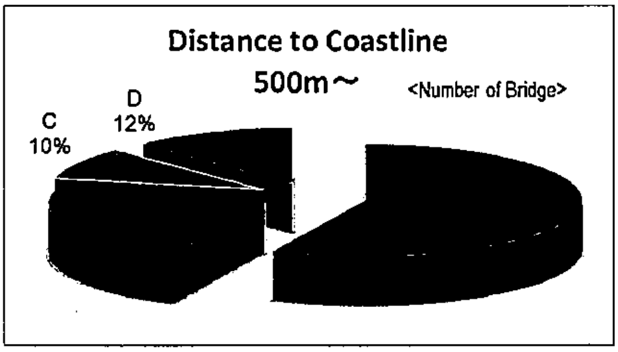
Sound

Serious

	Distance to Coastline				
	0～100m	100～300m	300～500m	0～500m	500m～
Soundness Classification: A	2	14	10	26	745
Soundness Classification: B	1	4	2	7	277
Soundness Classification: C	0	1	1	2	125
Soundness Classification: D	1	1	2	4	160
Total	4	20	15	39	1,307

- Composition of Bridges by Soundness Classification & Distance to Coastline





Comments:
There is NO clear trend such that "bridges close to the coastline are seriously deteriorated: are there many bridges categorized as "D" ? ".

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5. Repair & Maintenance Costs

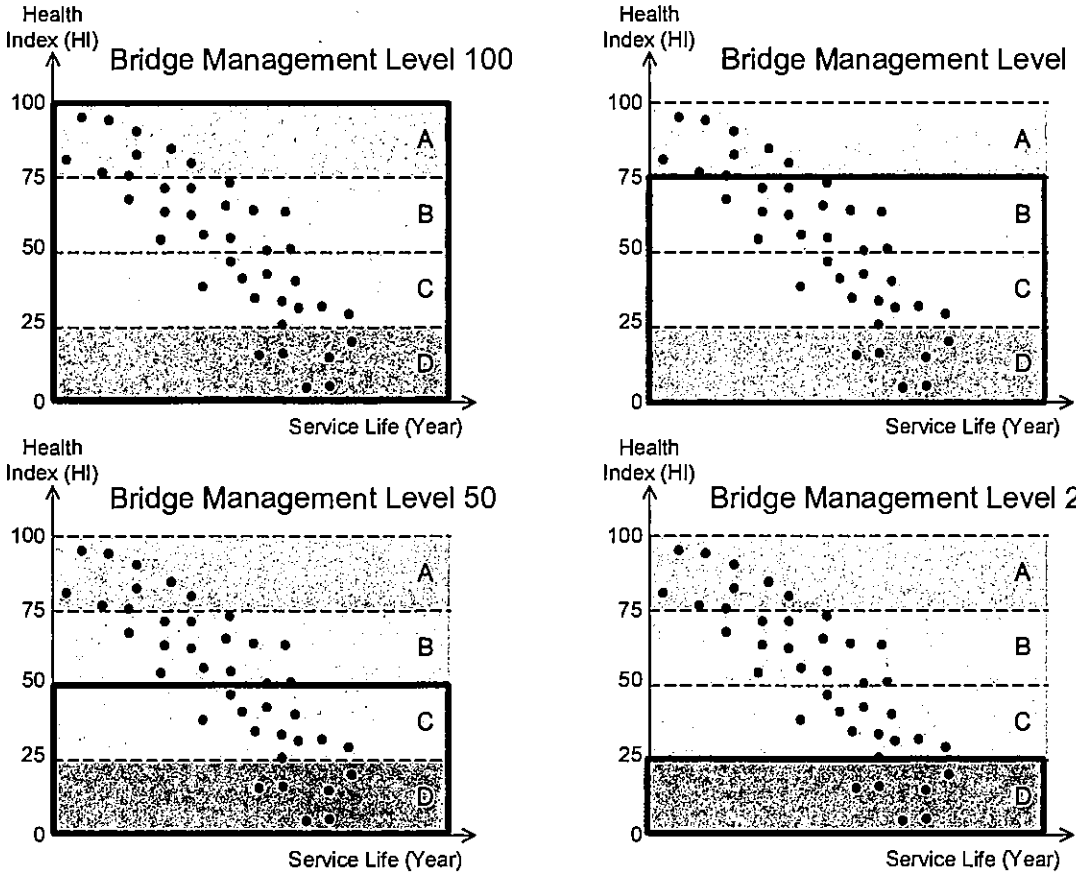
- For brief understanding of repair and maintenance costs by bridge management levels, trial calculation was implemented.
  - Bridge Management Level 100 (Very High)
  - Bridge Management Level 75 (High)
  - Bridge Management Level 50 (Medium)
  - Bridge Management Level 25 (Low)

(The number is Health Index)

	Bridge	Bridge Surface	Bridge Structure			
			Main Beam	Deck Slab	Bridge Bearing	Sub structure
Management Level 100	100	100	100	100	100	100
Management Level 75	75	10	75	75	10	75
Management Level 50	50	10	50	50	10	50
Management Level 25	25	10	25	25	10	25

25

Bridge Management Level



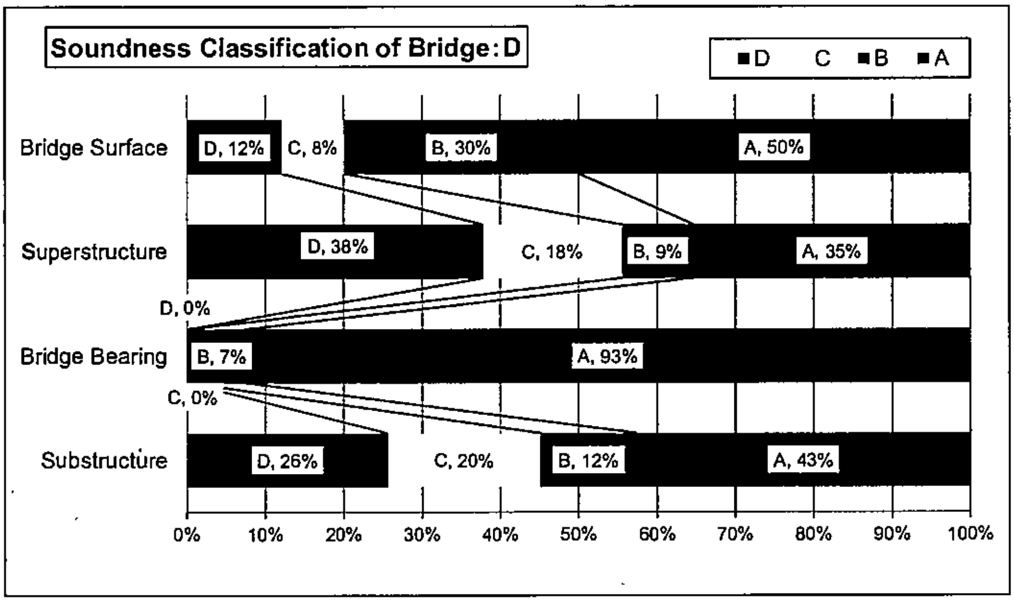
- Repair & Maintenance Costs by Bridge Management Levels for only 1,346 bridges in 3 sample provinces

(Unit: 1,000 SL Rupee)

	Bridge	Bridge Surface	Bridge Structure			
			Entire	Super structure	Bridge Bearing	Sub structure
Management Level 100	458,490	25,596	432,895	270,319	103,306	59,270
Management Level 75	194,645	4,135	190,510	144,111	0	46,399
Management Level 50	137,166	2,410	134,757	117,579	0	17,178
Management Level 25	91,569	876	90,693	79,864	0	10,829

6. Soundness Classification of Bridge

- Soundness Classification of Bridge : D

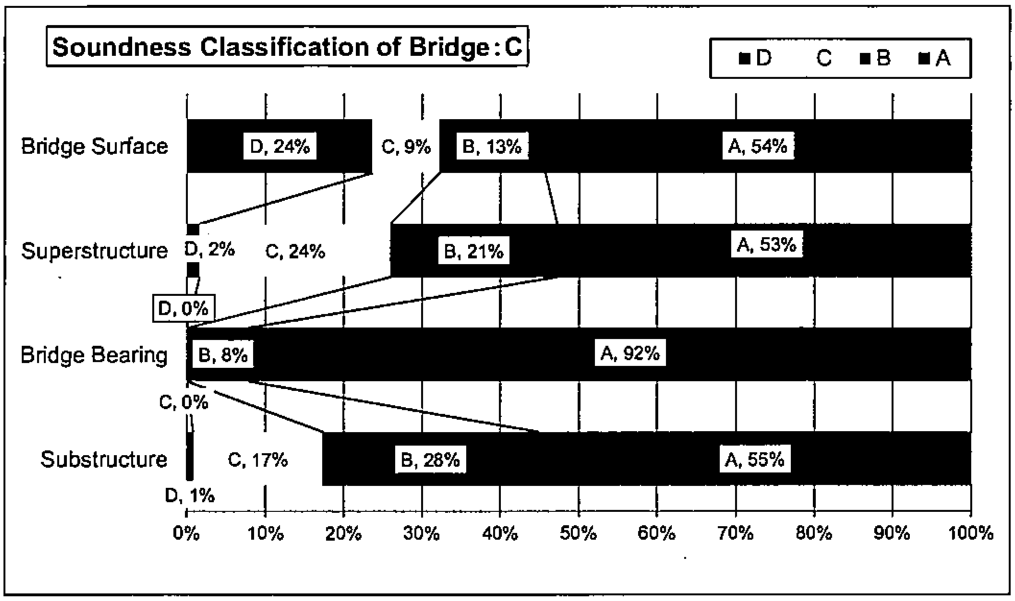


The above is the composition of soundness classification of bridge members for the bridges categorized as "Soundness Classification D".

It is verified as follows:

- ***Bridge soundness classification of "D" is determined predominantly by bridge structures (superstructure / substructure).***

● Soundness Classification of Bridge : C

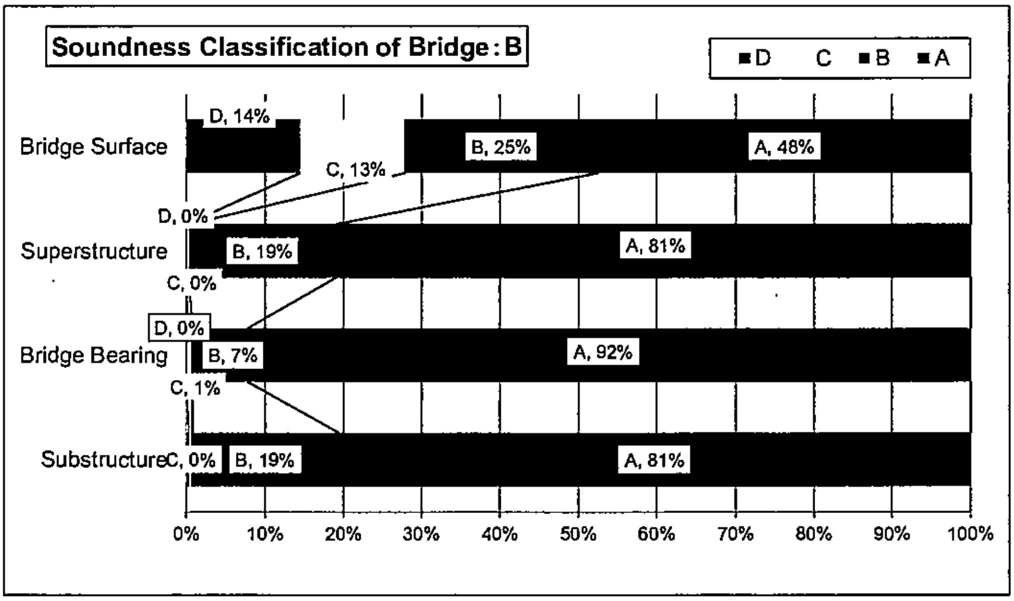


The above is the composition of soundness classification of bridge members for the bridges categorized as "Soundness Classification C".

It is verified as follows:

- ***Bridge soundness classification of "C" is determined predominantly by bridge structures (superstructure / substructure).***

● Soundness Classification of Bridge : B



The above is the composition of soundness classification of bridge members for the bridges categorized as "Soundness Classification C".

It is verified as follows:

- ***Bridge soundness classification of "B" is determined predominantly by bridge surface, followed by bridge structures (superstructure / substructure).***

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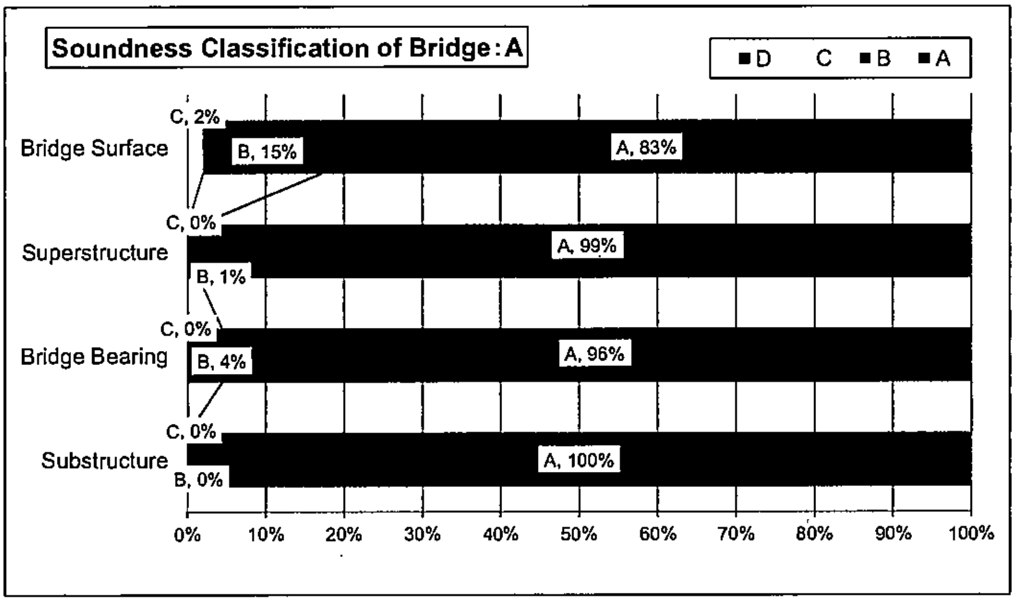
● Soundness Classification of Bridge : A



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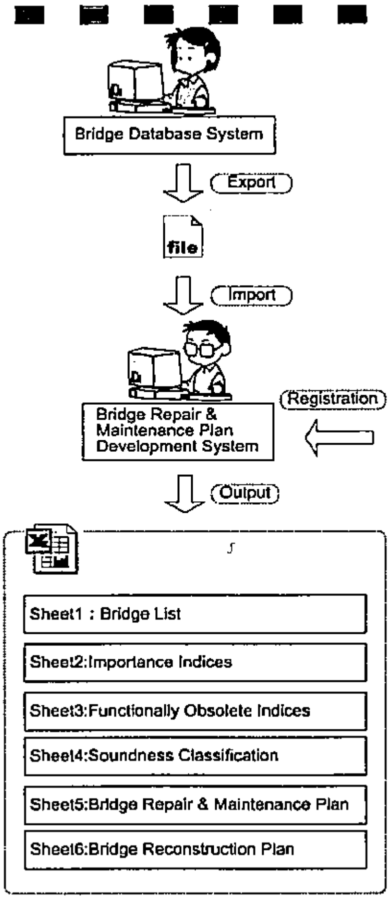
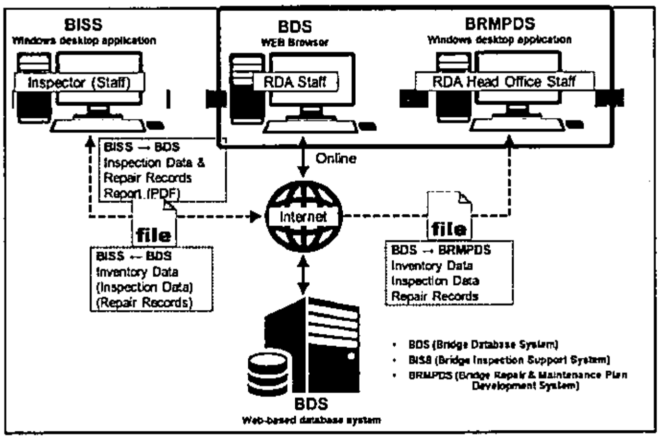
7. Output of BRMS





<Calculation Conditions>

- The necessary conditions to calculate the Importance Index
- The necessary conditions to calculate the Functionally Obsolete Index
- The necessary conditions for developing the Bridge Repair & Maintenance Plan
- The necessary conditions to develop the Bridge Reconstruction Plan
- The ways of prioritizing the Bridge Repair and Reconstruction

- **Output of Calculation Result File**

● Example-Sheet1：Bridge List (1)

Bridge ID	Bridge No.		Separation	Name of Bridge	Province	District	EE Division	Route No.	Exact Year of Construction	Rough Year of Construction	Type of Bridge	Length of Bridge (m)	Overall Width (m)
	km	No.											
1475	1	2	Not		Western	Colombo	Colombo	AA000			PSC Bridge	5.9	20
1439	5	1	Not		Western	Colombo	Colombo	AA000			PSC Bridge	10.8	22.68
1489	7	2	Not	Poldhuwa	Western	Colombo	Colombo	AA000		2014	Steel Bridg	72	[illegible]
145	28	3	Not		Western	Colombo	Colombo	AA000			PSC Bridge	5.4	[illegible]
1487	1	1	Not	Bridge Clos	Western	Colombo	Colombo	AA001			RCS Bridge	44.2	27.1
1175	3	3	Not	Ovissa Bric	Central	Kandy	Kandy	AA001	1936		Steel Bridg	17	4.2
819	6	1	Not	Ingurukade	Western	Colombo	Colombo	AA001			PSC Bridge	16.85	17.55
820	6	2	Not	Railway cro	Western	Colombo	Colombo	AA001			PSC Bridge	12.05	24.9

Traffic Volume (vehicle/day)	Crossings Expressway	Crossings Railway	Crossings River	Power Cable	Water Supply / Sewage Pipes	Telecommunication Cable (Metal)	Telecommunication Cable (Optic)	Oil Pipeline	Distance to Coastline (m)
50000	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	7645
50000	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	4260
	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	[illegible]
	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	[illegible]
	FALSE	FALSE	TRUE	FALSE	TRUE	TRUE	FALSE	FALSE	[illegible]
50000	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	85107
50000	FALSE	FALSE	TRUE	FALSE	TRUE	TRUE	FALSE	FALSE	1960
50000	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	2264
50000	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	3852

● Example-Sheet1：Bridge List (2)

Densely Inhabited Districts	Connectivity to Important Facilities	Difficulty in Restoration	Bridge Piers in Water in Need of Cofferdam	Access to Isolated Villages / Towns	Detour (Additional Period of Time)	Strategically Important Route	Geometry, Clearance	Design Loading	Nature of Bridge	Year-Round Mobility	History of Disaster
FALSE	No Connec	Space for T	FALSE	FALSE	0 – 29 Min	FALSE	Meet the R	Meet Desig	Permanent	No inundat	No disaster
FALSE	No Connec	Space for T	FALSE	TRUE	0 – 29 Min	FALSE	Meet the R	Meet Desig	Permanent	No inundat	No disaster
[illegible]	No Connec	Space for T	FALSE	FALSE	0 – 29 Min	FALSE	Meet the R	Meet Desig	Permanent	No inundat	[illegible]
[illegible]	No Connec	Space for T	FALSE	FALSE	0 – 29 Min	FALSE	Meet the R	Meet Desig	Permanent	No inundat	No disaster
FALSE	No Connec	Space for T	FALSE	FALSE	0 – 29 Min	FALSE	Meet the R	Meet Desig	Permanent	No inundat	No disaster
FALSE	No Connec	Space for T	FALSE	FALSE	0 – 29 Min	FALSE	Meet the R	Meet Desig	Permanent	No inundat	No disaster
FALSE	No Connec	Space for T	FALSE	FALSE	0 – 29 Min	FALSE	Meet the R	Meet Desig	Permanent	No inundat	No disaster
FALSE	No Connec	Space for T	FALSE	FALSE	0 – 29 Min	FALSE	Meet the R	Meet Desig	Permanent	No inundat	No disaster

Span length is more than 25m	Bridge length is more than 50m	Traffic Characteristics	Disturbance to Water Flow at Flood Times	Road Width Condition	Health Index of Bridge	Soundness Classification of Bridge	Importance Index	Functionally Obsolute Index	FO Classification
FALSE	FALSE	50,000–	Single Spar	Not satisfy			16.6	16	A'
FALSE	FALSE	50,000–	3 or More S	Satisfy Ker	59.3	B	20.4	0	A'
TRUE	TRUE	0–499	3 or More S	Satisfy Ker			13.4	0	A'
FALSE	FALSE	0–499	3 or More S	Satisfy Ker	0	D	3.8	0	A'
FALSE	FALSE	0–499	3 or More S	Satisfy Ker			7.6	0	A'
FALSE	FALSE	50,000–	2 Spans	Not satisfy			15.9	16	A'
FALSE	FALSE	50,000–	Single Spar	Satisfy Ker	56.5	B	24.2	0	A'
FALSE	FALSE	50,000–	3 or More S	Satisfy Ker	61.1	B	28.1	0	A'

● Example-Sheet2 : Importance Indices

Bridge ID	Bridge No.		Name of Bridge	Importance Index	Value of Importance of Providing Access					Value of Importance of Providing Mobility				Value of Third Party Effects			
	km	No.			Total	Value of Densely Inhabited Districts	Value of Connectivity to Important Facilities	Value of Difficulty in Restoration	Value of Access to Isolated Villages / Towns	Total	Value of Traffic Characteristics	Value of Detour (Additional Period of Time)	Value of Strategically Important Route	Total	Value of Crossings	Value of Utilities Attached	Value of Disturbance to Water Flow at Flood Times
1397	9	1	Horakandav	48.5	12.8	0	0	15	25	7.6	28	0	0	28.1	50	18.5	0
884	1	1		46.2	17.6	0	0	30	25	12	28	16.5	0	16.6	0	18.5	22
228	2	2		45.9	12.8	0	0	15	25	16.5	28	33	0	16.6	0	18.5	22
100	14	2		44	12.8	0	0	15	25	14.6	21	33	0	16.6	0	18.5	22
795	28	3		44	12.8	0	0	15	[illegible]	14.6	21	33	0	16.6	0	18.5	22
801	14	1	BRIDWELL	44	12.8	0	0	15	[illegible]	14.6	21	33	0	16.6	0	18.5	22
1342	1	1		44	12.8	0	0	15	25	14.6	21	33	0	16.6	0	18.5	22
1364	4	4		44	12.8	0	0	15	25	14.6	21	33	0	16.6	0	18.5	22
529	3	2		43.4	9.6	0	0	30	0	5.7	21	0	0	28.1	50	18.5	0
208	16	2		42.1	12.8	0	0	15	25	16.5	28	33	0	12.8	0	9.2	22
233	19	2		41.4	12.8	0	0	15	25	12	28	16.5	0	16.6	0	18.5	22
1398	4	3		41.4	12.8	0	0	15	25	12	28	16.5	0	16.6	0	18.5	22
1399	6	2		41.4	12.8	0	0	15	25	12	28	16.5	0	16.6	0	18.5	22

● Example-Sheet3 : Functionally Obsolete Indices

Bridge ID	Bridge No.		Name of Bridge	Functionally Obsolute Index	FO Classification	Value of Structural Details				Value of Nature of Bridge	Value of Resistance to Disaster		
	km	No.				Total	Value of Bridge Width	Value of Geometry, Clearance	Value of Design Loading		Total	Value of Year-Round Mobility	Value of History of Disaster
1	52	1	Maggona B	16	A'	16	40	0	0	0	0	0	0
2	32	2	Attanagalu	16	A'	16	40	0	0	0	0	0	0
4	20	1	DIGAROLL	16	A'	16	40	0	0	0	0	0	0
5	38	1		16	A'	16	40	0	0	0	0	0	0
7	8	1		16	A'	16	40	0	0	0	0	0	0
8	31	1		16	A'	16	40	0	0	0	0	0	0
9	36	4		16	A'	16	40	0	0	0	0	0	0
10	36	5		16	A'	16	40	0	0	0	0	0	0
11	34	4		16	A'	16	40	0	0	0	0	0	0
12	35	3		16	A'	16	40	0	0	0	0	0	0
13	42	1	KALUAGG	16	A'	16	40	0	0	0	0	0	0
14	37	2		16	A'	16	40	0	0	0	0	0	0
15	37	3		16	A'	16	40	0	0	0	0	0	0
16	38	1	Tunnana B	16	A'	16	40	0	0	0	0	0	0
17	54	2		16	A'	16	40	0	0	0	0	0	0
18	49	1		16	A'	16	40	0	0	0	0	0	0
19	59	5		16	A'	16	40	0	0	0	0	0	0
20	50	7		16	A'	16	40	0	0	0	0	0	0
22	60	2		16	A'	16	40	0	0	0	0	0	0
23	8	1		16	A'	16	40	0	0	0	0	0	0
24	53	3		16	A'	16	40	0	0	0	0	0	0
25	4	1		16	A'	16	40	0	0	0	0	0	0
26	9	3	Pattilla Bri	16	A'	16	40	0	0	0	0	0	0

● Example-Sheet4 : Soundness Classification

Bridge ID	Bridge No.		Name of Bridge	Soundness Classification of Bridge	Soundness Classification of Surface					Soundness Classification Suprestructure							Soundness Classification Bridge Bearing	Soundness Classification of Sub
	km	No.			Entire	Pavement	Expansion Joint	Accessrories	Approaches	Entire	Main Beam	Deck Slab	Diaphragm	Cross Beam	Rib	Spandrel		
100	14	2		D	A	A	A	A	A	A	A	A	A	A	A	A	A	D
801	14	1	BRIDWELL	D	A	A	A	A	A	C	A	C	A	A	A	A	A	C
296	17	1		D	C	D	A	A	A	D	D	D	A	A	A	A	B	A
120	4	2	Nuga Ela B	D	A	A	A	A	A	B	A	B	A	A	A	A	A	D
797	2	1		D	A	A	A	A	A	A	A	A	A	A	A	A	A	D
823	19	1	Dandugam	D	C	D	A	A	A	A	A	A	A	A	A	A	B	C
1024	11	5		D	D	D	D	A	A	C	C	A	A	A	A	A	A	A
24	53	3		D	C	A	B	A	A	A	A	A	A	A	A	A	B	D
262	3	3		D	A	A	A	A	A	B	A	B	A	A	A	A	A	D
104	8	1		D	A	A	A	A	A	B	A	B	A	A	A	A	A	D
535	62	2	Benthara B	D	B	B	A	A	A	D	D	A	A	D	A	A	A	A
51	12	1		D	A	A	A	A	A	B	A	B	A	A	A	A	A	D
1230	1	7		D	B	B	A	A	A	D	D	A	A	D	A	A	A	A
90	1	5		D	D	A	D	A	C	A	A	A	A	A	A	A	A	C
167	10	1	Udugama B	D	D	C	D	A	A	A	A	A	A	A	A	A	A	B
248	8	1		D	B	C	A	A	A	D	D	A	A	A	A	A	A	A
800	8	2		D	A	A	A	A	A	C	A	C	A	A	A	A	A	D
933	11	3	Medagamol	D	B	A	A	A	A	D	D	A	A	A	A	A	A	B
554	225	6		D	A	A	A	A	A	A	A	A	A	A	A	A	A	D
951	5	3		D	A	A	A	A	A	B	A	A	A	A	B	A	A	C
1282	1	2		D	B	B	A	A	A	D	D	A	A	D	A	A	A	A
1302	8	3		D	A	A	A	A	A	A	A	A	A	A	A	A	A	D
958	8	2		D	A	A	A	A	A	A	A	A	A	A	A	A	A	D
1204	1	7		D	A	A	A	A	A	D	D	A	A	A	A	A	A	A
1261	12	1	Kalupalama	D	A	A	A	A	A	D	D	A	A	A	A	A	A	A
496	1	4		D	A	B	A	A	A	D	D	D	A	A	A	A	A	A
434	10	5	Talathuoya	D	A	A	A	A	A	D	D	A	A	D	A	A	A	A
546	224	2		D	A	A	A	A	A	A	A	A	A	A	A	A	A	D

Repair Priority Point = α x (100 – HI) + β x II

● Example-Sheet5 : Bridge Repair & Maintenance Plan

Priority of Bridge Repair	Bridge ID	Bridge No.		Name of Bridge	Health Index of Bridge	Soundness Classification of Bridge	Importance Index	Repair Priority Point	Repair Cost (Unit: 1,000 SL Rupee)				
		km	No.						Bridge	Bridge Surface	Superstructure	Bridge Bearing	Substructure
1	100	14	2		0.0	D	44	83.2	210.1	1.4	76.5	0	132.2
2	801	14	1	BRIDWELL	0.0	D	44	83.2	405	1	315.8	0	88.2
3	296	17	1		0.0	D	37.6	81.3	823.8	17.4	573.9	226.9	5.6
4	120	4	2	Nuga Ela B	0.0	D	37	81.1	521.1	0.4	294	0	226.7
5	797	2	1		0.0	D	35.1	80.5	200.6	0	0	0	200.6
6	823	19	1	Dandugam	0.0	D	34.1	80.2	3664.1	376.6	0	2531.6	755.9
7	1024	11	5		0.0	D	29.3	78.8	299	42	169.3	87.7	0
8	24	53	3		0.0	D	28.6	78.6	1349.4	51.5	19.5	440.5	837.9
9	262	3	3		0.0	D	28.4	78.5	354.6	0.5	178.1	50.4	125.6
10	104	8	1		0.0	D	28.1	78.4	577.6	7.6	345.2	0	224.8
161	1167	4	5		25.4	D	14.7	56.6	188.3	5.5	182.8	0	0
162	1426	23	9		24.0	D	9.5	56.1	557.4	5.4	76	286.6	189.4
163	1254	1	2		25.3	D	7.6	54.6	128.8	15.2	0	12.2	101.4
164	443	92	12		25.3	D	3.8	53.4	268.2	36.9	0	0	231.3
165	208	16	2		25.8	C	42.1	64.6	247.1	41.5	0	127.3	78.3
166	743	32	3		26.8	C	29	59.9	109.1	6.1	0	0	103
167	1309	1	5	Galmulle Bi	27.5	C	27.7	59.1	259.4	6.2	247.7	0	5.5
168	668	61	5		28.0	C	27.4	58.6	365.2	0	365.2	0	0
169	508	1	1		26.3	C	22.3	58.3	717.1	0.7	680.8	0	35.6
170	226	7	6		25.7	C	20.4	58.1	158.1	6.7	138.5	0	12.9
171	1402	2	2		27.5	C	24.2	58	170.3	0	28.3	0	142
287	1295	42	3		50.0	C	14.7	39.4	52.3	0	0	0	52.3
288	1028	6	4		46.5	C	5.7	39.2	221.6	29.5	8.2	180.7	3.2
289	1140	58	1		49.0	C	11.4	39.1	1245.4	0	744.6	500.8	0
290	66	13	1		48.7	C	7.6	38.2	49.1	0	0	0	49.1
291	47	34	4		49.9	C	5.7	36.8	897.6	124.8	0	764.2	8.6
292	1398	4	3		52.9	B	41.4	45.4	813.8	41.5	661.3	78.8	32.2
293	859	2	1	Palam Thu	50.9	B	29.4	43.2	1002	87.4	78.5	718.5	117.6
294	835	2	1		51.1	B	29	42.9	399.9	41.9	0	342.1	15.9
295	328	2	2	GALA JUN	51.3	B	29	42.8	81.5	21.2	25.9	0	34.4
296	1364	4	4		58.7	B	44	42.1	272.2	20.5	0	226.9	24.8
297	335	1	5		51.0	B	25.5	42	426	59.8	0	366.2	0

● Example-Sheet6：Bridge Reconstruction Plan

Bridge ID	Bridge No.		Name of Bridge	Health Index of Bridge	Soundness Classification of Bridge	Importance Index	Functionally Obsolute Index	FO Classification	Reconstruction Priority Point	Priority of Bridge Reconstruction	Reconstruction Cost	Repair Priority Point	Repair Cost of Bridge
	km	No.											
100	14	2		0.0	D	44.0	16.0	A'	38.4	1	5,852	83.2	210
296	17	1		0.0	D	37.6	16.0	A'	37.1	2	3,574	81.3	824
120	4	2	Nuga Ela B	0.0	D	37.0	16.0	A'	37.0	3	6,747	81.1	521
797	2	1		0.0	D	35.1	16.0	A'	36.6	4	5,016	80.5	201
823	19	1	Dandugam	0.0	D	34.1	16.0	A'	36.4	5	470,728	80.2	3,664
24	53	3		0.0	D	28.6	16.0	A'	35.3	6	65,527	78.6	1,349
262	3	3		0.0	D	28.4	16.0	A'	35.3	7	4,953	78.5	355
104	8	1		0.0	D	28.1	16.0	A'	35.2	8	5,620	78.4	578
535	62	2	Benthara B	0.0	D	28.1	16.0	A'	35.2	9	111,007	78.4	10,656
51	12	1		0.0	D	25.2	16.0	A'	34.6	10	7,644	77.6	604
1230	1	7		0.0	D	24.3	16.0	A'	34.5	11	69,877	77.3	8,290
90	1	5		0.0	D	23.3	16.0	A'	34.3	12	5,242	77.0	138
248	8	1		0.0	D	23.3	16.0	A'	34.3	13	7,900	77.0	1,006
933	11	3	Medagampi	0.0	D	23.3	16.0	A'	34.3	14	6,026	77.0	799
1330	4	6		4.5	D	27.7	16.0	A'	34.2	15	22,698	75.2	376
1282	1	2		0.0	D	22.3	16.0	A'	34.1	16	23,464	76.7	2,774
233	19	2		19.2	D	41.4	16.0	A'	34.0	17	8,470	69.0	240
228	2	2		24.6	D	45.9	16.0	A'	33.9	18	6,970	66.6	119
8	31	1		12.9	D	33.7	16.0	A'	33.8	19	60,140	71.1	717
1302	8	3		0.0	D	21.0	16.0	A'	33.8	20	18,571	76.3	125
801	14	1	BRIDWELL	0.0	D	44.0	8.0	A'	33.6	21	4,752	83.2	405
496	1	4		0.0	D	19.5	16.0	A'	33.5	22	3,036	75.9	496
434	10	5	Talathuoya	0.0	D	18.5	16.0	A'	33.3	23	31,626	75.6	3,710
690	19	1		0.0	D	18.5	16.0	A'	33.3	24	3,689	75.6	375
803	25	6		0.0	D	18.5	16.0	A'	33.3	25	5,544	75.6	394
891	4	11		0.0	D	18.5	16.0	A'	33.3	26	2,869	75.6	372
893	5	7		0.0	D	18.5	16.0	A'	33.3	27	18,371	75.6	989
208	16	2		25.8	C	42.1	16.0	A'	32.9	28	6,336	64.6	247

$$\text{Reconstruction Priority Point} = \alpha' \times (100 - HI) + \beta' \times II + \gamma' \times FOI$$

WS-6

Work Shop Agenda

28th September, 2017

9AM – 11:30AM
4th Floor Conference Room RDA Head office

Topics

1. Bridge management Procedure (45 mon.)
   Discussion

2. Bridge Diagnosis & Emergency Action (30 min.)
   Discussion

Bridge Management Procedure

THE PROJECT
FOR CAPACITY DEVELOPMENT
ON BRIDGE MANAGEMENT

Contents

1. Outline of Bridge Management

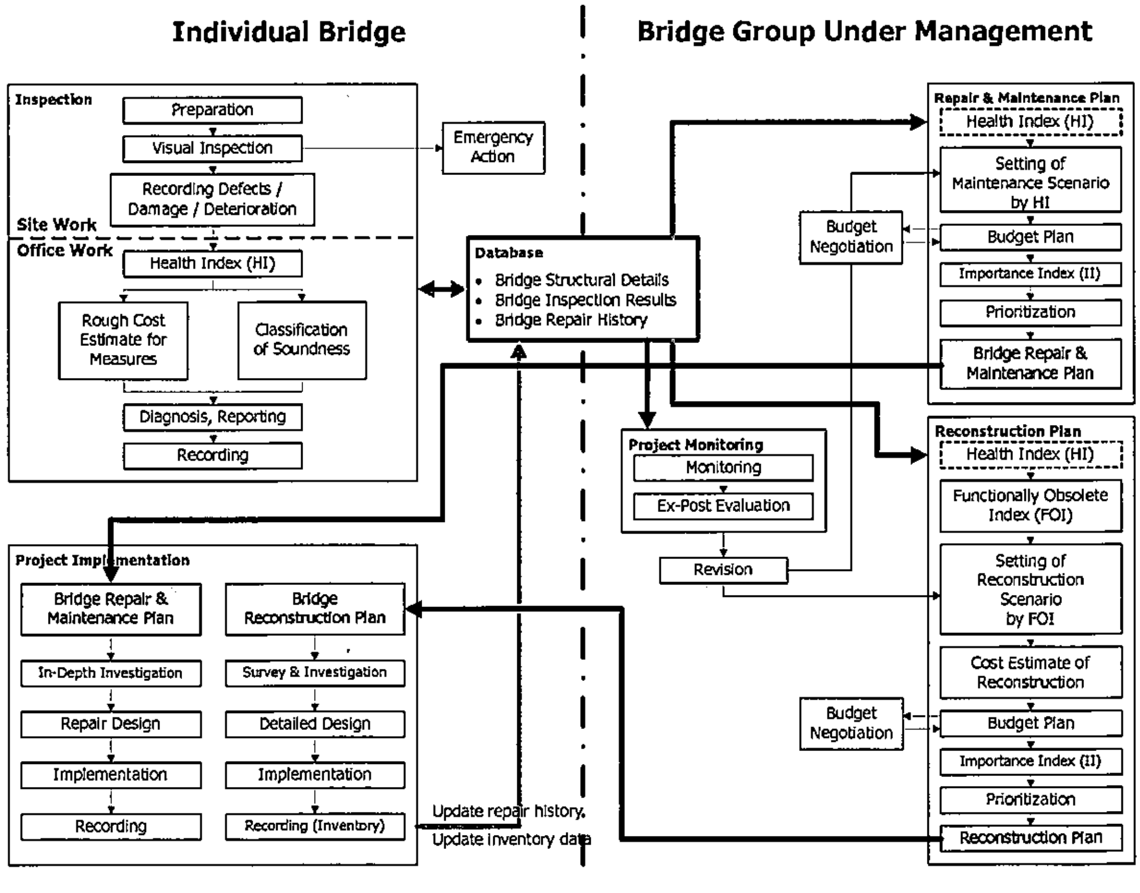
1-1. Structure of Bridge Management

- ☐ Each process does not work individually.
  Periodic inspection results link with emergency actions, in-depth investigation, repair & maintenance and reconstruction planning
- ☐ During the procedure, it is necessary to accumulate the required information for "Bridge Management".
- ☐ Repeating the management cycle enables to grasp the damage progress and re-evaluate the repair methods

- ✓ Bridge inspection will be carried out to understand the present condition of individual bridge.
- ✓ After the condition of the bridge is evaluated,
  - "Bridge Repair & Maintenance Plan" will be developed.
  - And, based on the evaluation of conditions and degree of functional obsolescence of the bridge, "Bridge Reconstruction Plan" will be developed.
- ✓ After repair & maintenance and reconstruction, ex-post evaluation should be conducted.

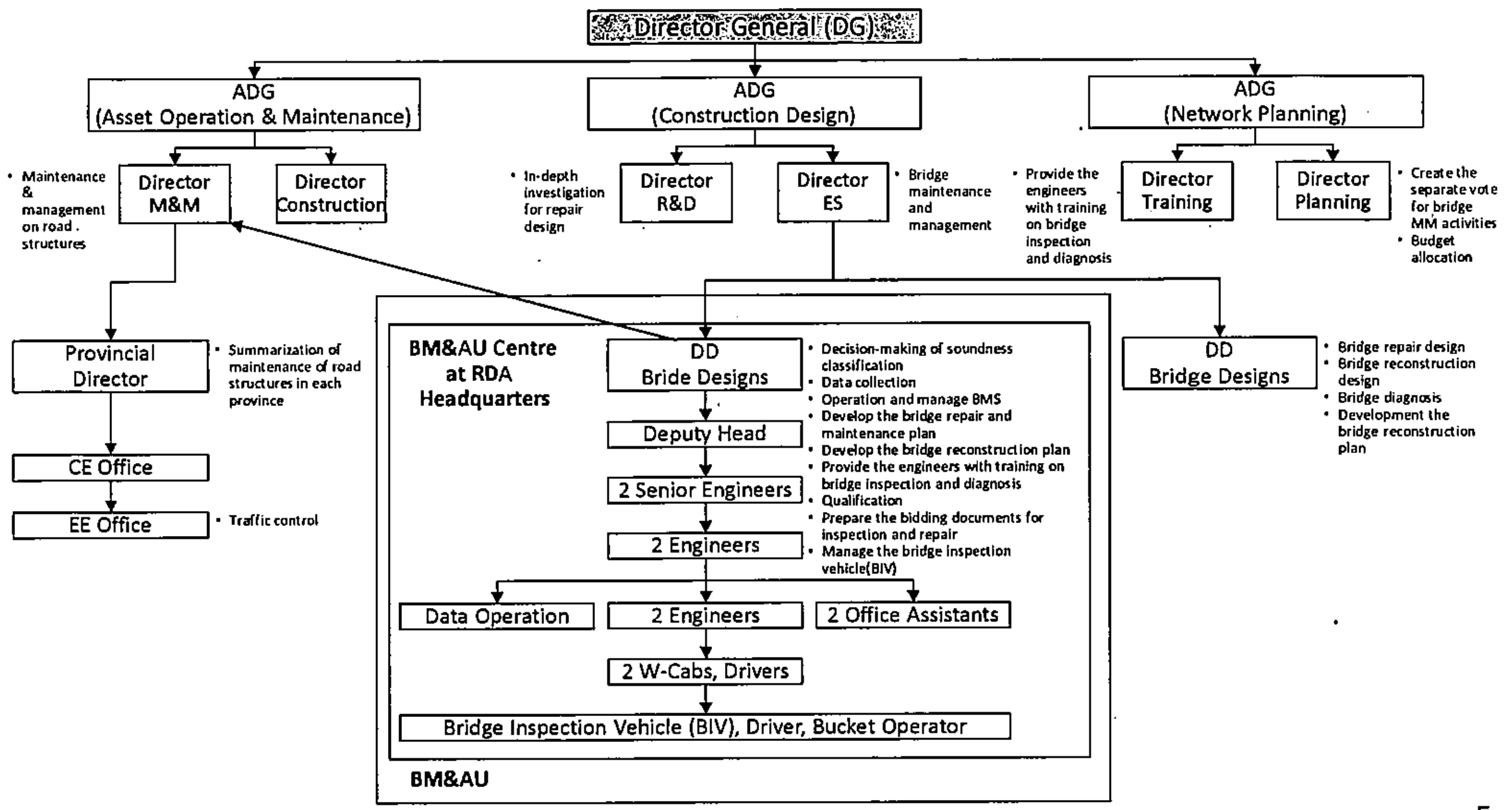
1. Outline of Bridge Management

1-1. Structure of Bridge Management



1. Outline of Bridge Management

1-2. Institutional Framework, Roles & Responsibility



1. Outline of Bridge Management

1-2. Institutional Framework, Roles & Responsibility

Division (Position)	Role and Responsibility
ADG CD	**Generalization of Bridge Management** • Confirmation of Periodic Inspection Plan • Confirmation of Emergency Action • Confirmation of Soundness Classification • Confirmation of Bridge Repair & Maintenance Scenario, Budget Plan and Bridge Repair & Maintenance Plan • Confirmation of Bridge Reconstruction Scenario, Budget Plan and Bridge Reconstruction Plan
Director, Engineering Service	• Approval of Periodic Inspection Plan • Approval of Emergency Action • Decision of Soundness Classification • Finalization of Bridge Repair & Maintenance Scenario, Budget Plan and Bridge Repair & Maintenance Plan • Finalization of Bridge Reconstruction Scenario, Budget Plan and Bridge Reconstruction Plan
Director, R&D	• In-depth Investigation for Repair Design
Director, Planning	• Preparation of Bridge Repair & Maintenance Scenario, Budget Plan and Bridge Repair & Maintenance Plan • Preparation of Bridge Reconstruction Scenario, Budget Plan / Bridge Reconstruction Plan • Budget Allocation

1. Outline of Bridge Management

1-2. Institutional Framework, Roles & Responsibility

Division (Position)	Role and Responsibility
Director M&M	• Responsible for Maintenance & Management of Road Structures
Director Training	• Provide the Engineers with Training on Bridge Management and Maintenance
BM&AU	
Head (Deputy Director)	• Finalization of Periodic Inspection Plan • Final Draft of Soundness Classification • Formulation of Bridge Repair & Maintenance Scenario, Budget Plan, and Development of Bridge Repair & Maintenance Plan • Formulation of Bridge Reconstruction Scenario, Budget Plan, and Development of Bridge Reconstruction Plan
Member of BM&AU Centre	• Formulation of Periodic Inspection Plan (Nation Wide) • System Operation
Member at PD Offices	• Preparation of Periodic Inspection Plan (for Each Province) • Date Entry of Periodic Inspection • Review of Soundness Classification
Provincial Director	• Approval of Emergency Action • Approval of Entered Data
EE Offices	• Assistance of Periodic Inspection • Development of Tender Document • Supervisor of Bridge repair (as needed)

1. Outline of Bridge Management

1-3. Process Schedule

- ☐ Strict management of the designated schedule for Bridge Management with limited management resource----Milestone of Management, Inspection are as follows
- ☐ Milestone of Management
  - Planning of repair & maintenance and reconstruction
  - Budget negotiation
- ☐ Milestone of Inspection
  - Planning of periodic inspection plan in the beginning of fiscal year
  - Periodic inspection by the end of fiscal year

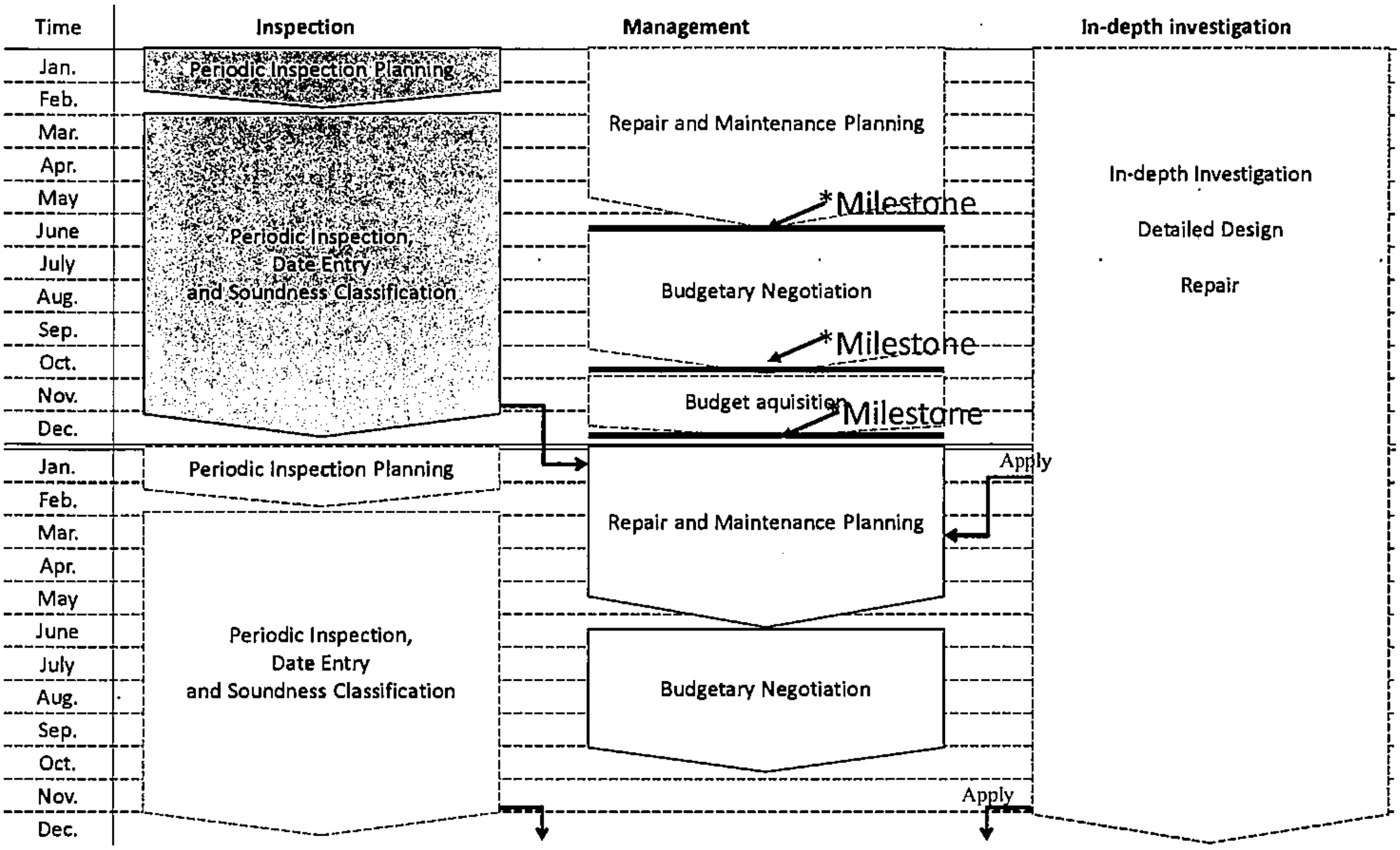
> In case that damage in need of immediate and major repair is detected during the periodic/routine inspection
>
> - Implementation the measure within fiscal budget
> - Development the other budget plan for the measure if the additional budget is needed

Planning of repair & maintenance and reconstruction within budget acquisition

- Next years budget plan is developed based on detailed design cost from periodic inspection results.

1. Outline of Bridge Management

1-3. Process Schedule



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1. Outline of Bridge Management

1-4. Rerated Manual

- Bridge Management Guidelines
  - Bridge Management Procedure Manual
    - Bridge Inventory Development Manual
    - Bridge Inspection & Diagnosis Manual
    - Bridge Repair Manual
    - Bridge Database System (BDS) User's Manual (for Administration)
    - Bridge Repair & Maintenance System (BRMS) User's Manual
    - Bridge Inspection Support System User's Manual

2. Periodic Inspection

2-1. Preparation of Periodic Inspection

✓ Items to be included in Periodic Inspection Plan

Item	Detail
Target Bridge List	• The number of target bridges in each year should be equal • Target bridges which couldn't be inspected in the past years must be included in the Plan
Target Bridge Inventory	• Overview of the target bridges (inventory, disaster history, repair history) • Confirmation of the inspection route and equipment location
Implementation Structure	• Allocation of the inspectors/staff for both on-site and in-office work should be clarified
Inspection Process	• Verification if there is traffic restrictions or the scaffolding settings due to repair work during periodic inspection, or not - Re-schedule of periodic inspection in/out the repair work period. • In case that periodic inspection is conducted at the same time with other maintenance or construction work - Some safety measures such as avoiding the construction site and allocating the safety supervisor - It could lead to the overall efficiency of Bridge Management by reducing overlapping cost for traffic restriction and scaffolding

2. Periodic Inspection

2-1. Preparation of Periodic Inspection

✓ Items to be included in Periodic Inspection Plan

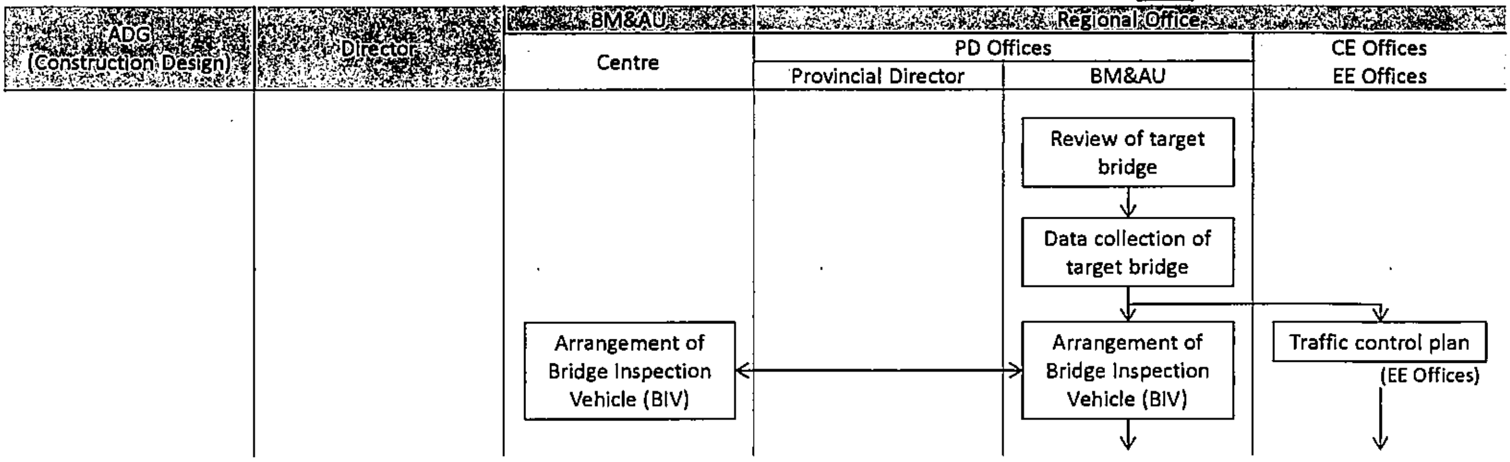
<table>
<tr><th>Item</th><th>Detail</th></tr>
<tr><td>Employed Equipment</td><td>• List of the required equipment (BIV, Traffic control tools, Boat)
• Alternate procedures for the inspection sites where visual inspection cannot be conducted
<table>
<tr><th>Location</th><th>Reasons</th><th>Countermeasures</th></tr>
<tr><td>High Bridge Pier</td><td>Unreachable with ladders</td><td>Pole Camera
Bridge Inspection Vehicle</td></tr>
<tr><td>Overhang Part near Center Median</td><td>No space under the beam
(No space between the bridge bottom and the roads, railways, rivers below the bridge)</td><td>Temporary closure of the roads and railways below the bridge
Pole camera
Boat</td></tr>
</table></td></tr>
<tr><td>Emergency Contact System</td><td>• Emergency contact list for accidents such as falling from the bridge, traffic accidents during inspection and the damage on bridge accessories
- BM&AU Centre, ambulance, fire department and each infrastructure</td></tr>
<tr><td>Safety Measures</td><td>• List of personal protective equipment (PPE) and the equipment needed for traffic restriction</td></tr>
<tr><td>Related Organizations</td><td>• List of the related organizations who manage the roads, railways and rivers under/along target bridges.</td></tr>
</table>

2. Periodic Inspection

2-1. Preparation of Periodic Inspection

: Planner or Applicant or Executor

: Decision maker or Approver



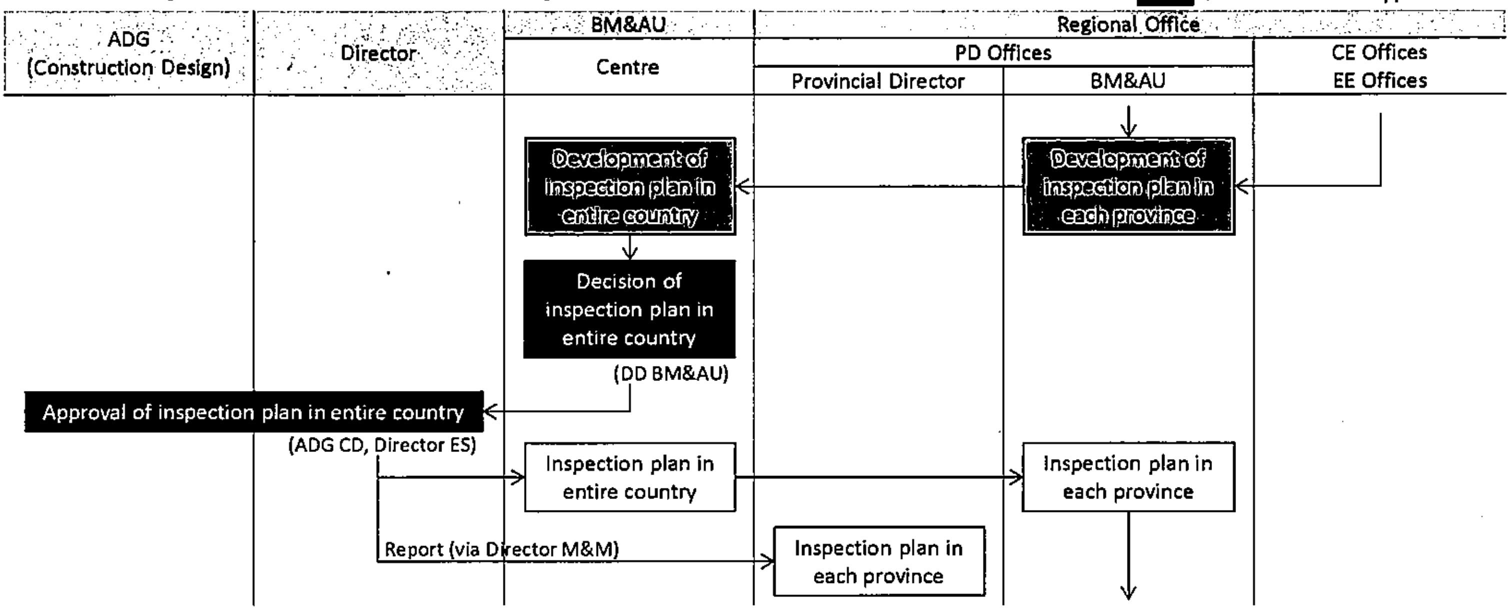
- Selection of Target Bridge
  - BM&AU at PD Offices organize a list of target bridges.
- Data Collection of Target Bridge data (Inventory, Inspection)
  - BM&AU at PD Offices is collecting the necessary data of the target bridges. The fieled survey and maps should be utilized as needed.
- Traffic Control Plan
  - EE Office must be in charge of planning of traffic control methods as needed.
- Arrangement of BIV, Equipment and Tools
  - BM&AU at PD Offices coordinate with BM& AU Centre. BM&AU Centre understand the planned use of BIV in each province, and notify operation schedule of BIV to each province after determination

2. Periodic Inspection

2-1. Preparation of Periodic Inspection

: Planner or Applicant or Executor

: Decision maker or Approver



- Development of Periodic Inspection Plan
  - BM&AU at PD Offices shall formulate Periodic Inspection Plan including the items in described here. BM&AU Centre puts inspection plans together as a nationwide Periodic Inspection Plan and reports it to Director ES. Director ES makes a decision on Periodic Inspection Plan.
  - After completion of the Inspection Plan, BM&AU at PD Offices is notified. In addition, Provincial Director should receive a report on Periodic Inspection Plan from Director M&M.

2. Periodic Inspection

2-2. Periodic Inspection (Site Work)

✓ Important Matters

Item	Detail
Preparation for Inspection	• Items available on the day of visual inspection are the following: - Information such as the inventory of target bridges, past inspection records, if any - Equipment necessary for visual inspection, and personal protective equipment (PPE) - Designated Inspection Record Forms from Bridge Inspection Support System - Written permit for traffic restriction - Bridge Inspection Vehicle (BIV)
Visual Inspection	• Periodic inspection is conducted primarily by visual inspection. Hammering inspection are conducted as needed.

• Grade of Damage

Grade of Damage	General Condition	
a	Sound	There is no damage on bridge member.
b	Almost Sound	Damage on bridge member is small.
c	Slight	There is a certain degree of damage on bridge member.
d	Remarkable	Damage on bridge member is remarkable.
e	Serious	Damage on bridge member is serious.

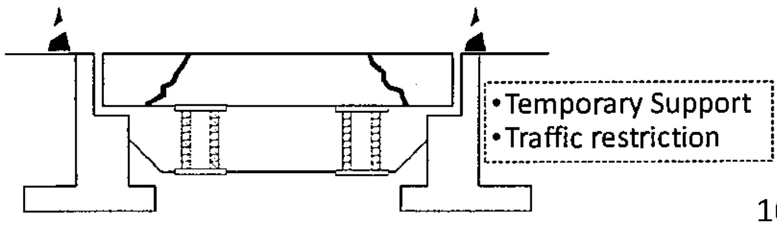
• Recording to the designated form, and taking pictures

2. Periodic Inspection

2-2. Periodic Inspection (Site Work)

✓ Important Matters

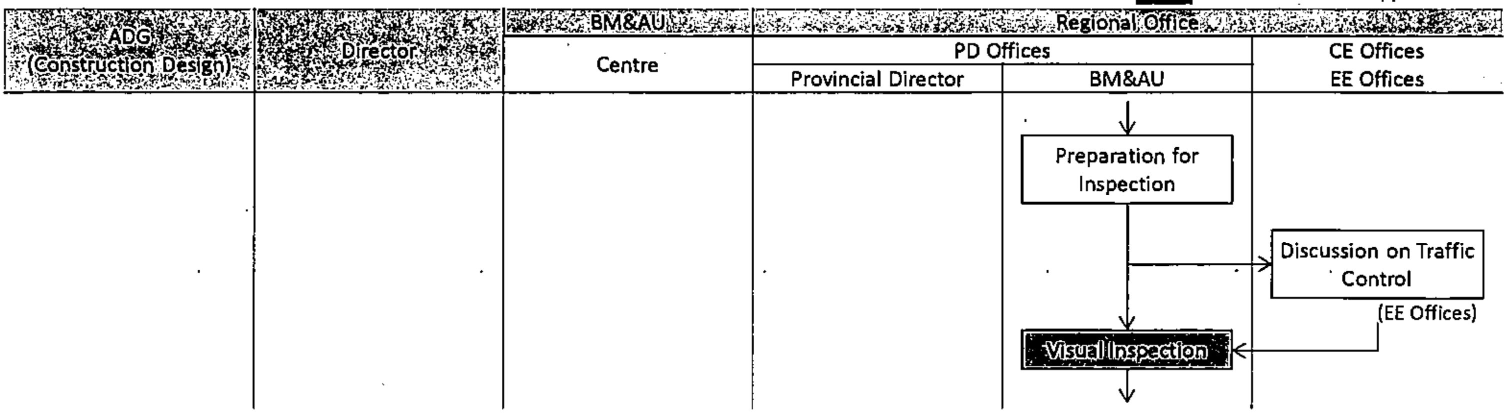
Item	Detail
Emergency Actions	• If damage in need of emergency action is detected, it shall be decided by Engineer of BM & AU and/or EE immediately during periodic inspection based on inspection results done by inspector. • To avoid the third-party effects, the measures shall be promptly implemented on site, for example, traffic restriction, knocking off the delamination and installation of the caution signboards, they should be implemented on site. • In case that the damage on the bridges under the management of RDA affects roads and railways under/along the bridges, RDA should immediately notify the matters to the relative road and railway administrators. It is necessary for RDA to require them to take appropriate actions such as roads/railways closure and installation of caution signboards.



2. Periodic Inspection

2-2. Periodic Inspection (Site Work)

: Planner or Applicant or Executor
: Decision maker or Approver

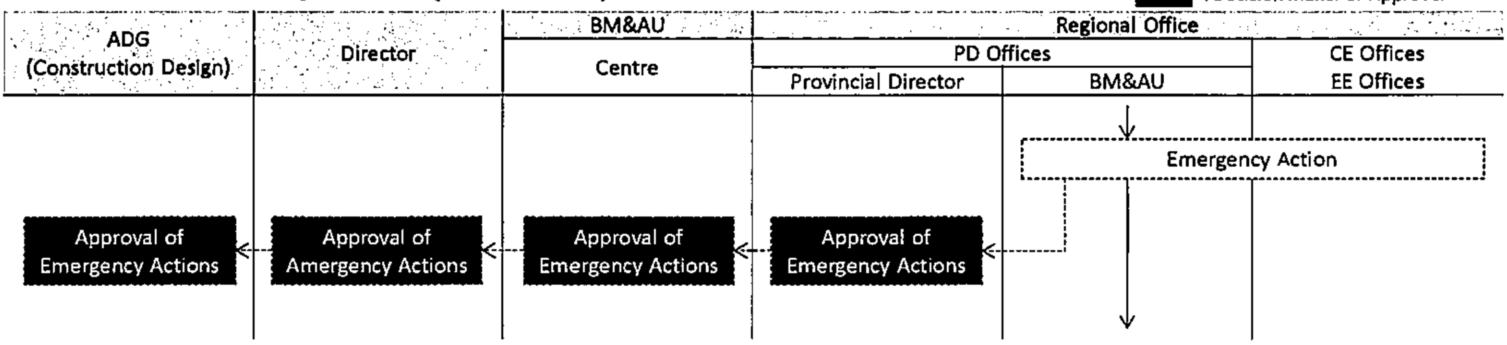


- Preparation for Inspection
  - BM&AU should understand Periodic Inspection Plan and confirm the bridge inventory, inspection route and emergency contact lists before visual inspection.
  - BM&AU at PD Offices print out the designated forms for target bridges from the System.
  - BM&AU at PD Offices arranges BIV and receives BIV from BM&AU Centre
- Discussion on Traffic Control
  - In case of traffic restriction for visual inspection. Therefore, BM&AU at PD Offices (EE Office) discuss with the Police Department.
- Visual Inspection
  - The inspectors conduct visual inspection.
  - The inspectors record the information obtained by inspection in the designated forms.

2. Periodic Inspection

2-2. Periodic Inspection (Site Work)

: Planner or Applicant or Executor
: Decision maker or Approver



- Emergency Actions
  - In case the damage in need of Emergency Actions is detected, the inspectors should implement the measures if the prompt measures are available. (i.e. tentative traffic control, knocking off the delamination)
  - Inspectors must report to BM&AU Centre and EE Office on the site conditions.
  - In the serious case, BM&AU Centre and EE Office should report to the Director ES. When the roads and railways without the management of RDA are being affected, they should inform the related administrators and request to take measures. EE Office must take over the traffic control from the inspectors and start the traffic control.

2. Periodic Inspection

2-3. Periodic Inspection (Office Work)

✓ Important Matters

Item	Detail
Data Entry to Bridge Inspection Support System	• After visual inspection, the data must be registered promptly and accurately • The incorrectly recorded data leads to inaccurate classification of the bridge soundness and calculation of the cost. • As a result, the proper bridge management would be impossible to be implemented.
Calculation of Health Index	• Health Index (HI) is calculated according to the data entered into the system in order to classify the bridge soundness and calculate the cost. • Health Index (HI) shall be calculated by each member, span and bridge based on the degree of damage on members.

2. Periodic Inspection

2-3. Periodic Inspection (Office Work)

✓ Important Matters

Item	Detail
Soundness Classification	• Bridge soundness is classified, with reference to the value of Health Index (HI).

Classification		Condition	Health Index
A	Sound	Structures are well functioning.	75 – 100
B	Preventive Maintenance Stage	Structures are will functioning. However, it is desirable to take necessary measures from the perspective of preventive maintenance.	50 – 75
C	Reactive Maintenance Stage	Functions of the structure will be possibly impaired. Necessary measures should be taken at an early stage (within 5 years)	25 – 50
D	Immediately Action Stage	Function of the structure are impaired or the possibility of impairment of functions is extremely high. Necessary measures should be taken immediately (within 2 years)	00 - 25

• Soundness classification is set up in addition to the health index. It is because it can be used for the road administrator to generally understand the condition of bridges under its management or to utilize as a convenient indicator for releasing the bridge conditions to the public.

2. Periodic Inspection

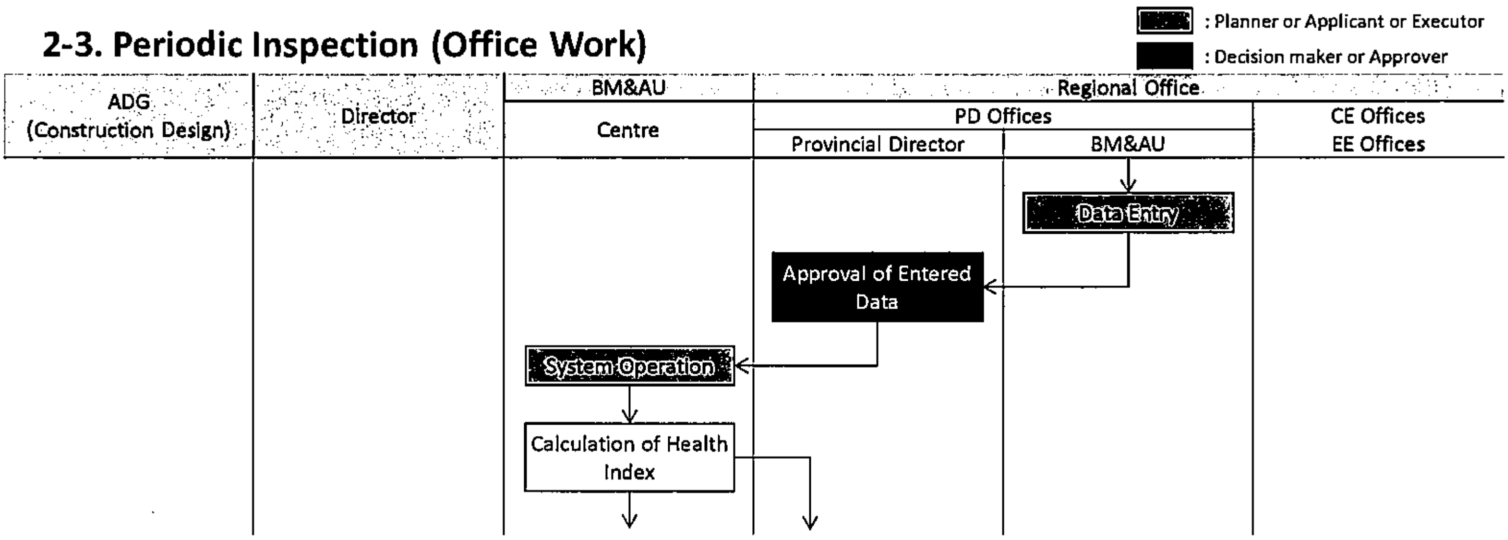
2-3. Periodic Inspection (Office Work)

✓ Important Matters

Item	Detail
Bridge Diagnosis	• Experienced experts within RDA review Soundness Classification of all Bridges at the end of Periodic Inspection. - HI does NOT consider the rate of progress of damage and the Influence of location of damage to the soundness • If the serious damage is NOT judged appropriately, the serious damage of bridges will NOT be repaired and strengthened. - Possibility of the collapse of a bridge suddenly without warning - The serious accident such as the DEAD and the INJURED. • In such case, Road Administrator (RDA) has responsibility
Estimation of Bridge Repair and Maintenance cost	• The standard repair cost shall be for the purpose of understanding the repair and maintenance budget of bridges under management and be determined based on the rates of bridge repair corresponding to the health index.

2. Periodic Inspection

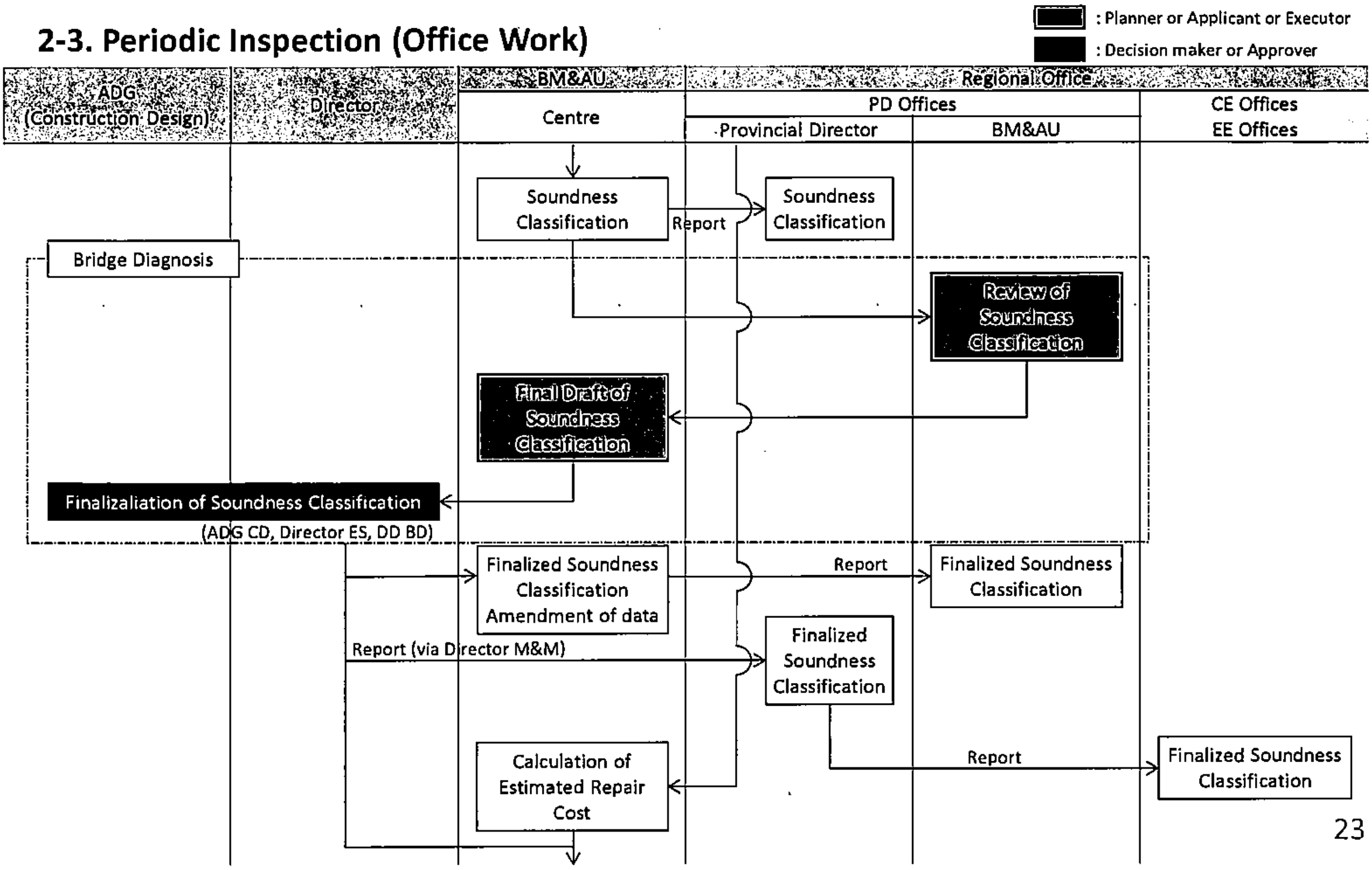
2-3. Periodic Inspection (Office Work)



- Data Entry to Bridge Inspection Support System
  - BM&AU at PD Offices inputs the inspection results into the system, and can appoint a person to perform the data entry. BM&AU at PD Offices have the responsibility of data entry.
  - The entered data needs to be approved by Provincial Director.
  - BM&AU Centre must confirm the progress of the data entry. (Notify the deadline for the data entry to BM&AU at PD Offices considering the process after the data entry)
- Calculation of Health Index (HI)
  - After the data entry, BM&AU Centre operates the system and calculates Health Index (HI).

2. Periodic Inspection

2-3. Periodic Inspection (Office Work)



2. Periodic Inspection

2-3. Periodic Inspection (Office Work)

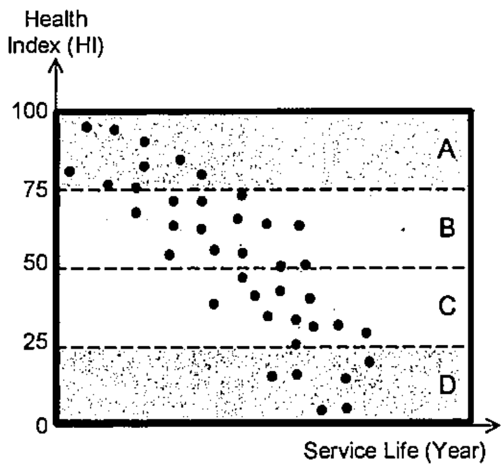
- Bridge Diagnosis
  - After receiving the Soundness Classification, BM&AU at PD Offices must conduct Bridge Diagnosis.
    Using the inspection results and pictures in the system
    Additional field investigation should be implemented as needed.
  - BM&AU Centre collects the diagnosis results from BM&AU at PD Offices and organizes them.
  - The diagnosis results should be finalized after the discussion with ADG-CD, Director ES and DD Bridge Design.
  - Finalized Bridge Soundness Classification must be reported to Provincial Director and BM&AU at PD Offices.
- Estimation of Bridge Repair and Maintenance costs (Not affected by the result of diagnosis)
  - The repair cost is utilized for the future Bridge Repair and Maintenance Plan.

3. Development of Bridge Repair & Maintenance Plan

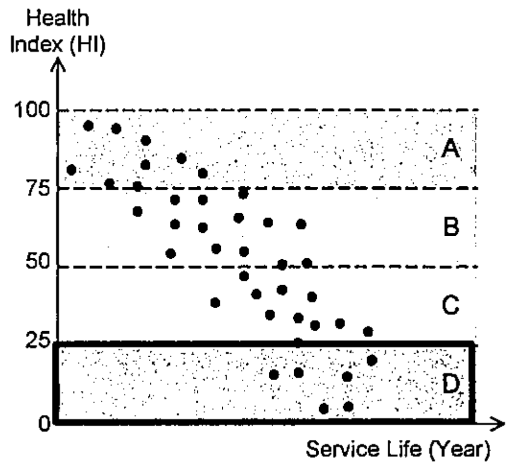
✓ Important Matters

Item	Detail

Setting of Bridge Management Scenarios	• Bridge management scenarios
	  - For Repair & Maintenance Plan feasible within the limited budget
	  - Objective scenarios
	• Repair & maintenance plan is valid for the negotiation with Ministry of Finance and the external accountability regarding the budgetary request
	• Health Index (HI) calculated objectively based on the damage degree



Large Cost



Small Cost

3. Development of Bridge Repair & Maintenance Plan

✓ Important Matters

Item	Detail

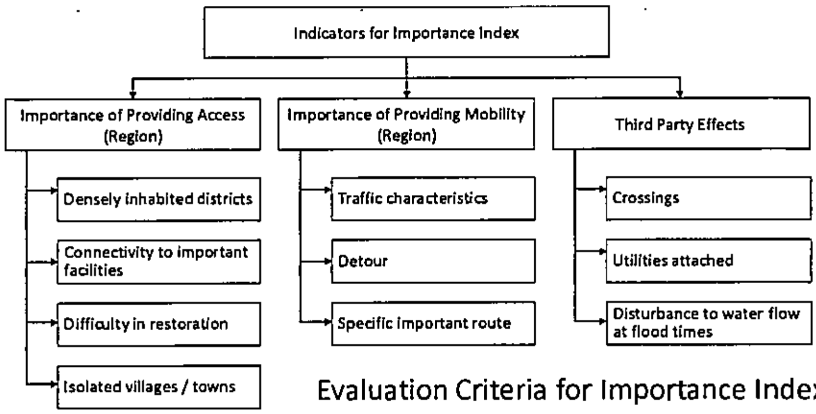
Development of Bridge Repair and Maintenance Budget Plan and Budget Negotiation	• The budget plan for the negotiation with Ministry of Finance is developed based on bridge management scenarios.
	• It is important to include the information required for the negotiation.
	  - Health Index (HI) of bridges
	  - Structures and members to repair
	  - Feasible budget and repair period
	• Repair cost is automatically calculated by the system based on HI.
	• Based on Management Scenarios, and period of repair work. Annual budget will be acquired after negotiation with Ministry of Finance.

3. Development of Bridge Repair & Maintenance Plan

✓ Important Matters

<table>
<tr><th>Item</th><th>Detail</th></tr>
<tr><td>Prioritization of Bridge Repairs and Development of Bridge Repair and Maintenance Plan</td><td>

- Based on prioritized for bridge repair and maintenance plan budgetary negotiation will be carry out.
- The prioritization of the bridges for repairs should be performed based on Health Index (HI) and Importance Index (II).



Evaluation Criteria for Importance Index

- Confirmation
  - Bridges in Soundness Classification "D" are prioritized

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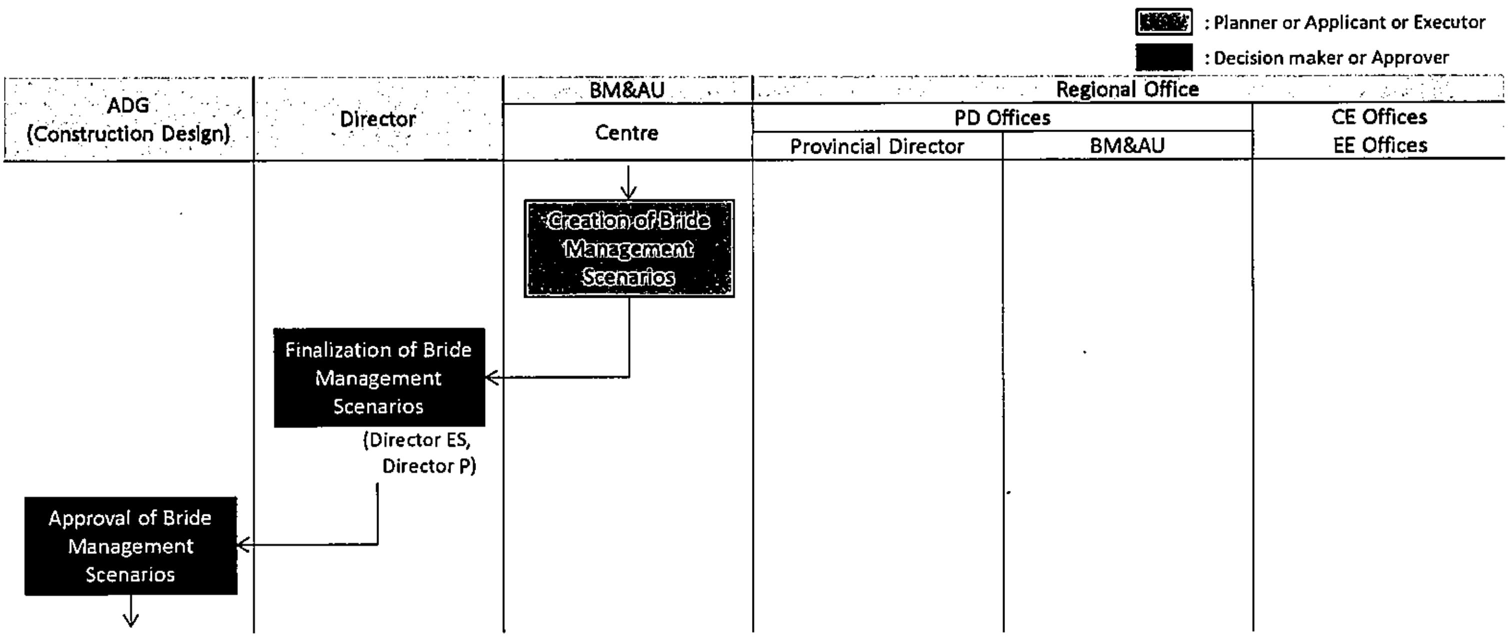
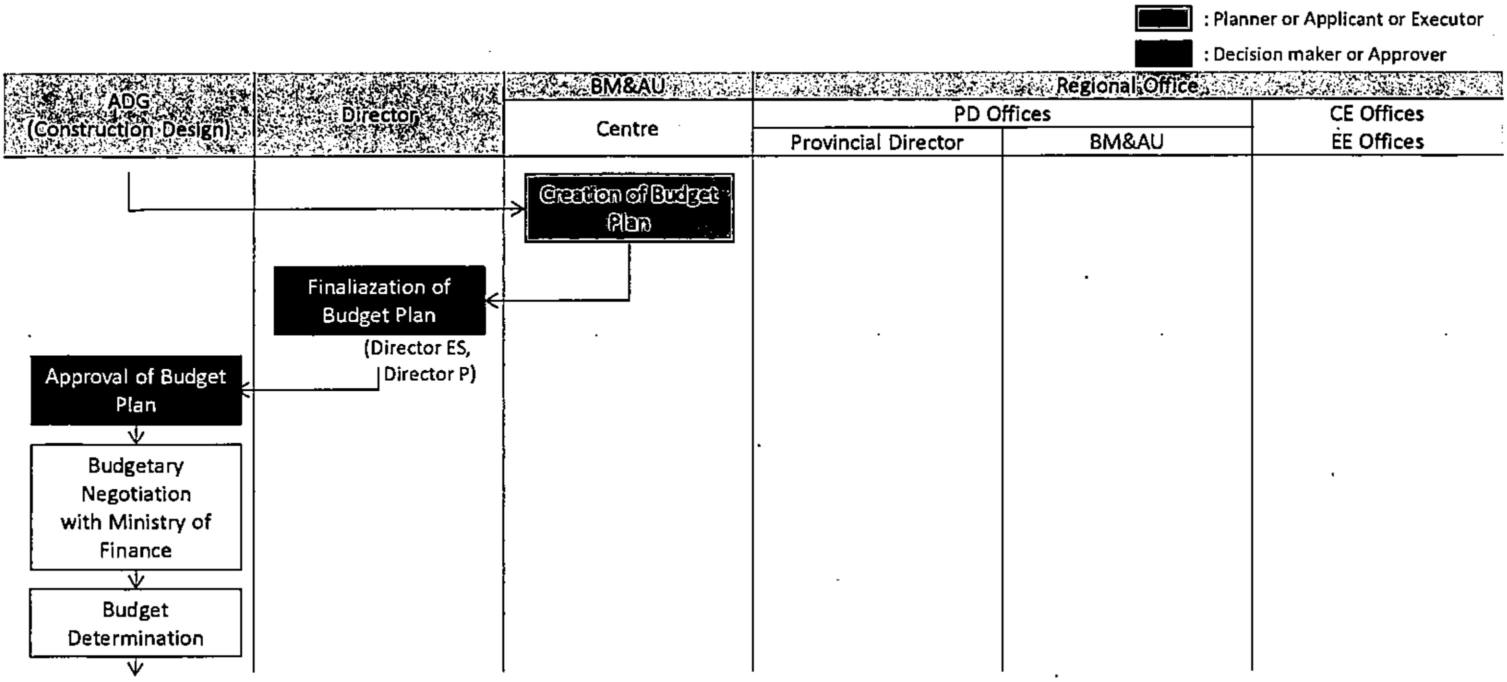
</table>

3. Development of Bridge Repair & Maintenance Plan



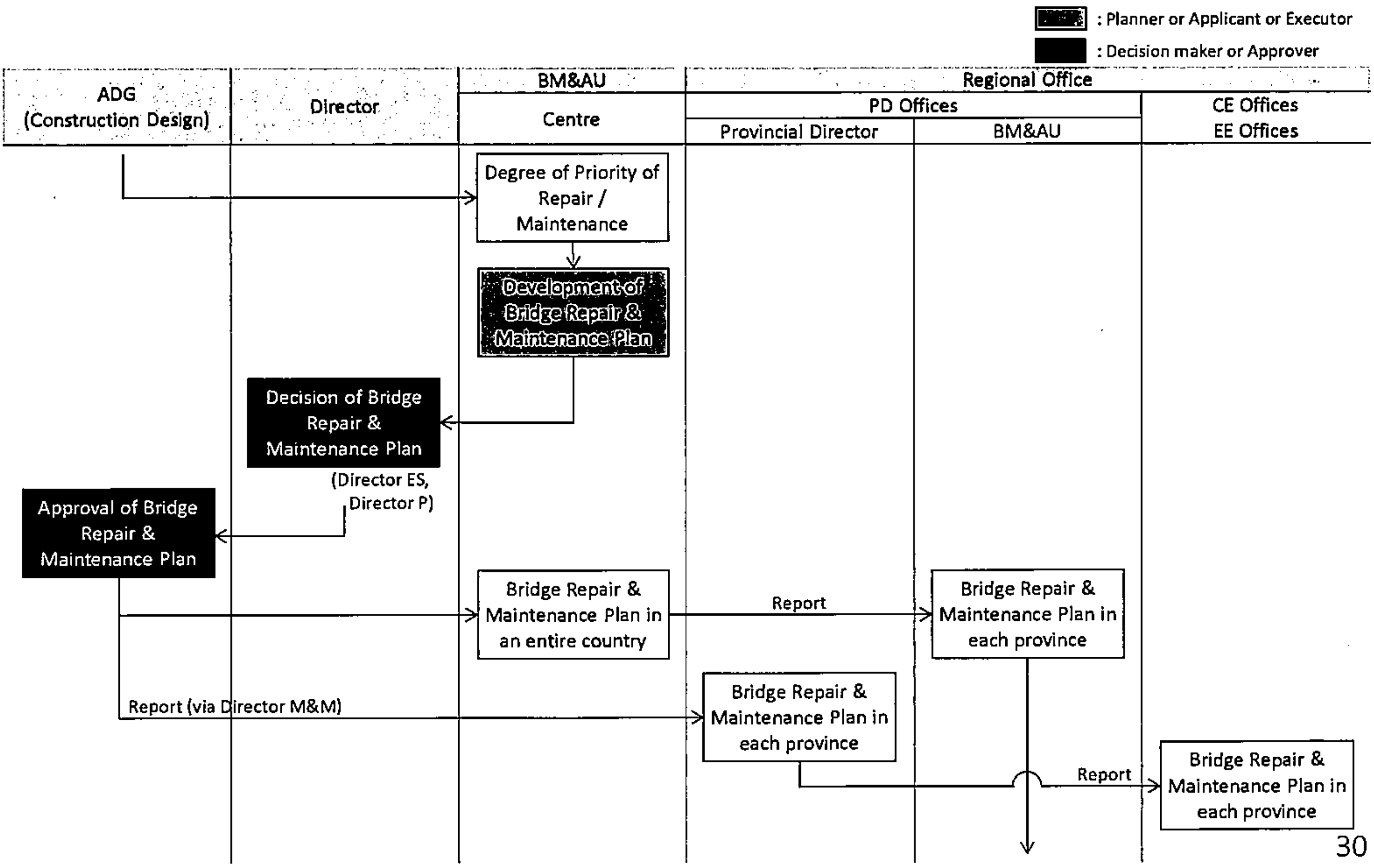
- Setting of Bridge Management Scenarios
  - BM&AU Centre determines bridge management scenarios based on Health Index (HI) and bridge repair cost calculated according to HI
  - The set scenarios should be finalized by Director ES and then approved by ADG CD

3. Development of Bridge Repair & Maintenance Plan



- Development of Bridge Repair and Maintenance Budget Plan and Budget Negotiation
  - BM&AU Centre develops Budget Plan to negotiate with Ministry of Finance according to the approved scenarios
  - Developed budget plan is finalized by Director ES and Director P, and approved by ADG CD
  - The approved budget plan is utilized for the negotiation with Ministry of Finance

3. Development of Bridge Repair & Maintenance Plan



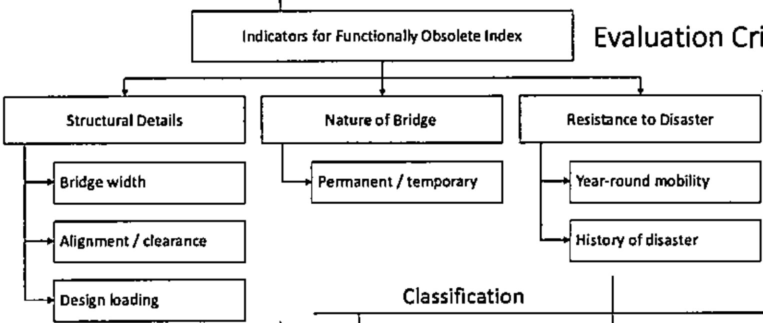
3. Development of Bridge Repair & Maintenance Plan

- Prioritization of Bridge Repairs and Development of Bridge Repair and Maintenance Plan
  - After negotiation approved budget by Ministry of Finance, bridge repair and maintenance plan is formulated. BM&AU Centre prioritizes the bridges on the repair list created based on Health Index (HI) and Importance Index (II) and then develops bridge repair and maintenance plan
  - BM&AU Centre needs to confirm the bridges from the past years' repair lists and more accurate cost
  - The created bridge repair and maintenance plan is finalized by Director ES and Director P, and the approved by ADG CD
  - The approved bridge repair and maintenance plan must be reported to BM&AU Centre, BM&AU at PD Offices, Provincial Director, CE Office and EE Office.

4. Development of Bridge Reconstruction Plan

✓ Important Matters

Item	Detail
Functionally Obsolete Index (FOI)	• Prioritization of reconstruction is performed based on Health Index (HI), Importance Index (II) and Functionally Obsolete Index (FOI) • Functionally Obsolete Index (FOI) represents the absoluteness of the bridge functions.



Evaluation Criteria for FOI

Classification of FOI

	Classification	Condition	FOI
A'	Satisfactorily functioning	A bridge exhibits the required functions satisfactorily.	00 - 25
B'	Functionally obsolete	A bridge is functionally obsolete. However, no adverse effect to socioeconomic activities is identified.	25 – 50
C'	Functionally obsolete remarkably	A bridge is functionally obsolete to the extent that socioeconomic activities are adversely and remarkably affected.	50 – 75
D'	Functionally obsolete seriously	A bridge is functionally obsolete to the extent that socioeconomic activities are adversely and seriously affected.	75 - 100

4. Development of Bridge Reconstruction Plan

✓ Important Matters

Item	Detail
Setting of Bridge Reconstruction Scenarios	• Prioritization of reconstruction is performed based on Health Index (HI), Importance Index (II) and Functionally Obsolete Index (FOI) • Functionally Obsolete Index (FOI) represents the obsoleteness of the bridge functions • The formulation of reconstruction plan feasible within the limited budget is required • Reconstruction scenarios - Based on FOI - Approval of Minister of Finance

4. Development of Bridge Reconstruction Plan

✓ Important Matters

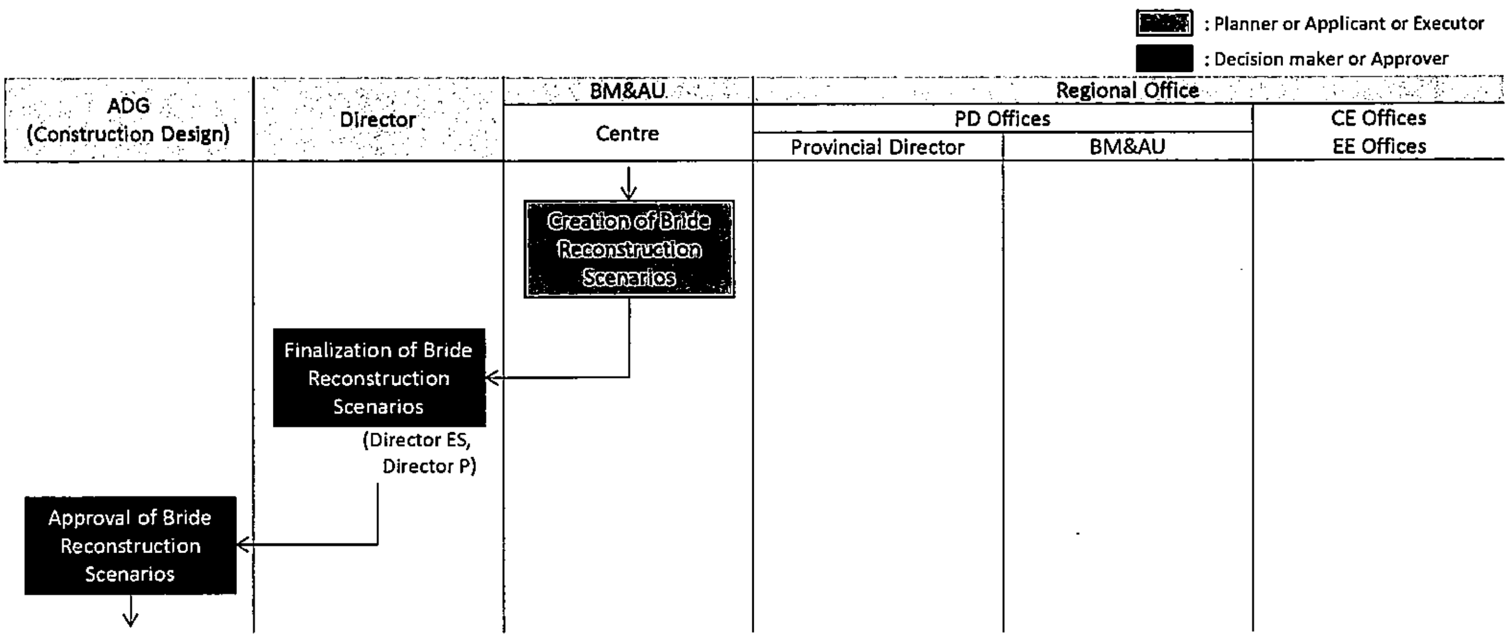
Item	Detail
Development of Bridge Reconstruction Budget Plan and Budget Negotiation	• Budget plan for the negotiation with Ministry of Finance is developed based on bridge reconstruction scenarios • It is important to include the information necessary for the negotiation - FOI of the bridges - Distribution for each fiscal year - Reconstruction period • Reconstruction cost is automatically calculated by the system • This year's list might contain the bridges from the past years' lists but still under construction. For those bridges, the accurate understanding of the construction cost and the change of cost could be possible due to the completion of the detailed design. Therefore, reconstruction cost for those bridges needs to be replaced as needed. • For the negotiation with Ministry of Finance, the formulated budge plan should be adopted.

4. Development of Bridge Reconstruction Plan

✓ Important Matters

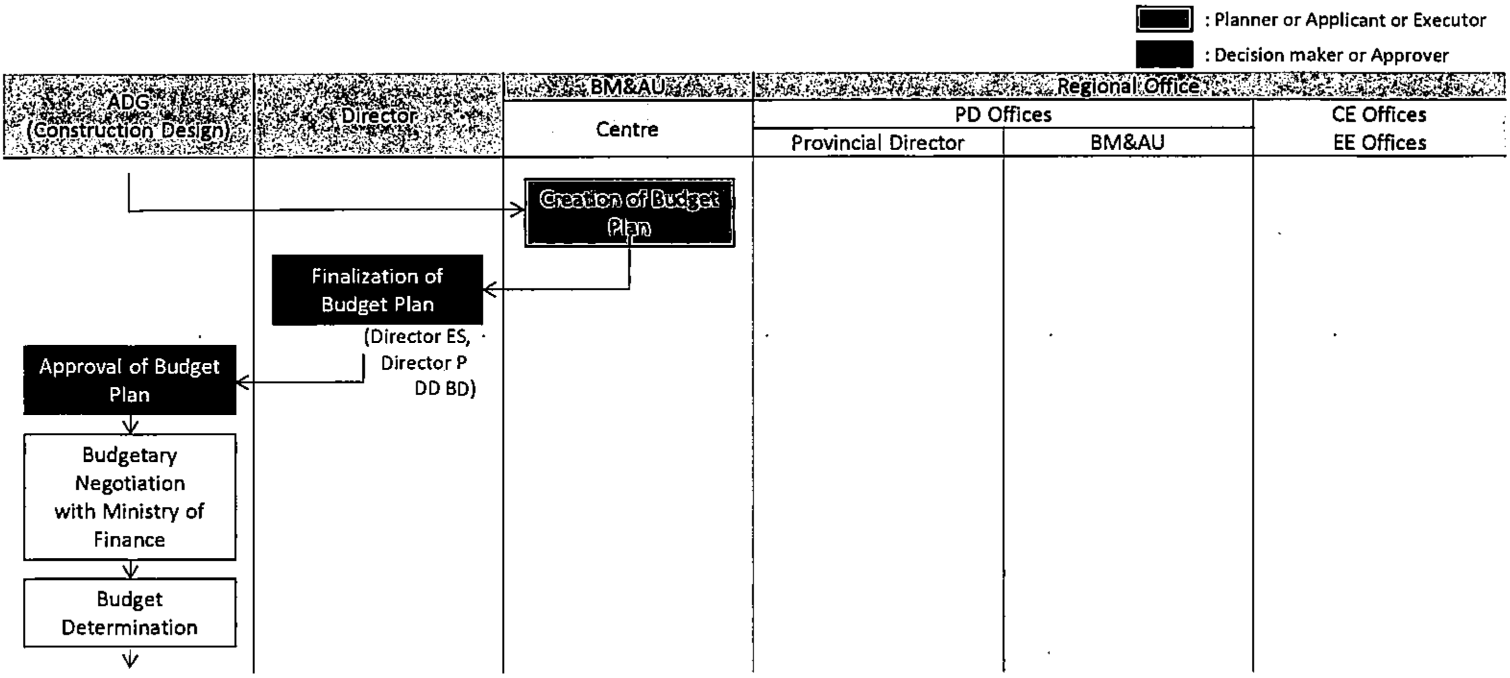
Item	Detail
Prioritization of Bridge Reconstruction and Development of Bridge Reconstruction Plan	• After the budget is fixed, the bridges on the reconstruction list should be prioritized prior to the development of reconstruction plan • The prioritization is based on Health Index (HI), Importance Index (II) and Functionally Obsolete Index (FOI) • Confirmation - Bridges in FOI Classification "D" are prioritized - Bridge list is including the bridge inspected in past year - Replacement of more accurate reconstruction cost of bridge inspected in past year as needed

4. Development of Bridge Reconstruction Plan



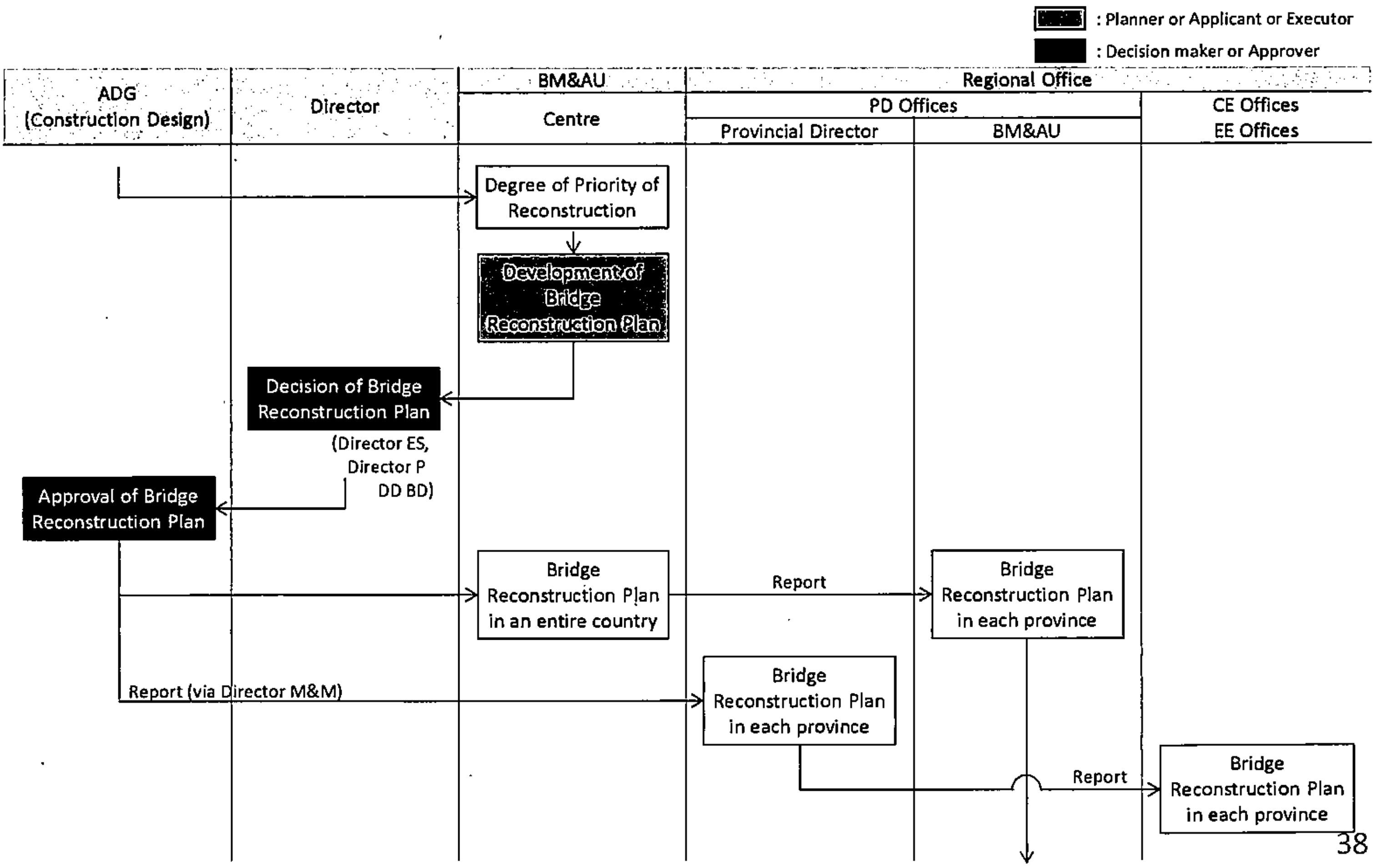
- Setting of Bridge Reconstruction Scenarios
  - BM&AU Centre formulates bridge reconstruction scenarios based on Functionally Obsolete Index (FOI)
  - The set scenarios should be finalized by Director ES and then approved by ADG CD

4. Development of Bridge Reconstruction Plan



- Development of Bridge Reconstruction Budget Plan and Budget Negotiation
  - BM&AU Centre develops Budget Plan to negotiate with Ministry of Finance according to the approved scenarios
  - Developed budget plan is finalized by Director ES, Director P, and Director ES and then approved by ADG CD
  - The approved budget plan is utilized for the negotiation with Ministry of Finance

4. Development of Bridge Reconstruction Plan



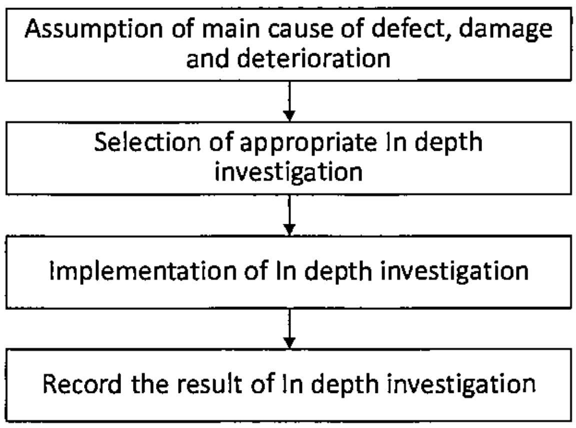
4. Development of Bridge Reconstruction Plan

- Prioritization of Bridge Reconstruction and Development of Bridge Reconstruction Plan
  - As the budget is fixed after the negotiation with Ministry of Finance, Bridge Repair and Maintenance Plan is formulated. BM&AU Centre is responsible for confirming the bridges on reconstruction list prioritized based on Health Index (HI), Importance Index (II) and Functionally Obsolete Index (FOI)
  - BM&AU Centre develops bridge reconstruction plan. BM&AU Centre is also responsible for verifying the list from the past years and more accurate construction cost
  - The formulated bridge reconstruction plan is finalized by Director ES, Director P, and DD BD, and approved by ADG CD
  - The approved bridge reconstruction plan must be reported to BM&AU Centre, BM&AU at PD Offices, Provincial Director, CE Office and EE Office.

5. Bridge Repair and Maintenance

✓ Important Matters

Item	Detail
In-depth Investigation	• Main objectives of in-depth investigation - Understanding the cause of defects, damage and deterioration - Identification of sevelity and extent of damage / defects, damage, deterioration and needs of measures - Selection of bridge repair method - Collection of data and information necessary for detail design • Standard procedure

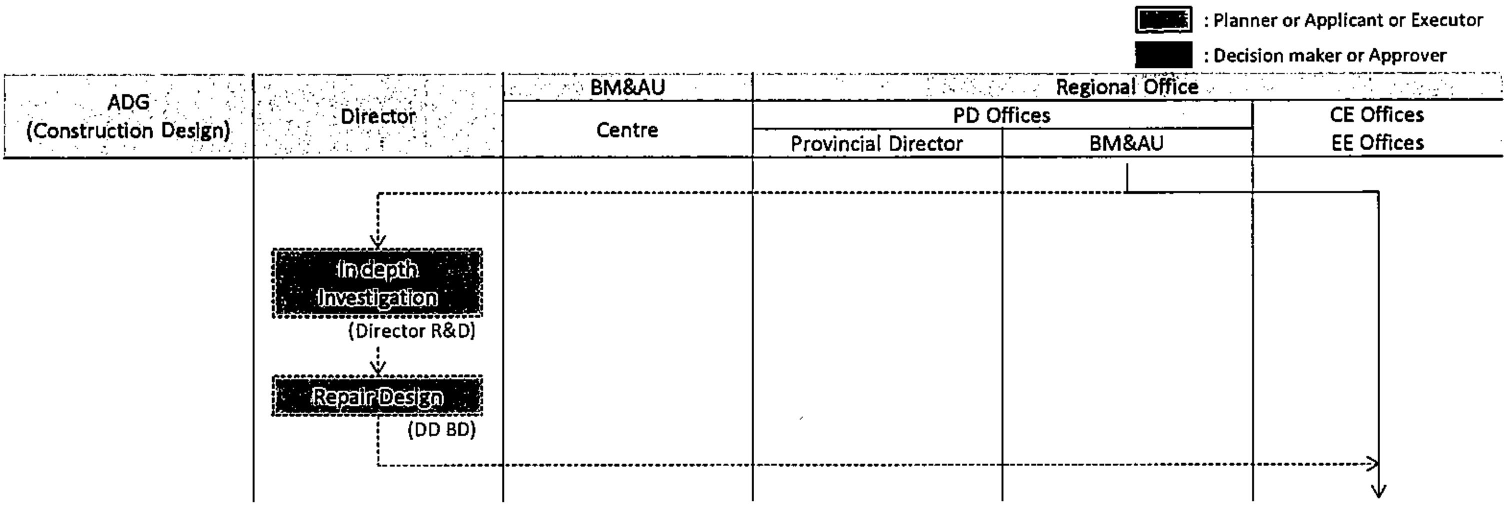


5. Bridge Repair and Maintenance

✓ Important Matters

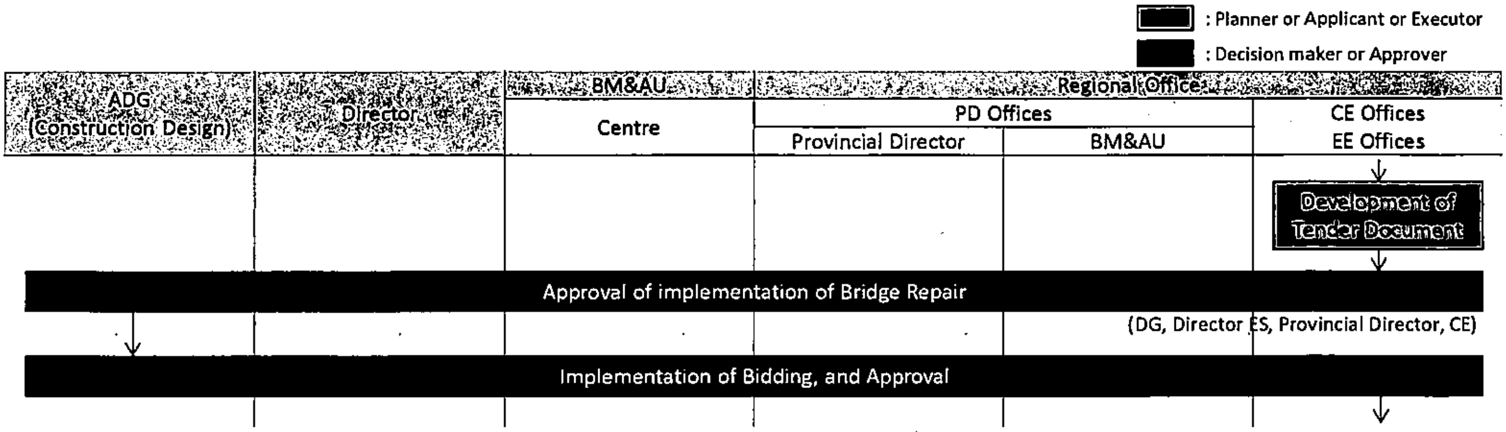
Item	Detail
Repair Design	• In case of complicate repair or large repair scale, repair design might be necessary • Replacement of repair cost as needed - After repair design, repair cost might be improved more accurately
Implementation of Bidding	• Approval and bidding of the construction should be conducted properly according to the procedures and authorities prescribed by RDA.
Implementation of Bridge Repair and Maintenance	• During construction, - Quality management for the long lifetime of the bridge - Safety control of the construction. • In case that construction cost is increased due to the unexpected incidents (i.e. progress of the damage and increasing of form / support / scaffolding) - Carry out the appropriate measures - Secure the necessary budget
Recording of Bridge Repair and Maintenance	• After the completion of repair and reinforcement, the construction history must be entered into the system • Soundness classification based on Health Index (HI) should be changed • This data is going to be utilized for the future bridge management

5. Bridge Repair and Maintenance



- In-depth Investigation
  - BM&AU at PD offices must request the in-depth investigation to Director R&D with bridge inventory and inspection results as needed
  - Director R&D carries out the investigation, and report the results of the investigation to BM&AU at PD offices
- Repair Design
  - BM&AU at PD offices must request the repair design to DD BD with bridge inventory, inspection results and investigation results
  - DD BD carries out the repair design, and report the results of the repair design to BM&AU at PD offices, and BM&AU at PD offices reports them to EE office for Tender Document

5. Bridge Repair and Maintenance

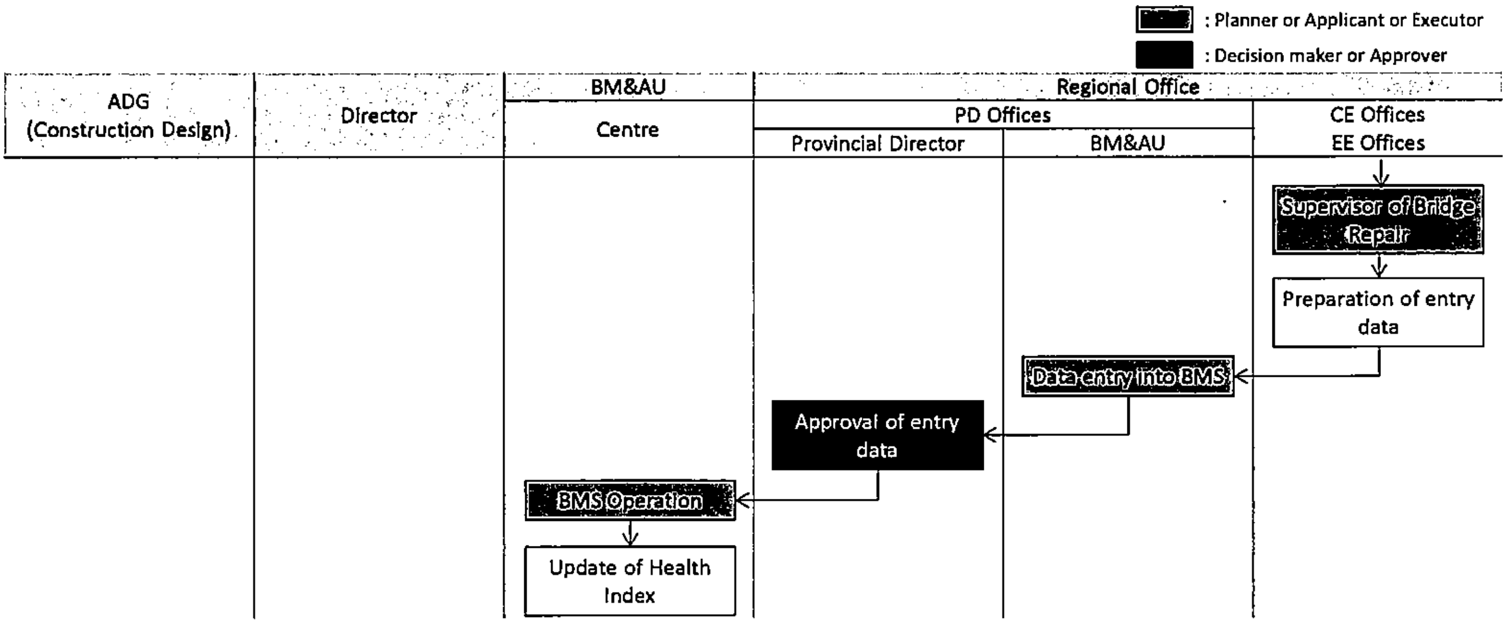


- Implementation of Bidding
  - EE Office develops tender document
  - Procedure for approval of the construction should be started
  - Bidding and contracting of the construction are implemented after the approval

Categories	Approver
Direct Labor	There is no upper limit if it's within the budget. However, the limit per 1 material purchase is 1,000,000LKR.
Construction Cost: less than 1,000,000LK	Chief Engineering
Construction Cost: less than 5,000,000LK	Provincial Director
Construction Cost: more than 5,000,000LKR	Director M&M or Director General

Categories	For Bidding and Approval
Construction Cost: less than 1,000,000LK	Bidding : EE Office Approval : CE Office
Construction Cost: less than 3,000,000LK	Bidding : CE Office Approval : PD Office
Construction Cost: less than 5,000,000LK	Bidding : PD Office Approval : Head Office
Construction Cost: more than 5,000,000LKR	Bidding : Director M&M Approval : Director General

5. Bridge Repair and Maintenance



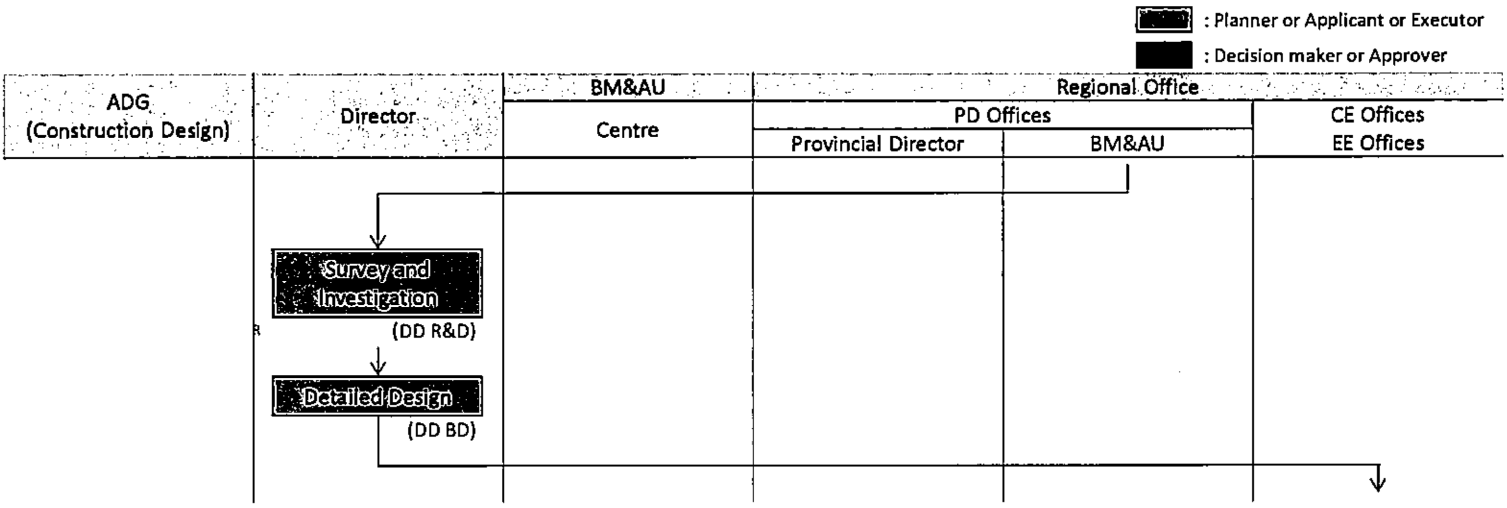
- Implementation of Bridge Repair and Maintenance
  - Director ES appoints division to supervise the construction.
- Recording of Bridge Repair and Maintenance
  - Division in charge of the construction supervision submit the information of construction history to BM&AU at PD offices after the completion of repair and reinforcement
  - BM&AU at PD offices must enter the information into the system
  - PD confirms the information, and BM&AU Centre operates the system to update health Index (HI)

6. Bridge Reconstruction

✓ Important Matters

Item	Detail
Survey and Investigation	• As a preparation for detailed design, it is necessary to consider the utilization consideration of existing bridges and conduct the soil survey.
Detailed Design	• Detailed design is conducted based on the data and information obtained by survey and investigation.
Implementation of Bidding	• Approval and bidding of construction should be properly conducted according to the procedures and authorities prescribed by RDA.
Implementation of Bridge Reconstruction	• During construction, - Quality management for the long lifetime of the bridge - Safety control of the construction. • In case that construction cost is increased due to the unexpected incidents (i.e. settlement of ground and the change in erection method - Carry out the appropriate measures - Secure the necessary budget
Initial Inspection and Data Entry into BMS	• Initial inspection is conducted within a year after the completion of reconstruction • After Initial Inspection, the necessary data (inventory data and inspection results) must be entered in the system for the future bridge management

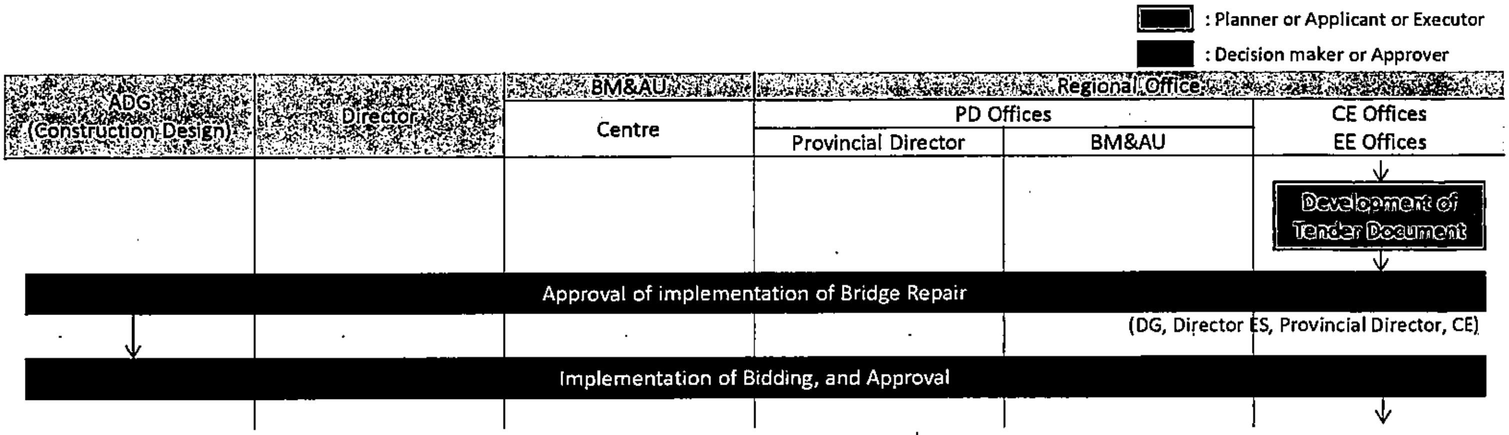
6. Bridge Reconstruction



● Survey and Investigation
- BM&AU at PD offices must request survey and investigation for reconstruction to DD BD (R&D) with bridge inventory and inspection
- DD BD (R&D) carries out survey and investigation

● Detailed Design
- Detailed design should be developed under the responsibility of DD BD. In case survey and investigation has been carried out, the results of survey and investigation should be reflected to detailed design.
- DD BD carries out the detailed design, and report the results of the repair design to BM&AU at PD offices, and BM&AU at PD offices reports them to EE office for Tender Document

6. Bridge Reconstruction



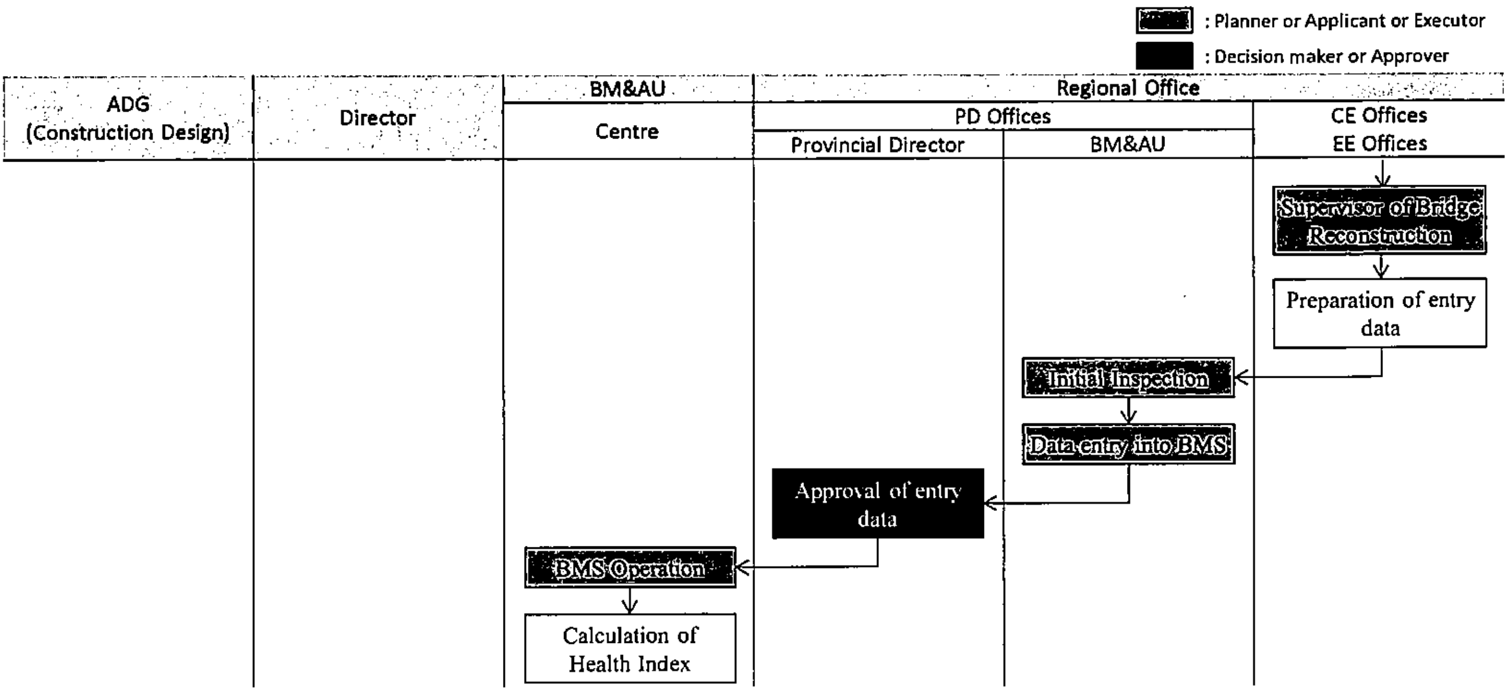
- Implementation of Bidding
  - EE Office develops tender document
  - Procedure for approval of the construction should be started

Categories	Approver
Direct Labor	There is no upper limit if it's within the budget. However, the limit per 1 material purchase is 1,000,000LKR.
Construction Cost: less than 1,000,000LK	Chief Engineering
Construction Cost: less than 5,000,000LK	Provincial Director
Construction Cost: more than 5,000,000LKR	Director M&M or Director General

  - Bidding and contracting of the construction are implemented after the approval

Categories	For Bidding and Approval
Construction Cost: less than 1,000,000LK	Bidding : EE Office Approval : CE Office
Construction Cost: less than 3,000,000LK	Bidding : CE Office Approval : PD Office
Construction Cost: less than 5,000,000LK	Bidding : PD Office Approval : Head Office
Construction Cost: more than 5,000,000LKR	Bidding : Director M&M Approval : Director General

6. Bridge Reconstruction



- Implementation of Bridge Reconstruction
  - Director ES appoints division to supervise the construction.
- Initial Inspection and Entry Data Entry into BMS
  - Initial inspection must be conducted by BM&AU at PD offices
  - BM&AU at PD Offices should input the damage data obtained by initial inspection into the system. The registered data should be approved by Provincial Director.

Bridge Diagnosis
&
Emergency Action

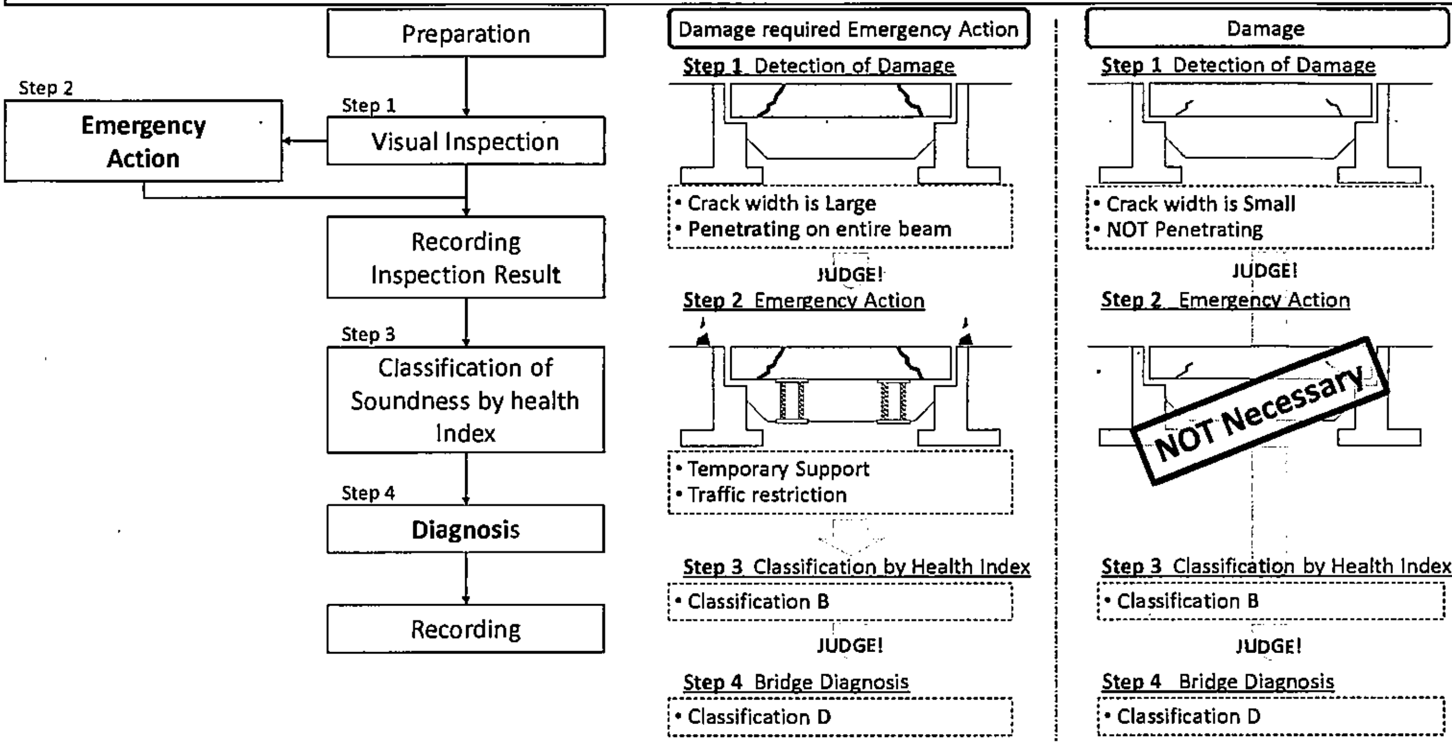
THE PROJECT
FOR CAPACITY DEVELOPMENT
ON BRIDGE MANAGEMENT

Contents

1. Emergency Action and Diagnosis

1-1. Timing of Emergency Action and Diagnosis

☐ Damage shall be **judged twice during Periodic Inspection**
- During visual inspection : **Emergency Action is needed**, or not
- End of periodic inspection : **Soundness Classification is changed**, or not

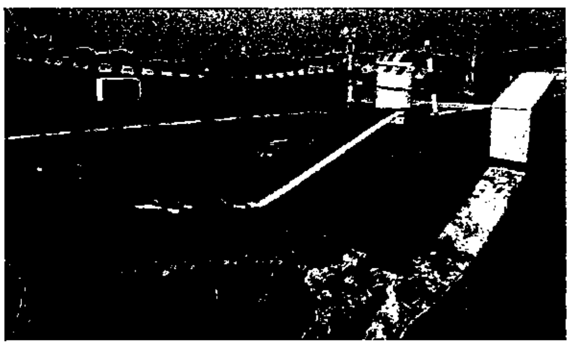


1. Emergency Action and Diagnosis

1-2. Purpose of Emergency Action

☐ In case of detection of the following situations during visual inspection, "Emergency Action" should be implemented.
- **Safety of bridge structures**
- **Third-party effects**

- **Safety of Bridge Structures**
  Bridge structures might **COLLAPSED** due to damage, which results in the decrease of load carrying capacity.
- **Third- Party Effects**
  When it is suspected that vehicles, **trains and/or pedestrians on/under the bridge are adversely affected** by the damage thereof, emergency actions shall be taken immediately.



Collapse of a bridge

1. Emergency Action and Diagnosis

1-3. Purpose of Bridge Diagnosis

- ☐ Experienced experts within RDA **review Soundness Classification of Bridge at the end of Periodic Inspection**.
- ☐ **All bridges** inspected based on periodic inspection **must be reviewed**.

WHY "the bridge soundness" should be reviewed ?

✓ However, HI does **NOT** consider

- **Rate of progress** of damage
- **Influence of location** of damage to the soundness

WHY all bridges ?

✓ If the serious damage is **NOT** judged appropriately,

- **NOT** repair and strengthen the serious damage

Possibility of the collapse of a bridge suddenly without warning

The serious accident such as the **INJURED** and the **DEAD**.

Who has Responsibility ?

In the case, **Road Administrator** has responsibility

1. Emergency Action and Diagnosis

1-2. Purpose of Bridge Diagnosis

☐ Change of soundness classification

Before Diagnosis	After Diagnosis
A	C or D
B	C or D
C	D

☐ After diagnosis, soundness of an entire bridge could be changed as "D" or "C", regardless of the bridge soundness classification determined by HI.

Soundness classification by Health Index (HI)

Sound

Classification		Conditions
A	Sound	Structures are well functioning.
B	Preventive Maintenance Stage	Structures are well functioning. However, it is desirable to take necessary measures from the perspective of preventive maintenance.
C	Reactive Maintenance Stage	Functions of the structure will be possibly impaired. Necessary measures should be taken at an early stage (within 5 years).
D	Immediate Action Stage	Functions of the structure are impaired or the possibility of impairment of functions is extremely high. Necessary measures should be taken immediately (within 2 years).

Serious

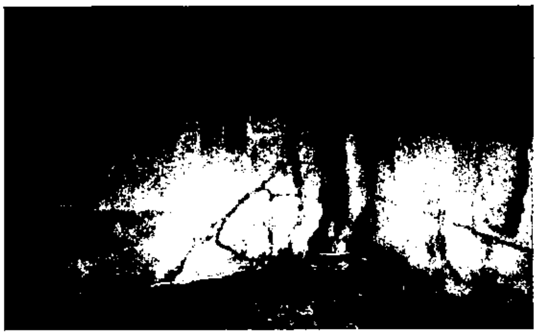
2. Situation in need of Emergency Action

2-1. Example of Damage – Impairing safety of Bridge Structures –

Other Damage on Concrete

•Example of Damage

Bearing failure near support



•Crack width is 0.3mm or more
•Impairing the bearing function

Delamination in wide area of the deck slab / main beam

•Ex-rebar with remarkable corrosion or broken re-bar, or delamination
•Damage on about 60% of its all area

with remarkable corrosion or break of rebar / PC cable.

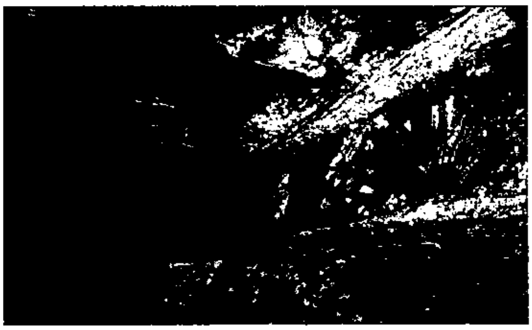
2. Situation in need of Emergency Action

2-1. Example of Damage – Impairing safety of Bridge Structures –

Corrosion and Break on Steel Member

•Example of damage

Remarkable loss of structural steel



•Loss of web steel on its entire depth
•Loss of lower flange steel by 50% or more
•Near support

Break of the diagonal member

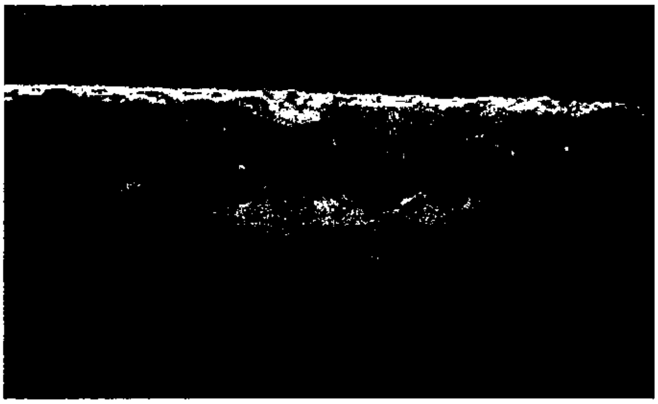
2. Situation in need of Emergency Action

2-1. Example of Damage – Impairing safety of Bridge Structures –

Rivet / HSFG on Steel Member

• Example of Damage

Damaged bolts, such as the serious corrosion and the missing of bolts, are about more than 25% of one bolt group and more in number



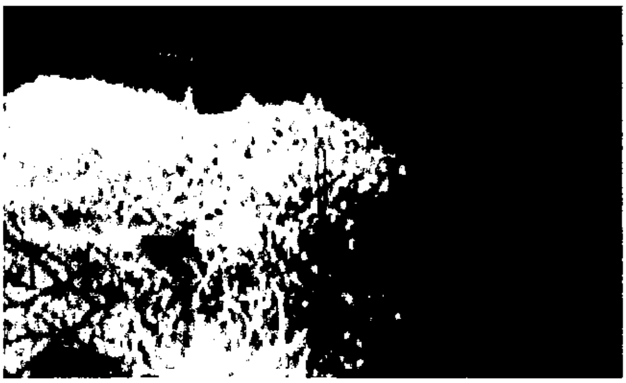
2. Situation in need of Emergency Action

2-1. Example of Damage – Impairing safety of Bridge Structures –

Arch Line

• Example of Damage

Large deformation of the arch line at its crown



Bridge Pier / Abutment in Water

• Example of Damage

Exposed foundation due to riverbed degradation and / or local scour

• Scoured under footing of pier/abutment

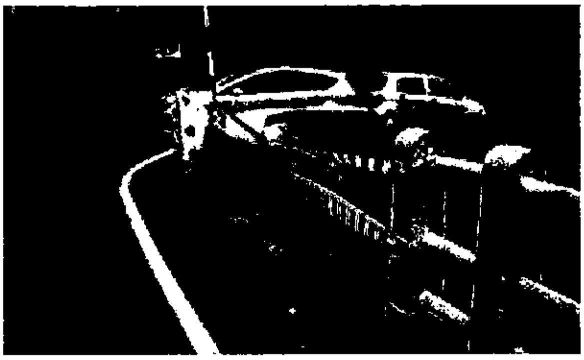
2. Situation in need of Emergency Action

2-1. Example of Damage – Third-party Effects –

Railing / Parapet

- Example of Damage

Missing, break, and large deformation



Approach Road / River Bank

- Example of Damage

Large collapse of approach road / riverbank that causes the depression and crack of road surface

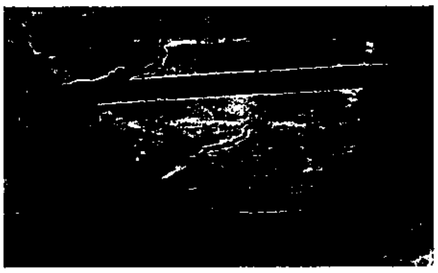
2. Situation in need of Emergency Action

2-1. Example of Damage – Third-party Effects –

Damage on Deck Slab

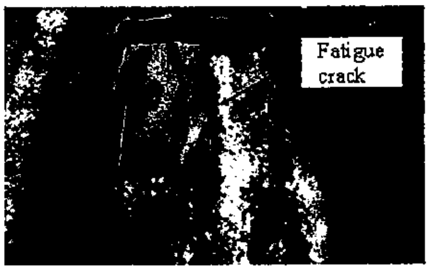
- Example of Damage

Large cracks



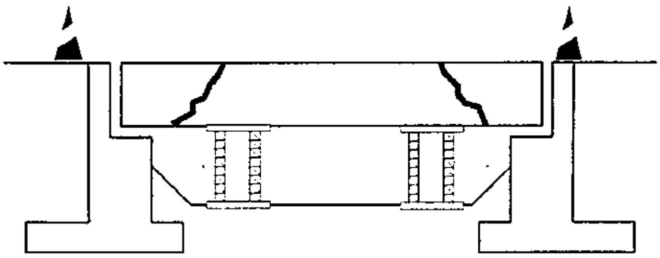
Fallen down of a concrete block from the deck slab

Severe damage of steel deck slab, such as large crack and large loss of structural steel



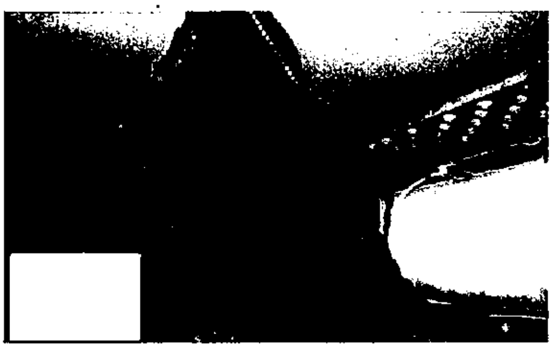
2. Situation in need of Emergency Action

2-2. Summary of Emergency Action

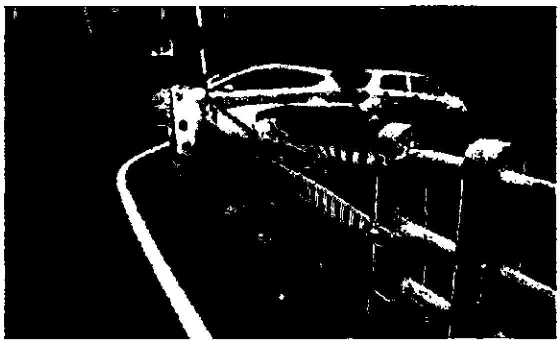


Temporary support & Traffic restriction

Filling with pavement mixture (Pothole)



Temporary fixing of drainage pipe



Installation Caution sign (Damage on railing/parapet)

3. Bridge Diagnosis

3-1. Example of Bridge Diagnosis – Concrete structure –

Classification C

Spall / Dela / Ex-rebar(No,12), Concrete Crack (No.13)

- Delamination on main concrete beam / slab to a large extent
- Large crack on main concrete beam / slab
  It is suspected that <u>steel re-bars in concrete may be seriously corroded</u>, resulted in <u>the decrease of load carrying ca</u>

- Crack with water leakage on concrete structure
  It is supposed <u>that concrete will deteriorate earlier near such cracks than other areas</u>.

3. Bridge Diagnosis

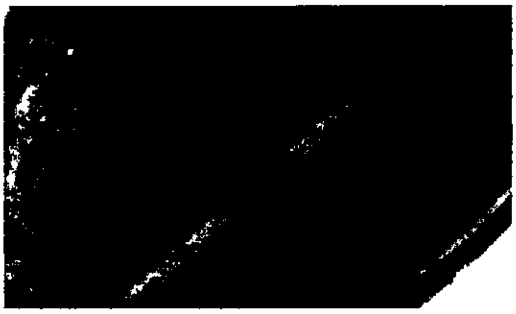
3-1. Example of Bridge Diagnosis – Concrete structure –

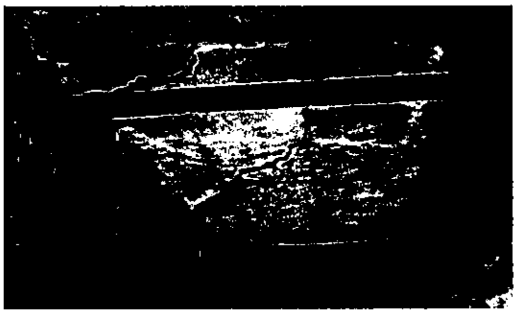
Classification C

Damage on Deck Slab (RC) (No.22-1)

- Pattern cracking on bridge deck slab
  It is suspected that excess load is delivered to a main beam due to the degradation of such load distribution function and damages the said beam. It will impair the structural safety of an entire bridge.

- Penetrating crack on concrete main beam / slab
  Load carrying capacity thereof will be decreased.





3. Bridge Diagnosis

3-1. Example of Bridge Diagnosis – Concrete structure –

Classification D

Spall / Dela / Ex-rebar(No,12), Concrete Crack (No.13)

- Delamination on main beam / slab
  The break of the steel rebars is suspected.

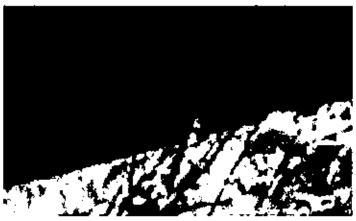
3. Bridge Diagnosis

3-2. Example of Bridge Diagnosis – Steel structure –

Classification C

Corrosion (No.20)

- Serious extensive corrosion and local loss of structural steel
- 30% or more of the lower flange steel has been lost.
- Steel web has been lost on one-third or more of its depth.
- For the truss bridge, 20% or more of steel of its diagonal / vertical member or chord has been lost.
  Load carrying capacity will be decreased. It will impair the structural safety of an entire bridge.

- Unusual corrosion on galvanized coating with local loss of structural steel
  It is suspected that load carrying might be decreased.

3. Bridge Diagnosis

3-2. Example of Bridge Diagnosis – Steel structure –

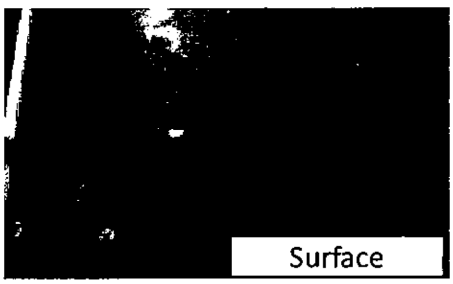
Classification C

Damage on Deck Slab (Steel) (No.22-2)

- Crack on steel deck slab & Damage on steel deck slab
  It is suspected that excess load is delivered to a main beam due to the degradation of load distribution function and damages the said beam.



Fatigue crack

Large loss of structural steel

3. Bridge Diagnosis

3-2. Example of Bridge Diagnosis – Steel structure –

Classification D

Corrosion (No.20)

- Loss of web steel on its entire depth
- Loss of lower flange steel by 50% or more.

Damage might cause
<u>sudden collapse of the bridge structure</u>.

- Break of diagonal members of truss
- For the truss bridge, 40% or more of steel of its diagonal / vertical member or chord has been lost.

Damage might cause
<u>sudden collapse of the bridge structure</u>.

3. Bridge Diagnosis

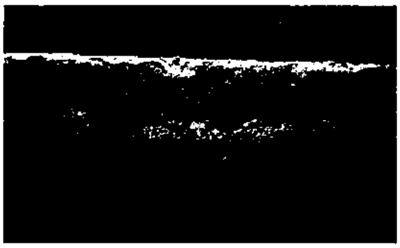
3-2. Example of Bridge Diagnosis – Steel structure –

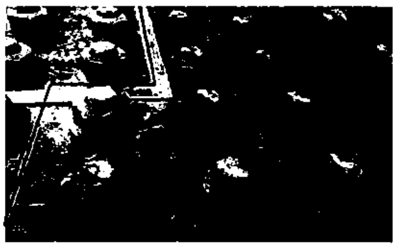
Classification D

Damage (Rivet / HSFG) (No.21)

- 25% or more of the bolts in number in one group are seriously corroded or missed

<u>It is difficult to transmit the force</u> between members due to the above damage.
As the result, this damage might cause sudden collapse of the bridge structure.





3. Bridge Diagnosis

3-3. Example of Bridge Diagnosis – Others –

Classification D

Scour (No.17)

- Exposed foundation due to riverbed degradation and/or local scour
  Unusual deflection and the collapse of a bridge might occur due to riverbed degradation and local scour.

Arch Line (Displacement) (No.23), Deteriorated (Loose) (No.24)

- Large deformation of arch line at its crown
  For the stone arch, it is quite important to retain the arch line as designed. Deformation of arch line will result in the entire collapse of the arch structure.

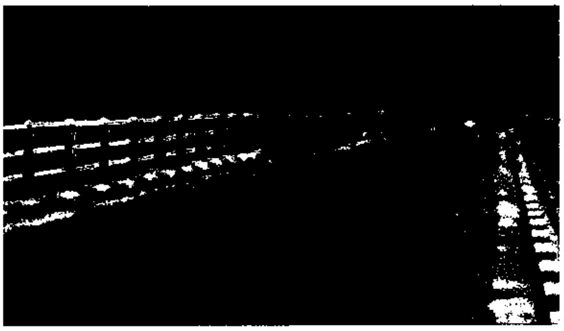
3 Bridge Diagnosis

3-3. Example of Bridge Diagnosis – Others –

Classification D

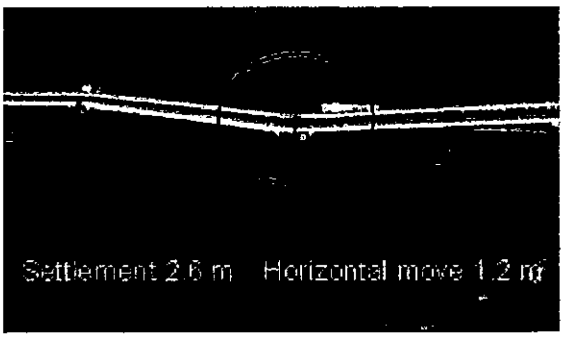
Deflection

- Unusual deflection on an entire bridge
  Unusual deflection may be the sign of settlement, movement or tilting of bridge piers and abutments, and others.



Settlement, movement and tilting of substructures

- Settlement, movement or tilting of piers / abutments
  When the settlement, movement or tilting of bridge piers and abutments are detected, emergency action shall be taken to prevent the collapse of bridge structure.



7th Work Shop Agenda

4th October 2107

No	Duration	Topic
1	9.00 am to 9.03 am	Address by ADG (CD)
2	9.03 am to 9.05 am	Address by Team leader – JICA PT
3	9.05 am to 9.25 am	Analysis of Bridge Inspection Result in 3 Provinces
4	9.25 am to 9.45 am	RDA Action Plan for Bridge Management
5	9.45 am to 10.05 am	Amendment of work procedure
6	10.05 am to 10.25 am	JICA Recommendation of Human Resources Development Plan
7	10.25 am to 11.00 am	Question & Discussion

Conditions of Bridges under RDA Management in Sample Provinces

The Project for Capacity Development on Bridge Management

JICA Project Team
Kazuya URANO

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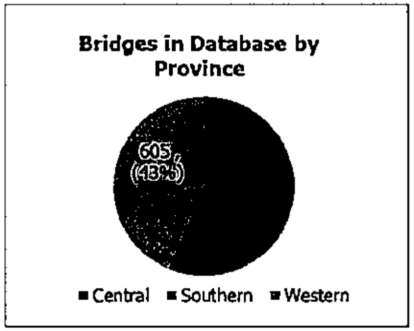
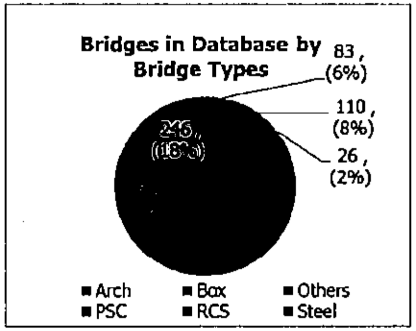
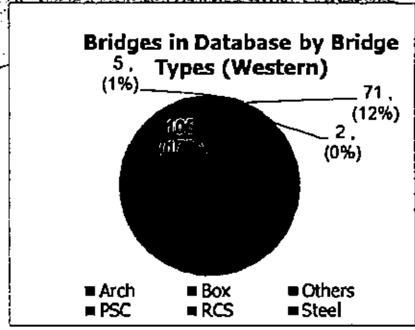
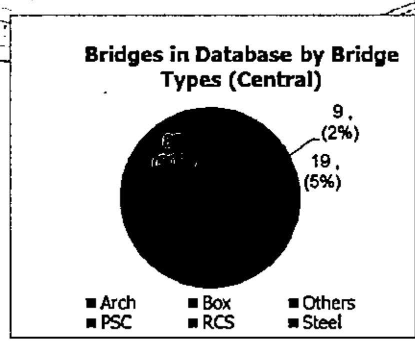
1. Bridges Registered in Database

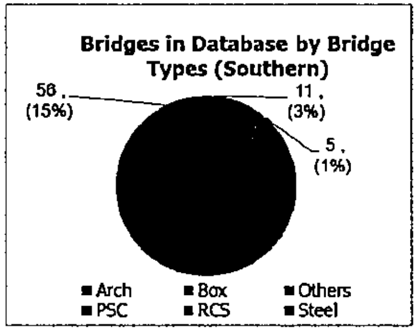




- ❑ Total number of bridges registered in database is **1,392**.







- ❑ There is a large share of Arch Bridge in Central Province (specific feature of mountainous areas?).
- ❑ There is a large share of PSC Bridges in all samples provinces.

---

2. Soundness Classification of Bridges by Types

	SC-A	SC-B	SC-C	SC-D	Total
Arch	63	3	2	15	83
PSC	436	38	7	**83**	564
RCS	190	48	20	**105**	363
Steel	88	45	44	**69**	246
Box	108	1	1	-	110
Others	5	5	4	12	26
Total	890	140	78	284	**1,392**

- ❑ There have recognised the serious damage on PSC, RCS and Steel.
- ❑ It is to analyse the causes of these three bridge types with soundness classification "D".

3. Results of Analysis (RCS)

☐ Among RCS Bridges, there are **105** bridges classified as Soundness Classification "D".

RCS SC-D by Bridge Surface / Structure

	SC-A	SC-B	SC-C	SC-D	Total
Bridge Surface	72	9	19	5	105
Bridge Structure	0	0	4	**101**	105

RCS Structure SC-C & SC-D by Bridge Components

	SC-A	SC-B	SC-C	SC-D	Total
Superstructure	58	13	11	23	105
Bridge Bearing	105	0	0	0	105
Substructure	16	1	2	**86**	105

RCS Superstructure SC-D by Member

	SC-A	SC-B	SC-C	SC-D	Total
RC Deck Slab	0	0	0	23	105

RCS Deck Slab SC-D by Span

	SC-A	SC-B	SC-C	SC-D	Total
RC Deck Slab	0	0	0	25	25

Damage Types of RCS Deck Slab (Span) SC-D

Deduction Point (DP)	0-25 (A)	25-50 (B)	50-75 (C)	75-100 (D)	Total
Spall / Dela / Ex-Rebar	0	5	8	**12**	25
Crack	0	0	9	**16**	25

❖ Bridge RCS Deck Slab seriously damaged are majorly come from **spall / dela / ex-rebar** and **cracks.**

❖ There are **12 spans** with spall / dela / ex-rebar (DP of 75 – 100), of which **6** in **Western Province, 4** in **Central Province,** and **2** in **Southern Province.**

4. Results of Analysis (PSC)

☐ Among PSC Bridges, there are **83** bridges classified as Soundness Classification "D".

PSC SC-D by Bridge Surface / Structure

	SC-A	SC-B	SC-C	SC-D	Total
Bridge Surface	33	1	44	5	83
Bridge Structure	0	0	0	**83**	83

PSC Structure SC-D by Bridge Components

	SC-A	SC-B	SC-C	SC-D	Total
Superstructure	67	1	2	**13**	83
Bridge Bearing	83	0	0	0	83
Substructure	12	0	1	**70**	83

PSC Superstructure SC-D by Member

	SC-A	SC-B	SC-C	SC-D	Total
Main Beam	0	0	0	**13**	13
Deck Slab	13	0	0	0	13
Cross Beam	12	0	1	1	13

RSC Main Beam SC-D by Span

	SC-A	SC-B	SC-C	SC-D	Total
Main Beam	0	0	0	**14**	14

Damage Types of PSC Main Beam (Span) SC-D

Deduction Point (DP)	0-25 (A)	25-50 (B)	50-75 (C)	75-100 (D)	Total
Spall / Dela / Ex-Rebar	8	2	2	2	14
Crack	2	0	3	**9**	14
Damage on Anchorage	14	0	0	0	14

- Bridge PSC main beams seriously damaged are majorly come from **cracks.**
- There are **9 spans** with cracks (DP of 75 – 100), of which **5** in **Southern Province** and **4** in **Western Province**.

5. Results of Analysis (Steel)

- Among Steel Bridges, there are **69** bridges classified as Soundness Classification "D".

Steel SC-D by Bridge Surface / Structure

Bridge Surface	33	5	23	8	69
Bridge Structure	0	0	2	**67**	69

Steel Structure SC-C & SC-D by Bridge Components

Superstructure	2	4	6	**57**	69
Bridge Bearing	69	0	0	0	69
Substructure	49	1	1	**18**	69

Steel Superstructure SC-D by Member

Main Beam	1	0	1	**55**	57
Deck Slab	38	5	4	10	57
Cross Beam	48	0	2	7	57

Steel Main Beam SC-D by Span

Main Beam	152	57	35	**68**	312

Damage Types of Steel Main Beam (Span) SC-D

Mud Deposition	38	8	13	9	68
Paint Degradation	0	0	2	**66**	68
Corrosion	0	1	5	**62**	68
Damage (Rivet / HSFG)	41	1	15	11	68

- ❖ Bridge steel main beams seriously damaged are majorly come from **paint degradation** and **corrosion.**
- ❖ There are **62 spans** with corrosion (DP of 75 – 100), of which **29** in **Western Province, 28** in **Central Province** and **5** in **Southern Province.**
- ❖ It will need periodic cleaning of steel members off the mud and debris so that wet condition can be prevented.
- ❖ In addition, periodic re-painting should be implemented.

6. Results of Analysis (Substructure)

- ☐ Among 3,185 Piers / Abutments, there are **285** piers / abutments classified as Soundness Classification "D".

Substructures by Soundness Classification (SC)

	SC-A	SC-B	SC-C	SC-D	Total
Substructure	2,861	22	17	285	3,185

Damage Types of Substructures SC-D

	SC-A	SC-B	SC-C	SC-D	Total
Spall / Dela / Ex-Rebar	284	1	0	0	285
Crack	266	16	3	0	285
Mud Deposition	279	5	1	0	285
Scour	0	0	2	**283**	285

- ❖ Bridge piers and abutments with Soundness Classification "D" are subject to **scour** seriously.
- ❖ It will need immediate measures against exposed bridge foundation.
- ❖ In addition, sand mining upstream of bridge sites should be legally prohibited.

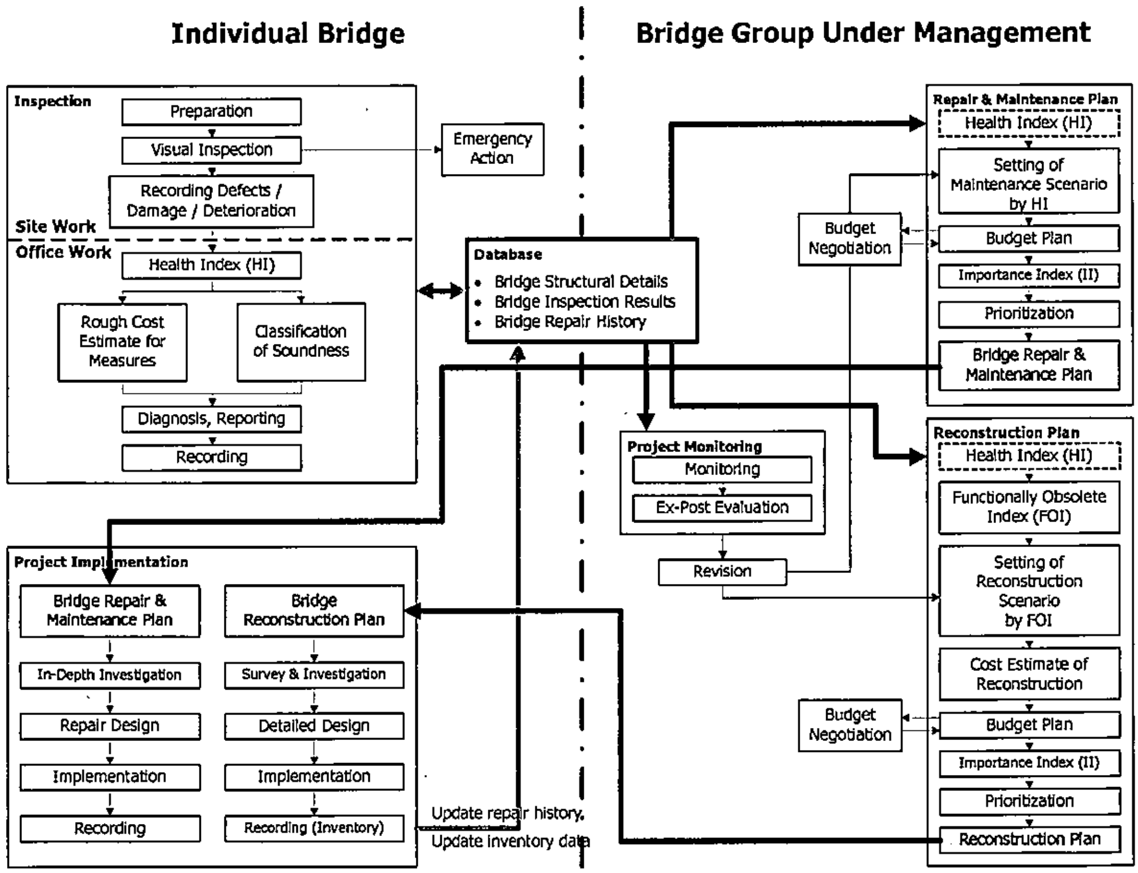
7. Direction of Bridge Management in Sri Lanka (Strategy)

- ☐ Periodically implement the bridge management cycle, especially in inspection, bridge condition data collection, update of database.
- ☐ Measures against scouring (scour protection, ban of sand mining, etc.).
- ☐ Periodic cleaning and re-painting of steel members.
- ☐ Good quality control of bridge construction.

Amendment of Bridge Management Procedure

THE PROJECT
FOR CAPACITY DEVELOPMENT
ON BRIDGE MANAGEMENT

Structure of Bridge Management



Some Amendments on Bridge Management Procedure

BM&AU Head Office

Deputy Head In between DD and Senior Engineer no position in RDA. Therefore 3 Senior Engineer to be assigned to BM&AU Head Office

BM&AU,Engineer in PD Office

1 BM&AU Engineer and no any Engineer is appointed under him. Support staff is utilizing from PD office staff.

Work of EE Office

Support staff for Inspection will be nominated from Engineer from EE office. BM&AU, Engineer trains Engineer from EE office to be BM&AU Engineer.

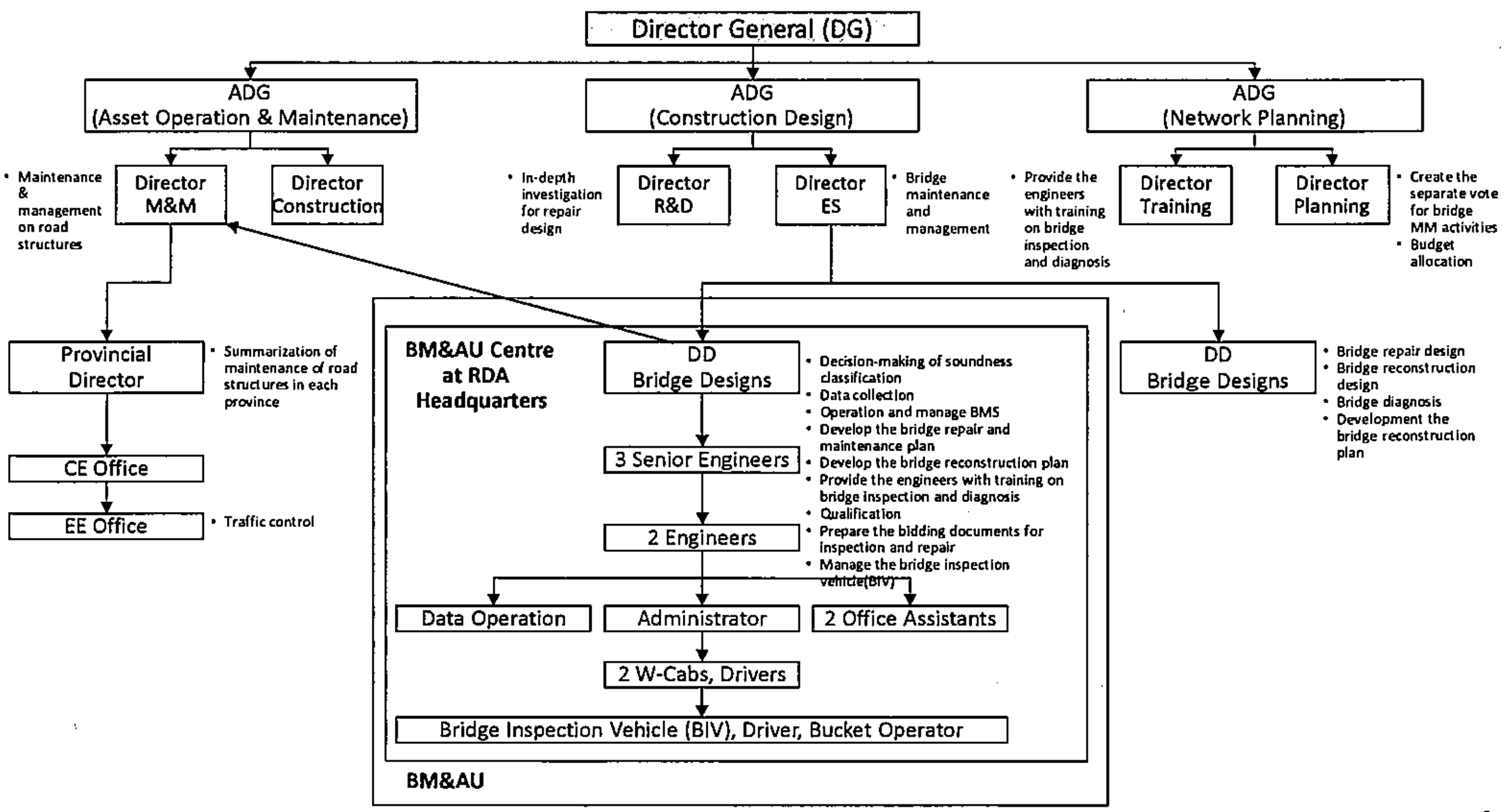
Repair Manual

Other specification and manual in RDA should compile together with repair manual.

R&D Division

So far R&D division is conducting only soil survey. Relating bridge maintenance and indeapth survey of damage involvement of R&D division will discuss later.

Institutional Framework, Roles & Responsibility



[illegible]
Plan
(Draft)

The Project for Capacity Development
on Bridge Management
JICA Project Team
Hideaki TAKAURA

Contents

1. Purpose of Human Resources Development Plan
2. Main Requirement of Bridge Maintenance Work
3. Target Group of 3 Categories
4. Training Program

[illegible] Development Plan

- Sustainability of Maintenance work – Training of Engineer & Staff
- New Construction & Maintenance – Importance of Maintenance

The personnel who have been trained under the plan / program will have the certificates, depending on the level of the training: Certified Bridge Management Specialist, Certified Bridge Maintenance Expert, Certified Bridge Inspector, etc.

2.Main Requirements of Bridge Management work

1. Basic knowledge of bridges
2. Bridge planning skills
3. Bridge design skills
4. Bridge inspection skills
5. Bridge diagnosis skills
6. Bridge maintenance work
7. Bridge repair design skills
8. Bridge repair work
9. Quality control of bridge construction an repairs
10. Bridge management procedures
11. Bridge management guidelines
12. Bridge Management System (BMS)

3 Target group of 3 Categories

Management at RDA Head Office

❖ Necessary studying about the contents of Bridge Management Guidelines as the base of bridge management. In addition, RDA should provide them with the knowledge of major repairs, which were not provided in the Project.

Management at Regional Offices

❖ RDA should provide them with the training program on the above, as well as improved quality control, bridge management procedure and use of BMS.

Engineers & Technical Officers at Regional Offices

❖ RDA should provide them with the training program on basic knowledge of bridges, bridge inspection and maintenance work, minor repair works as well as improved quality control.

Requirements for Target group of 3 categories

Management at RDA Head Office	Management at Regional Offices	Engineers & TOs at Regional Offices
● Basic knowledge of bridges ● Bridge planning ● Bridge design ● Bridge inspection ● Bridge diagnosis ● Bridge maintenance work ● Bridge repair design and work ● Understanding of bridge management procedures ● Understanding of bridge management guidelines ● Use of entire bridge management system (BMS): BISS, BDS, BRMS	● Basic knowledge of bridges ● Bridge planning ● Bridge design ● Bridge inspection ● Bridge diagnosis ● Bridge maintenance work ● Bridge repair design and work ● Quality control of bridge construction and repairs ● Understanding of bridge management procedures ● Use of BISS and BDS	● Basic knowledge of bridges ● Bridge inspection ● Bridge maintenance work ● Bridge repair work ● Quality control of bridge construction and repairs ● Use of BISS

4. Training Program

Contents

Agenda of Bridge Management Theoretical/ Practical Seminar

Theoretical Seminar	**20th Aug.2015**
• Outline of the Project • Bridge maintenance work • Purpose of inspection • Explanation of bridge type • Inspection work • Diagnosis • BMS • Repair work • Report from sample provinces	
Practical Seminar	**21st Aug.2015** **24th Aug. 2015**
• Recognition of present condition of RDA Bridge • Explanation of site inspection	

Seminar on Bridge Management

Outline of the Project

August 20.2015

Hideaki Takaura
Team Leader

Contents

- The purpose of this Seminar
- Present condition of Bridge Maintenance
- Back ground of this Project
- BM&AU
- Explaining about Model Provinces
- Sustainability --- Ownership
- 3 year project
- 5 output to improve the present situation
- Today's Explanation from PT

Welcome

from Western, Central, Southern

Provinces.

Welcome from Western, Central, Southern Provinces.

- 3 year project for capacity improvement of RDA bridge maintenance and management.
- February 2015 – 3 years
- 1st JCC (Joint Committee Meeting) 7th Aug. 2015.

- Soon after the JCC, Seminar with Engineers from Model Provinces.

The purpose of this Seminar

- Explanation of this 3 years project.
- Purpose and importance of Bridge Maintenance
- Role of BM&AU
- Role of Model Province Engineers
- Explanation of Basic Idea of Bridge Maintenance

Back ground of this Project

- Responsibility of RDA which support people's daily life is greatly important.
- RDA realized the present condition of bridges
- Requested the Project of bridge maintenance to Japanese government.
- ↓
- This project was started based on the needs of your social requirement

Present condition of Bridge Maintenance

- Road and Bridges are rapidly constructed
- Now RDA Bridge stock is 4,800 bridges
- Maintenance of bridges were not focused
- Road and Bridge surface are maintained but underneath of bridge is not observed carefully

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BM&AU

- 20 years ago RDA had BAU for bridge maintenance.
- This time BAU is revived as BM&AU.
- BAU from 9 Provinces.

- Firstly Japanese Project team → BM&AU
- BM&AU → Model Provinces.
- Model Provinces → whole Sri Lanka.

Explaining about Model Provinces

- Representative of whole Sri Lanka.
- Features of each places—Town area, hilly area,sea side area
- Convenience of the Project activities

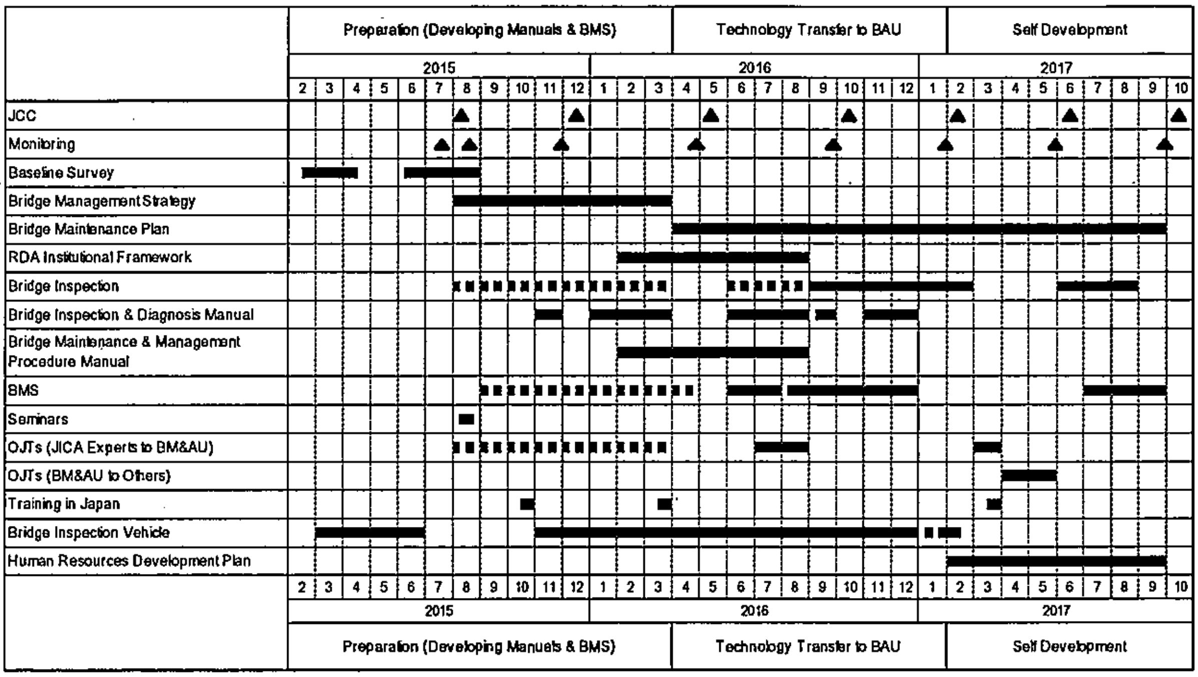
Sustainability --- Ownership

- Your Engineer will manage everything by your initiative after 3 years.
- JICA Technical assistance project.
- Different from projects like construction or procurement something.
- Japanese expert work together with your Engineers

3 year project

- 1st year Preparetion Work
- 2nd JICA Team instruct BM&AU
- 3rd year BM&AU member will spread the idea to other Engineers.

Project Schedule



5 output to improve the present situation.

- Output 1 Strategy of bridge maintenance
- Output 2 Work framework in RDA fir Bridge Maintenence
- Output 3 Preparation of Manual for inspection and diagnosis
- Output 4 BMS Bridge management System
- Output 5 Seminar and OJT

Today's Explanation from PT

- Inspection, diagnosis, repair work, BMS.
- Not only explain from our side, BM&AU and from Model Province Engineers express your idea or experiences.

END

Seminar on Bridge Management

Bridge Inspection

August 20.2015

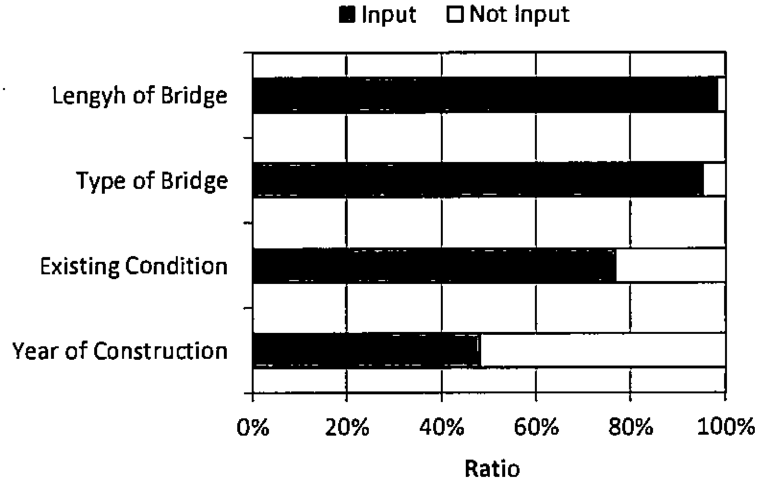
Minobu Aoyama, Ph.D
Bridge Inspection Expert

CONTENTS

1. Existing Bridge Inventory Data

I carried out an analysis of existing Bridge inventory data .

【Ratio of Input /missing data】



All data number is 4696.

A lot of important data is MISSING!

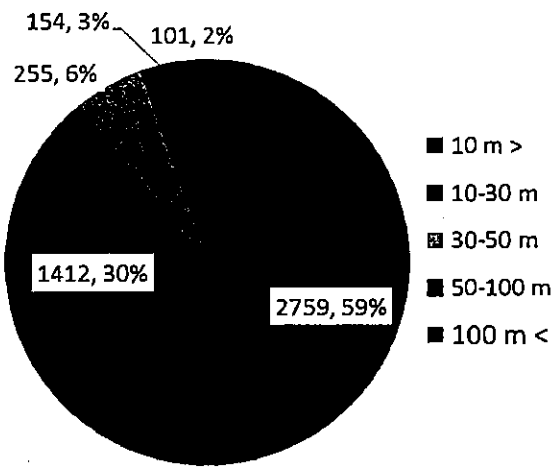
Source:Planning Division/RDA(2015)

【Ratio of missing data】 Year of Construction 52%, Existing Condition 23%, Type of Bridges 5%, Length of Bridges 2%.

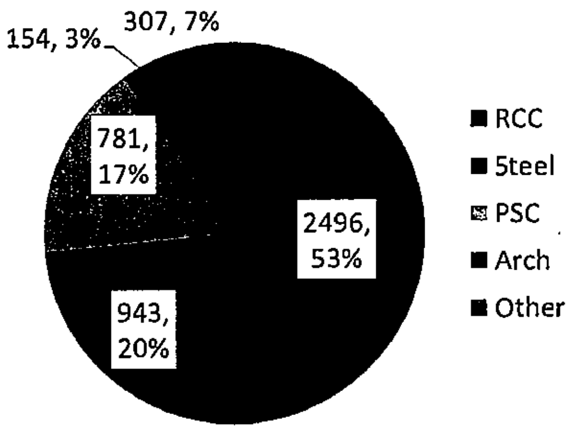
2

Analysis on Existing Inventory Data

【 Bridge length 】



【Bridge type】

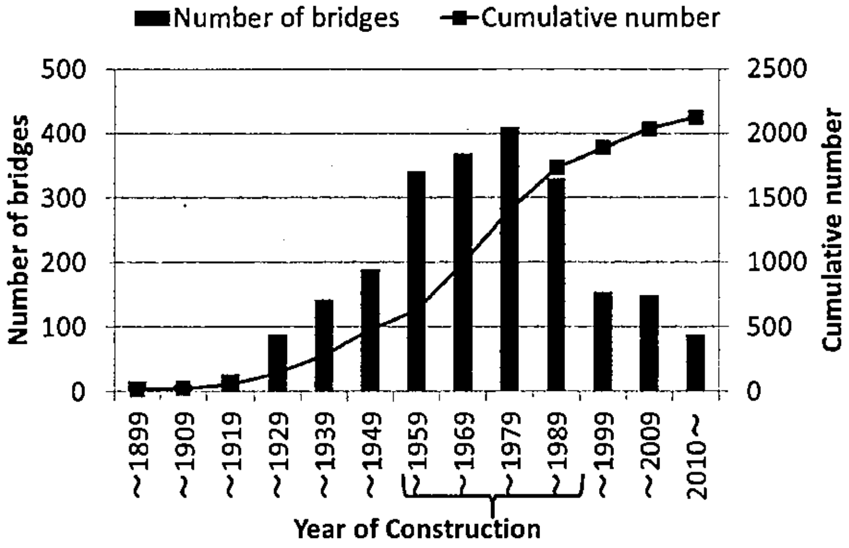


510 bridges:30 m or more
(Only 11%)

- 73 % : concrete.
- 17 % : steel.

3

【Construction Year】

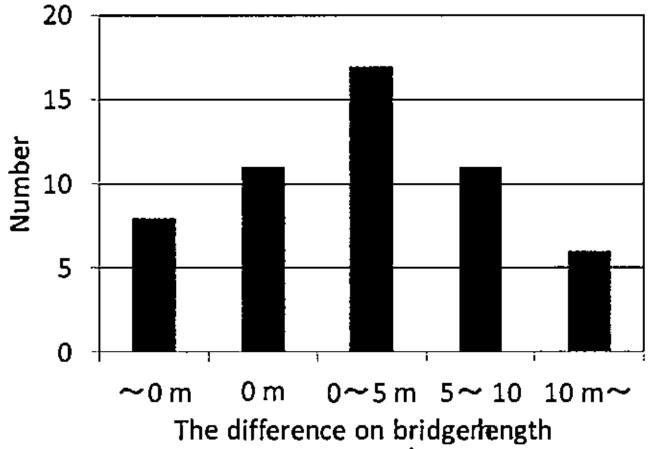


- Many bridges were constructed during '50 – '89.
- Average age of all bridges is 48 yo.

Accuracy of Existing Inventory Data

【Bridge Length】

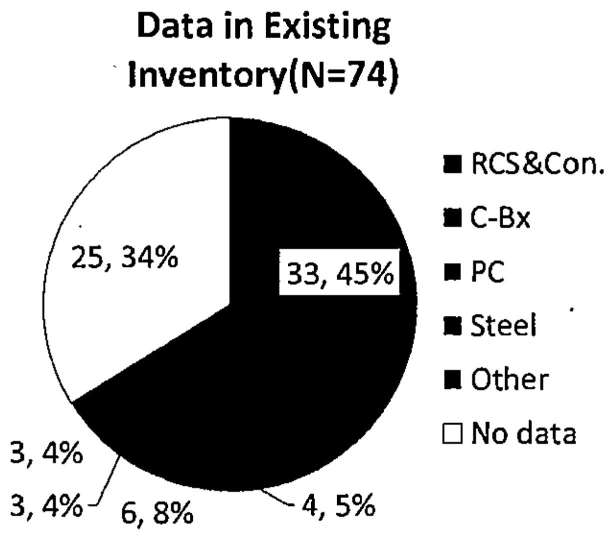
Difference on bridge length was investigated on 53 bridges in Eastern and Northern Provinces.

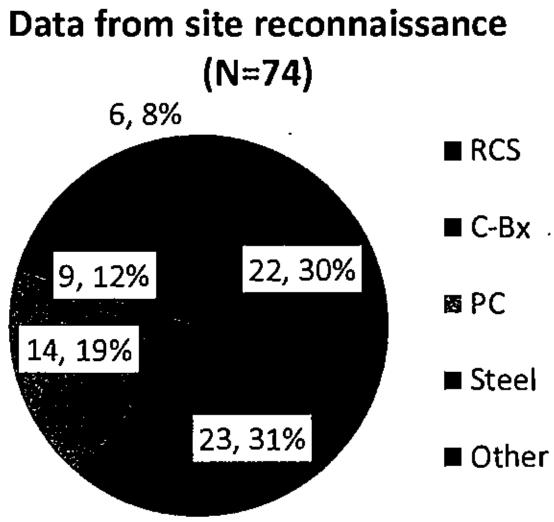


Actual Bridge Length is shorter than with recorded the inventory database.

- Bridge length is longer in many bridges.
- Bridge length data in existing DB is not accurate.

【Bridge Type】





There is a lot of Blank data.

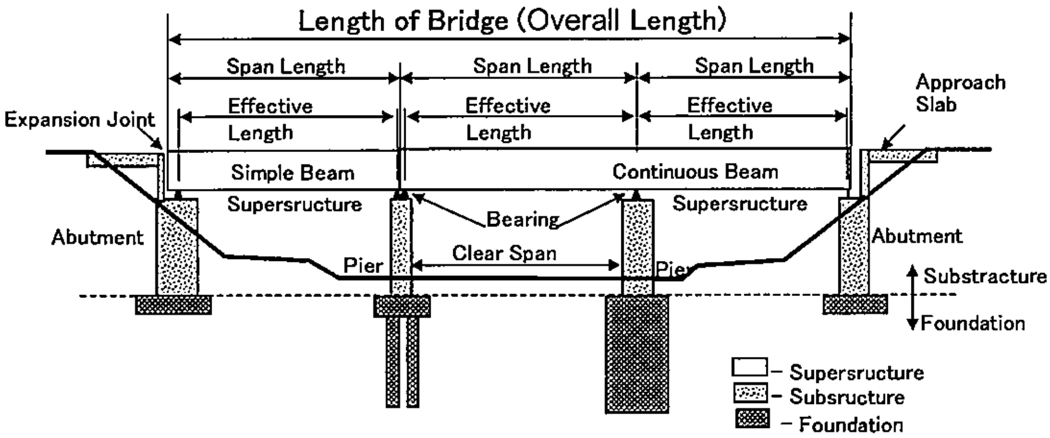
Input data of the C-Bx is less.

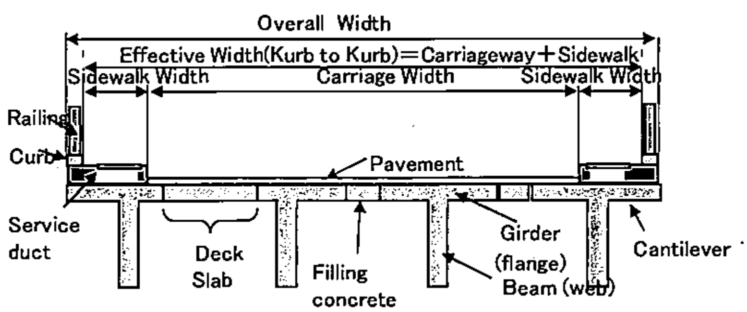
Accuracy of data is low.

It is not possible to grasp current situation of bridge assets.

2. Basic Knowledge of Bridge

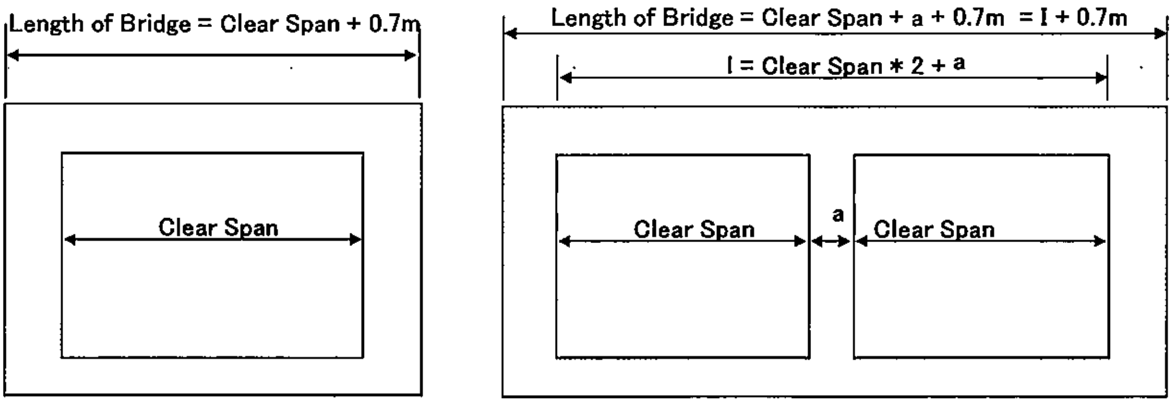
【Naming determination bridge member】





#【Box Bridge】

Clear span ≧ 3 m



1 Cell

2 Cells

- If possible, measure bridge length of box bridge and use the value.
- Otherwise, use "Clear Span + 0.7m(2@0.35m)"

#【Type of Bridge】

Material of Superstructure

Material of Superstructure	
1	Concrete
2	Steel
3	Composite
4	Stone
5	Bricks
6	Timber
7	Others

Large Classification of bridge

Classification of Bridges	
1	RCS Bridges
2	PSC Bridges
3	Box Bridges
4	Steel Bridges
5	Arch Bridges
6	Other Bridges
7	Causeway

3. Current Situation on Bridge Inspection

【Issues on Bridge Inspection Related Manual】

"ROAD MAINTENANCE MANUAL" 1989.02
"BRIDGE MAINTENANCE MANUAL" 1997.

No information

- How frequent ?
- Who does ?
- How to Inspect ? (practical way)
- Criteria on Rating /Diagnosis.

⇨

Bridge condition is indistinct

- Inspection is not carried out in some regions.
- No Accumulate Data.
- Rating differs depending on Inspector.

10

Situation of Bridge Inspection

Inspection is the 1st step of the Bridge Management Cycle

⬇

However

- Inaccurate inventory data.
- No inspection for Bridge structure /Only for bridge surface in most of bridges.
- No quantitative record in inspection.
- Rating is not reliable due to no united rules.

How to Improve ?

【Current situation】
・Bridge condition is unknown.
・Thus. No plan for maintenance.
・Thus. No remediation on structural meaning is implemented

⬇

Recognize and Understand "exact" condition of the bridge inspection.

⬇

You can develop a "Bridge Maintenance Plan" of bridges.
(When, Which bridge,How should be repaired / replaced.)

4. Procedure of Bridge Inspection

【 Purpose of Bridge Inspection】

To obtain information necessary for diagnosis / maintenance planning by recognizing size and position of damages.

【Information to be collected in bridge inspection】
- Inventory data.
- Recording the position and size of the damages.

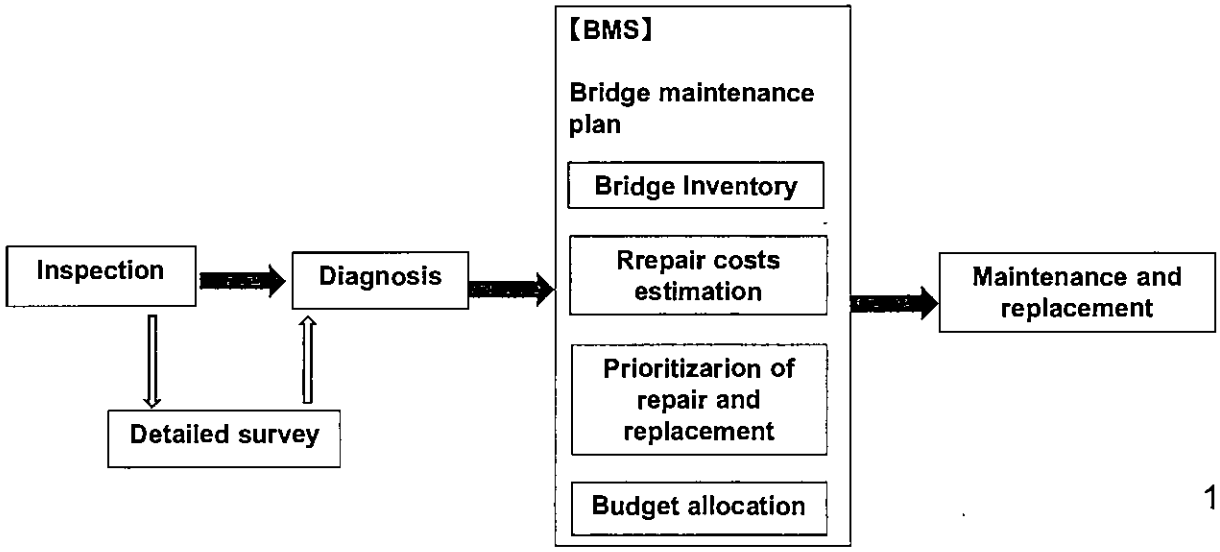
【Engineering Bridge Judgment in Bridge Inspection】
- Necessity of Urgent repairs.
- When & How to repair.
- Evaluation on Safety of whole Bridge.
- Necessity of Detailed Investigation.

Relation between Inspection and Maintenance

【For What】

Diagnosis, Repair costs estimation, Prioritization of repair and developing bridge maintenance plan.

【Relationship between inspection and maintenance】



Implementing Structure / Interval of Bridge Inspection

【Implementing Structure】

(1) Effective / Efficient for formation (2 or more engineer) for collection / record quantitative data on damaged bridges.

(2) Sustainable for development and transmission of inspection technology.

【Interval of Bridge Inspection】

Varies by severity of bridge / importance of route,etc. (To be discussed in the Project).

(FYR: In Japan, every 5-years).

Inspection method 1

Collection of Basic Information

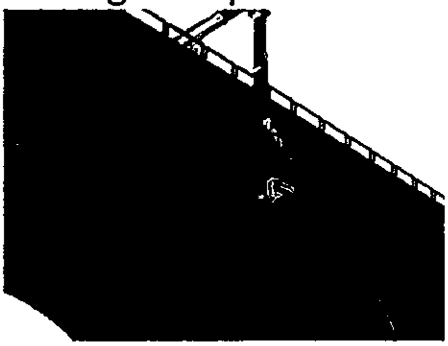
Location, Length, Width and dimension of the structural members.
· Examine the year of construction.

Visual Inspection

Use of Inspection Camera

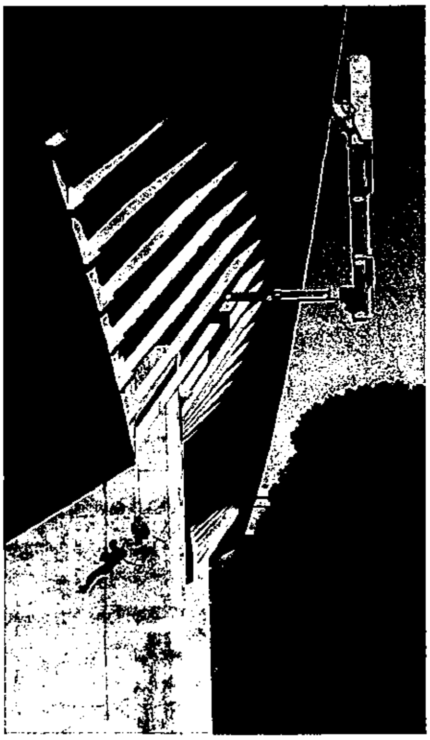
Inspection Method 2

Use of Bridge Inspection Vehicle

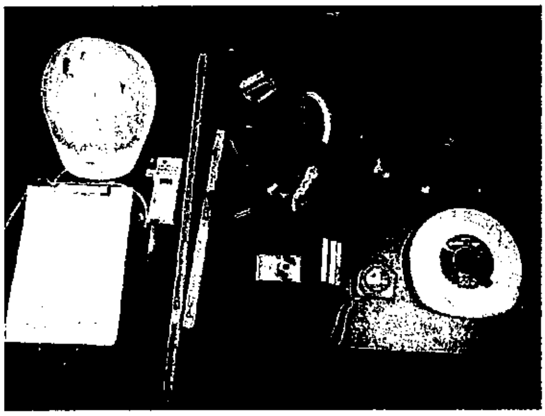


Hammering Inspection

Ropework



Personal Tools and Safety Equipment



Personal Tools

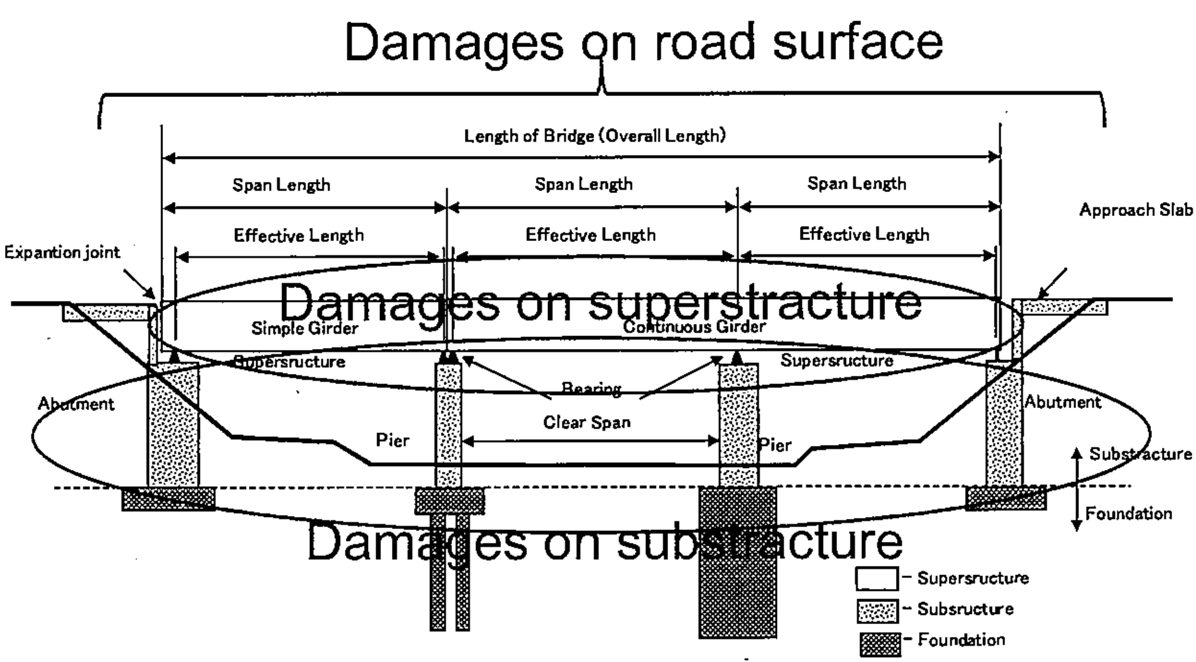
- Inspection Hammers
- Measuring Tape
- Crack scale
- Binoculars
- Camera

Safety Equipment

Protection for your own Safety

- Helmet
- Gloves
- Safety Jacket
- Safety Belt

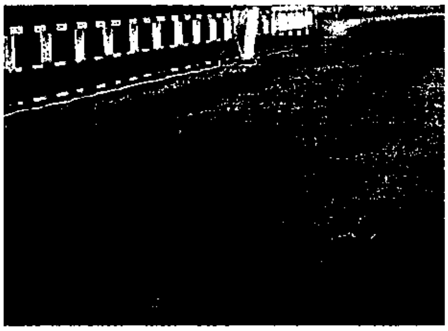
5. Damage Examples



Damages on Road Surface

Mud deposition

Rutting



Pot hole

Damage along Expansion

Damage on Concrete Superstructure

Cracks on main beam

Exfoliation

Corrosion of steel bars

Water leakage

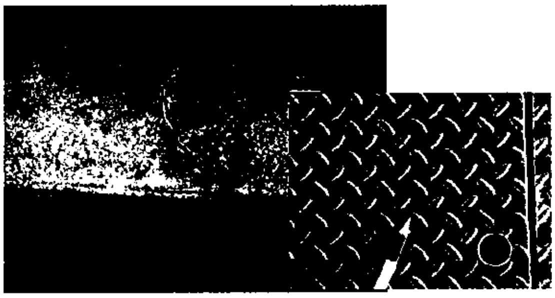
Damage on Steel Superstructure

Degradation of paint

Corrosion of HTB

Loss of section of steel
menbers due to corrosion

Fatigue cracking

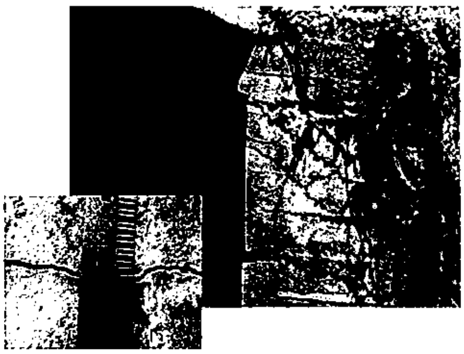


Damage on Substructure

Wearing of pier

Exfoliation of pier

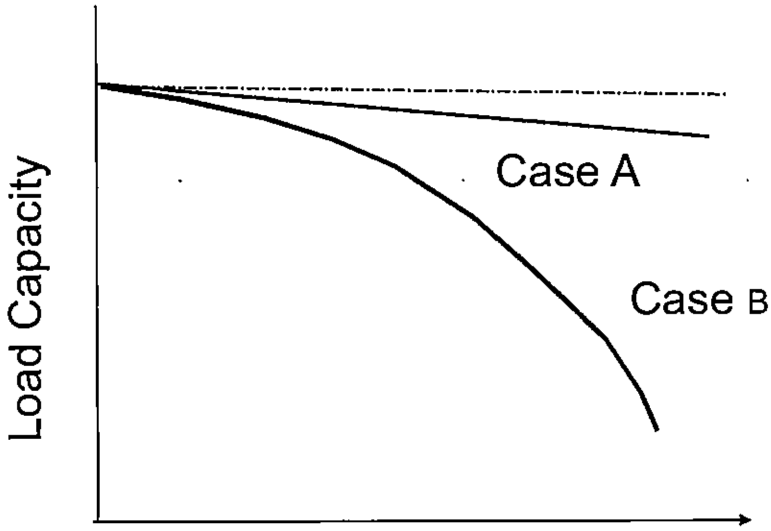
Cracking of wing wall



Reduction of the riverbed

Priority of Repair for Damage

Q, Which damage should be repaired earlier ?



A : Deterioration with rapid progress (Case B) should be highly prioritized for repair.

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Engineering Judgement for Emergency Repair

Damage of Railing

Damage on Road

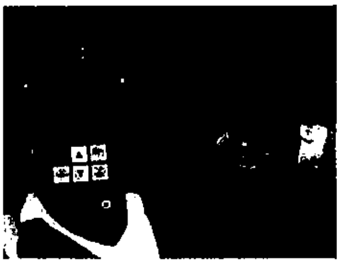
To keep Traffic / Pedestrian Safety

6. Detailed Investigation

【Safety Examination, measuring of steel corrosion for repair plan design】

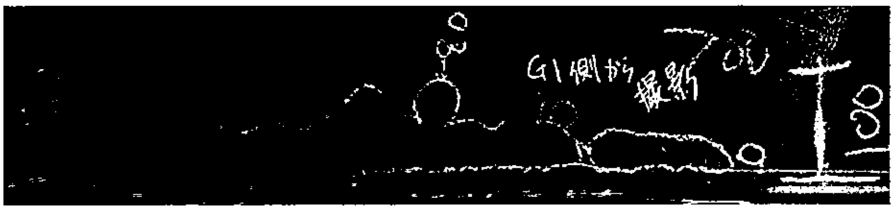
【Measuring instrument】

Micrometer

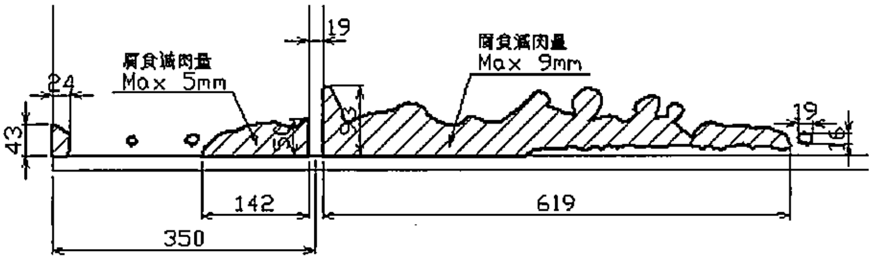


Ultrasonic thickness gauge

【Measurement example】



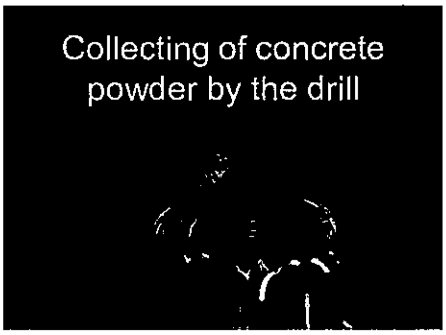
a) The photograph of the damage

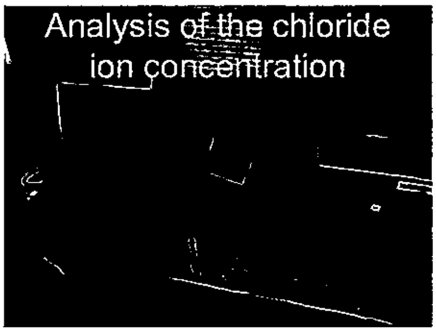


c) Processed figure of corroded aria

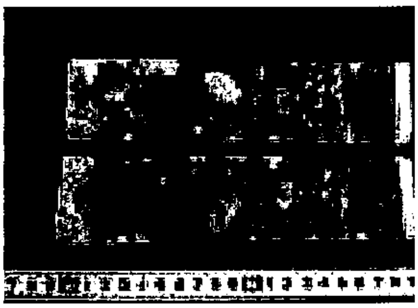
Investigation for Preventive Maintenance of RC members

【Chloride ion concentration measurement in concrete】





【Measurement of carbonation depth】



END

Seminar on Bridge Management

Bridge Inspection

August 20.2015

Minobu Aoyama, Ph.D
Bridge Inspection Expert

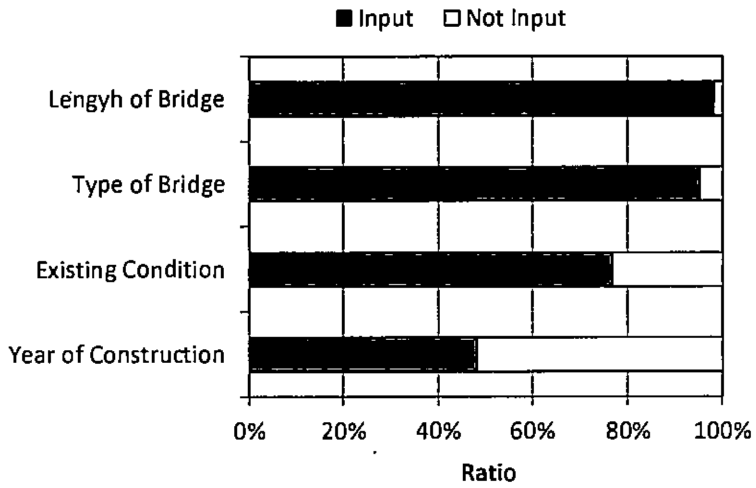
CONTENTS

1. Existing Bridge Inventory Data
2. Basic Knowledge of Bridges
3. Current Situation of Bridge Inspections
4. Procedure of Bridge Inspections
5. Damage Examples
6. Necessity of Detailed Investigation

1 . Existing Bridge Inventory Data

I carried out an analysis of existing Bridge inventory data .

【Ratio of Input /missing data】



All data number is 4696.

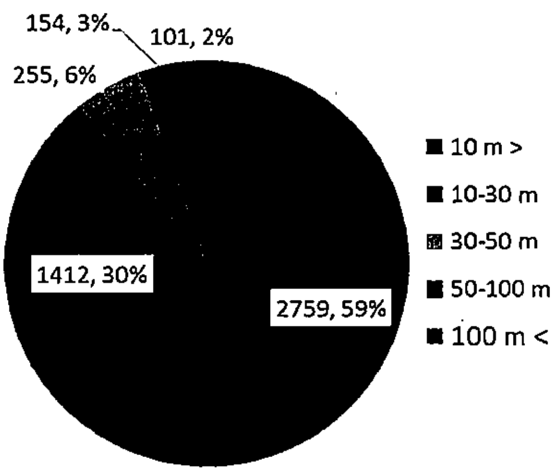
A lot of important data is MISSING!

Source:Planning Division/RDA(2015)

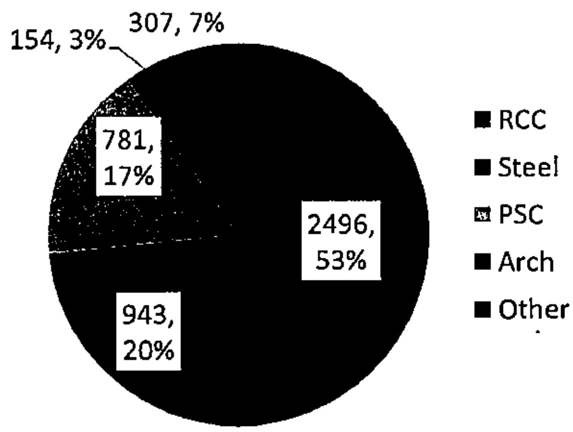
【Ratio of missing data】 Year of Construction 52%, Existing Condition 23%, Type of Bridges 5%, Length of Bridges 2%.

Analysis on Existing Inventory Data

【 Bridge length 】



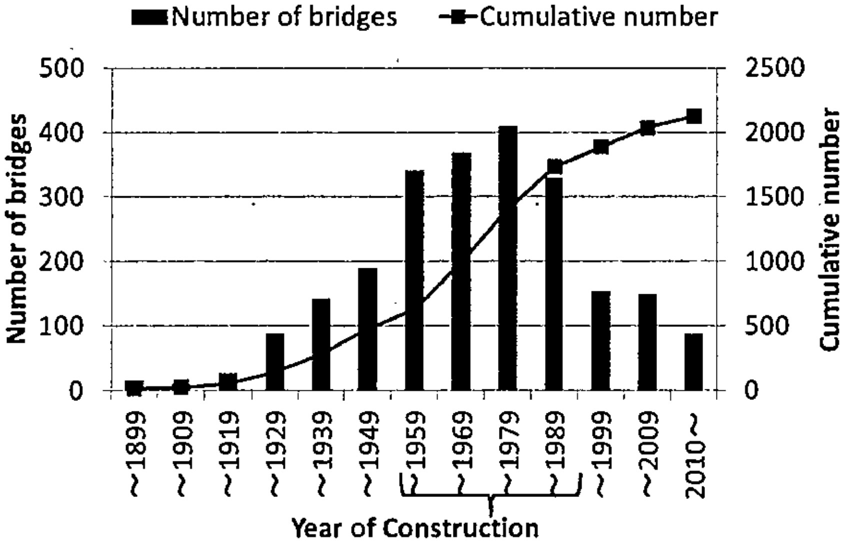
【Bridge type】



510 bridges:30 m or more (Only 11%)

- 73 % : concrete.
- 17 % : steel.

【 Construction Year】

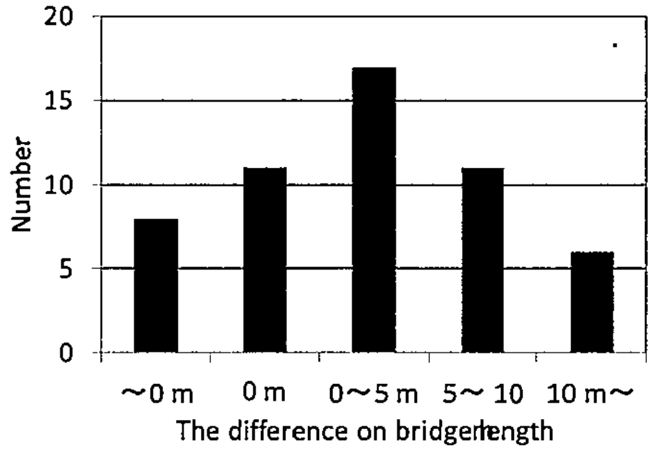


- Many bridges were constructed during ‘50 – ‘89.
- Average age of all bridges is 48 yo.

Accuracy of Existing Inventory Data

【Bridge Length】

Difference on bridge length was investigated on 53 bridges in Eastern and Northern Provinces.

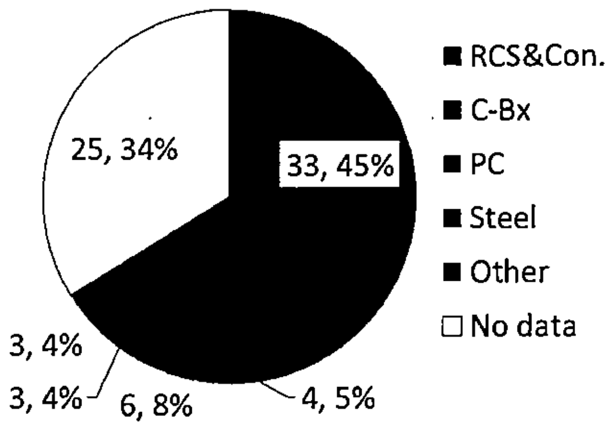


Actual Bridge Length is shorter than with recorded the inventory database.

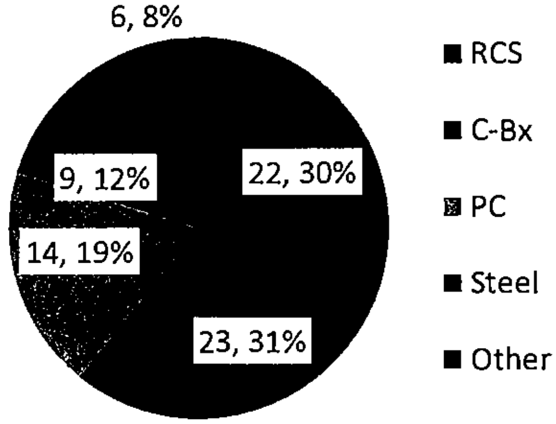
- Bridge length is longer in many bridges.
- Bridge length data in existing DB is not accurate.

【Bridge Type】

Data in Existing Inventory(N=74)



Data from site reconnaissance (N=74)



There is a lot of Blank data.

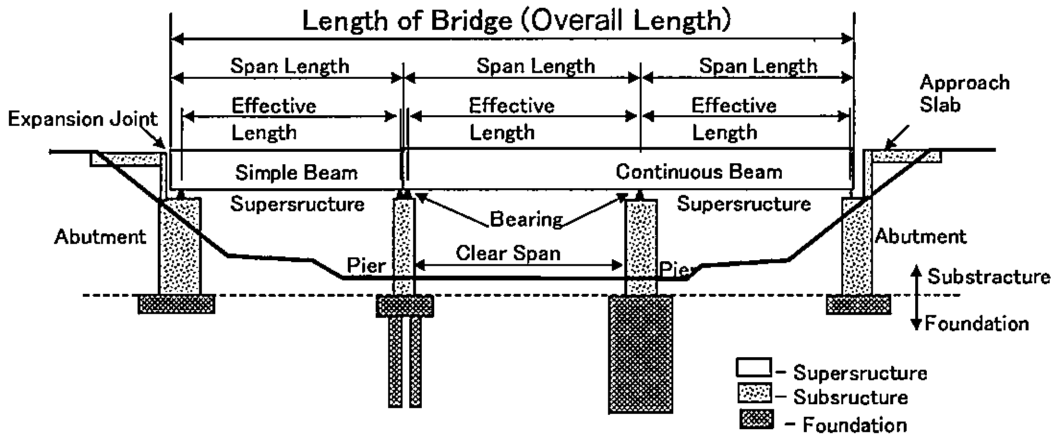
Input data of the C-Bx is less.

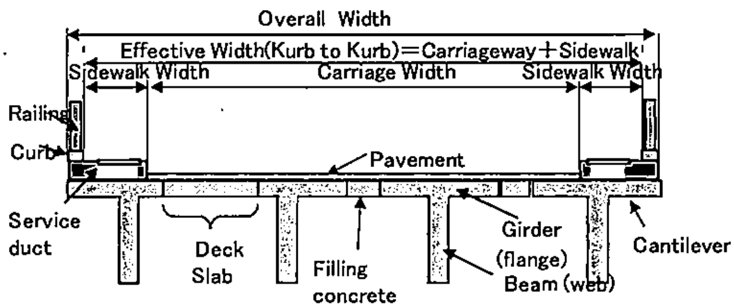
Accuracy of data is low.

It is not possible to grasp current situation of bridge assets.

2. Basic Knowledge of Bridge

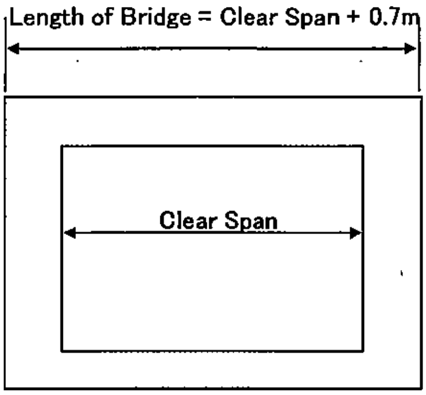
【Naming determination bridge member】



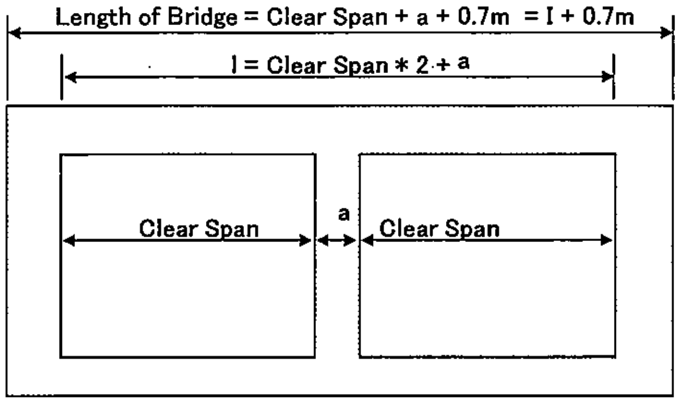


【Box Bridge】

Clear span ≧ 3 m



1 Cell



2 Cells

- If possible, measure bridge length of box bridge and use the value.
- Otherwise, use "Clear Span + 0.7m(2@0.35m)"

【Type of Bridge】

Material of Superstructure

Material of Superstructure	
1	Concrete
2	Steel
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4	Stone
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6	Timber
7	Others

Large Classification of bridge

Classification of Bridges	
1	RCS Bridges
2	PSC Bridges
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4	Steel Bridges
5	Arch Bridges
6	Other Bridges
7	Causeway

3. Current Situation on Bridge Inspection

【Issues on Bridge Inspection Related Manual】

"ROAD MAINTENANCE MANUAL" 1989.02
"BRIDGE MAINTENANCE MANUAL" 1997.

No information		Bridge condition is indistinct
• How frequent ? • Who does ? • How to Inspect ? (practical way) • Criteria on Rating /Diagnosis.	⇨	• Inspection is not carried out in some regions. • No Accumulate Data. • Rating differs depending on Inspector.

Situation of Bridge Inspection

Inspection is the 1st step of the Bridge Management Cycle

⬇

However

- Inaccurate inventory data.
- No inspection for Bridge structure /Only for bridge surface in most of bridges.
- No quantitative record in inspection.
- Rating is not reliable due to no united rules.

How to Improve ?

【Current situation】
- Bridge condition is unknown.
- Thus. No plan for maintenance.
- Thus. No remediation on structural meaning is implemented

⬇

Recognize and Understand "exact" condition of the bridge inspection.

⬇

You can develop a "Bridge Maintenance Plan" of bridges. (When, Which bridge,How should be repaired / replaced.)

4. Procedure of Bridge Inspection

【 Purpose of Bridge Inspection】

To obtain information necessary for diagnosis / maintenance planning by recognizing size and position of damages.

【Information to be collected in bridge inspection】
- Inventory data.
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【Engineering Bridge Judgment in Bridge Inspection】
- Necessity of Urgent repairs.
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- Evaluation on Safety of whole Bridge.
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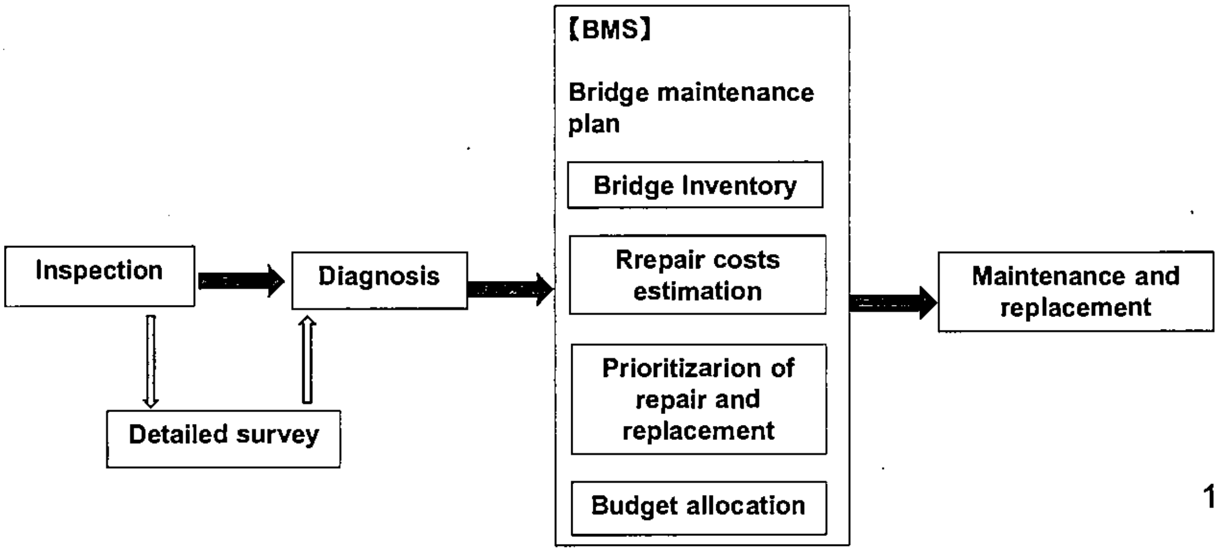
Relation between Inspection and Maintenance

【For What】

Diagnosis, Repair costs estimation, Prioritization of repair and developing bridge maintenance plan.

【Relationship between inspection and maintenance】



Implementing Structure / Interval of Bridge Inspection

【Implementing Structure】

(1) Effective / Efficient for formation (2 or more engineer) for collection / record quantitative data on damaged bridges.

(2) Sustainable for development and transmission of inspection technology.

【Interval of Bridge Inspection】

Varies by severity of bridge / importance of route,etc. (To be discussed in the Project).

(FYR: In Japan, every 5-years).

Inspection method 1

Collection of Basic Information

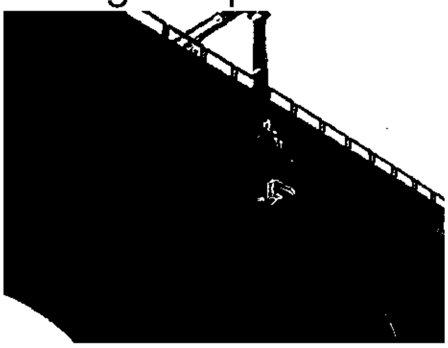
Location, Length, Width and dimension of the structural members.
· Examine the year of construction.

Visual Inspection

Use of Inspection Camera

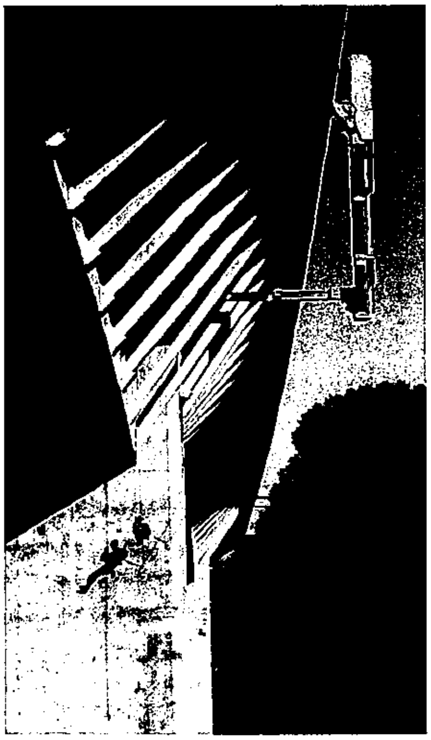
Inspection Method 2

Use of Bridge Inspection Vehicle

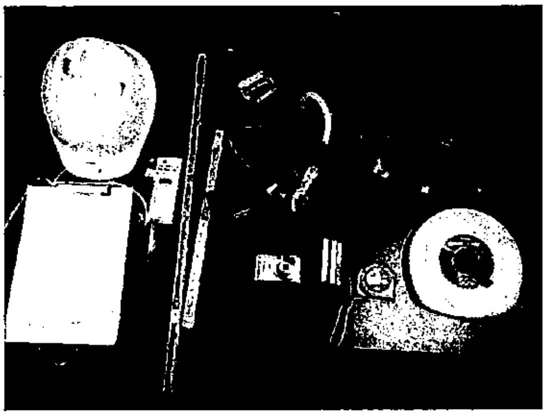


Hammering Inspection

Ropework



Personal Tools and Safety Equipment



Personal Tools

- ・Inspection Hammers
- ・Measuring Tape
- ・Crack scale
- ・Binoculars
- ・Camera

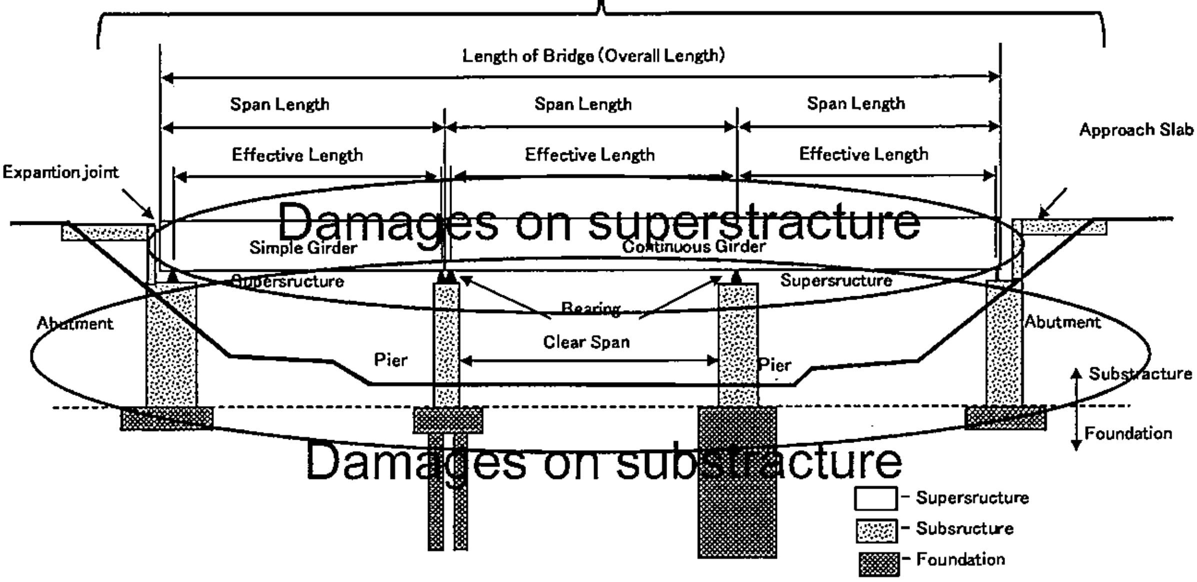
Safety Equipment

Protection for your own Safety

- ・Helmet
- ・Gloves
- ・Safety Jacket
- ・Safety Belt

5． Damage Examples

Damages on road surface

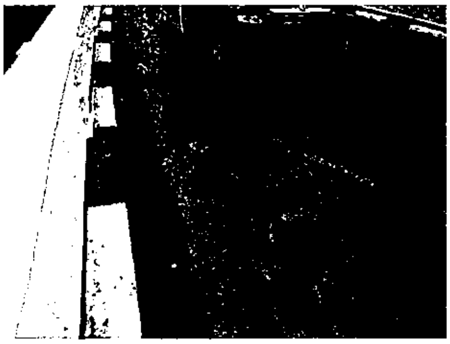


Damages on Road Surface

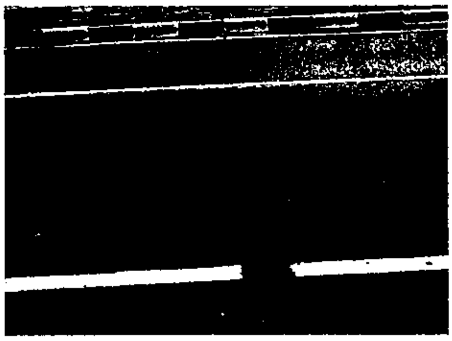
Mud deposition

Rutting

Pot hole



Damage along Expansion



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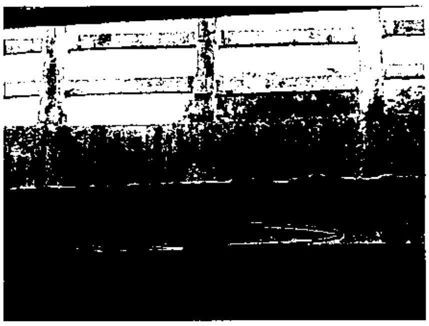
Damage on Concrete Superstructure

Cracks on main beam



Exfoliation

Corrosion of steel bars

Water leakage

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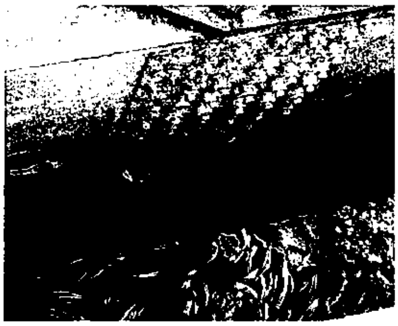
Damage on Steel Superstructure

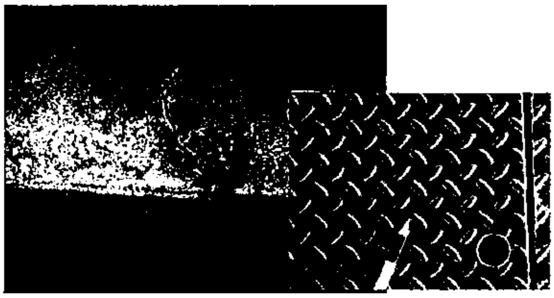
Degradation of paint

Corrosion of HTB



Loss of section of steel menbers due to corrosion

Fatigue cracking



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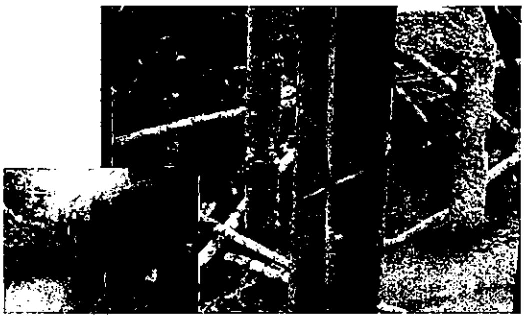
Damage on Substructure

Wearing of pier



Exfoliation of pier

Cracking of wing wall

Reduction of the riverbed

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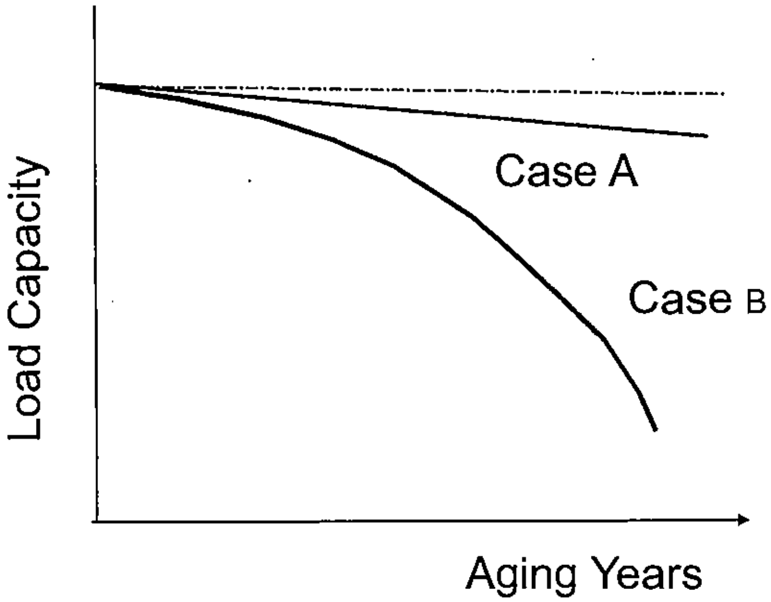
Priority of Repair for Damage

Q, Which damage should be repaired earlier ?



A : Deterioration with rapid progress (Case B) should be highly prioritized for repair.

Engineering Judgement for Emergency Repair

Damage of Railing

Damage on Road

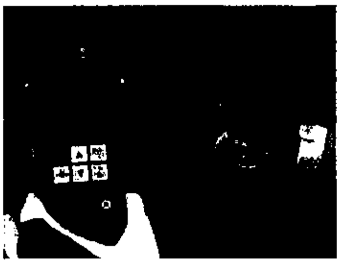
To keep Traffic / Pedestrian Safety

6 . Detailed Investigation

【Safety Examination, measuring of steel corrosion for repair plan design】

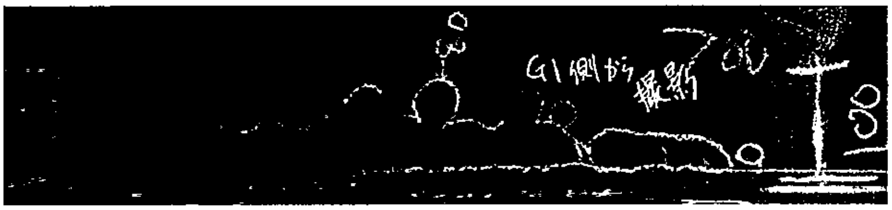
【Measuring instrument】

Micrometer

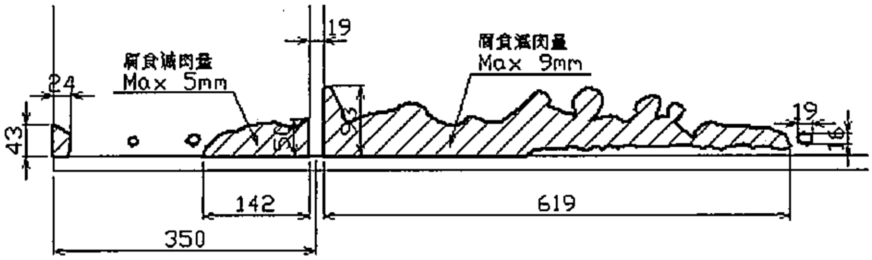


Ultrasonic thickness gauge

【Measurement example】



a) The photograph of the damage



c) Processed figure of corroded aria

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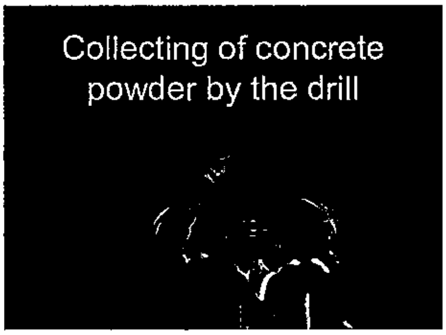
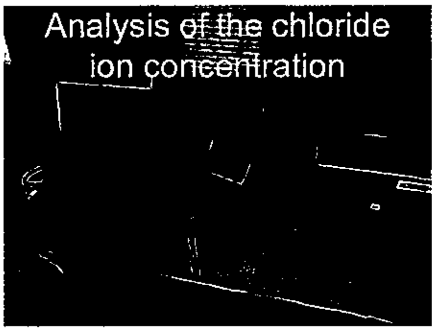
Investigation for Preventive Maintenance of RC members

【Chloride ion concentration measurement in concrete】





【Measurement of carbonation depth】

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S-2

Repair Work Seminar

January 2017
February 2017

Agenda for Concrete Bridge/Steel Bridge

1. General information of bridge repair method
2. Plastering method for concrete structure and zone painting for steel structure
3. Demonstration for plastering method for concrete structure and zone painting for steel structure
4. Generation of rust

Site visit – Inspection method

Road Development Authority

Japan International Cooperation Agency

The Project for Capacity Development
on Bridge Management in
The Democratic Socialist Republic of
Sri Lanka

Trial bridge repair work and on-the-job training

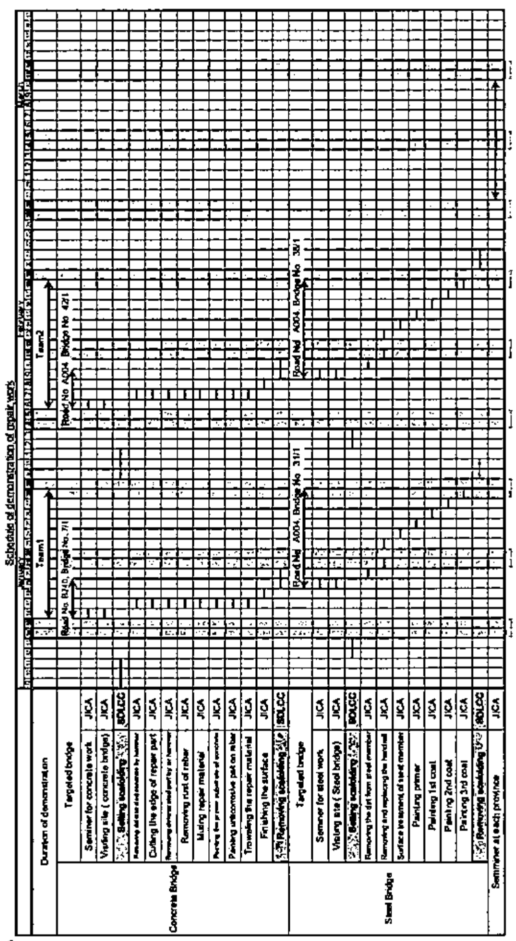
January - February 2017

Road Development Authority

Japan International Cooperation Agency

CONTENTS

1. Schedule of trial repair work



MEETING PLACE AND TIME (TEAM1)

DATE				MEETING TIME	MEETING PLACE	
January	16th	Mon	AM	9:00	JICA PROJECT TEAM OFFICE	
			PM	13:00	AT SITE	Road No.:B240, Bridge No.:7/1
	17th	Tue	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	18th	Wed	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	19th	Thu	AM	9:00	JICA PROJECT TEAM OFFICE	
			PM	According to work procedure	AT SITE	Road No : A004, Bridge No : 31/1
	20th	Fri	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	21st	Sat	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	22nd	Sun	AM	REST		
			PM			
	23rd	Mon	AM	9:00	AT SITE	Road No : A004, Bridge No : 31/1
			PM	According to work procedure	AT SITE	
	24th	Tue	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	25th	Wed	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	26th	Thu	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	27th	Fri	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	28th	Sat	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	29th	Sun	AM			
			PM			
	30th	Mon	AM			
			PM			
	31st	Tue	AM			
			PM			

MEETING PLACE AND TIME (TEAM2)

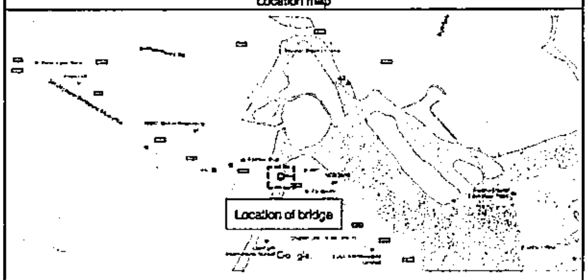
DATE				MEETING TIME	MEETING PLACE	
February	1st	Wed	AM			
			PM			
	2nd	Thu	AM			
			PM			
	3rd	Fri	AM			
			PM			
	4th	Sat	AM			
			PM			
	5th	Sun	AM			
			PM			
	6th	Mon	AM	9:00	JICA PROJECT TEAM OFFICE	
			PM	13:00	AT SITE	Road No.:A004, Bridge No.:42/1
	7th	Tue	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	8th	Wed	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	9th	Thu	AM	9:00	JICA PROJECT TEAM OFFICE	
			PM	According to work procedure	AT SITE	Road No : A004, Bridge No : 38/1
	10th	Fri	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	11th	Sat	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	12th	Sun	AM	REST		
			PM			
	13th	Mon	AM	9:00	AT SITE	Road No : A004, Bridge No : 38/1
			PM	According to work procedure	AT SITE	
	14th	Tue	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	15th	Wed	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	16th	Thu	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	17th	Fri	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	18th	Sat	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	19th	Sun	AM			
			PM			
	20th	Mon	AM			
			PM			
	21th	Tue	AM			
			PM			

2. Location of targeted Bridged

Targeted Concrete Bridge for Team1

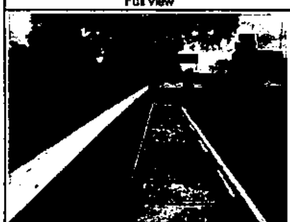
Road and Bridge No.							
Road No.	B240	Bridge No.	7 / 1 in Km	EE Division		Colombo (Western)	

Location map

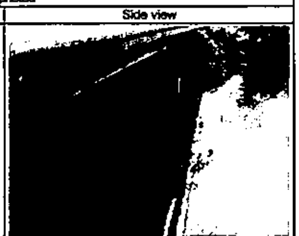


Site photos

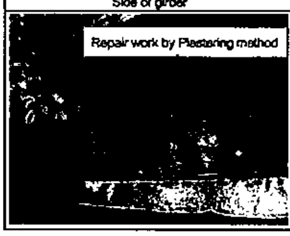
Full view



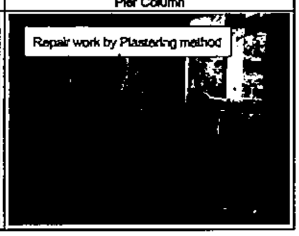
Side view

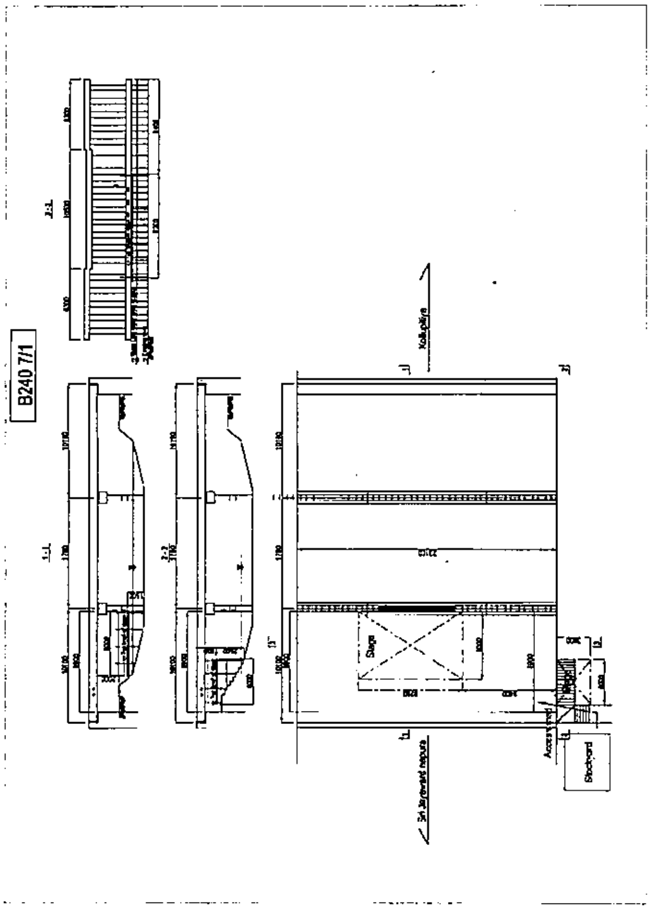


Side of girder



Pier Column

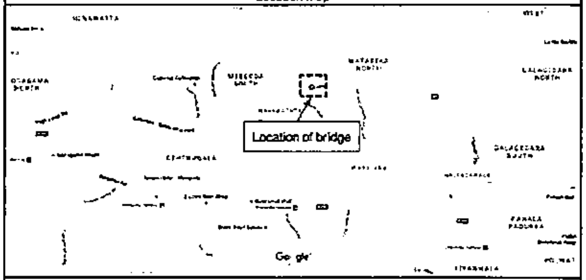




Targeted Steel Bridge for Team1

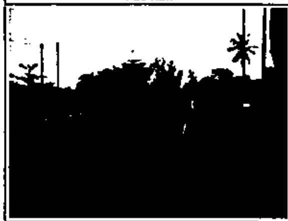
Road and Bridge No.						
Road No.	A004	Bridge No.	31 / 1 in Km	EE Division	Awissawella (Western)	

Location map

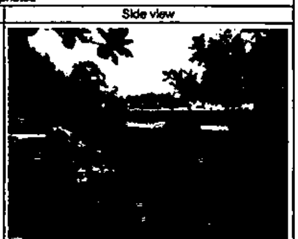


Site photos

Full view

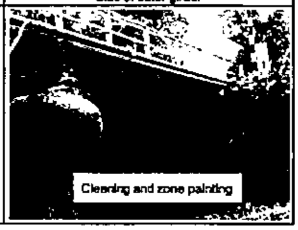


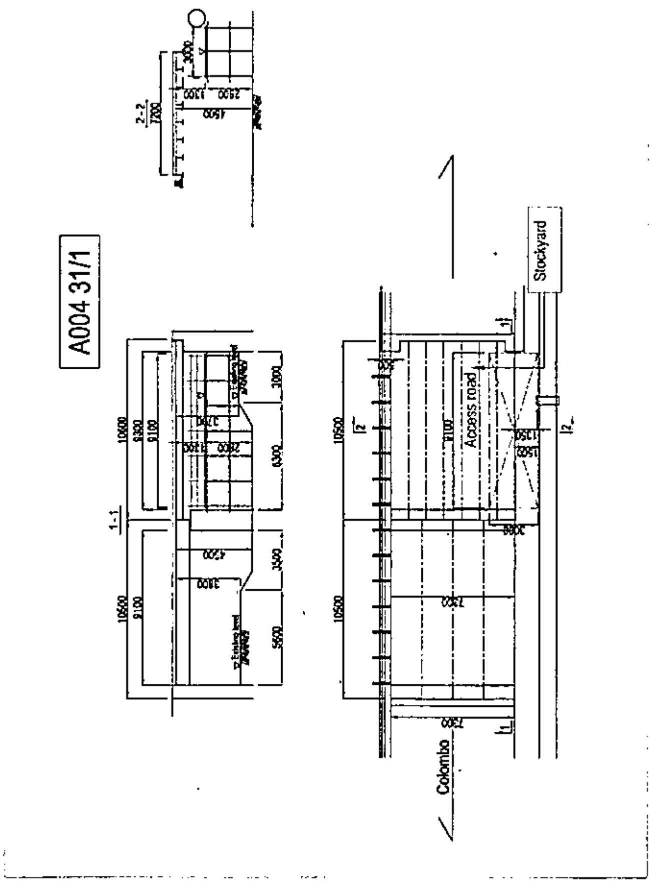
Side view



Side of outer girder

Side of outer girder

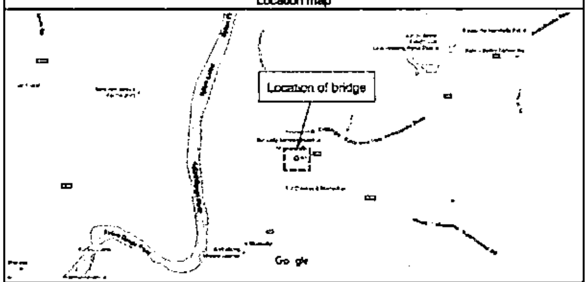




Targeted Concrete Bridge for Team2

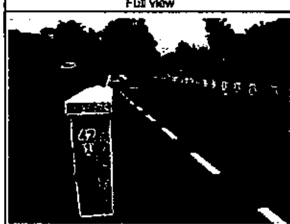
Road and Bridge No.						
Road No.	A004	Bridge No.	42 / 1 in Km	EE Division	Awissawella (Western)	

Location map

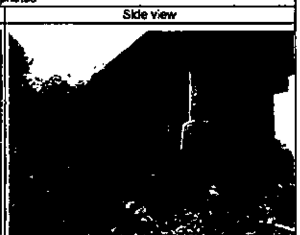


Site photos

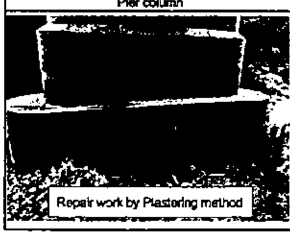
Full view



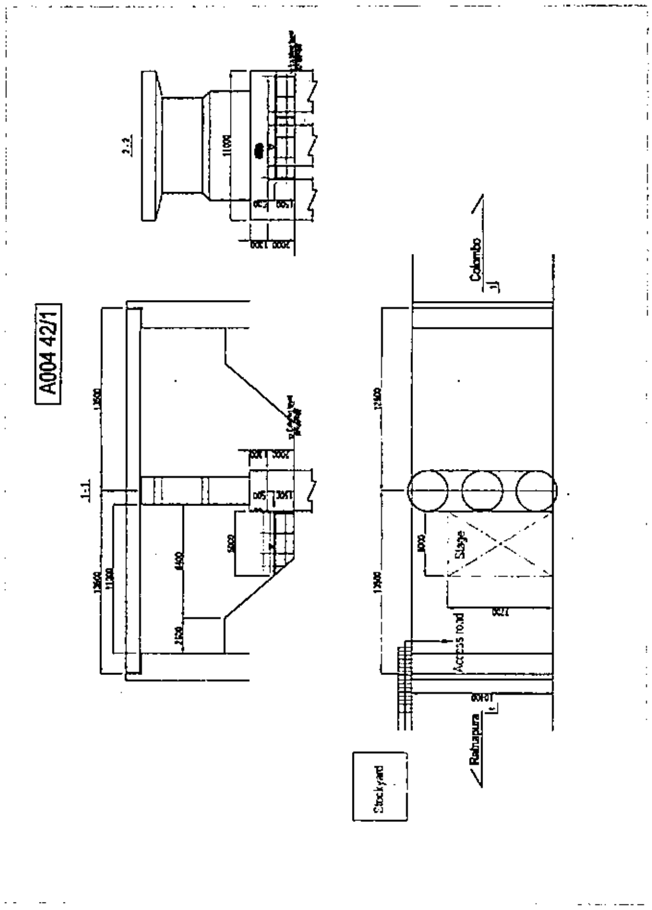
Side view



Pier column

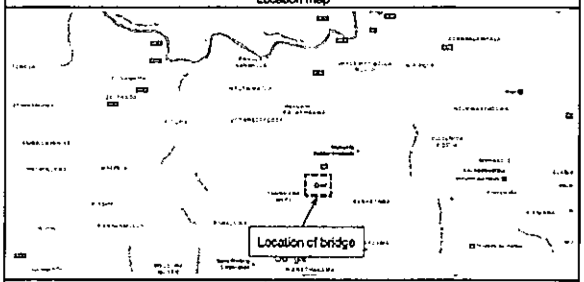


Zoom at deteriorated part

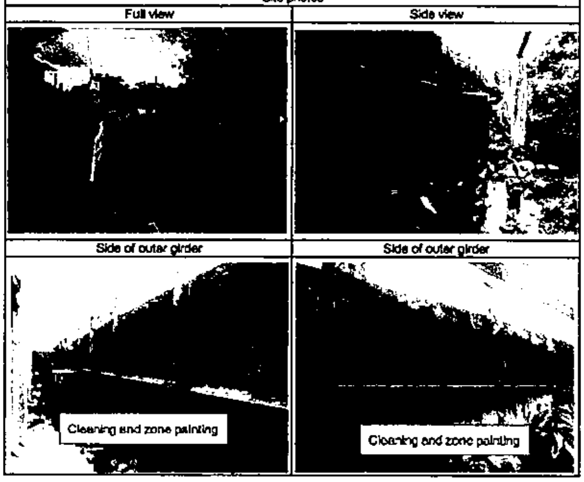


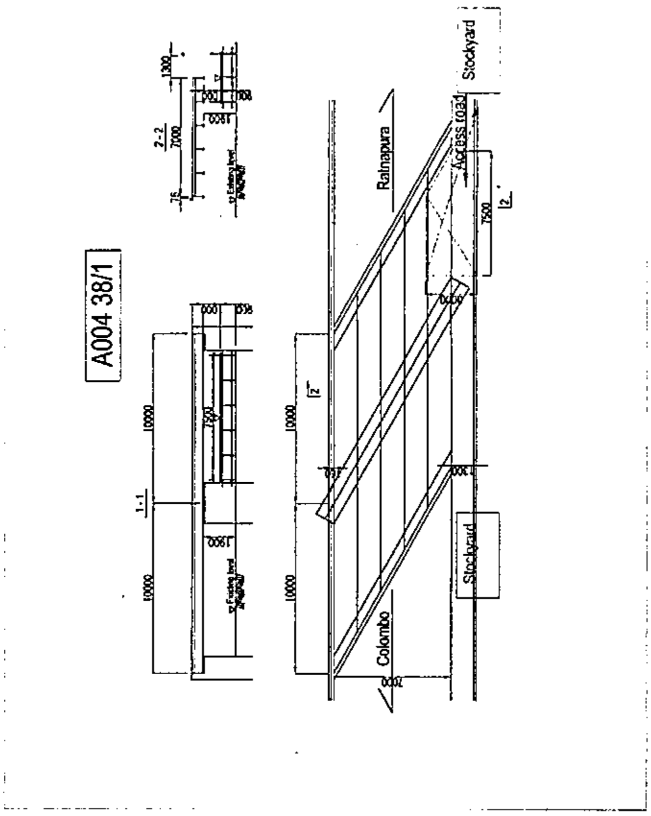
Road and Bridge No.						
Road No.	A004	Bridge No.	38 / 1 in Km	EE Division	Awissawella (Western)	

Location map



Site photos





3. Method statement for Plaster method for concrete structure (Draft)

Plastering method

1. Work flow and requirement

2. Materials

3. Equipment

4. Storage and shelf time of materials

5. Quality control

6. Inspection sheet and repair record

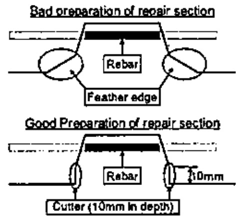
7. Health and safety

1. **Work flow and requirement**
   The contractor shall submit the Methodology of work (procedure) to the Engineer in charge for his review and approval before commencement of the work.

1). Preparatory Inspection
Identify the location of delaminating, spalling surface deteriorated concrete by hammer or other method.

2). Making cut lines
Making the cutting lines. It should be at approximately 30mm set off from the edge of deteriorated surface.

3). Saw cut
In order to prevent featheredge, saw cut or disk cutter shall be done. Depth of the saw cut is around 10mm. Feather edge cause of separation of repair material. Attention to the existing rebar not to damage.



4). Removal of defective concrete
Remove all defective, unsound and contaminated concrete and prepare the edge for the patch area as shown in the attached photo. If local corrosion in reinforcement with section loss is found which would require additional bars, remove only the damaged concrete including the length needed to bond the new reinforcement.
Concrete within marked out areas shall be removed using light mechanical breakers or hammer and chisel. The exposed reinforcing steel shall be cut and sound of concrete substrate shall be determined to the satisfaction of the Engineer in charge, without breaking out concrete behind the reinforcing steel.
Using high pressure water blasting is recommended in order to avoid generation of micro cracks.

5). Inspection after chipping
Inspect overhang, featheredge, air ventilation, loose materials, rust on rebar, rebar and surrounding space suitable for repair mortal etc.

As defined in EN 1504-10, water jet categories are as follows;

Grade of water pressure	Description
Low Pressure (Up to 18N/mm2(MPa) / 180bar / ~2,600PSI	Used for cleaning concrete and steel substrate
High Pressure (From 18 to 60 N/mm²(MPa) / 600bar / ~ 8,700PSI	Used for cleaning steel substrate and for removal of concrete
Very High Pressure (From 60 to 110N/mm2(MPa) / 1,100bar / ~ 16,000PSI	Used for concrete removal when low water volume is available

6). Cleaning of concrete and rebar
Remove loose particles and dust using light pressure water or vacuum cleaner. Concrete surface to be bonded must be free from dirt, oil, grease, asphalt etc. Corrosion must be removed before placing the new concrete. If deterioration is due to chloride contamination or if the reinforcing steel is covered with loose corrosion elements having pits, use high pressure water blasting until all the rust is removed. The concrete surfaces selected for repair shall be prepared by mechanical scrubbing to remove loose materials, surface laitance, organic contaminants and moss, and then then coated by bonding primer. Utmost care shall be taken to ensure that vibration generated during the process does not cause delamination of adjacent render or concrete.

7). Additional concrete breakout
Where the breakout indicates that the exposed reinforcing steel is further corroded or the surrounding concrete is not sound, an enlarged area shall be agreed to be broken to the satisfaction of the Engineer in charge.
The contractor shall test the concrete for extent of carbonation at the reinforcing steel at his own expense. The depth of breakout in clearly defined areas can be increased based on written instructions from Engineer in charge, in order to remove all carbonated concrete. The additional concrete breakout shall not extend more than20mm behind the bottom layer main reinforcing steel. During breakout, utmost care shall be undertaken to minimize damage to existing reinforcing steel.

Case1. Rebar unaffected

Case.2 Rebar affected

Note : W and D shall be at least 20mm

8). Additional or replacement reinforcing steel

The contractor shall report to the Engineer any rebar which has 10% or more section loss as a result of corrosion. Additional or replacement reinforcing steel shall be provided as instructed by the Engineer. Replacement reinforcing steel shall be cleaned to the same standard as the exiting reinforcing steel. This replacement reinforcing steel shall be lapped on the side of the existing bars and be spot welded on one side. It shall be fixed along its length at suitable intervals to prevent sagging. The corroded rebar shall be cleaned and applied with zinc rich primer to prevent further corrosion. The contractor shall obtain Engineer's approval for the rebar coating prior to proceeding with repair mortar application.

9). Bonding coating to concrete and reinforcing steel

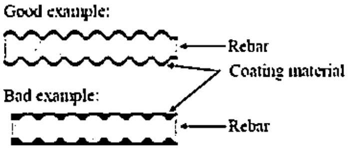
Concrete surface shall be saturated with clean low pressure water a minimum 2 hours before application ensuring that all pores and pits are adequate wet. The surface shall not be allowed to dry before application.

Epoxy bonding coats are applied to dry and clean concrete surfaces in order to bond firmly. Specially formulated resins are also available for damp surfaces. Apply the selected bonding coat to steel bars as shown in the photo. With a brush working vigorously to ensure that they are evenly covered all around. In case, substrate of existing concrete is in dry condition, there is some possibility of occurrence of dry out phenomenon. It occurs when water in repair material will be absorbed by existing concrete and which will induce restraint of hydration reaction. This phenomenon cause hardening or adhesive failure. For the purpose of prevention of Dry out phenomenon, painting the primer (water absorption adjustment material) on substrate of the concrete will be effective.

Apply primer as stipulation of date sheet. Moisture condition of base surface before application of primer shall be in accordance with date sheet. In case that usage of primer is misunderstood, bonding strength might be lower than that of without application of primer.

No matter if application paint (epoxy based zinc rich paint) is single or two components, mix thoroughly until a uniform consistency is obtained because epoxy based zinc rich paint is precipitated before using. Mix again occasionally during application for avoid re precipitation.

When painting epoxy based zinc rich paint on reinforcing steel, it is necessary to keep the surface of it in unevenness condition.



10). Filling up repair material

The mortar should be placed in layers of about 20mm thickness. Compact each layer thoroughly over the entire surface using a wooden trowel or hammer.

Generally, there should be no time delays between the placing and compacting of layers. The plastering to the surrounding concrete is performed using a form material, and then hammered using a mallet, wood float or steel trowel. The mortar shall be mixed using equipment (normally a force action mixer) approved by the Engineer.

The mixing liquid shall be added to the dry components and thoroughly mixed to achieve a uniform consistency, unless otherwise approved by the Engineer. The mortar shall then be applied to the bonding agent using hand packing and trowel to the satisfaction of Engineer in charge. The textured finish of the final repair mortar layer shall match the finish on the existing interior surface.

The repair mortar application shall be built up to the original surface profile in layers not exceeding 20mm and the final layer shall not exceed 15mm, unless otherwise recommended by the manufacturer and approved by the Engineer in charge. The Engineer may approve mortar application thickness of up to 50mm for lightweight mortars, provided the mortar manufacturer can finish a technical date to justify a layer thickness of greater than 20mm.

11). Curing

All types of cement repair need through and continuous curing to develop strength and impermeability, and to minimize drying shrinkage while bond strength is developing. Curing of the repair mortar shall be in accordance with the polymer modified additive manufacturer's instructions. Where curing agents are specified by manufacturer, they shall be applied immediately after the surface have been scarified for the next repair mortar layer or troweled to a finish.

Avoid direct sunlight during curing by means of sheet or boards.

12). Visual and hitting sound check

After hardening of the repair part, sounding by hammer for confirmation of separation does not occur.

2. Material

1). Specifications

Specification of Structural and Non-Structural Repair (BS EN 1504-3)

Item	Requirement			
	Structural		Non-Structural	
	Class R4	Class R3	Class R2	Class R1
Compressive Strength	≧45MPa	≧25MPa	≧15MPa	≧10MPa
Chloride Ion Content	≦0.05%		≦0.05%	
Adhesive Bond	≧2.0MPa	≧1.5MPa	≧0.8MPa	
Restrained shrinkage Expansion	Max average crack width < 0.05mm No crack width > 0.1mm No delamination			No requirement
	≧2.0MPa	≧1.5MPa	≧0.8MPa	
DURABILITY Carbonation Resistance (not required if coated)	dk≦Control concrete C(0.45)			Not requirement
Elastic Modulus	≧20GPa	≧15GPa	Not required	

Specification of Epoxy Bonding Agent to concrete surface

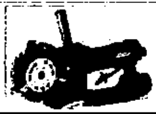
Item	Test Method	Specification
Compressive strength	ASTM D695M	70N/mm²
Flexural strength	ASTM D790M	40N/mm²
Tensile strength	ASTM D638M	30N/mm²
Tensile shear bond to steel	ASTM 1002	15N/mm²
Slant shear bond to mortar	ASTM C882	15N/mm²
Bond strength of cured concrete to fresh concrete	ASTM D7274	15N/mm²

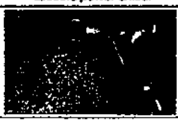
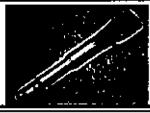
Specification of Zinc Rich Primer for rebar

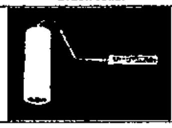
Item	Test Method	Specification
Adhesion	ASTM D3359	Minimum Rating : 3A
Salt spray resistance	ASTM D3-37	Excellent

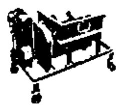
Specifications of Water

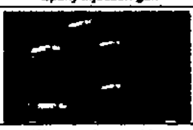
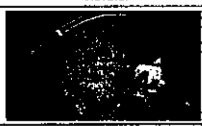
3. Equipment list

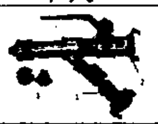
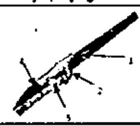
Surface preparation (Concrete work)		
Power disc grinder	Air gun	Wire brush
		
High pressure water blasting	Electric wire brush	Electric cup wire brush
		
Scraper	Bristle Blaster	
		

Removing damaged concrete (Concrete work)		
Electric pick hammer	Electric power chisel	Chisel
		
Power disc cutter	Electric drill with U shape bit	Concrete breaker
		
Concrete cutter	Handy concrete cutter	High pressure water blasting
		

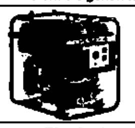
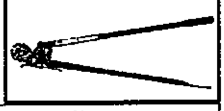
Painting (Concrete work)		
Brush	Brush roller	Spray gun
		

Mixing repair material (Concrete work)		
Hand mixer	Concrete mixer	Grout mixer
		
Mortar mixer		
		

Setting repair material (Concrete work)		
Air compressor	Caulking gun	Squeeze pump
		
Grout injection gun	Epoxy injection gun	Vibrator
		
Hopper	Wet spraying machine	Dry spraying machine
		

Setting repair material (Concrete work)	
Wet spraying nozzle	Dry spraying nozzle
	

Finishing (Concrete work)	
Steel trowel	
	

Others		
Portable generator	High pressure water pump	Reinforcing steel cutter
		
Plastic sheet	Scales	Measure cup
Bucket		

4. Storage and shelf life

- Top priority shall be in accordance with date sheet.
- X can be kept for 12 months if store in original unopened bags in cool and dry warehouse conditions. Generally, refer to material date sheet.
- Keep away from direct sunlight and rainfall.
- Unopened and undamaged sealed packing in dry condition at temperatures between +5℃ and 30℃. Generally, refer to material date sheet.
- Avoid excessive compaction.
- Utilize the opened bags to the fullest.
- Clear of the ground on pallets protected from rainfall.
- For detailed information refer to material date sheet.

5. Quality Control

1). Standard check (Before repair work)

These tests are purposed to confirm performance of material and equipment through trial tests for verifying feasibility of designed plans such as sectional repair, thickness increment, lining concrete and so on. This test may be omitted when assessment result of below contents are satisfied.

Substrate Quality Control (Before, during and after preparation)

Characteristic	Reference	Frequency	Parameters
Temperature(ambient and substrate)	Record	During application	Within PDS limits
Ambient Humidity	Record	During application	Within PDS limits
Precipitation	Record	During application	Keep records and provide protection
Packaging	Visual	Every bag	No damage
Dry Product aspect	Visual	2 bags per 10	Loose, no lumps and not compacted
Mixed material	Visual	Every mix	Homogeneous, no lumps no un-mixed dry powder
Cleanliness of Concrete	Visual	After preparation and immediately before application	No contamination, loose particles or defects
Cleanliness of Steel Bars	DIN EN ISO8501-1	After preparation and immediately before application	No rust, scale or contamination.(Grade Sa 2 or SA 2½
Delaminating Concrete	Hammer Sounding	After preparation	No delamination concrete
Roughness	Visual or EN 1766 on horizontal surfaces	After preparation	Minimum roughness 2mm(repair area) No laitance layer(smoothing mortars)
Surface Tensile Strength of the Substrate	EN 1542	After preparation works	>1.0N/mm² for structural repair

Quality Control (After completion)

Characteristic	Reference	Frequency	Parameters
Cracking	Visual	28 days after application	No cracking on application
Presence of Voids / Delaminating	EN 12504-1 Hammer sounding or ultrasonic testing	After application	No delaminating concrete

6. Inspection Sheet and Repair Record

Repair record shall be reported. The component of repair record should be, but not limited to, as-built drawings, inspection sheets, investigation reports, repair design report, construction scene photograph, and method statement.

※Please refer to appendix

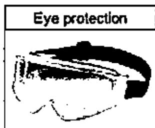
7. Health and Safety

Risk Assessment

The risk to health and safety from falling objects or defects in the structure shall be properly assessed. Platforms and temporary structures shall provide a stable and safe area to work. Do not take any unnecessary risks.

Personal Protection

Handling or processing cement products may generate dust which can cause mechanical irritation to the eyes, skin, nose and throat.
Appropriate eye protection shall be worn at all times while handling and mixing products.
Approved dust masks shall be worn to protect the nose and throat from dust.
Safety shoes, gloves and other appropriate skin protection shall be worn at all times.
Always wash hands with suitable soap after handling products and before food consumption

Eye protection	Gloves	Helmet	Dust masks
			
Work wear	Safety shoes	Safety vest	Safety belt
			
Soundproofing earplugs			
			

First Aid

Seek immediate medical attention in the event of excessive inhalation, ingestion or eye contact causing irritation. Do not induce vomiting unless directed by medical personnel.
Flush eyes with plenty of clean water occasionally lifting upper and lower eyelids. Remove contact lenses immediately. Continue to rinse eye for 10 minutes and then seek medical attention. Rinse contaminated skin with plenty of water. Remove contaminated clothing and continue to rinse for 10 minutes and seek medical attention.
For detailed information refer to the material safety data sheet.

Traffic control

If the repair work will be conduced under open traffic, the inspectors shall pay attention to provide safety for cars and pedestrians. Flagmen and safety cones must be placed to notice the working site to cars/pedestrians. The work shall be complied with all relative low/regulations in Sri Lanka.

Inspection sheet for Plaster method (Draft)

Form.1

PROJECT NAME

Client :
Consultant :
Contractor :

INSPECTION OF MATERIAL

INSPECTION DATE :
STRUCTURE NAME :

1.Main materials

Materials	Description	Name / source	Expire date
Cement	☐Ready mixed		
	☐Ordinary Portland cement		
	☐Early strength Portland cement		
	☐Ultra early strength Portland ceme		
	☐Others		
Aggregate	☐≦ mm		
Fiber	☐Steel / Organic		
Admixture	☐Polymer		
	☐Quick setting agent		
	☐Ultra fine powder		
	☐Others		

2.Other materials

Materials	Description	Name / source	Expire date
Primer	☐		
Curing comp	☐		
	☐		

3.Purchased Quantity

Materials	Mode of packing	Unit	Quantity	Total Amount	Condition	Mill sheet
Cement						
Aggregate						
Fiber						
Admixture						
Primer						
Curing comp.						

4.Note

5.Judgment

☐Accepted ☐Not Accepted

The contractor	The Consultant	The Client
Signature : Name :	Signature : Name :	Signature : Name :

Form.2

PROJECT NAME

Client :
Consultant :
Contractor :

INSPECTION OF MATERIAL

INSPECTION DATE :
STRUCTURE NAME :

1.Quantity Table

Repair Area in Contract

No.	Length (m)	Width (m)	Area (m^2)	Repair method
1				
2				
3				

Actual Area Removed (Accepted for payment)

No.	Length (m)	Width (m)	Depth (m)	Area (m^2)	Repair method
1					
2					
3					

2.Sketch

3.Concrete surface,Edge

Item	Check	
Feather edge	☐ NG	☐OK : No feather edge is exist
Concrete edge	☐ NG	☐OK : Saw cut(about 10mm) is made at the concrete edge
Concrete surface	☐ NG	☐OK : Base surface to be filled is appropriately roughen
Overhang	☐ NG	☐OK : No overhang which cause problem of concrete filling

4.Remarks

5.Judgement

☐Accepted ☐Not Accepted

The contractor	The Consultant	The Client
Signature : Name :	Signature : Name :	Signature : Name :

Form.3

PROJECT NAME

Client :
Consultant :
Contractor :

INSPECTION OF MATERIAL

INSPECTION DATE :
STRUCTURE NAME :

1.Steel bar

Items	Description	Judge	
		OK	NG
Corrosion removed by	☐Sand blast ☐Other method		
Existance of corrosion	Harmful corrosion is removed		
Additional steel bar	Arranged or not required		
Splicing / fixation of steel bar	Firmly fixed		
Spacing of steel bar	ufficient spacing for repair material fillin		

2.Anti-corrosion primer
a. Neccesity of application ☐Required ☐Not required
b. Product name and component

Product name	Comp.A (Liquid, Powder)	Comp.B (Liquid, Powder)

c. Standard coverage
for

d. Quantity used

Plan	
Actual	
Difference	

e. Application

Items	Judge	
	OK	NG
Quantity		
Visual		

3.Note

4.Judgement
☐Accepted ☐Not Accepted

The contractor	The Consultant	The Client
Signature :	Signature :	Signature :
Name :	Name :	Name :

Form.4

PROJECT NAME

Client :
Consultant :
Contractor :

INSPECTION OF MATERIAL

INSPECTION DATE :
STRUCTURE NAME :

1.Mix Propotion of repair material

☐ Site mix

Material	W / C	Cement	Water	Aggregate	Admixture1	Admixture2
Amount						

☐ Ready mixed

2.Primer ☐Use ☐Do not use (Is substrate sartuation confirmed?)

Product name	Comp.A (Liquid, Powder)	Comp.B (Liquid, Powder)

3.Mixing of repair material

Batch No.	Mixing Equipment		Weight / Volume				
			Cement	Water	Aggregate	Admixture	Admixture
	OK	NG	( )	( )	( )	( )	( )
1	☐	☐					
2	☐	☐					
3	☐	☐					
4	☐	☐					

Batch No.	Mix time(min)		Judge		Note
	Start	End			
	hh mm	hh mm	OK	NG	
1					
2					
3					
4					

4.Application / casting / spraying

Batch No.	Equipment		Application time(min)		Temperature	Judge	
			Start	End			
	OK	NG	hh mm	hh mm		OK	NG
1	☐	☐					
2	☐	☐					
3	☐	☐					
4	☐	☐					

Form.4

4.Note

5.Judgement
☐Accepted ☐Not Accepted

The contractor	The Consultant	The Client
Signature :	Signature :	Signature :
Name :	Name :	Name :

Form.5

PROJECT NAME

Client :
Consultant :
Contractor :

INSPECTION OF MATERIAL

INSPECTION DATE :
STRUCTURE NAME :

1.Curing

Item	Description	Check	
		OK	NG
Curing method	Water spray / Water mat / Curing compound	☐	☐
Curing period	More not less than hrs	☐	☐
Wind protection	If required	☐	☐
Sunlight protection	If required	☐	☐
	If required	☐	☐

2.Visual Inspection

Item	Check		Note
	OK	NG	
Dimensions	☐	☐	
Roughness	☐	☐	
Existance of loosing material	☐	☐	
Color	☐	☐	
Cracks	☐	☐	
	☐	☐	

3.Physical Inspection

Item	Check		Note
	OK	NG	
Sounding (hammer) test	☐	☐	Required
Rebound hammer test	☐	☐	When required

4.Remark

5.Judgement
☐Accepted ☐Not Accepted

The contractor	The Consultant	The Client
Signature :	Signature :	Signature :
Name :	Name :	Name :

Date sheet of repair materials

BASF
The Chemical Company

MasterEmaco® S 5400

High-strength, shrinkage compensated, fibre reinforced, structural repair mortar

BASF
The Chemical Company

MasterEmaco® S 5400

BASF
We create chemistry

MasterEmaco® P158

BASF
We create chemistry

MasterEmaco® P158

SBR acrylic based bonding and polymer modifying agent for concrete and mortars

BASF
We create chemistry

MasterEmaco® 8100 AP

(Formerly known as Concresive ZR)

BASF
We create chemistry

MasterEmaco® 8100 AP

(Formerly known as Concresive ZR)

Single component epoxy based zinc rich primer for steel

Road Development Authority

Japan International Cooperation Agency

The Project for Capacity Development on Bridge Management in The Democratic Socialist Republic of Sri Lanka

Trial bridge repair work and on-the-job training

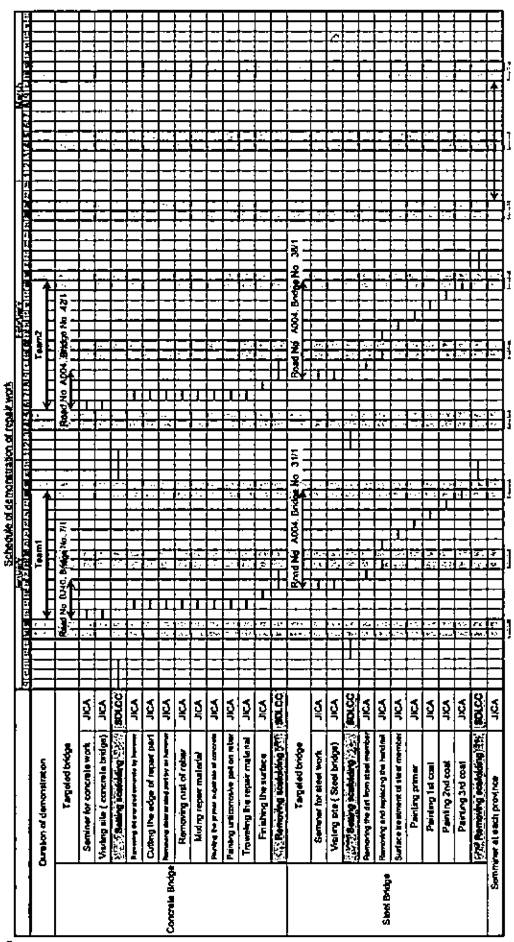
January - February 2017

Road Development Authority

Japan International Cooperation Agency

CONTENTS

1. Schedule of trial repair work



MEETING PLACE AND TIME (TEAM1)

DATE				MEETING TIME	MEETING PLACE	
January	16th	Mon	AM	9:00	JICA PROJECT TEAM OFFICE	
			PM	13:00	AT SITE	Road No.:B240, Bridge No.:7/1
	17th	Tue	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	18th	Wed	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	19th	Thu	AM	9:00	JICA PROJECT TEAM OFFICE	
			PM	According to work procedure	AT SITE	Road No : A004, Bridge No : 31/1
	20th	Fri	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	21st	Sat	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	22nd	Sun	AM	REST		
			PM			
	23rd	Mon	AM	9:00	AT SITE	Road No : A004, Bridge No : 31/1
			PM	According to work procedure	AT SITE	
	24th	Tue	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	25th	Wed	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	26th	Thu	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	27th	Fri	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	28th	Sat	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	29th	Sun	AM			
			PM			
	30th	Mon	AM			
			PM			
	31st	Tue	AM			
			PM			

MEETING PLACE AND TIME (TEAM2)

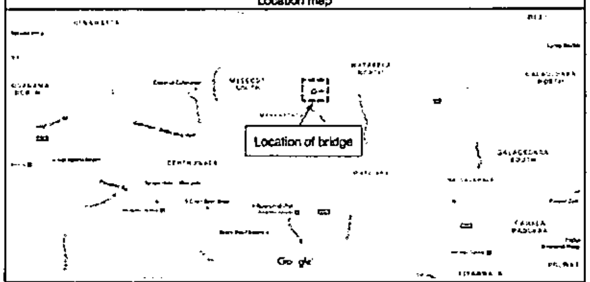
DATE				MEETING TIME	MEETING PLACE	
February	1st	Wed	AM			
			PM			
	2nd	Thu	AM			
			PM			
	3rd	Fri	AM			
			PM			
	4th	Sat	AM			
			PM			
	5th	Sun	AM			
			PM			
	6th	Mon	AM	9:00	JICA PROJECT TEAM OFFICE	
			PM	13:00	AT SITE	Road No.:A004, Bridge No.:42/1
	7th	Tue	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	8th	Wed	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	9th	Thu	AM	9:00	JICA PROJECT TEAM OFFICE	
			PM	According to work procedure	AT SITE	Road No : A004, Bridge No : 38/1
	10th	Fri	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	11th	Sat	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	12th	Sun	AM	REST		
			PM			
	13th	Mon	AM	9:00	AT SITE	Road No : A004, Bridge No : 38/1
			PM	According to work procedure	AT SITE	
	14th	Tue	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	15th	Wed	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	16th	Thu	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	17th	Fri	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	18th	Sat	AM	9:00	AT SITE	
			PM	According to work procedure	AT SITE	
	19th	Sun	AM			
			PM			
	20th	Mon	AM			
			PM			
	21st	Tue	AM			
			PM			

2. Location of targeted Bridged

Targeted Steel Bridge for Team1

Road and Bridge No.					
Road No.	A004	Bridge No.	31 / 1 in Km	EE Division	Awissawella (Western)

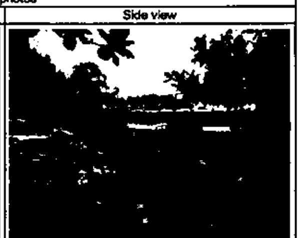
Location map



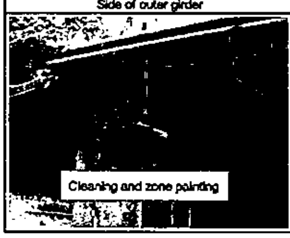
Site photos

Full view

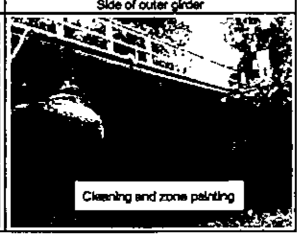
Side view

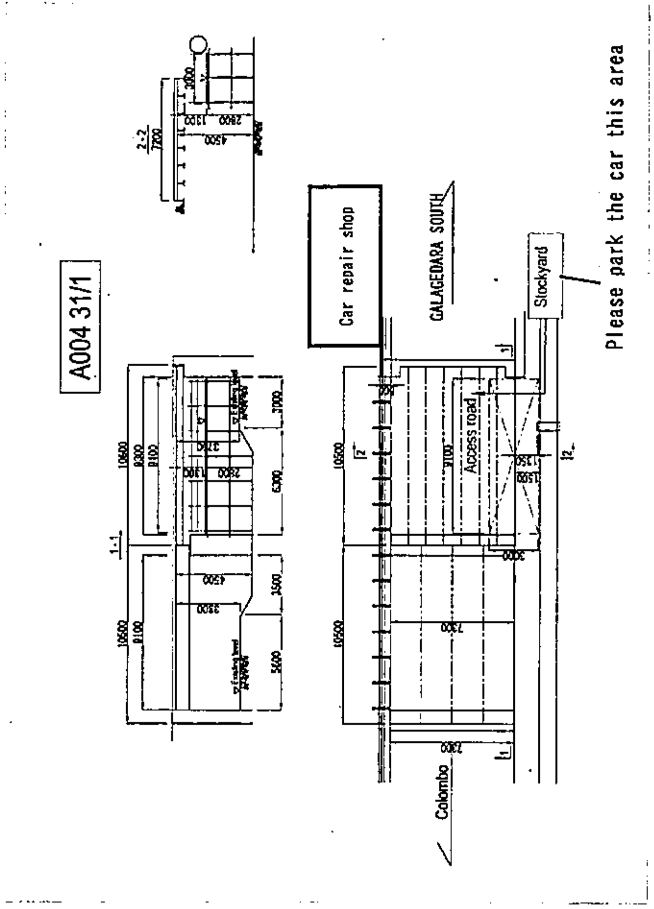


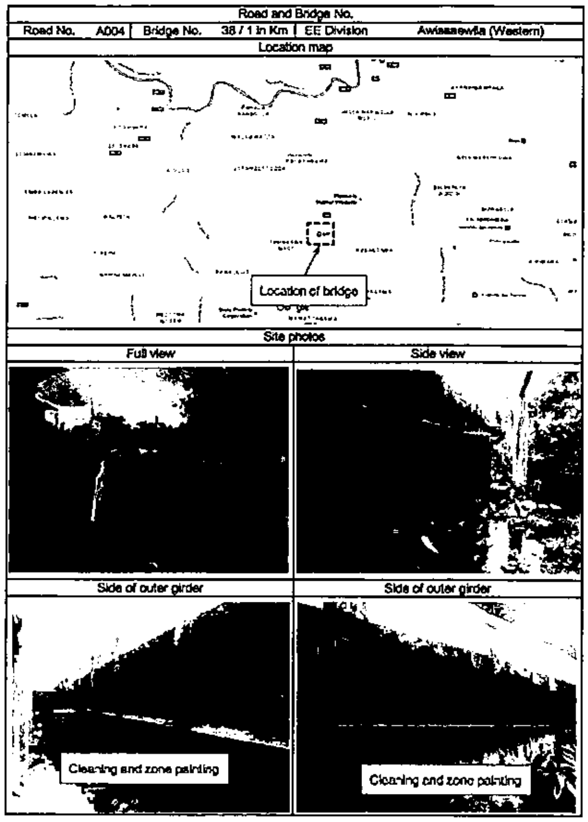
Side of outer girder

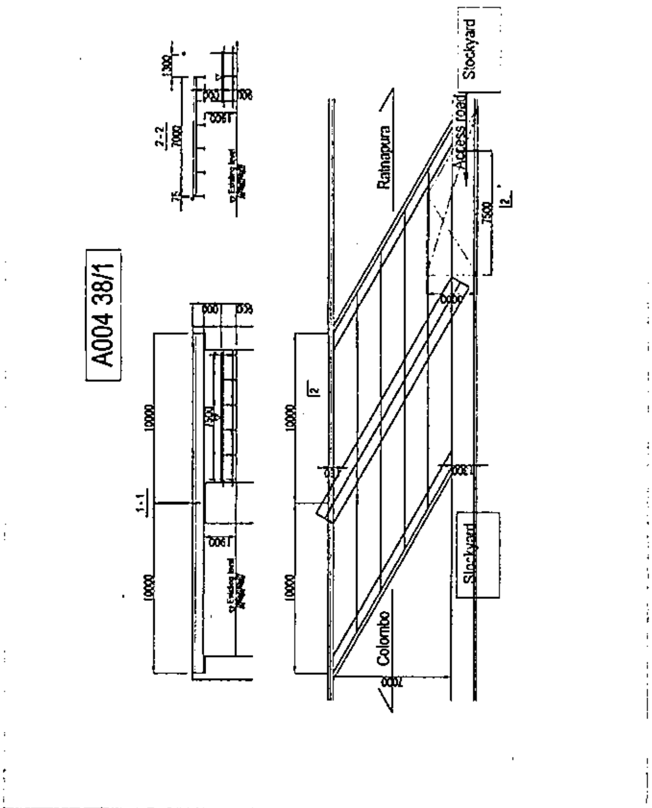


Side of outer girder









3. Method statement for cleaning the surface of steel member (Draft)

Cleaning the surface of steel members

1. Work description

2. Work sequence and requirement

3. Application criteria

4. Required material and tools / equipment

1. Work description

During the serviceable life of a bridge, several components get unclean due to deposition of foreign materials. Materials that accumulate on the deck slab surface flow with the rain water towards the drainage spouts which may choke the outlets and affect drainage. Also the materials that accumulate on the deck and carried by the rain water towards the expansion joint can pass through any opening present therein and accumulate on the pier cap, abutment caps and around the bearings. Such accumulation can cause malfunction of bearings / corrosion in metal bearing since debris tend to hold water. Also growth of vegetation such as grass, shrubs and other plants on the components of bridge equally affect the functioning of those components.

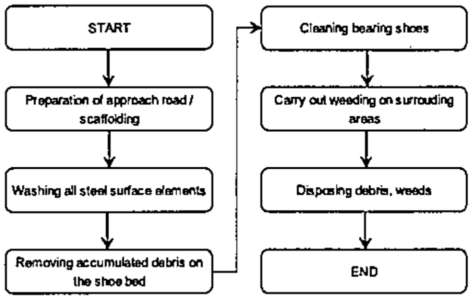
Various components of bridge, namely deck surface, curb and side walks, expansion joints, pier caps, abutment caps, trusses and their web members, lower flanges of beams and girder, wind bracing and drains shall be thoroughly cleaned from accumulated dust, debris and other foreign materials as regular intervals. This is to prevent deterioration of the bridge, which will therefore preserve the bridge components in their intended conditions resulting in increased service life of the bridge as well as provide safety and comfort to the road users. Areas which have been cleaned shall ensure relief from accumulated sand, gravel, dirt, and other foreign materials. So the vegetation grown on the components of bridges shall be removed as soon as noticed. Also vegetation near the bridges shall be removed as soon as noticed. Also vegetation near the bridge that might affect the natural flow of water underneath the bridges, shall have to be remove.

2. Work sequence and requirement

VIDEO

1). Work sequence

Work sequence of cleaning due to debris accumulation is as shown below.



2). Work requirement

General

All accumulated foreign materials shall be removed from bridge sidewalks, bridge decks, top of curbs, beam flanges, gusset plates, abutment bridge seats, top of pier, truss joints, deck drain systems, and other locations specified and as directed by the Engineer, prior to cleaning with water pressure. Removal shall be performed using hand brooms, hand shovels, scrapers, vacuum cleaners of other methods acceptable to the Engineer. The removed materials shall be collected and disposed at an approved waste area in accordance with governing local regulations. In no case these materials shall be allowed to be disposed of into the river or on dry land portion below the bridge.

High pressure water

Salt contaminants, dirt, and other detrimental foreign matters shall be removed without damaging or peeling the paint from any structure steel. If high-pressure water is used, the maximum water pressure shall not be so high that any paints is damaged. The cleaning operation shall be discontinued if the foreign materials have not been easily removed or if cleaning operation is causing damage to existing paint coating. In this situation, the high pressure water shall be adjusted to clean the surface without damaging the paint coating.

All deck drains and its accessories shall be flushed with high pressure water after accumulated foreign material have been properly removed. Drainage system may have to be disassembled to remove large blockage of accumulate foreign material. Should this be necessary, these shall be reassembled to their original configuration immediately after cleaning and checked whether the system is operating properly.

The high pressure water jet shall be used to flush out the interior surface of all girders and truss members until clear water comes out from the other end.

The exterior surface of all truss members, miscellaneous structural steel connecting the truss members, and floor beam ends projecting outwardly from the row of exterior stringers shall be thoroughly washed using high pressure water.

The source of water used for cleaning purposes shall be an approved one. The freshwater should also be free from sediments and salt contaminants and the expenses involved in securing the approved water will be the responsibility of the entrusted body if outsourced.

In Japan

3. Application criteria

Criteria for cleaning applied to the bridge including its steel surface, deck and substructure are recommended below:

1). Surface of steel plate

The surface of steel bridge should be cleaned and washed by brushing with fresh water or using high water blasting, including the top and bottom flanges, web plates, diaphragms, lateral members and gusset plate. For convenience, inspection vehicle may be utilized to carry out cleaning of the bridge soffit.

2). Bridge deck slab

All surface areas of the bridge deck should be cleaned including the curbs, expansion joints, drain pits and railing. This may be performed by manual shoveling / sweeping or using high pressure water blasting.

3). Bridge substructure

All areas under the superstructure should be cleaned, including the bearing bed, concrete diaphragms and pier caps. This may be done by manual shoveling / sweeping or using high pressure water blasting. Accessing the top of piers, a higher ladder or hang ladder will be useful and an inspection vehicle can be utilize, if possible.

4. Required material and tools / equipment

1). Required materials

Freshwater suitable for cleaning

Water to be used for cleaning of the bridge components shall be clean and free from unwanted foreign materials such as sediments, salt contaminants, chemicals, grease, oil, rubbish and other substance, which are harmful to the bridge components.

The contractor shall obtain necessary approvals of the source of water to be used for cleaning. Engineer's approval shall be taken on the source and quality of water. All necessary tests shall be performed on water samples at laboratories to be specified by the Engineer, and test certificates shall be provided as required.

The water should be pH Value between 7 – 8 with Conductivity level below 60μs / m.

2). Required tools / equipment

- Hand Shovel
- Hand Brush
- Water bucket
- High pressure water blasting machine (Water pressure 5MPa – 20MPa)
- Generator

4. Method statement for Zone painting for steel structure (Draft)

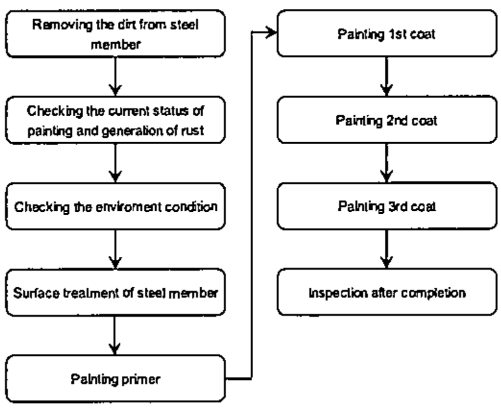
Zone painting

1. Work description

1). Introduction

Due to thin paint coverage on steel surfaces or formation of pin-holes in paint, the steel surface may exposed to atmosphere resulting in initiation of corrosion. Zone painting at the early stage prevents progress of corrosion.

Work included in this section comprises field zone painting on steel members at localized areas including surface preparation and other associated works. This covers only painting on relatively small affected areas which can be carried out with the use of small power tools/ hand tools. Painting of large areas require sand blast cleaning should be carried out in accordance with the specifications covered under major repair.



Work flow for zone painting

2). Surface preparation

Pretreated ISO St-3

※Please refer Table.6 and 8.

3). Application method

Surface treatment : Localized hand and power tool

Painting : Brush / Roller

2. Design conditions

1). Durability

The durability range is not a "guarantee time". Durability is a technical consideration that can help the owner set up a maintenance programme. A guarantee time is the subject of clauses in the contract and is not within the scope of this part of ISO 12944. There are no rules that link the two periods of time.

Table.1 Durability is expressed in terms of three ranges (ISO12944-1)

Durability	Durability Range
Low (L)	2 years to 5 years
Medium (M)	5 years to 15 years
High (H)	More than 15 years

2). Classification of environment

Table.2 Classification of environments (ISO12944-2)

Environmental Category		Description
C1	Very low	Rural Areas, Low pollution, Dry & Neutral atmospheres
C2	Low	Unheated Building, Possible condensation
C3	Medium	Urban atmospheres, Moderate SO2 pollution
C4	High	Industrial and Coastal
C5 I	Very high Industrial	Industry with high humidity and aggressive atmospheres
C5 M	Very high marine	Marine coastal, offshore high salinity

Table.3 Recommendation classification of area based on Japanese standard

Environmental Category	Area	Definition
C3	Rural / Land / Country area	Over than 20km from coastline
C5-M	Marine / Coastal area	Less than 20km from coastline

Table.4 Atmospheric-corrosivity category and example of typical environments (ISO12944-2)

Table 1 — Atmospheric-corrosivity categories and examples of typical environments

Corrosivity category	Mass loss per unit surface/thickness loss (after first year of exposure)				Examples of typical environments in a temperate climate (informative only)	
	Low-carbon steel		Zinc		Exterior	Interior
	Mass loss g/m²	Thickness loss μm	Mass loss g/m²	Thickness loss μm		
C1 very low	< 10	< 1,3	< 0,7	< 0,1	—	Heated buildings with clean atmospheres, e.g. offices, shops, schools, hotels.
C2 low	10 to 200	1,3 to 25	0,7 to 5	0,1 to 0,7	Atmospheres with low level of pollution. Mostly rural areas.	Unheated buildings where condensation may occur, e.g. depots, sports halls.
C3 medium	200 to 400	25 to 50	5 to 15	0,7 to 2,1	Urban and industrial atmospheres, moderate sulfur dioxide pollution. Coastal areas with low salinity.	Production rooms with high humidity and some air pollution, e.g. food-processing plants, laundries, breweries, dairies.
C4 high	400 to 650	50 to 80	15 to 30	2,1 to 4,2	Industrial areas and coastal areas with moderate salinity.	Chemical plants, swimming pools, coastal ship- and boatyards.
C5-I very high (industrial)	650 to 1 500	80 to 200	30 to 60	4,2 to 8,4	Industrial areas with high humidity and aggressive atmosphere.	Buildings or areas with almost permanent condensation and with high pollution.
C5-M very high (marine)	650 to 1 500	80 to 200	30 to 60	4,2 to 8,4	Coastal and offshore areas with high salinity.	Buildings or areas with almost permanent condensation and with high pollution.

NOTES

1 The loss values used for the corrosivity categories are identical to those given in ISO 9223.

2 In coastal areas in hot, humid zones, the mass or thickness losses can exceed the limits of category C5-M. Special precautions must therefore be taken when selecting protective paint systems for structures in such areas.

3). Surface preparation method (ISO8501-1)

The primary object of surface preparation is to ensure the removal of deleterious matter and to obtain a surface that permits satisfactory adhesion of priming paint to the steel. It will also assist in reducing the amounts of contaminants that initiate corrosion.

※Please refer to Table.6 and 8.

Table.5 Standard preparation grades for primary (overall) surface preparation (ISO12944-4)

Standard preparation grade 1)	Surface preparation method	Representative photographic examples in ISO 8501-1 2) 3) 4)	Essential features of prepared surfaces For further details, including treatment prior to and after surface preparation (column 2), see ISO 8501-1.	Field of application
Sa 1	Blast-cleaning (6.2.3)	B Sa 1 C Sa 1 D Sa 1	Poorly adhering mill scale, rust and paint coatings and foreign matter are removed. 5)	The surface preparation of a) uncoated steel surfaces; b) coated steel surfaces, if the coatings are removed to the extent that the specified preparation grade is achieved. 6)
Sa 2		B Sa 2 C Sa 2 D Sa 2	Most of the mill scale, rust, paint coatings and foreign matter is removed. Any residual contamination shall be firmly adhering.	
Sa 2½		A Sa 2½ B Sa 2½ C Sa 2½ D Sa 2½	Mill scale, rust, paint coatings and foreign matter are removed. Any remaining traces of contamination shall show only as slight stains in the form of spots or stripes.	
Sa 3 7)		A Sa 3 B Sa 3 C Sa 3 D Sa 3	Mill scale, rust, paint coatings and foreign matter are removed. The surface shall have a uniform metallic colour.	
St 2	Hand- or power-tool cleaning (6.2.1, 6.2.2)	B St 2 C St 2 D St 2	Poorly adhering mill scale, rust, paint coatings and foreign matter are removed. 5)	-
St 3		B St 3 C St 3 D St 3	Poorly adhering mill scale, rust, paint coatings and foreign matter are removed. 5) However, the surface shall be treated much more thoroughly than for St 2 to give a metallic sheen arising from the metal substrate.	
Fl	Flame cleaning (6.3)	A Fl B Fl C Fl D Fl	Mill scale, rust, paint coatings and foreign matter are removed. Any remaining residues shall show only as a discoloration of the surface (shades of different colours).	6) -
Be	Acid pickling (6.1.6)		Mill scale, rust and residues from paint coatings are removed completely. Paint coatings shall be removed prior to acid pickling by suitable means	Prior to hot-dip-galvanizing, for example.

1) Key to symbols used:
Sa = blast-cleaning (ISO 8501-1)
St = hand-tool or power-tool cleaning (ISO 8501-1)
Fl = flame cleaning (ISO 8501-1)
Be = acid pickling

2) A, B, C and D are initial conditions of uncoated steel surfaces (see ISO 8501-1).

3) The representative photographic examples show only surfaces or surface areas that were previously uncoated

4) In the case of steel surfaces with painted or unpainted metal coatings, an analogous application of certain standard preparation grades may be agreed, provided that these are technically feasible under the given conditions.

5) Mill scale is considered to be poorly adhering if it can be removed by lifting with a blunt putty knife

6) The factors influencing assessment shall be given particular consideration

7) This surface preparation grade can only be achieved and maintained under certain conditions which it may not be possible to produce on site.

Table.6 Standard preparation grades for secondary (partial) surface preparation (ISO12944-4)

Standard preparation grade 1)	Surface preparation method	Representative photographic examples in ISO 8501-1 or ISO 8501-2 2) 4) 6)	Essential features of prepared surfaces For further details, including treatment prior to and after surface preparation (column 2), see ISO 8501-2.	Field of application
P Sa 2 3)	Localized blast-cleaning	B Sa 2 C Sa 2 D Sa 2 (apply to uncoated parts of the surface)	Firmly adhering paint coatings shall be intact. 5) From the surface of the other parts, loose paint coatings and most of the mill scale, rust and foreign matter are removed. Any residual contamination shall be firmly adhering.	The surface preparation of coated steel surfaces on which some paint coatings remain. 7)
P Sa 2½ 3)		B Sa 2½ C Sa 2½ D Sa 2½ (apply to uncoated parts of the surface)	Firmly adhering paint coatings shall be intact. 5) From the surface of the other parts, loose paint coatings and mill scale, rust and foreign matter are removed. Any remaining traces of contamination shall show only as slight stains in the form of spots or stripes.	
P Sa 3 3) 6)		C Sa 3 D Sa 3 (apply to uncoated parts of the surface)	Firmly adhering paint coatings shall be intact. 5) From the surface of the other parts, loose paint coatings and mill scale, rust and foreign matter are removed. The surface shall have a uniform metallic colour.	
P Ma 3)	Localized machine abrading	P Ma	Firmly adhering paint coatings shall be intact. 5) From the surface of the other parts, loose paint coatings and mill scale, rust and foreign matter are removed. Any remaining traces of contamination shall show only as slight stains in the form of spots or stripes.	
P St 2 3)	Localized hand- and power-tool cleaning	C St 2 D St 2	Firmly adhering paint coatings shall be intact. 5) From the surface of the other parts, poorly adhering mill scale, rust, paint coatings and foreign matter are removed.	
P St 3 3)		C St 3 D St 3	Firmly adhering paint coatings shall be intact. 5) From the surface of the other parts, poorly adhering mill scale, rust, paint coatings and foreign matter are removed. However, the surface shall be treated much more thoroughly than for P St 2 to give a metallic sheen arising from the metal substrate.	

For footnotes, see next page.

Surface treatment VIDEO

Table.7 Standard preparation grades for secondary (partial) surface preparation (1/2) (ISO8501-2)

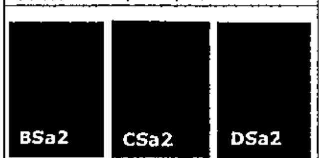
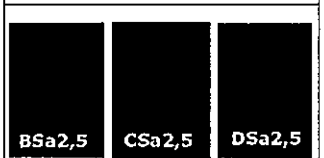
Representative photographic examples in ISO8501-1 or ISO8501-2	Essential features of prepared surface
ISO 12944-4 : P Sa 2 ISO 8501 : B Sa2, C Sa2, D Sa2 	Firmly adhering paint coating shall be intact. From the surface of the other parts, loose paint coatings and most of the mill scale, rust and foreign matter are removed. Any residual contamination shall be firmly adhering.
ISO 12944-4 : P Sa 2.5 ISO 8501 : B Sa2.5, C Sa2.5, D Sa2.5 	Firmly adhering paint coating shall be intact. From the surface of the other parts, loose paint coating and mill scale, rust and foreign matter are removed. Any remaining traces of contamination shall only as slight stains in the form of spots of stripes.
ISO 12944-4 : P Sa 3 ISO 8501 : B Sa3, C Sa3, D Sa3 	Firmly adhering paint coatings shall be intact. From the surface of the other parts, loose paint coating and mill scale, rust and foreign matter are removed. The surface shall have a uniform metallic color.

Table.8 Standard preparation grades for secondary (partial) surface preparation (2/2) (ISO8501-2)

Representative photographic examples in ISO8501-1 or ISO8501-2	Essential features of prepared surface
ISO 12944-4 : P St 2 ISO 8501 : C St2, D St2 	Firmly adhering paint coatings shall be intact. From the surface of the other parts, poorly adhering mill scale, rust, paint coating and foreign matter are removed.
ISO 12944-4 : P St 3 ISO 8501 : C St3, D St3 	Firmly adhering paint coatings shall be intact. From the surface of the other parts, poorly adhering mill scale, rust, paint coatings and foreign matter are removed. However, the surface shall be treated much more thoroughly than for P St2 to give a metallic sheen arising from the metal substrate.

4). Painting system (ISO12944-5)

The surface encountered in new structures are low-alloy steel of rust grade A,B and C as defined in ISO8501-1, as well as galvanized steel and metallized steel (see ISO 12944-1). Possible preparation of the different substrates is described in ISO12944-4.

The substrate and the recommended preparation grade are given at head of table A1 to A8 in this part of ISO12944 for each corrosive category. The paint system listed in Annex A are typical examples of systems used in the enviromental defined in ISO 12944-2 when applied to steel surface with rust grade A to C, as defined in ISO8501-1, or to hot-dip-galvanized steel or metallized steel. Where the steel has deteriorated to the extent that pitting corrosion has taken place (rust grade D in ISO 8501-1),the dry film thickness or the number of coats shall be increase surface roughness, and the paint manufacturer should be consulted for recommendations.

Where the steel has deteriorated to the extent that pitting corrosion has taken place (rust grade D in ISO 8501-1), the dry film thickness or the number of coats shall be increase to compensate for the increase surface roughness, and the paint manufacturer should be consulted for recommendations.

Table 10. Film thickness (ISO12944-5)

Environmental Category	Durability Range	Recommended Film Thickness	Recommendation of area to apply
C1	Low	75μm	
	Medium	75μm	
	High	75μm	
C2	Low	80μm	
	Medium	150μm	
	High	200μm	
C3	Low	120μm	Rural / Land / Country area
	Medium	160μm	
	High	200μm	
C4	Low	160μm	
	Medium	200μm	
	High	240μm	
C5 I & C5 M	Low	200μm	Marine / Coastal area
	Medium	280μm	
	High	320μm	

Zinc rich paint or Primers with miscellaneous types of anticorrosive pigments

To protect the steel member from corrosion. The main component of Zinc rich pait contains Zinc

Alloy Powder which having an electrochemically base potential to the steel material.

Priming coat:

First coat of a coating system.

Priming coats provide good adhesion to sufficiency roughened, cleaned metal and/or cleaned old coating, ensuring a sound base for, and offering adhesion to, the subsequent coats. They normally also provide corrosion protection during the over coating interval and the whole service life of the paint system.

Intermadiate coat :

Any coat between the priming coat and the finishing coat.

Top coat :

Final coat of a coating system. High weather resistance is required to keep long gloss and color retension

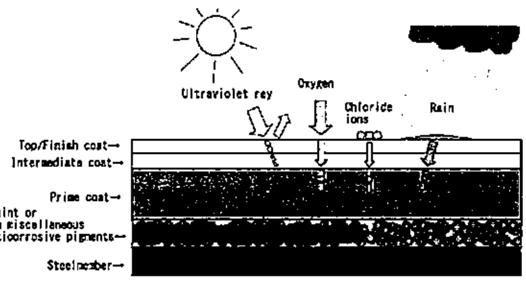


Table.11 Paint systems for low-alloy carbon steel for corrosivity category C2 (ISO12944-5)

Table A.2 — Paint systems for low-alloy carbon steel for corrosivity category C2

Substrate: Low-alloy carbon steel

Surface preparation: For Sa 2½ from rust grade A, B or C only (see ISO 8501-1)

System No.	Priming coat(s)				Subsequent coat(s)	Paint system		Expected durability		
	Binder	Type of primer [a]	No. of coats	NDFT [b] in μm	Binder type	No. of coats	NDFT [b] in μm	Low	Med	High
A2.01	AK	Misc.	1	40	AK	2	80			
A2.02	AK	Misc.	1-2	80	AK	2-3	120			
A2.03	AK	Misc.	1-2	80	AK, AY, PVC, CR [c]	2-4	160			
A2.04	AK	Misc.	1-2	100	-	1-2	100			
A2.05	AY, PVC, CR	Misc.	1-2	80	AY, PVC, CR [c]	2-4	160			
A2.06	EP	Misc.	1-2	80	EP, PUR	2-3	120			
A2.07	EP	Misc.	1-2	80	EP, PUR	2-4	160			
A2.08	EP, PUR, ESI [d]	Zn (R)	1	60 [e]	—	1	60			

Binder for priming coat(s)	Type	Water-borne possible	Binder for subsequent coat(s)	Type	Water-borne possible
AK = Alkyd	1-pack	X	AK = Alkyd	1-pack	X
CR = Chlorinated rubber	1 pack		CR = Chlorinated rubber	1 pack	
AY = Acrylic	1-pack	X	AY = Acrylic	1-pack	X
PVC = Poly(vinyl chloride)	1-pack		PVC = Poly(vinyl chloride)	1-pack	
EP = Epoxy	2-pack	X	EP = Epoxy	2-pack	X
ESI = Ethyl silicate	1- or 2-pack	X	PUR = Polyurethane, aliphatic	1- or 2-pack	X
PUR = Polyurethane, aromatic or aliphatic	1- or 2-pack	X		-	

[a] Zn (R) = Zinc-rich primer, see 5.2. Misc. = Primers with miscellaneous types of anticorrosive pigments.

[b] NDFT = Nominal dry film thickness. See 5.4 for further details.

[c] It is recommended that compatibility be checked with the paint manufacturer.

[d] It is recommended for ESI primers that one of the subsequent coats be used as a tie coat.

[e] It is also possible to work with an NDFT from 40 μm to 80 μm provided the zinc-rich primer chosen is suitable for such an NDFT.

Surface preparation grade		Surface preparation method
	Sa2 – 3	Blast cleaning
	St2 – 3	Hand or Power cleaning

Table.12 Paint systems for low-alloy carbon steel for corrosivity category C3 (ISO12944-5)

Table A.3 — Paint systems for low-alloy carbon steel for corrosivity category C3

Substrate: Low-alloy carbon steel

Surface preparation: For Sa 2½ from rust grade A, B or C only (see ISO 8501-1)

System No.	Priming coat(s)				Subsequent coat(s)	Paint system		Expected durability		
	Binder	Type of primer[a]	No. of coats	NDFT[b] in µm	Binder type	No. of coats	NDFT[b] in µm	Low	Med	High
A3.01	AK	Misc.	1-2	80	AK	2-3	120			
A3.02	AK	Misc.	1-2	80	AK	2-4	160			
A3.03	AK	Misc.	1-2	80	AK	3-5	200			
A3.04	AK	Misc.	1-2	80	AY, PVC, CR[c]	3-5	200			
A3.05	AY, PVC, CR[c]	Misc.	1-2	80	AY, PVC, CR[c]	2-4	160			
A3.06	AY, PVC, CR[c]	Misc.	1-2	80	AY, PVC, CR[c]	3-5	200			
A3.07	EP	Misc.	1	80	EP, PUR	2-3	120			
A3.08	EP	Misc.	1	80	EP, PUR	2-4	160			
A3.09	EP	Misc.	1	80	EP, PUR	3-5	200			
A3.10	EP, PUR, ESI[d]	Zn (R)	1	60[e]	—	1	60			
A3.11	EP, PUR, ESI[d]	Zn (R)	1	60[e]	EP, PUR	2	160			
A3.12	EP, PUR, ESI[d]	Zn (R)	1	60[e]	AY, PVC, CR[c]	2-3	160			
A3.13	EP, PUR	Zn (R)	1	60[e]	AY, PVC, CR[c]	3	200			

Binder for priming coat(s)	Type	Water-borne possible	Binder for subsequent coat(s)	Type	Water-borne possible
AK = Alkyd	1-pack	X	AK = Alkyd	1-pack	X
CR = Chlorinated rubber	1-pack		CR = Chlorinated rubber	1-pack	
AY = Acrylic	1-pack	X	AY = Acrylic	1-pack	X
PVC = Poly(vinyl chloride)	1-pack		PVC = Poly(vinyl chloride)	1-pack	
EP = Epoxy	2 pack	X	EP = Epoxy	2 pack	X
ESI = Ethyl silicate	1- or 2-pack	X	PUR = Polyurethane, aliphatic	1- or 2-pack	X
PUR = Polyurethane, aromatic or aliphatic	1- or 2-pack	X			

[a] Zn (R) = Zinc-rich primer, see 5.2. Misc. = Primers with miscellaneous types of anticorrosive pigment.

[b] NDFT = Nominal dry film thickness. See 5.4 for further details.

[c] It is recommended that compatibility be checked with the paint manufacturer.

[d] It is recommended for ESI primers that one of the subsequent coats be used as a tie coat.

[e] It is also possible to work with an NDFT from 40 µm up to 80 µm provided the zinc-rich primer chosen is suitable for such an NDFT.

Surface preparation grade		Surface preparation method
	Sa2 – 3	Blast cleaning
	St2 – 3	Hand or Power cleaning

Table.13 Paint systems for low-alloy carbon steel for corrosivity category C4 (ISO12944-5)

Table A.4 — Paint systems for low-alloy carbon steel for corrosivity category C4

Substrate: Low-alloy carbon steel

Surface preparation: For Sa 2½ from rust grade A, B or C only (see ISO 8501-1)

System No.	Priming coat(s)				Subsequent coat(s)	Paint system		Expected durability		
	Binder	Type of primer[a]	No. of coats	NDFT[b] in µm	Binder type	No. of coats	NDFT[b] in µm	Low	Med	High
A4.01	AK	Misc.	1-2	80	AK	3-5	200			
A4.02	AK	Misc.	1-2	80	AY, CR, PVC[c]	3-5	200			
A4.03	AK	Misc.	1-2	80	AY, CR, PVC[c]	3-5	240			
A4.04	AY, CR, PVC	Misc.	1-2	80	AY, CR, PVC[c]	3-5	200			
A4.05	AY, CR, PVC	Misc.	1-2	80	AY, CR, PVC[c]	3-5	240			
A4.06	EP	Misc.	1-2	160	AY, CR, PVC[c]	2-3	200			
A4.07	EP	Misc.	1-2	160	AY, CR, PVC[c]	2-3	280			
A4.08	EP	Misc.	1	80	EP, PUR	2-3	240			
A4.09	EP	Misc.	1	80	EP, PUR	2-3	280			
A4.10	EP, PUR, ESI[d]	Zn (R)	1	60[e]	AY, CR, PVC[c]	2-3	160			
A4.11	EP, PUR, ESI[d]	Zn (R)	1	60[e]	AY, CR, PVC[c]	2-4	200			
A4.12	EP, PUR, ESI[d]	Zn (R)	1	60[e]	AY, CR, PVC[c]	3-4	240			
A4.13	EP, PUR, ESI[d]	Zn (R)	1	60[e]	EP, PUR	2-3	160			
A4.14	EP, PUR, ESI[d]	Zn (R)	1	60[e]	EP, PUR	2-3	200			
A4.15	EP, PUR, ESI[d]	Zn (R)	1	60[e]	EP, PUR	3-4	240			
A4.16	ESI	Zn (R)	1	60[e]	—	1	60			

Binder for priming coat(s)	Type	Water-borne possible	Binder for subsequent coat(s)	Type	Water-borne possible
AK = Alkyd	1-pack	X	AK = Alkyd	1-pack	X
CR = Chlorinated rubber	1-pack		CR = Chlorinated rubber	1-pack	
AY = Acrylic	1-pack	X	AY = Acrylic	1-pack	X
PVC = Poly(vinyl chloride)	1-pack		PVC = Poly(vinyl chloride)	1-pack	
EP = Epoxy	2-pack	X	EP = Epoxy	2-pack	X
ESI = Ethyl silicate	1- or 2-pack	X	PUR = Polyurethane, aliphatic	1- or 2 pack	X
PUR = Polyurethane, aromatic or aliphatic	1- or 2-pack	X			

[a] Zn (R) = Zinc-rich primer, see 5.2. Misc. = Primers with miscellaneous types of anticorrosive pigments.

[b] NDFT = Nominal dry film thickness. See 5.4 for further details.

[c] It is recommended that compatibility be checked with the paint manufacturer.

[d] It is recommended for ESI primers that one of the subsequent coats be used as a tie coat.

[e] It is also possible to work with an NDFT from 40 µm up to 80 µm provided the zinc-rich primer chosen is suitable for such an NDFT.

Surface preparation grade		Surface preparation method
	Sa2 – 3	Blast cleaning
	St2 – 3	Hand or Power cleaning

Table.14 Paint systems for low-alloy carbon steel for corrosivity category C5 – I and C5 - M (ISO12944-5)

Table A.5 — Paint systems for low-alloy carbon steel for corrosivity categories C5-I and C5-M

Substrate: Low-alloy carbon steel

Surface preparation: For Sa 2½ from rust grade A, B or C only (see ISO 8501-1)

System No.	Priming coat(s)				Subsequent coat(s)	Paint system		Expected durability		
	Binder	Type of primer[a]	No. of coats	NDFT[b] in µm	Binder type	No. of coats	NDFT[b] in µm	Low	Med	High
C5-I										
A5I.01	EP, PUR	Misc.	1-2	120	AY, CR, PVC[c]	3-4	200			
A5I.02	EP, PUR	Misc.	1	80	EP, PUR	3-4	320			
A5I.03	EP, PUR	Misc.	1	150	EP, PUR	2	300			
A5I.04	EP, PUR, ESI[d]	Zn (R)	1	60[e]	EP, PUR	3-4	240			
A5I.05	EP, PUR, ESI[d]	Zn (R)	1	60[e]	EP, PUR	3-5	320			
A5I.06	EP, PUR, ESI[d]	Zn (R)	1	60[e]	AY, CR, PVC[c]	4-5	320			
C5-M										
A5M.01	EP, PUR	Misc.	1	150	EP, PUR	2	300			
A5M.02	EP, PUR	Misc.	1	80	EP, PUR	3-4	320			
A5M.03	EP, PUR	Misc.	1	400	—	1	400			
A5M.04	EP, PUR	Misc.	1	250	EP, PUR	2	500			
A5M.05	EP, PUR, ESI[d]	Zn (R)	1	60[e]	EP, PUR	4	240			
A5M.06	EP, PUR, ESI[d]	Zn (R)	1	60[e]	EP, PUR	4-5	320			
A5M.07	EP, PUR, ESI[d]	Zn (R)	1	60[e]	EPC	3-4	400			
A5M.08	EPC	Misc.	1	100	EPC	3	300			

Surface preparation grade		Surface preparation method
	Sa2 – 3	Blast cleaning
	St2 – 3	Hand or Power cleaning

Table.15 General properties of different generic types of paint (ISO12944-5)

Table C.1 — General properties of different generic types of paint

Suitability ■ Good ▲ Limited ● Poor — Not relevant	Poly(vinyl chloride) (PVC)	Chlorinated rubber (CR)	Acrylic (AY)	Alkyd (AK)	Polyurethane, aromatic (PUR, aromatic)	Polyurethane, aliphatic (PUR, aliphatic)	Ethyl zinc silicate (ESI)	Epoxy (EP)	Epoxy combination (EPC)
Gloss retention	▲	▲	▲	▲	●	■	—	●	●
Colour retention	▲	▲	■	▲	●	■	—	●	●
Resistance to chemicals:									
Water immersion	▲	■	▲	●	▲	●	▲	■	■
Rain/condensation	■	■	■	▲	■	▲	■	■	■
Solvents	●	●	●	▲	■	▲	■	■	▲
Solvents (splash)	●	●	●	■	■	■	■	■	■
Acids	▲	■	▲	▲	■	▲	●	▲	■
Acids (splash)	■	■	▲	▲	■	■	●	■	■
Alkalis	▲	▲	▲	▲	▲	▲	●	■	■
Alkalis (splash)	■	■	▲	▲	■	■	●	■	■
Resistance to dry heat:									
up to 70 °C	●	●	▲	■	■	■	■	■	■
70 °C to 120 °C	—	—	▲	■	■	■	■	■	▲
120 °C to 150 °C	—	—	▲	●	▲	●	■	▲	▲
> 150 °C but ≤ 400 °C	—	—	—	—	—	—	■	—	—
Physical properties:									
Abrasion resistance	●	●	●	▲	■	▲	■	■	▲
Impact resistance	▲	▲	▲	▲	■	▲	▲	■	▲
Flexibility	■	■	■	▲	▲	■	●	▲	▲
Hardness	▲	▲	▲	■	■	▲	■	■	■

C3 - Rural / Land / Country side (More than 20km from coastline)

Table 16. Painting system for surface preparation - St 2 & St 3

Coating process	Coating system	DFT(μm)
Surface preparation	St 2 & St 3	
Priming coat	Two Component Epoxy Primer / Coating	60
Intermediate coat 1st coat	Two Component Epoxy MIO Pigmented Intermediate Coat	70
Intermediate coat 2nd coat	Two Component Epoxy Build Up Coat	70
Top coat 3rd coat	Two Component Aliphatic Acylic Polyurethane	70

Table 17. Painting system for surface preparation grade - Sa 2.5 (Blasted)

Coating process	Coating system	DFT(μm)
Surface preparation	Sa 2.5 (Blasted)	
Priming coat	Two Component High Zinc Epoxy System Primer	60
Intermediate coat 1st coat	Two Component Epoxy MIO Pigmented Intermediate Coat	70
Intermediate coat 2nd coat	Two Component Epoxy Build Up Coat	70
Top coat 3rd coat	Two Component Aliphatic Acylic Polyurethane	70

C5-M - Marine / Coastal location (Less than 20km from coastline)

Table 18. Painting system for surface preparation - St 2 & St 3

Coating process	Coating system	DFT (μm)
Surface preparation	St 2 & St 3	
Priming coat	Two Component Marine Quality Polymide Cured High Build Surface Tolerant Epoxy Primer / Coating	125
Intermediate coat 1st coat	Two Component Marine Quality Polymide cured Epoxy MIO Pigmented Intermediate Coat	150
Intermediate coat 2nd coat	Two Component Marine Quality Polymide Cured Epoxy Build Up Coat	150
Top coat 3rd coat	Two Component Marine Quality Aliphatic Acylic Polyurethane	75

Table 19. Painting system for surface preparation grade - Sa 2.5 (Blasted)

Coating process	Coating system	DFT (μm)
Surface preparation	Sa 2.5 (Blasted)	
Priming coat	Two Component Marine Quality Polymide Cured High Zinc Epoxy System Primer	75
Intermediate coat 1st coat	Two Component Marine Quality Polymide Cured Epoxy MIO Pigment Intermediate Coat	150
Intermediate coat 2nd coat	Two Component Marine Quality Polymide Cured Epoxy Build Up Coat	150
Top coat 3rd coat	Two Component Marine Quality Aliphatic Acylic Polyurethane	75

3. Equipment

1). For surface treatment

Table.9 Equipment for surface preparation

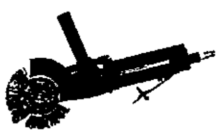
Surface Preparation method	Equipment
Hand tools cleaning	Chipping hammers, Spatulas , Hand scrapers, Hand wire brushes, Abrasive papers, Plastic fleece with embedded abrasive, Emery cloth
Power tool cleaning	Rotary de-scalers, Rotary wire brushes, Sanding machines, Sanding disc, Rotary abrasive-coated paper wheels (flap wheels),Abrasive grinders, Plastic fleece with embedded abrasive, Chipping hammers and needle guns, Percussion hammer
Blast cleaning	Centrifugal abrasive blast cleaning, Compressed air abrasive blast cleaning, Vacuum or sunction head abrasive blast cleaning, Moisture injection abrasive blast cleaning, Compressed air wet abrasive blast cleaning, Slurry blast cleaning

※For reference

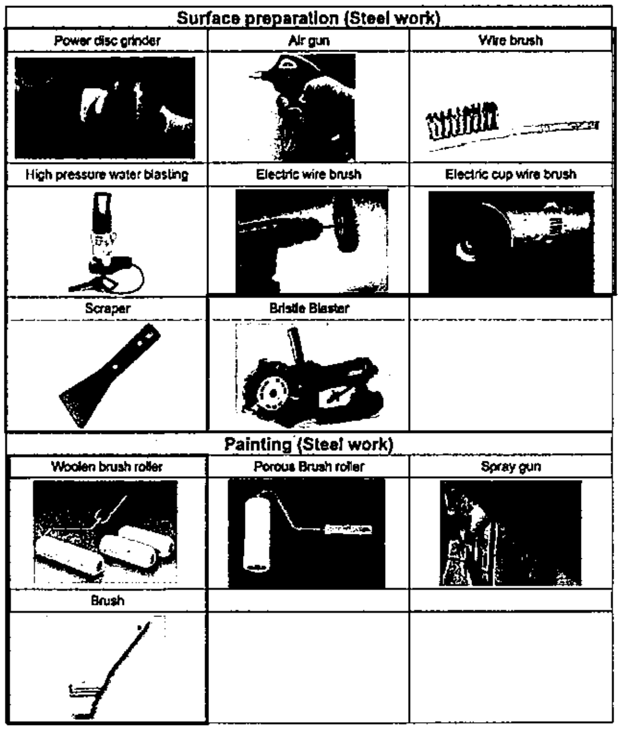
Equipment : Bristle Blaster

Advantage :

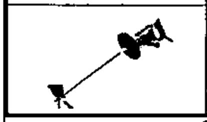
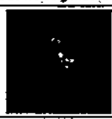
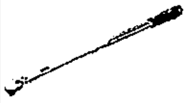
- ➢ Removes corrosion, coating, scale and adhesive residues
- ➢ Surface preparation grade comperable with SA 2.5 – 3 per ISO8501 - 1
- ➢ Roughness level of up to 120μm Rz
- ➢ ATEX –approved for use in Zone 1 (potentially explosive) atmospheres in accordance with Ex II 2G c IIAT4X
- ➢ Fast, flexible and cost – effective to use
- ➢ Eco – friendly and safe to use
- ➢ Ideal for spot – repairs, touch – up jobs and preparing welds



2). General



Painting VIDEO

Mixing Paint (Steel work)	
Hand mixer	Bucket for paint
	
Steel process (Steel work)	
Gas cutter	Gas welding machine
	
Bolting (Steel work)	
Torque wrench	Torque wrench
	
Others	
Portable generator	High pressure water pump
	

4. Quality Control

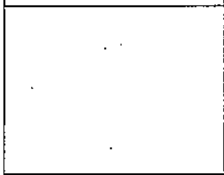
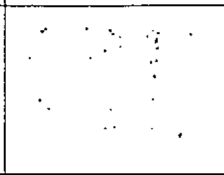
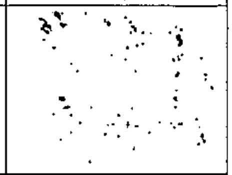
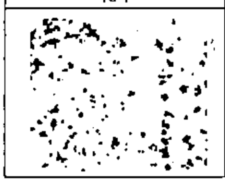
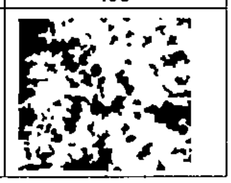
1). Standard check for the current status of painting and rust

➤ Status of rust on the existing painting
ISO4628-3 Paints and varnish – Evaluation of degradation of coating

Table.20 Degree of rusting and rusted area

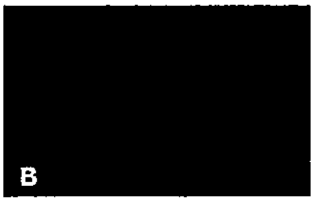
Degree of rusting	Rusted areas (%)
Ri 0	0
Ri 1	0.05
Ri 2	0.5
Ri 3	1
Ri 4	8
Ri 5	40 to 50

Table.21 Degree of rusting and rusted area on a coating (ISO 4628-3)

Ri 1	Ri 2	Ri 3
		
Ri 4	Ri 5	
		

➤ Status of generation of rust on steel

Table.22 Representative photographic examples of rust grades of initial condition of uncoated substrate (ISO 8501-1)

Grade A	Grade B
	
Steel surface largely covered with adhering mill scale but little, if any, rust.	Steel surface which has begun to rust and from which the mill scale has begun to flake.
Grade C	Grade D
	
Steel surface on which the mill scale has rusted away or from which it can be scraped, but with slight pitting visible under normal vision.	Steel surface on which the mill scale has rusted away and on which general pitting is visible under normal vision.

➤ ISO8502-6,9 Extracting soluble salts using bresle sampler and analyzing conductivity

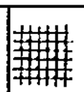
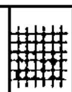
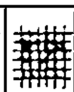
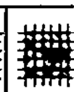
This Chloride Test on steel or Salt Test on steel using the Bresle Patch method will help to prevent coating failure due to salts such as chlorides and sulphates contaminating the surface prior to the coating application. This contamination can be tested quickly and simply using the Bresle Method to ensure the correct surface cleanliness.
Complying with International Standards: ISO 8502-6 and ISO 8502-9.

➤ Adhesion Test in compliance to ASTM D3359 Method A or Method B

These test methods are used to establish whether the adhesion of coating to a substrate is at a generally adequate level.
Test method A- An X-cut is made in the film to the substrate, pressure – sensitive tape is applied over the cut and then removed, and adhesion is assessed qualitatively on the 0 to 5 scale.

Test method B – A lattice pattern with either six or eleven cuts in each direction is made in the film to the substrate, pressure- sensitive tape is applied over the lattice and then removed, and adhesion is evaluated by comparison with descriptions and illustrations.

Test Method A is primarily intended for use at job sites while Test method B is more suitable for use in laboratory. Also, Test method B is not considered suitable for films thicker than 5mils(125 μm).

Surface of cross-cut area from which flaking has occurred. (Example for 6 parallel cuts)	None					Greater than 65%
Classification	5	4	3	2	1	0

5: The edges of the cuts are completely smooth; none of the squares of the lattice is detached.
4: Small flakes of the coating are detached at intersections; less than 5 % of the area is affected.
3: Small flakes of the coating are detached along edges and at intersections of cuts. The area affected is 5 to 15 % of the lattice.
2: The coating has flaked along the edges and on parts of the squares. The area affected is 15 to 35 % of the lattice.
1: The coating has flaked along the edges of cuts in large ribbons and whole squares have detached. The area affected is 35 to 65 % of the lattice.
0: Flaking and detachment worse than Grade 1.

Table23. Measuring Adhesion by Tape Test Method A (X-cut)

Rating	Description
5A	No peeling or removal
4A	Trace peeling or removal along the incisions
3A	Jagged removal along the incisions up to 1/16 on either side
2A	Jagged removal along the incisions up to 1/8 on either side
1A	Removal of most of the coating from the area of the "X" under the tape
0A	Removal of coating beyond the area of the "X"

2). Standard check after surface preparation

- Surface Dust to be Tested after Dry-abrasive Blasting to comply ISO8502-3
- Surface Profile Test either via Needle Gauge or Text Test Tape suitable for required average Blast profile- ASTM D4417(method C), ISO 8503-5

3). Standard check before painting

- ASTM F2420-05(2011) – Environment Test to be carried out – Relative humidity(RH) is on or below 85% & substrate temperature should at least 3℃ Higher than the dew point correspond to the prevailing RH at the time of application. Equipment

4). Standard check during painting

- Application must be carried out with Wet Film Monitoring should also be done in compliance to ISO2808-7B and BS3900-C5-7

5). Standard check after painting

- Measurement of DFT to comply ISO19840 and SSPC PA2. SSPC – PA2 ISO 1416 : 1999(E)-3.4 Measurement of Dry Film thickness by digital / ultrasonic elecometer or similar Equipment
- Pin hole / holiday / Misses identification test to be carried out internally to comply NACE Standard SP 0188 and ISO 2960 : 2011& 2960 : 011 &ASTM – D4787

5. Recommended substrate conditions and temperature

- Top priority shall be in accordance with date sheet.
- Maximum relative humidity during application and curing is 85%
- Do not apply in rain, fog or mist.
- During application and curing, a substrate temperature down to 5℃ is acceptable provided substrate is dry and free from ice
- Previous coat; dry and free from any contamination
- Substrate temperature should be at least 3℃ above dew point correspond to the prevailing RH at the time of application

6. Inspection Sheet and Repair Record

Repair record shall be reported. The component of repair record should be, but not limited to, as-built drawings, inspection sheets, investigation reports, repair design report, construction scene photograph, and method statement.
※Please refer to appendix

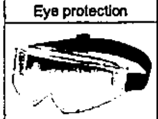
7. Health and Safety

Risk Assessment

The risk to health and safety from falling objects or defects in the structure shall be properly assessed. Platforms and temporary structures shall provide a stable and safe area to work.Do not take any unnecessary risks.

Personal Protection

Handling or processing cement products may generate dust which can cause mechanical irritation to the eyes, skin, nose and throat.
Appropriate eye protection shall be worn at all times while handling and mixing products.
Approved dust masks shell be worn to protect the nose and throat from dust.
Safety shoes, gloves and other appropriate skin protection shall be worn at all times.
Always wash hands with suitable soap after handling products and before food consumption

Eye protection	Gloves	Helmet	Dust masks
			
Work wear	Safety shoes	Safety vest	Safety belt
			
Soundproofing earplugs			
			

First Aid

Seek immediate medical attention in the event of excessive inhalation, ingestion or eye contact causing irritation. Do not induce vomiting unless directed by medical personnel.
Flush eyes with plenty of clean water occasionally lifting upper and lower eyelids. Remove contact lenses immediately. Continue to rinse eye for 10 minutes and then seek medical attention. Rinse contaminated skin with plenty of water. Remove contaminated clothing and continue to rinse for 10 minutes and seek medical attention.
For detailed information refer to the material safety data sheet.

Traffic control

If the repair work will be conduced under open traffic, the inspectors shall pay attention to provide safety for cars and pedestrians. Flagmen and safety cones must be placed to notice the working site to cars/pedestrians. The work shall be complied with all relative low/regulations in Sri Lanka.

Appendix : Type of failure of painting

Table 24. Coating defects (1/2)

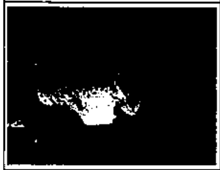
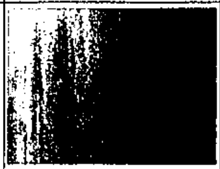
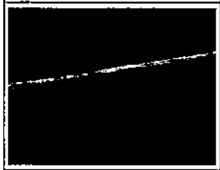
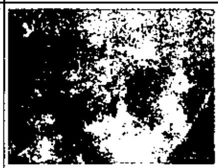
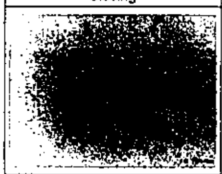
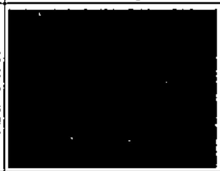
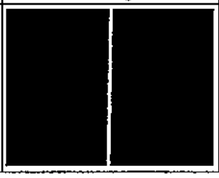
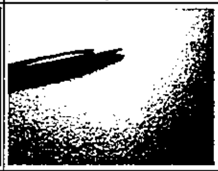
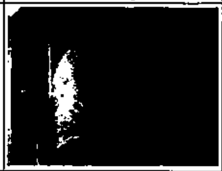
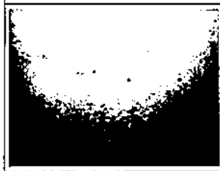
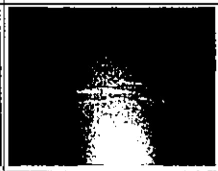
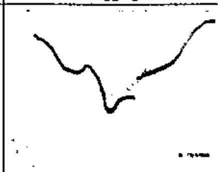
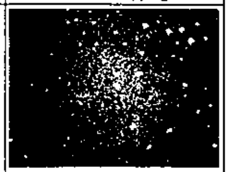
Adhesion	Alligatoring	Bleeding
		
Blistering	Bloom	Chalking
		
Cissing	Cratering	Delamination
		
Dry spray	Fading	Filiform
		

Table 24. Coating defects (2/2)

Mud Cracking	Orange Peel	Peeling
		
Pinhole	Runs	Rust Rash
		
Rust Spotting	Sagging	Solvent Popping
		
Wrinkling		
		

Inspection sheet for zone painting (Draft)

Form.1

PROJECT NAME

Client :

Consultant :

Contractor :

INSPECTION OF MATERIAL

INSPECTION DATE :

STRUCTURE NAME :

Item	Description	
Area of Zone painting		
Surface preparation		
Date of painting		
Prime Coat		
1st Coat		
2nd Coat		
3rd Coat		
Note		
Photos	Before Zone painting	After Zone painting

Form.2

PROJECT NAME

Client :

Consultant :

Contractor :

INSPECTION OF MATERIAL

INSPECTION DATE :

STRUCTURE NAME :

Method of surface preparation

Date of surface preparation

Grade of surface preparation

	Prime coat	1st	2nd	3rd
Contractor				
Supplier				
Name of painting				
Standard				
Color				
Date of painting				
Weather				
Temperature				
RH				
Status of existing paint				
Grade				
Equipment				
Cleaning the paintin				
Name of painting				
Area of Zone painting (m^2)				
Method of painting				
Paint consumption (kg)				
Paint consumption (kg/m^2)				
Thickness (μm)				
Location of storage from previous painting				
Note				

Form.3

PROJECT NAME

Client :

Consultant :

Contractor :

INSPECTION OF MATERIAL

INSPECTION DATE :

STRUCTURE NAME :

1.General

Item	Description
Area of painting	
Date of measurement	
tandard total thickness of paintin	

2.Measurment results of painting thickness

Location of measurement		Thickness of painting 1	2	3	4	5	Average XI
1							
2							
3							
4							
5							
6							
7							
8							
9							

Average value and Standard deviation

$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$ = #### μm

$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(\bar{x} - x_i)^2}$ = #### μm

Management thickness									
	Average thickness	####	####	0	×	0.90	=	0 μm	####
	Minimum thickness	0	<	0	×	0.70	=	0 μm	NG
	Standard deviation	####	####	0	×	0.20	=	0 μm	####

NOTE

1.Measurement location : 1nos / 10m^2

2.Measurement number at 1 location : 5nos

3.Average thickness shall be thicker than 90% of targeted total thickness

4.Minimum thickness shall be thicker than 70% of targeted total thickness

5.Standard deviation shall be smaller than 20% of targeted total thickness

If the average thickness is thicker than targeted total thickness , thickness of painting meet the requirement even standard deviation is bigger than 20% of targeted total

6.Measurement of film thickness shall be carry out after completion of painting

Date sheet of repair materials

DATA

SIGMACOVER 280

SIGMA COATINGS

DATA

SIGMACOVER 280

SIGMA COATINGS

SIGMACOVER 280

[illegible]

September 2001

BRUSH/ROLLER

Recommended thinner	no extra thinner is necessary,
Volume of thinner	but up to 5% Sigma thinner 91-92 can be added if desired

CLEANING SOLVENT Sigma thinner 90-53

SAFETY PRECAUTIONS for paint and recommended thinner see safety sheets 1430, 1431 and relevant material safety data sheets

this is a solvent based paint and care should be taken to avoid inhalation of spray mist or vapour as well as contact between the wet paint and exposed skin or eyes

ADDITIONAL DATA Film thickness and spreading rate

theoretical spreading rate m²/l	11.4	7.6	5.7
dft in µm	50	75	100

max. dft when brushing 50 µm

Overcoating table for SigmaCover 280 for dft up to 100 µm

for various two pack epoxy or polyurethane paint

substrate temperature	0°C	10°C	20°C	30°C	40°C
minimum interval	36 hours	16 hours	8 hours	6 hours	4 hours
maximum interval when not exposed to sunshine	6 months	6 months	6 months	4 months	3 months
maximum interval when exposed to direct sunshine	3 months	3 months	3 months	2 months	2 months

- surface should be dry and free from any contamination

SIGMACOVER 280

[illegible]

September 2001

Overcoating table for SigmaCover 280 for dft up to 100 µm

for other types of paint like most chlorinated rubber, vinyl, alkyd paint

substrate temperature	0°C	10°C	20°C	30°C	40°C
minimum interval	16 hours	10 hours	5 hours	3 hours	2 hours
maximum interval	21 days	21 days	10 days	7 days	4 days

- surface should be dry and free from any contamination
- glossy finishes require a corresponding undercoat

Curing table

substrate temperature	touch dry	dry to handle	full cure
0°C	8 hours	13 hours	21 days
10°C	4 hours	6 hours	14 days
20°C	2 hours	2.5 hours	7 days
30°C	1 hour	1.5 hour	5 days
40°C	45 min	1 hour	3 days

- adequate ventilation must be maintained during application and curing (please refer to sheet 1433 and 1434)

Pot life (at application viscosity)

15°C	10 hours
20°C	8 hours
30°C	5 hours
35°C	4 hours

Worldwide availability Whilst it is always the aim of Sigma Coatings to supply the same product on a worldwide basis, slight modification of the product is sometimes necessary to comply with local or national rules/circumstances. Under these circumstances an alternative product data sheet is used.

REFERENCES

Explanation to product data sheets	see information sheet 1411
Safety indications	see information sheet 1430
Safety in confined spaces and health safety	
Explosion hazard - toxic hazard	see information sheet 1431
Safe working in confined spaces	see information sheet 1431
Directives for ventilation practice	see information sheet 1431

SIGMACOVER 280

[illegible]

September 2001

LIMITATION OF LIABILITY

[illegible]

[illegible]

[illegible]

The English text of this document shall prevail over any translation thereof.

UK	7417
[illegible]	[illegible]
[illegible]	[illegible]

SIGMACOVER 435

Globally Available

5 pages

October 2012
Revision of April 2012

Description two component high build micaceous iron oxide pigmented polyamide cured recoatable epoxy coating

PRINCIPAL CHARACTERISTICS
- general purpose epoxy build coat or finish in protective coating systems for steel and concrete structures exposed to atmospheric land or marine conditions
- easy application, both by airless spray and brush
- cures even at temperatures down to -10°C
- a high relative humidity max. 95%, during application and curing does not influence the quality of the coating
- good adhesion on most aged, sound alkyd-, chlorinated rubber- and epoxy coatings
- can be recoated with various two component and conventional coatings even after long weathering periods
- resistant to water and splash of mild chemicals
- excellent durability
- tough, with long term flexibility
- resistant to temperatures up to 200°C (see system sheet 4062)

COLOURS AND GLOSS light grey (9553-05), dark grey (9556-05), green (9441-05), aluminum (9590-05) – eggshell

BASIC DATA AT 20°C (1 g/cm³ = 8.35 lb/US gal; 1 m²/l = 40.7 ft²/US gal)

(data for mixed product)

Mass density	1.4 g/cm³
Volume solids	63% ± 2%
VOC (Directive 1999/13/EC, SED)	max. 241 g/kg (Directive 1999/13/EC, SED)
VOC (UK PG 6/23(92) appendix 3)	max. 344 g/l (approx. 2.9 lb/gal)
Recommended dry film thickness	75 - 150 µm depending on system
Theoretical spreading rate	6.3 m²/l for 100 µm *
Touch dry after	2 hours at 20 °C
Overcoating interval	min. 3 hours *
	max. unlimited
Full cure after	4 days * at 20 °C

(data for components)

Shelf life (cool and dry place)	at least 24 months

* see additional data

SIGMACOVER 435

October 2012

RECOMMENDED SUBSTRATE CONDITIONS AND TEMPERATURES
- steel; blast cleaned to ISO-Sa2½, blasting profile 40 - 70 µm
- steel with approved zinc silicate shop primer; pretreated according to SPSS or powertool cleaned to SPSS-Pt3
- previous coat; dry and free from any contamination
- during application and curing a substrate temperature down to -10°C is acceptable provided substrate is dry and free from ice
- substrate temperature should be at least 3°C above dew point

SYSTEM SPECIFICATION marine — system sheets: 3102, 3103

INSTRUCTIONS FOR USE mixing ratio by volume: base to hardener 82 : 18
- the temperature of the mixed base and hardener should preferably be above 10°C, otherwise extra solvent may be required to obtain application viscosity
- thinner should be added after mixing the components
- too much solvent results in reduced sag resistance

Induction time	none
Pot life	5 hours at 20 °C *

* see additional data

AIR SPRAY

Recommended thinner	Thinner 91-92
Volume of thinner	10 - 15%, depending on required thickness and application conditions
Nozzle orifice	2 - 3 mm
Nozzle pressure	0.3 - 0.4 MPa (= approx. 3 - 4 bar; 44 - 58 p.s.i.)

AIRLESS SPRAY

Recommended thinner	Thinner 91-92
Volume of thinner	5 - 10%, depending on required thickness and application conditions
Nozzle orifice	approx. 0.48 - 0.58 mm (= 0.019 - 0.023 in)
Nozzle pressure	15 MPa (= approx. 150 bar; 2176 p.s.i.)

BRUSH/ROLLER

Recommended thinner	Thinner 91-92
Volume of thinner	0 - 5%

CLEANING SOLVENT Thinner 90-53

ADDITIONAL DATA Film thickness and spreading rate

theoretical spreading rate m²/l	8.4	6.3	4.2
dft in µm	75	100	150

Maximum dft when brushing 75 µm

SIGMACOVER 435

October 2012

Overcoating table for dft up to 150 µm

	substrate temperature	-5°C	5°C	10°C	20°C	30°C	40°C
for Sigma Vikote 46, SigmaDur 550, SigmaDur 520 and Sigmarine 40	minimum interval	72 hours	24 hours	16 hours	8 hours	5 hours	3 hours
	maximum interval	no limitation					
for SigmaCover 435, SigmaCover 456	minimum interval	36 hours	10 hours	4 hours	3 hours	2 hours	2 hours
	maximum interval	no limitation					

- surface should be dry and free from chalking and contamination
- SigmaCover 435 should not be overcoated with coal tar epoxy coatings
- finishes require a corresponding undercoat

Curing Curing table for dft up to 150 µm

substrate temperature	dry to handle	full cure
-10°C	24 - 48 hours	20 days
-5°C	24 - 30 hours	14 days
0°C	18 - 24 hours	10 days
5°C	18 hours	8 days
10°C	12 hours	6 days
15°C	8 hours	5 days
20°C	6 hours	4 days
30°C	4 hours	3 days
40°C	3 hours	2 days

- adequate ventilation must be maintained during application and curing (please refer to sheets 1433 and 1434)

In exceptional cases SigmaCover 435 may be applied at lower substrate temperatures (down to -15 C) provided that the surface is free from ice and other contamination. In such cases special care must be taken to avoid thick film application as this may lead to checking/crazing or solvent entrapment. It should be clear that application at lower temperatures will require additional thinning to obtain application viscosity, however this will affect the sag resistance of the applied coating and can induce solvent retention. Optimal curing and designed product properties will only be achieved when minimum required substrate temperature is reached.

SIGMACOVER 435

October 2012

Pot life (at application viscosity)

10 °C	12 hours
20 °C	5 hours
30 °C	4 hours
40 °C	2 hours

Worldwide availability Whilst it is always the aim of Sigma Coatings to supply the same product on a worldwide basis, slight modification of the product is sometimes necessary to comply with local or national rules/circumstances. Under these circumstances an alternative product data sheet is used.

REFERENCES

Explanation to product data sheets	see information sheet 1411
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Safety in confined spaces and health safety	
Explosion hazard - toxic hazard	see information sheet 1431
Safe working in confined spaces	see information sheet 1433
Directives for ventilation practice	see information sheet 1434
Conversion tables	see information sheet 1410
Cleaning of steel and removal of rust	see information sheet 1490
Specification for mineral abrasives	see information sheet 1491
Relative humidity - substrate temperature - air temperature	see information sheet 1650

SAFETY PRECAUTIONS
- for paint and recommended thinners see safety sheets 1430, 1431 and relevant material safety data sheets
- this is a solvent borne paint and care should be taken to avoid inhalation of spray mist or vapour as well as contact between the wet paint and exposed skin or eyes

SIGMACOVER 435

October 2012

WARRANTY

PPG warrants (i) its title to the product, (ii) that the quality of the product conforms to PPG's specifications for such product in effect at the time of manufacture and (iii) that the product shall be delivered free of the rightful claim of any third person for infringement of any U.S. patent covering the product.
THESE ARE THE ONLY WARRANTIES THAT PPG MAKES AND ALL OTHER EXPRESS OR IMPLIED WARRANTIES, UNDER STATUTE OR ARISING OTHERWISE IN LAW, FROM A COURSE OF DEALING OR USAGE OF TRADE, INCLUDING WITHOUT LIMITATION, ANY OTHER WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE OR USE, ARE DISCLAIMED BY PPG.
Any claim under this warranty must be made by Buyer to PPG in writing within five (5) days of Buyer's discovery of the claimed defect, but in no event later than the expiration of the applicable shelf life of the product, or one year from the date of the delivery of the product to the Buyer, whichever is earlier. Buyer's failure to notify PPG of such non-conformance as required herein shall bar Buyer from recovery under this warranty.

LIMITATIONS OF LIABILITY

IN NO EVENT WILL PPG BE LIABLE UNDER ANY THEORY OF RECOVERY (WHETHER BASED ON NEGLIGENCE OF ANY KIND, STRICT LIABILITY OR TORT) FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES IN ANY WAY RELATED TO, ARISING FROM, OR RESULTING FROM ANY USE MADE OF THE PRODUCT.
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	PDS	7465
179075	lightgrey	9533052700
179496	darkgrey	9568052700

SIGMACOVER 456

Globally Available

5 pages

April 2012
Revision of August 2010

Description two component high build polyamide cured recoatable epoxy coating

PRINCIPAL CHARACTERISTICS
- general purpose epoxy build coat or finish in protective coating systems for steel and concrete structures exposed to atmospheric land or marine conditions
- easy application, both by airless spray and brush
- cures even at temperatures down to -10°C
- a high relative humidity max. 95%, during application and curing does not influence the quality of the coating
- good adhesion on most aged, sound alkyd-, chlorinated rubber- and epoxy coatings
- can be recoated with various two component and conventional coatings even after long weathering periods
- resistant to water and splash of mild chemicals
- excellent durability
- tough, with long term flexibility

COLOURS AND GLOSS white and various other colours (see also the SigmaCare Shade Card of PPG Protective & Marine Coatings) – semigloss

BASIC DATA AT 20 °C (1 g/cm³ = 8.35 lb/US gal; 1 m²/l = 40.7 ft²/US gal)

(data for mixed product)

Mass density	1.4 g/cm³
Volume solids	65% ± 2%
VOC (Directive 1999/13/EC, SED)	max. 250 g/kg (Directive 1999/13/EC, SED)
VOC (UK PG 6/23(92) appendix 3)	max. 344 g/l (approx. 2.9 lb/gal)
Recommended dry film thickness	75 - 150 μm depending on system
Theoretical spreading rate	6.5 m²/l for 100 μm 8.7 m²/l
Touch dry after	2 hours at 20 °C
Overcoating interval	min. 3 hours * max. unlimited
Full cure after	4 days * at 20 °C

(data for components)

Shelf life (cool and dry place)	at least 24 months * see additional data

RECOMMENDED SUBSTRATE CONDITIONS AND TEMPERATURES
- previous coat; dry and free from any contamination
- during application and curing a substrate temperature down to -10°C is acceptable provided substrate is dry and free from ice
- substrate temperature should be at least 3°C above dew point

SYSTEM SPECIFICATION marine system sheets: 3102, 3103, 3104, 3105

SIGMACOVER 456

April 2012

INSTRUCTIONS FOR USE mixing ratio by volume: base to hardener 82 : 18
- too much solvent results in reduced sag resistance
- the temperature of the mixed base and hardener should preferably be above 10°C, otherwise extra solvent may be required to obtain application viscosity
- thinner should be added after mixing the components

Induction time	none
Pot life	5 hours at 20 °C *see additional data

AIR SPRAY

Recommended thinner	Thinner 91-92
Volume of thinner	5 - 10%, depending on required thickness and application conditions
Nozzle orifice	2 - 3 mm
Nozzle pressure	0.3 - 0.4 MPa (= approx. 3 - 4 bar; 44 - 58 p.s.i.)

AIRLESS SPRAY

Recommended thinner	Thinner 91-92
Volume of thinner	0 - 5%, depending on required thickness and application conditions
Nozzle orifice	approx. 0.48 - 0.58 mm (= 0.019 - 0.023 in)
Nozzle pressure	15 MPa (= approx. 150 bar; 2175 p.s.i.)

BRUSH/ROLLER

Recommended thinner	Thinner 91-92
Volume of thinner	0 - 5%

CLEANING SOLVENT Thinner 90-53

Film thickness and spreading rate

theoretical spreading rate m²/l	8.7	6.5	4.3
dft in μm	75	100	150

Maximum dft when brushing: 60 μm

SIGMACOVER 456

April 2012

Overcoating table for dft up to 150 μm

	substrate temperature	-5°C	5°C	10°C	20°C	30°C	40°C
for Sigma Vikote 46, SigmaDur 550, SigmaDur 520 and Sigmarine 40	minimum interval	72 hours	24 hours	16 hours	8 hours	5 hours	3 hours
	maximum interval	no limitation					
for SigmaCover 435, SigmaCover 456	minimum interval	36 hours	10 hours	4 hours	3 hours	2 hours	2 hours
	maximum interval	no limitation					
for Sigma Vikote 56 * and Sigmarine 48 *	maximum interval	17 days	14 days	10 days	7 days	4 days	2 days

- finishes require a corresponding undercoat
- surface should be dry and free from chalking and contamination
- SigmaCover 456 should not be overcoated with coal tar epoxy coatings
- surface should be dry and free from chalking and contamination

* colour of SigmaCover 456 should be adapted to the colour of Sigma Vikote 56 or Sigmarine 48

Curing

Curing table for dft up to 150 μm

substrate temperature	dry to handle	full cure
-10°C	24 - 48 hours	20 days
-5°C	24 - 30 hours	14 days
0°C	18 - 24 hours	10 days
5°C	18 hours	8 days
10°C	12 hours	8 days
15°C	8 hours	5 days
20°C	6 hours	4 days
30°C	4 hours	3 days
40°C	3 hours	2 days

- adequate ventilation must be maintained during application and curing (please refer to sheets 1433 and 1434)

In exceptional cases SigmaCover 456 may be applied at lower substrate temperatures (down to -15 C) provided that the surface is free from ice and other contamination. In such cases special care must be taken to avoid thick film application as this may lead to checking/crazing or solvent entrapment. It should be clear that application at lower temperatures will require additional thinning to obtain application viscosity, however this will affect the sag resistance of the applied coating and can induce solvent retention. Optimal curing and designed product properties will only be achieved when minimum required substrate temperature is reached.

SIGMACOVER 456

April 2012

Pot life (at application viscosity)

10 °C	12 hours
20 °C	5 hours
30 °C	4 hours
40 °C	2 hours

Worldwide availability Whilst it is always the aim of Sigma Coatings to supply the same product on a worldwide basis, slight modification of the product is sometimes necessary to comply with local or national rules/circumstances.
Under these circumstances an alternative product data sheet is used.

REFERENCES

Explanation to product data sheets	see information sheet 1411
Safety indications	see information sheet 1430
Safety in confined spaces and health safety	
Explosion hazard - toxic hazard	see information sheet 1431
Safe working in confined spaces	see information sheet 1433
Directives for ventilation practice	see information sheet 1434
Conversion tables	see information sheet 1410
Surface preparation of concrete (floors)	see information sheet 1498
Relative humidity - substrate temperature - air temperature	see information sheet 1650

SAFETY PRECAUTIONS
- for paint and recommended thinners see safety sheets 1430, 1431 and relevant material safety data sheets
- this is a solvent borne paint and care should be taken to avoid inhalation of spray mist or vapour as well as contact between the wet paint and exposed skin or eyes

SIGMACOVER 456

April 2012

WARRANTY

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	PDS	7468
179073	white	7000002200

SIGMADUR 188

4 pages | December 2007
Revision of September 2003

DESCRIPTION two component aliphatic acrylic polyurethane finish

PRINCIPAL CHARACTERISTICS
- Unlimited recoatable
- excellent resistance to atmospheric exposure
- excellent color and gloss retention
- non chalking, non yellowing
- cures at temperatures down to -5°C
- tough and abrasion resistant
- resistant to splash of mineral and vegetable oils, paraffins, aliphatic petroleum products and mild chemicals
- can be recoated even after long atmospheric exposure

COLOURS AND GLOSS white and black, colors available on request - gloss

BASIC DATA (Data for mixed product at 20°C)

Mass density	Approx. 1.2 g/cm³
Solids content	Approx. 56% by volume
VOC (supplied)	Max. 3.3 lb/gal - 396 g/l
Recommended dry film Thickness	50-60 µm depending on system
Theoretical spreading rate	11.2 m²/l for 50 µm *
Touch dry after	1 hour
Overcoating interval	min. 6 hours * max. unlimited
Full cure after	4 days*

(data for components)

Shelf life (cool and dry place)	at least 24 months
Flash point	Base 26°C, hardener 38°C

RECOMMENDED SUBSTRATE CONDITIONS AND TEMPERATURES
- previous coat (epoxy or polyurethane) dry and free from any contamination and sufficiently roughened if necessary
- during application and curing, a substrate temperature down to -5°C is acceptable provided the substrate is free from water or ice
- substrate temperature should be at least 3°C above dew point
- maximum relative humidity during application and curing is 85%
- premature exposure to early condensation and rain may cause colour and gloss change

INSTRUCTIONS FOR USE mixing ratio by volume: base to hardener 88:12
- the temperature of the mixed base and hardener should preferably

SIGMADUR 188

December 2007

be above 10°C, otherwise extra solvent may be required to obtain application viscosity
- too much solvent results in reduced sag resistance
- thinner should be added after mixing the components

Induction time	none
Pot life at 20°C	5 hours *

APPLICATION METHODS High gloss thin film polyurethane finishes tend to atomise less easy. The widely used airless spray application method is for these kinds of finishes possible but not be the best option as small nozzles and high pressures can easily result in overspray. Better suitable methods are pressure pot and air assisted airless (e.g. airmix) application which result in better dry film thickness control, better appearance and much less overspray.

AIRLESS SPRAY

Recommended thinner	Sigma thinner 21-06
Volume of thinner	5 - 15 %, depending on required thickness and application conditions
Nozzle orifice	0.28 - 0.33 mm (=0.011 - 0.013 in)
Nozzle pressure	20 MPa (=approx. 200 bar; 2800 p.s.i.)

AIR SPRAY

Recommended thinner	Sigma thinner 21-06
Volume of thinner	5 - 10 %, depending on required thickness and application conditions
Nozzle orifice	1 - 1.5 mm
Nozzle pressure	0.3 - 0.4 MPa (=approx. 3-4 bar; 40-60 p.s.i.)

BRUSH/ROLLER

Recommended thinner	Sigma thinner 21-06
Volume of thinner	5 - 10%

CLEANING SOLVENT Sigma thinner 90-53

SAFETY PRECAUTION For paint and recommended thinners see safety sheets 1430, 1431 and relevant material safety datasheets

This is a solvent based paint and care must be taken to avoid inhalation of spray mist or vapor as well as contact between the wet paint and

SIGMADUR 188

December 2007

exposed skin or eyes

- contains a toxic polyisocyanate curing agent
- avoid at all times, inhalation of aerosol/ spraymist

ADDITIONAL DATA
Film thickness and Spreading rate

Theoretical Spreading rate m²/l	11.2	9.3
dft in µm	50	60

Overcoating table for Sigmadur 188

substrate temperature	-5°C	0°C	10°C	20°C	30°C	40°C
minimum interval	24 hours	16 hours	8 hours	6 Hours	5 hours	3 hours
maximum interval	unlimited					

surface should be dry and free from any contamination

Curing table

temperature	Dry to handle	Full cure
-5°C	24 hours	15 days
0°C	16 hours	11 days
10°C	8 hours	6 days
20°C	6 hours	4 days
30°C	5 hours	3 days
40°C	3 hours	2 days

Adequate ventilation must be maintained during application and curing (Please refer to sheet 1433 and 1434)

premature exposure to early condensation and rain may cause colour and gloss change

Pot life (at application viscosity)

10°C	6 hours
20°C	4 hours
30°C	3 hours
40°C	2 hours

Worldwide availability Whilst it is always the aim of Sigma Coatings to supply the same product on a worldwide basis, slight modification of the product is sometimes necessary to comply with local or national rules/circumstances. Under these circumstances an alternative product data sheet is used.

SIGMADUR 188

December 2007

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PDS 6624

Agenda of Bridge Management Seminar July 25th 2017 at PD Office Central

Opening (9:00-9:05)	• Opening Address by Provincial Director Central	PD Central
Explanation of the Seminar (9:05-9:10) (5 min)	• Today's program	Mr.Takaura
Basic Knowledge of Bridges (9:10-9:30)(20 min)	• Terminologies and definition thereof related to bridges • Bridge types in Sri Lanka	Mr. Jayasuriya
Functions Required on Bridges (9:30-9:40) (10 min)	• Functions required on bridge superstructure (deck slab, main beam, diaphragm / cross beam, etc.) • Functions required on bridge pier and abutment (body and foundation) • Functions required on ancillary works (bridge bearing, bridge expansion joint, drainage, pavement, railing, etc.) • Issues arisen from the functional disorders	Mr. Takaura
About Bridge Management (9:40-10:00) (20 min)	• What is "managing the bridges"? • Important issues on developing the system / mechanism of bridge management provided to RDA, Sri Lanka	Mr. Urano
Bridge Management (10:00-10:20) (20 min)	• Flow of bridge management • Health index (HI) • Bridge management indicator • Bridge management scenario • Importance index (II) • Functionally obsolete index (FOI) • Prioritization of bridges for repair and rehabilitation • Prioritization of bridges for reconstruction • Bridge reconstruction cost • Bridge repair and maintenance plan • Bridge reconstruction plan • Bridge management system (BMS)	Mr. Urano
Q & A (10:20-10:30) (10 min)		
Break (10:30-10:40)(10 min)		
Bridge Inspection (10:40 -:11:20) (40 min)	• Purpose and Method of Bridge Inspection • Work Flow of Bridge Inspection • Details of Bridge Inspection • Record of Damage on Bridge • Damage Examples • Major Damage Example with Their Mechanisms of Bridges • Bridge Inspection by Bridge Inspection Vehicle (BIV)	Dr. Aoyama
Bridge Diagnosis (11:20 -12:00) (40 min)	• HI=0 • Purpose of bridge diagnosis • Examples of bridge diagnosis • Examples of emergency actions • Practical seminar on bridge diagnosis	Mr. Hajima
Lunch Break		
Bridge Repair (13:00 – 13:50) (50 min)	• Definition of repair and strengthening • Typical bridge repair method on each type of damage • Description of minor and major bridge repairs • Safety measures • Repair costs • Introduction of trial bridge repairs	Mr. Kagami
Q&A 13:50-14:00 (10 min)		
Closing 14:00	• Closing Address by Provincial Director Central	PD Central

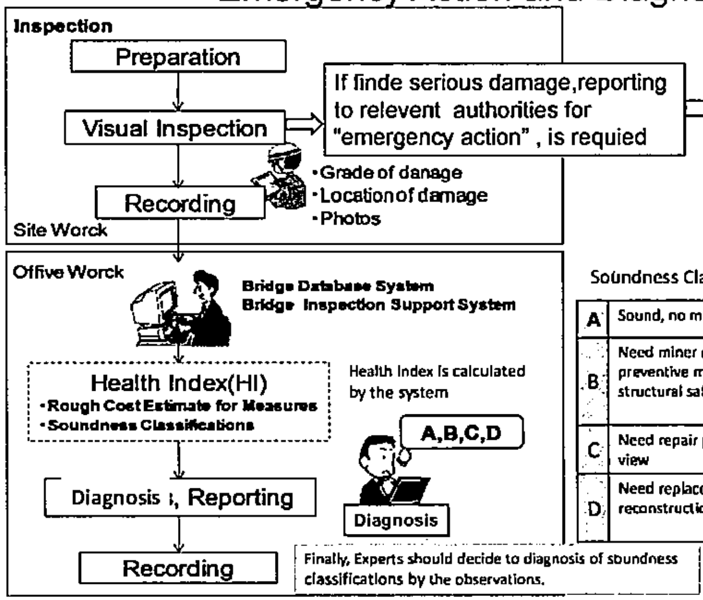
After above program move to 2 bridge site to conduct site seminar up to 16:30.

Bridge Diagnosis
&
Emergency Action

THE PROJECT
FOR CAPACITY DEVELOPMENT
ON BRIDGE MANAGEMENT

Contents

Flow of Periodic Bridge Inspection & Emergency Action and Diagnosis



Soundness Classifications(A,B,C,D)

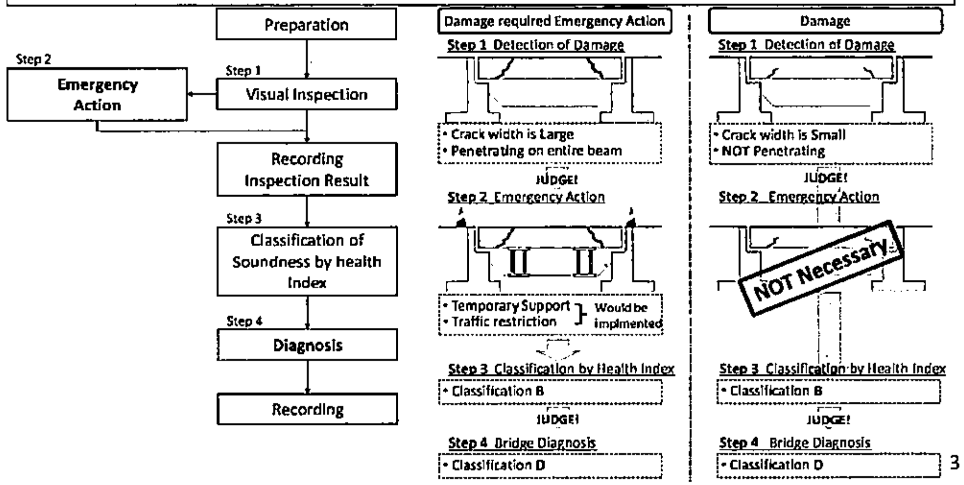
A	Sound, no measure required minor damage
B	Need miner repair for damage needed for preventive maintenance purpose recommended for structural safety points of view at early stage
C	Need repair promptly for structural safety points of view
D	Need replacement of member / strengthening / reconstruction of entire bridge

+α

1. Emergency Action and Diagnosis

1-1. Timing of Emergency Action and Diagnosis

- Damage shall be judged twice during Periodic Inspection
  - During visual inspection : Whether Emergency Action is needed, or not
  - End of periodic inspection : Whether Soundness Classification is changed, or not



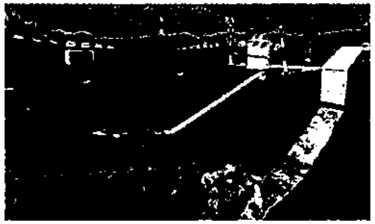
1. Emergency Action and Diagnosis

1-2. Purpose of Emergency Action

☐ In case of detection of the following situations during visual inspection, "Emergency Action" should be implemented.
- Impairing the safety of bridge structures
- Third-party effects

● **Impairing the Safety of Bridge Structures**
Bridge structures might be COLLAPSED or FALLEN DOWN due to damage, which results in the decrease of load carrying capacity.

● **Third- Party Effects**
When it is suspected that vehicles, trains and/or pedestrians on/under the bridge are adversely affected by the damage. thereof, emergency actions shall be taken immediately.



Collapse of a bridge

1. Emergency Action and Diagnosis

1-3-1. Purpose of Bridge Diagnosis

☐ Experienced experts within RDA review Soundness Classification of Bridge at the end of Periodic Inspection.

☐ All bridges inspected based on periodic inspection must be reviewed.

WHY "the bridge soundness" should be reviewed ?

✓ However, HI does NOT consider
- Rate of progress of damage - Influence of location of damage to the soundness

WHY all bridges ?

✓ If the serious damage is **NOT** judged appropriately,
- **NOT** repair and strengthen the serious damage

Possibility of the collapse of a bridge suddenly without warning

The serious accident occur such as the **INJURED** and the **DEAD**.

Who has Responsibility ?

In the case, Road Administrator has responsibility

1. Emergency Action and Diagnosis

1-3-2. Purpose of Bridge Diagnosis

☐ In diagnosis, soundness of an entire bridge could be changed as "D" or "C", regardless of the bridge soundness classification determined by HI.

☐ Change of soundness classification

Before Diagnosis(by HI)	After Diagnosis
A	C or D
B	C or D
C	D

Soundness classification by Health Index (HI)

Sound → Serious

	Classification	Conditions
A	Sound	Structures are well functioning.
B	Preventive Maintenance Stage	Structures are well functioning. However, it is desirable to take necessary measures from the perspective of preventive maintenance.
C	Reactive Maintenance Stage	Functions of the structure will be possibly impaired. Necessary measures should be taken at an early stage (within 5 years).
D	Immediate Action Stage	Functions of the structure are impaired or the possibility of impairment of functions is extremely high. Necessary measures should be taken immediately (within 2 years).

2. Situation in need of Emergency Action

2-1-1. Example of Damage – Impairing safety of Bridge Structures –

Other Damage on Concrete

•Example of damage

Bearing failure near support

•Crack width is 0.3mm or more
•Impairing the bearing function

Delamination in wide area of the deck slab / main beam

•Ex-rebar with remarkable corrosion or broken re-bar, or delamination
•Damage on about 60% of its all area

with remarkable corrosion or break of rebar / PC cable.

2. Situation in need of Emergency Action

2-1-2. Example of Damage – Impairing safety of Bridge Structures –

Corrosion and Break on Steel Member

•Example of damage

Remarkable loss section of steel beam

Break of the diagonal member of truss

•Loss of web steel on its entire depth
•Loss of lower flange steel by 50% or more
•Near support

HSFG on Steel Member

•Example of damage

Damaged bolts, such as the serious corrosion is about more than 25% of one bolt group and more in number

Damage on HSFG

2. Situation in need of Emergency Action

2-1-3. Example of Damage – Impairing safety of Bridge Structures –

Arch Line

•Example of damage

Large deformation of the arch line

Bridge Pier / Abutment in Water

•Example of damage

Exposed foundation due to riverbed degradation and / or scour

•Scoured under footing of pier/abutment

2. Situation in need of Emergency Action

2-1-4. Example of Damage – Third-party Effects –

Railing / Parapet

•Example of damage

Missing of railing

Approach Road / River Bank

•Example of damage

Large collapse of approach road that causes the depression and crack of road surface

Damage on Deck Slab

•Example of damage

Large cracks

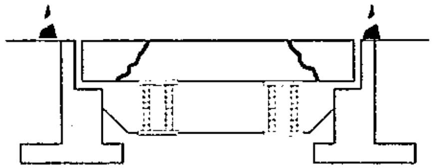
Fallen down of a concrete block from the deck slab

Severe damage of steel deck slab

These damage would cause the depression of road surface

2. Situation in need of Emergency Action

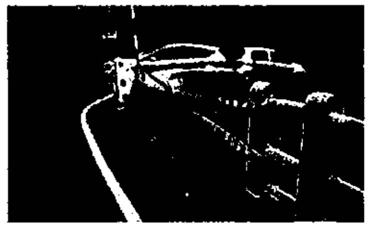
2-2. Example of Emergency Action



Temporary support with saddles & Traffic restriction

Filling with pavement mixture (Pothole)

Temporary fixing of drainage pipe



Installation Caution sign (Damage on railing/parapet)

3. Bridge Diagnosis

3-1-1. Example of Bridge Diagnosis – Concrete structure –

Classification C

Spall / Dela / Ex-rebar(No.12), Concrete Crack (No.13)

- Delamination on main concrete beam / slab to a large extent
- Large crack on main concrete beam / slab
  It is suspected that steels in concrete may be seriously corroded, resulted in the decrease of load carrying capacity.


- Crack with water leakage on concrete structure
  It is supposed that concrete will deteriorate earlier near such cracks than other areas.

3. Bridge Diagnosis

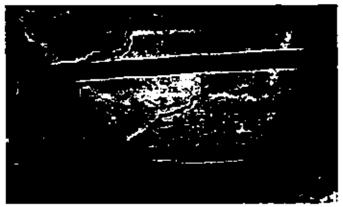
3-1-2. Example of Bridge Diagnosis – Concrete structure –

Classification C

Damage on Deck Slab (RC) (No.22-1)

- Pattern cracking on bridge deck slab
  It is suspected that excess load is delivered to a main beam due to the degradation of such load distribution function and damages the said beam. It will impair the structural safety of an entire bridge.

- Penetrating crack on concrete main beam / slab
  Load carrying capacity there will be decreased.

3. Bridge Diagnosis

3-1-3. Example of Bridge Diagnosis – Concrete structure –

Classification D

Spall / Dela / Ex-rebar(No.12), Concrete Crack (No.13)

- Delamination on main beam / slab
  The break of the steels is suspected.

3. Bridge Diagnosis

3-2-1. Example of Bridge Diagnosis – Steel structure –

Classification C

Corrosion (No.20)

- Serious extensive corrosion and local loss of structural steel
- 30% or more of the lower flange steel has been lost.
- Steel web has been lost on one-third or more of its depth.
- For the truss bridge, 20% or more of steel of its diagonal / vertical member or chord has been lost.
  Load carrying capacity will be decreased. It will impair the structural safety of an entire bridge.




- Unusual corrosion on galvanized coating with local loss of structural steel
  It is suspected that load carrying capacity might be decreased.

3. Bridge Diagnosis

3-2-2. Example of Bridge Diagnosis – Steel structure –

Classification C

Damage on Deck Slab (Steel) (No.22-2)

- Crack on steel deck slab & Damage on steel deck slab

  It is suspected that excess load is delivered to a main beam due to the degradation of load distribution function and damages the said beam.

Fatigue crack

Large loss section of steel deck

3. Bridge Diagnosis

3-2-3. Example of Bridge Diagnosis – Steel structure –

Classification D

Corrosion (No.20)

- Loss section of web steel on its entire depth
- Loss section of lower flange steel by 50% or more. Damage might cause sudden collapse of the bridge structure.

- Break of diagonal members of truss
- For the truss bridge, 40% or more of steel of its diagonal / vertical member or chord has been lost. Damage might cause sudden collapse of the bridge structure.

3. Bridge Diagnosis

3-2-4. Example of Bridge Diagnosis – Steel structure –

Classification D

Damage (HSFG) (No.21)

- 25% or more of the bolts in number in one group are seriously corroded or missed

  It is difficult to transmit the force between members due to the above damage.
  As the result, this damage might cause sudden collapse of the bridge structure.

3. Bridge Diagnosis

3-3-1. Example of Bridge Diagnosis – Others –

Classification D

Scour (No.17)

- Exposed foundation due to riverbed degradation and/or scour

  Unusual deflection and the collapse of a bridge might occur due to riverbed degradation and scour.

Arch Line (Displacement) (No.23), Deteriorated (Loose) (No.24)

- Large deformation of arch line at its crown

  For the stone arch, it is quite important to retain the arch line as designed.
  Deformation of arch line will result in the entire collapse of the arch structure.

3 Bridge Diagnosis

3-3-2. Example of Bridge Diagnosis – Others –

Classification D

Deflection

- Unusual deflection on an entire bridge
  Unusual deflection may be the sign of settlement, movement or tilting of bridge piers and abutments, and others.

Settlement, movement and tilting of substructures

- Settlement, movement or tilting of piers / abutments
  When the settlement, movement or tilting of bridge piers and abutments are detected, emergency action shall be taken to prevent the collapse of bridge structure.

Desk exercise of inspection record method (Recording result)

THE PROJECT
FOR CAPACITY DEVELOPMENT
ON BRIDGE MANAGEMENT

Minobu AOYAMA

CONTENTS

On-site Memo for Recording Damage of Bridge Surface

Inspection Recorad Sheet [Bridge Surface] No. 1 A1 - A2

Route No.		Bridge No.	/ in Km	Bridge Name		Insp.Date		Inspector :	

Surface Marking

		a	b	c	d	e	Σ	Location (Superstructure Plan Marking: Start / Center / End; Left / Center / Right)	Photo Check (Distant / Close)		Remark
Pavement	1.Pot hole	7		1		1	9	✓ Left: Start ✓		a: a=9-(c+e) c:(Slab is covered by asphalt or Depth < 50mm), and Exist Pothole e:(Exposed slab or Depth >= 50mm) ,and Exist Pothoal	
Pavement	2.Crack	6		1		2	9	✓ Right: Center ✓, End ✓		a: a=9-(c+e) c: Crack width < 5 mm e: Crack width >= 5 mm	
Pavement	3,Rutting	8		1		0	9	✓ Left: Center ✓		a: a=9-(c+e) c:Difference in level (凹凸) about 20mm< and < about 30mm e:Difference in level (凹凸): >= about 30mm	
Pavement	4,Waving	9		0		0	9	✓		a: a=9-(c+e) c: Difference in level (凹凸): <about 20mm /3.0m e: Difference in level (凹凸): >= about20mm / 3.0m	
Expansion Joint	5.Dmage on Joint	81				19	100 %	✓ Center: Start ✓; Right: Start ✓		a: a=100-e e:Total % of damage length in total length of expansion joint(100%) , (the steel finger is widely opened / including trace of touching)	
Expansion Joint	6.Difference in Leavel	100		0		0	100 %	✓		a: a=100-(c+e) Total % of damage in total length of expansion joint(100%) c: Difference in level < about 20mm e: Difference in level : >=about 20mm	
Accessories	7.Damage of Drainage	83				17	100 %	✓ Left: Center ✓		Total % of damaged drainage / 100% a: a=100-e e:% of damaged catch basin or pioe is plugged with mad	
Accessories	8.Damage on Service Duct						%			Total % of damaged service duct in length / total of service duct in length(100%) a: a=100-e e:% of damaged in length	
Accessories	9.Damage on Railing/Parapet	87				13	100 %	✓ Left: Center ✓		Total % of damage in length /total length of handrail(100%) a: a=100-e e:% of Broke in length	
Approaches	10.Settlment of Surface	6				0	6	✓		a: a= 6 −e e:Exist(i>=about 1/20)	
Approaches	11.Approach Bank/River Bank	6				0	6	✓		a: a= 6 −e e:Exist	
Others	25 Others						9	✓			

On-site Memo for Recording Damage of RC-S

Inspection Recorad Sheet [Bridge RC-S] No. 1 -1 A1 - A2

Route No.		Bridge No.	/	in Km	Bridge Name		Insp.Date		Inspector :

[Superstructure]

Superstructure Plan Marking

Deck Slab

		Count of Element						
12 Spall/Dela/Ex-Rebar	Quantify	a	b	c	d	e	Σ	Σ =Total numbers of beams a:Not Exist
		7		0	1	1	9	
	Location	✓	Start	Center	End		Photo Check	c to e : Shown in the table below
		Left		✓			Distant	
		Center					Close	
		Right						
		Superstructure Plan Marking						
	Remark							
13 Crack	Quantify	a	b	c	d 1	e	1 Σ	Σ =Total numbers of beams a:Not Exist and Expect for b to e b to e : Shown in the table below
		5	0	0	2	2	9	
	Location	✓	Start	Center ·	End		Photo Check	
		Left		✓			Distant	
		Center					Close	
		Right		✓				
		Superstructure Plan Marking						
	Remark							
25 Others	Quantify	a	b	c	d	e	Σ	
							9	
	Location	✓	Start	Center	End		Photo Check	
		Left					Distant	
		Center					Close	
		Right						
		Supe Superstructure Plan Marking						
	Remark							

Bridge Bearing

		Count of Element (Numbers of bearing)						
15 Water Leakage from Expansion Joint	Quantify	a	b	c	d	e	Σ	a; a= Σ -(c+e) % of total length of damage/ total length of expansion
		80		20		0	100 %	
	Location	✓	Start	Center	End		Photo Check	c: Water leakage is existed e: Extreme water leakage from expansion joint and/or there is pond at bearing seat.
		Left			✓		Distant	
		Center			✓		Close	
		Right						
		Superstructure Plan Marking						
	Remark							
16 Damage on Bridge Bearing	Quantify	a	b	c	d ·	e	Σ	a; a= Σ -(c+e) % of total in numbers of damaged bearings/ total number of bearings c:Slight damage e:There is lack of bearing function such as broken
		100		0		0	100 %	
	Location	✓	Start	Center	End		Photo Check	
		Left	·				Distant	
		Center					Close	
		Right						
		Superstructure Plan Marking						
	Remark							
25 Others	Quantify	a	b	c	d	e	Σ	
							9	
	Location	✓	Start	Center	End		Photo Check	
		Left					Distant	
		Center					Close	
		Right						
		Superstructure Plan Marking						
	Remark							

Spall / Dela / Ex-Rebar of Grading

c	Spall without ex-rebar.
d	Ex-rebar with slight corrosion
e	Ex-rebar with remarkable corrosion or broken re-bar. Or delamination of surface concrete.

Cracks of Greading

b	Width <about 0.2mm and Interval >50 cm
c	Width about<0.2mm and Interval =<50cm Or about 0.3mm> Width > =about 0.2mm and Interval >50cm
d	Width >= about 0.3mm and Interval >50cm Or about 0.3mm> Width >=about 0.2mm and Interval =<50cm
e	Width >=about 0.3mm and Interval =<50cm

On-site Memo for Recording Damage of PSC-PRE

Inspection Recorad Sheet [Bridge PSC-PRE] No. 1 -1 A1 - A2

Route No.		Bridge No.	/	in Km	Bridge Name		Insp.Date		Inspector :

[Superstructure]

Superstructure Plan Marking

Main Beam

		Count of Element (Numbers of beam)						
12 Spall/Dela/Ex-Rebar	Quantify	a	b	c	d	e	Σ	Σ =Total numbers of beams a:Not Exist
		17		0	1	0	18	
	Location	✓	Start	Center	End		Photo Check	c to e : Shown in the table Right
		Left					Distant	
		Center	✓				Close	
		Right						
		Superstructure Plan Marking						
	Remark							
13 Crack	Quantify	a	b	c	d 1	e	Σ	Σ =Total numbers of beams a:Not Exist and Expect for b to e b to e : Shown in the table Right
		16	0	0	2	0	18	
	Location	✓	Start	Center	End		Photo Check	
		Left					Distant	
		Center	✓				Close	
		Right		✓				
		Superstructure Plan Marking						
	Remark							
14 Damage on Anchorage	Quantify	a	b	c	d	e	Σ	Σ =(Numbers of beams) x 2 a:Not Exist c: Crack on plug concrete e: Trace of rust, Broken plug concrete or remarkable damage on anchorage part etc.
		32		0		0	32	
	Location	✓	Start	Center	End		Photo Check	
		Left					Distant	
		Center					Close	
		Right			·			
		Supe Superstructure Plan Marking						
	Remaek							
25 Others	Quantify	a	b	c	d	e	Σ	
							9	
	Location	✓	Start	Center	End		Photo Check	
		Left					Distant	
		Center					Close	
		Right						
		Superstructure Plan Marking						
	Remark							

Bridge Bearing

		Count of Element (Numbers of bearing)						
15 Water Leakage from Expansion Joint	Quantify	a	b	c	d	e	Σ	a; a= Σ -(c+e) % of total length of damage/ total length of expansion
		89		11		0	100 %	
	Location	✓	Start	Center	End		Photo Check	c: Water leakage is existed e: Extreme water leakage from expansion joint and/or there is pond at bearing seat.
		Left			✓		Distant	
		Center					Close	
		Right			✓			
		Superstructure Plan Marking						
	Remark							
16 Damage on Bridge Bearing	Quantify	a	b	c	d	e	Σ	a; a= Σ -(c+e) % of total in numbers of damaged bearings/ total number of bearings c:Slight damage e:There is lack of bearing function such as broken
		100		0		0	100 %	
	Location	✓	Start	Center	End		Photo Check	
		Left					Distant	
		Center					Close	
		Right						
		Superstructure Plan Marking						
	Remark							
25 Others	Quantify	a	b	c	d	e	Σ	
							9	
	Location	✓	Start	Center	End		Photo Check	
		Left					Distant	
		Center					Close	
		Right						
		Superstructure Plan Marking						
	Remark							

Spall / Dela / Ex-Rebar of Grading

c	Spall without ex-rebar.
d	Ex-rebar with slight corrosion
e	Ex-rebar with remarkable corrosion or broken re-bar. Or delamination of surface concrete.

Cracks of Greading

b	Width < about 0.1mm and Interval >50 cm
c	Width <about 0.1mm and Interval =<50cm Or about 0.2mm> Width > =about 0.1mm and Interval >50cm
d	Width >= about 0.2mm and Interval >50cm Or about 0.2mm> Width >= about 0.1mm and Interval =<50cm
e	Width >= about 0.2mm and Interval =<50cm

On-site Memo for Recording Damage of PSC-POS

Inspection Recorad Sheet [Bridge PSC-POS] No. 1 -1 A1 - A2

Route No.	Bridge No. / in Km	Bridge Name	Insp.Date	Inspector :

[Superstructure]

Superstructure Plan Marking

Main beam

12 Spall/Dela/Ex-Rebar

Count of Element (Numbers of beam)

Quantify	a	b	c	d	e	Σ
	15		0	2	3	20

Σ=Total numbers of beams
a:Not Exist
c to e : Shown in the table bolow

Location	Start	Center	End	Photo Check
Left		✓		Distant ✓
Center			✓	Close
Right		✓		

Superstructure Plan Marking

Remark

13 Crack

Quantify	a	b	c	d	e	Σ
	13	0	1	3	3	20

Σ=Total numbers of beams
a:Not Exist and Expect for b to e
b : Width < about 0.1mm and Interval >50 cm
c to e : Shown in the table bolow

Location	Start	Center	End	Photo Check
Left		✓		Distant
Center				Close
Right		✓		

Superstructure Plan Marking

Remark

14 Damage on Anchorage

Quantify	a	b	c	d	e	Σ
	10		0		0	10

Σ=(Numbers of beams) × 2
a:Not Exist
c: Crack on plug concrete
e: Trace of rust, Broken plug concrete or remarkable damage on anchorage part etc.

Location	Start	Center	End	Photo Check
Left				Distant
Center				Close
Right				

Superstructure Plan Marking

Remaek

Deck Slab

12 Spall/Dela/Ex-Rebar

Count of Element (Slab devided by girder and cross beam)

Quantify	a	b	c	d	e	Σ
	16		0	0	2	18

Σ=Total numbers of beams
a:Not Exist
c to e : Shown in the table bolow

Location	Start	Center	End	Photo Check
Left				Distant
Center	✓			Close
Right				

Superstructure Plan Marking

Remark

13 Crack

Count of Element

Quantify	a	b	c	d	e	Σ
	16	0	0	0	2	18

Σ=Total numbers of beams
a; a= Σ-(b+c+d+e)
b : W< 0.2mm & l >50 cm
c: W<0.2mm & l=<50cm, Or 0.3mm>W>=0.2mm & l>50cm
d: W>=0.3mm & l>50cm, Or 0.3mm>W>=0.2mm & l=<50cm
e: W>=0.3mm & l=<50cm

Location	Start	Center	End	Photo Check
Left				Distant
Center	✓			Close
Right				

Superstructure Plan Marking

Remark

Diaphragm

12 Spall/Dela/Ex-Rebar

Count of Element (Slab devided by girder and cross beam)

Quantify	a	b	c	d	e	Σ
	18		0	1	1	20

Σ=Total numbers of beams
a:Not Exist
c to e : Shown in the table bolow

Location	Start	Center	End	Photo Check
Left				Distant
Center		✓		Close
Right				

Superstructure Plan Marking

Remark

13 Crack

Count of Element

Quantify	a	b	c	d	e	Σ
	17	0	0	2	1	20

Σ=Total numbers of beams
a:Not Exist and Expect for b to e
b : Width < about 0.1mm and Interval >50 cm
c to e : Shown in the table bolow

Location	Start	Center	End	Photo Check
Left				Distant
Center		✓		Close
Right				

Superstructure Plan Marking

Remark

Bridge Bearing

15 Water Leakage from Expansion Joint

Count of Element (Numbers of bearing)

Quantify	a	b	c	d	e	Σ	
	90		10		0	100	%

a; a= Σ-(c+e)
% of total length of damage/ total length of expansion
c: Water leakage is existed
e: Extreme water leakage from expansion joint and/or there is pond at bearing seat.

Location	Start	Center	End	Photo Check
Left				Distant
Center				Close
Right			✓	

Superstructure Plan Marking

Remark

16 Damage on Bridge Bearing

Quantify	a	b	c	d	e	Σ	
	100		0		0	100	%

a; a= Σ-(c+e)
% of total in numbers of damaged bearings/ total number of bearings
c: Slight damage
e: There is lack of bearing function such as broken

Location	Start	Center	End	Photo Check
Left				Distant
Center				Close
Right				

Superstructure Plan Marking

Remark

Others

25 Others

If there is a others damage in the superstructure / bearing, record it here(superstructure / bearing)

Quantify	a	b	c	d	e	Σ
						9

Location	Start	Center	End	Photo Check
Left				Distant
Center				Close
Right				

Superstructure Plan Marking

Remark

Spall / Dela / Ex-Rebar of Grading

c	Spall without ex-rebar.
d	Ex-rebar with slight corrosion
e	Ex-rebar with remarkable corrosion or broken re-bar. Or delamination of surface concrete.

Cracks of Greading

c	Width <about 0.1mm and Interval =<50cm Or about 0.2mm> Width > =about 0.1mm and Interval >50cm
d	Width >= about 0.2mm and Interval >50cm Or about 0.2mm> Width >= about 0.1mm and Interval =<50cm
e	Width >= about 0.2mm and Interval =<50cm

18

On-site Memo for Recording Damage of Steel Bridge

Inspection Recorad Sheet [Steel Bridge] No. 1 -1 A1 - A2

Route No.	Bridge No. / in Km	Bridge Name	Insp.Date	Inspector :

[Superstructure]

Superstructure Plan Marking

Main Beam

19 Paint Degradation

Count of Element (Beam devided by crosss beam)

Quantity	a	b	c	d	e	Σ
	0		3		1	4

a= Σ-(c+e)
a:Not Exist
b: Discoloring on top coat or partial delamination of paint film
e: Loss of paint film is degraded >1/2 of surface area or rust exists

Location	Start	Center	End	Photo Check
Left				Distant
Center				Close
Right	✓	✓	✓	

Superstructure Plan Marking

Remark

20 Corrosion

Count of Element (Beam devided by crosss beam)

Quantity	a	b	c	d	e	Σ
	0	2	0	1	1	4

a:Not Exist
b: Rust and Area < 1/2 of element
C: Rust and Area > 1/2of element
d: Loss of section and Area < 1/2 of element
e: Shown in the table below

Location	Start	Center	End	Photo Check
Left				Distant
Center				Close
Right	✓	✓	✓	

Superstructure Plan Marking

Remark

21 Damage (Rivet / HSFG)

Count of Element (Beam devided by crosss beam)

Quantity	a	b	c	d	e	Σ

a:Not Exist
c: Nos of loose or lost bolt < 5% of bolt group
e: Nos of loose or lost bolt > 5% of bolt group

Location	Start	Center	End	Photo Check
Left				Distant
Center				Close
Right				

Superstructure Plan Marking

Remark

18 Mud Deposition / Vegetation

Count of Element (Beam devided by crosss beam)

Quantity	a	b	c	d	e	Σ
	2				2	4

a:Not Exist
e: Exist

Location	Start	Center	End	Photo Check
Left	✓	✓	✓	Distant
Center				Close
Right	✓	✓	✓	

Remark

Deck Slab

12 Damage on Deck Slab

Count of Element (Slab devided by beam and cross beam)

Quantity	a	b	c	d	e	Σ
	1	1	1	0	0	3

a:Not Exist
b to e : Shown in the table bolow

Location	Start	Center	End	Photo Check
Left				Distant
Center				Close
Right	✓	✓	✓	

Superstructure Plan Marking

Remark

Cross Beam

20 Corrosion

Count of Element (Slab devided by girder and cross beam)

Quantity	a	b	c	d	e	Σ

a:Not Exist
b: Rust and Area < 1/2 of element
C: Rust and Area > 1/2of element
d: Loss of section and Area < 1/2 of element
e: Shown in the table below

Location	Start	Center	End	Photo Check
Left				Distant
Center				Close
Right				

Superstructure Plan Marking

Remark

21 Damage (Rivet / HSFG)

Count of Element (Slab devided by girder and cross beam)

Quantity	a	b	c	d	e	Σ

a:Not Exist
c: Nos of loose or lost bolt < 5% of bolt group
e: Nos of loose or lost bolt > 5% of bolt group

Location	Start	Center	End	Photo Check
Left				Distant
Center				Close
Right				

Superstructure Plan Marking

Remark

Bridge Bearing

15 Water Leakage from Expansion Joint

Quantity	a	b	c	d	e	Σ	
	100		0		0	100	%

a; a= Σ-(c+e)
% of total length of damage/ total length of expansion
c: Water leakage is existed
e: Extreme water leakage from expansion joint and/or there is pond at bearing seat.

Location	Start	Center	End	Photo Check
Left				Distant
Center				Close
Right				

Superstructure Plan Marking

Remark

16 Damage on Bridge Bearing

Quantity	a	b	c	d	e	Σ	
	100		0		0	100	%

a; a= Σ-(c+e)
% of total in numbers of damaged bearings/ total number of bearings
c: Slight damage
e: There is lack of bearing function such as broken

Location	Start	Center	End	Photo Check
Left				Distant
Center				Close
Right				

Superstructure Plan Marking

Remark

Others

25 Others

If there is a others damage in the superstructure / bearing, record it here(superstructure / bearing)

Quantify	a	b	c	d	e	Σ
						9

Location	Start	Center	End	Photo Check
Left				Distant
Center				Close
Right				

Superstructure Plan Marking

Remark

Corosion(Steel)

e	Loss section and Area >= 1/2of element Or break of steel or crack of steel

Steel deck slab

b	Surface rust and no water leak
c	Surface rust and water leak
d	Loss of section and slight water leak
e	Loss of section and remarkable water leak / Other serious damage such as crack of steel

RC deck slab

b to e	Refer to the manual (22-1 Deck Slab on RC Bride, Attachment 1: Guidelines for Development of Bridge Inspection Record Sheets (Example))
e	Broken slab

22

On-site Memo for Recording Damage of Arch Bridge

Inspection Recorad Sheet [Arch Bridge] No. 1 -1 A1 - A2

Route No.		Bridge No.	/	in Km	Bridge Name		Insp.Date		Inspector :

[Superstructure]

Superstructure Plan Marking

Arch Rib

Element	Item	Count of Element						Note
23 Arch Line(Displacement)	Quantity	a	b	c	d	e	Σ	a:Not Exist a=9-e e: Deformation of arch line(
		9				0	9	
	Location	✓	Start	Center	End	Photo Check		
		Left				Distant		
		Center				Close		
		Right						
	Remark							
13 Cracks	Quantity	a	b	c	d	e	Σ	a=9-(b+c+d+e) b to e : Shown in the table right
		3	0	3	3	0	9	
	Location	✓	Start	Center	End	Photo Check		
		Left	✓	✓	✓	Distant		
		Center				Close		
		Right						
	Remark							
24 Deteriorated (Loose)	Quantity	a	b	c	d	e	Σ	a:Not Exist a=9-e e: Loose or material of arch rib
		9				0	9	
	Location	✓	Start	Center	End	Photo Check		
		Left				Distant		
		Center				Close		
		Right						
	Remark							
18 Mud Deposition / Vegetation	Quantity	a	b	c	d	e	Σ	a:Not Exist a=9-e e: Exist
		5				4	9	
	Location	✓	Start	Center	End	Photo Check		
		Left	✓	✓	✓	Distant		
		Center				Close		
		Right			✓			
	Remark							

Spandrel

Element	Item	Count of Element						Note
13 Cracks	Quantity	a	b	c	d	e	Σ	a=6-(b+c+d+e) b to e : Shown in the table below
		6	0	0	0	0	6	
	Location	✓	Start	Center	End	Photo Check		
		Left				Distant		
		Center				Close		
		Right						
	Remark							
24 Deteriorated (Loose)	Quantity	a	b	c	d	e	Σ	a:Not Exist a=6-e e: Loose or material of supandrel
		6				0	6	
	Location	✓	Start	Center	End	Photo Check		
		Left				Distant		
		Center				Close		
		Right						
	Remark							
18 Mud Deposition / Vegetation	Quantity	a	b	c	d	e	Σ	a:Not Exist a=6-e e:Exist
		4				2	6	
	Location	✓	Start	Center	End	Photo Check		
		Left				Distant		
		Center				Close		
		Right	✓	✓				
	Remark							

If there is a others damage in the superstructure, record it here

Others

Element	Item	Count of Element						Note
25 Others	Quantity	a	b	c	d	e	Σ	
							9	
	Location	✓	Start	Center	End	Photo Check		
		Left				Distant		
		Center				Close		
		Right						
	Remark							

Cracks of Greading

b	Width <about10 mm and No water leack
c	about 10 mm=< Width < about 30 mm and No water leack
	Width <about 10 mm and water leac
d	about 10 mm=< Width <about 30 mm and water leak
	Width>=about 30 mm and No water leack
e	Width>= about 30 mm and Water leack

26

On-site Memo for Recording Damage of Sub Structure

Inspection Recorad Sheet [Bridge] No. 1 -2 A1 - A2

Route No.	0	Bridge No.	0 / 0	in Km	Bridge Name	0	Insp.Date	0	Inspector :	0

[Substructure] A1, A2

[A1 Side]

Element	Item	Count of Element						Note
17 Scour	Quantify	a	b	c	d	e	Σ	a:Not Exist c:Sorround of footing (0 or 1) e:Under footing (0 or 1)
		0		0		1	1	
	Location	✓	Left	Center	Right	Photo Check		
		Upper				Distant		
		Middle				Close		
		Lower						
	Remark							
12 Spall/Dela/Ex-Rebar	Quantify	a	b	c	d	e	Σ	a:Not Exist c:Spall without ex-rebar. d:Ex-rebar with slight corrosion e:Ex-rebar with remarkable corrosion or broken re-bar or Ex-rebar with remarkable corrosion or broken re-bar.
		9		0	0	0	9	
	Location	✓	Left	Center	Right	Photo Check		
		Upper				Distant		
		Middle				Close		
		Lower						
	Remark							
13 Crack	Quantify	a	b	c	d	e	Σ	Σ =Total numbers of beams a:Not Exist and Expect for b to e b to e : Shown in the table bolow
		7	0	0	2	0	9	
	Location	✓	Left	Center	Right	Photo Check		
		Upper				Distant		
		Middle		✓		Close		
		Lower		✓				
	Remark							
18 Mud Deposition / Vegetation	Quantify	a	b	c	d	e	Σ	a:Not Exist e:Exist
		9				0	9	
	Location	✓	Left	Center	Right	Photo Check		
		Upper				Distant		
		Middle				Close		
		Lower						
	Remark							
25 Others	Quantify	a	b	c	d	e	Σ	
							9	
	Location	✓	Start	Center	End	Photo Check		
		Left				Distant		
		Center				Close		
		Right						
	Remark							

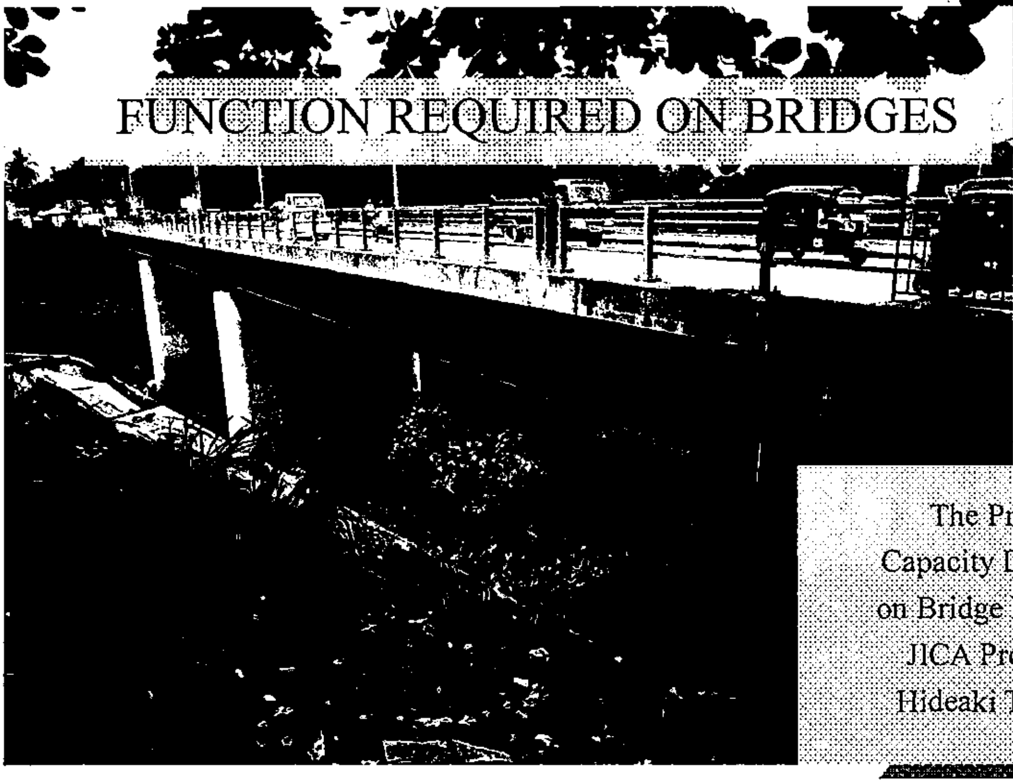
[A2 Side]

Element	Item	Count of Element						Note
17 Scour	Quantify	a	b	c	d	e	Σ	a:Not Exist c:Sorround of footing (0 or 1) e:Under footing (0 or 1)
							1	
	Location		Left	Center	Right	Photo Check		
		Upper				Distant		
		Middle				Close		
		Lower						
	Remark							
12 Spall/Dela/Ex-Rebar	Quantify	a	b	c	d	e	Σ	a:Not Exist c:Spall without ex-rebar. d:Ex-rebar with slight corrosion e:Ex-rebar with remarkable corrosion or broken re-bar or Ex-rebar with remarkable corrosion or broken re-bar.
							9	
	Location		Left	Center	Right	Photo Check		
		Upper				Distant		
		Middle				Close		
		Lower						
	Remark							
13 Crack	Quantify	a	b	c	d	e	Σ	Σ =Total numbers of beams a:Not Exist and Expect for b to e b to e : Shown in the table bolow
							9	
	Location		Left	Center	Right	Photo Check		
		Upper				Distant		
		Middle				Close		
		Lower						
	Remark							
18 Mud Deposition / Vegetation	Quantify	a	b	c	d	e	Σ	a:Not Exist e:Exist
							9	
	Location		Left	Center	Right	Photo Check		
		Upper				Distant		
		Middle				Close		
		Lower						
	Remark							
25 Others	Quantify	a	b	c	d	e	Σ	
							9	
	Location		Start	Center	End	Photo Check		
		Left				Distant		
		Center				Close		
		Right						
	Remark							

Cracks of Greading

b	Width < about 0.2mm and Interval >50 cm
c	Width <about 0.2mm and Interval =<50cm Or about 0.3mm> Width >=about 0.2mm and Interval >50cm
d	Width >= about 0.3mm and Interval >50cm Or about 0.3mm> Width >=about 0.2mm and Interval =<50cm
e	Width >= about 0.3mm and Interval =<50cm

FUNCTION REQUIRED ON BRIDGES

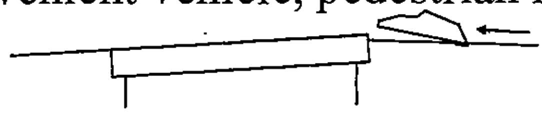


The Project for
Capacity Development
on Bridge Management
JICA Project Team
Hideaki TAKAURA

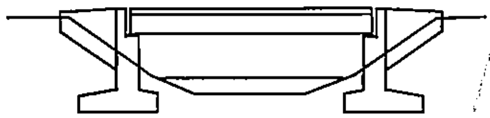
Contents

1.Function of bridge

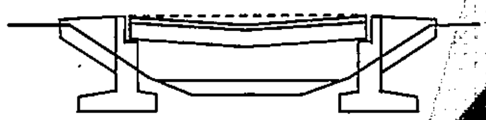
Transportation function – Should maintain safe and comfortable/convenient vehicle, pedestrian move



Properly functioning bridge



Improper conditioned bridge

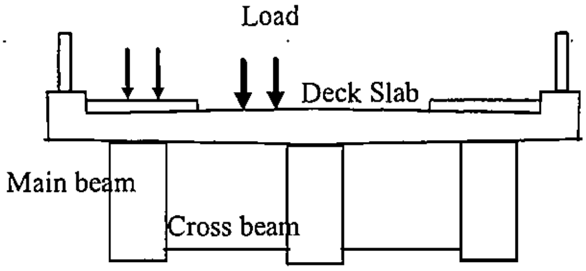


	Parts	Function
Super/Structure	Deck Slab	Bear traffic load such as vehicle, pedestrian.
	Main Beam	Bear load of deck slab and transfer this work force to abutment of pier through bearing.
	Cross beam	Connection of main beams, working force from a main beam to others.
Sub/Structure	Substructure body	Transfer working force from superstructure to foundation.
	Foundation	Transfer working force from substructure to ground.
Accessories	Bridge bearing	Working force from superstructure to substructure.
	Expansion Joint	Maintain flatness of bridge surface against temperature difference, creep and dry shrinkage, live load.
	Drainage	Remove stagnating water on the bridge quickly to secure traffic safety.
	Pavement	Protecting slab from traffic loads, rainwater, secure safety traffic vehicles traffic.

2.Function of superstructure

Deck Slab

Bear Live load



Main beam

Bear Slab/Live load

Transfer them to substructure

Cross beam and diaphragm

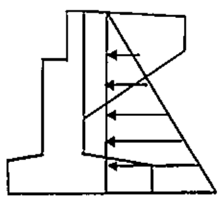
Connect main beams

3.Function of substructure and foundation

Abutment

Bear superstructure, Live load, Earth Pressure

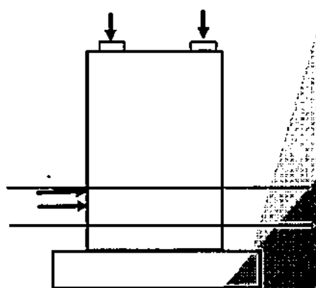
Transfer to foundation



Pier

Bear superstructure, Live load, Water current

Transfer to foundation



Foundation

Bear super/substructure and other loads

Transfer to ground

Abutment and pier
water leaking is observed

4.Function of accessories

Bridge Bearing

Transfer load from superstructure to substructure

Expansion Joint

Buffer between beam to Abutment

Handrail

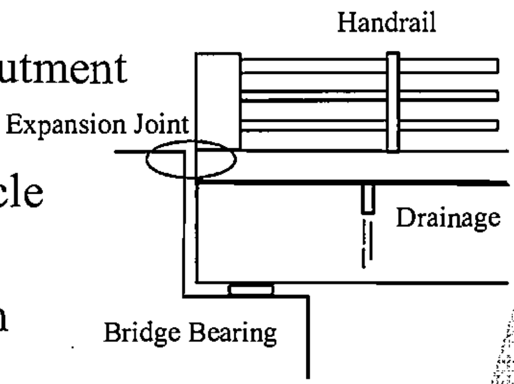
Protection of pedestrian, vehicle

Drainage

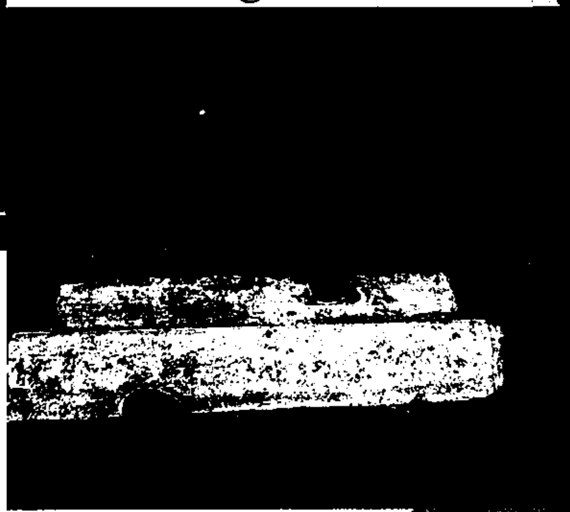
Prevention of water stagnation

Pavement

Protection of deck slab



Drainage
Prevention of w
stagnation on the



Expansion Joint
Gap, step
Water leaking

5.Functional disorders

Slab and beam

Crack,Section loss ---- Deformation, vibration

Substructure

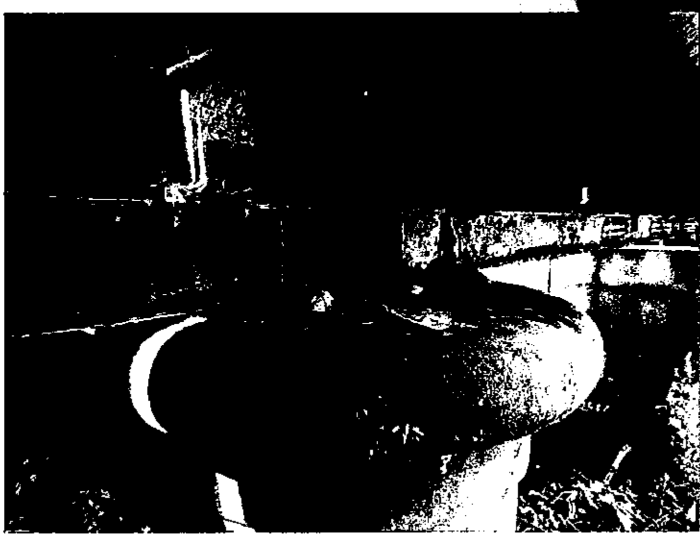
Bearing capacity, Score ---- Settlement, Tilting

Accessories

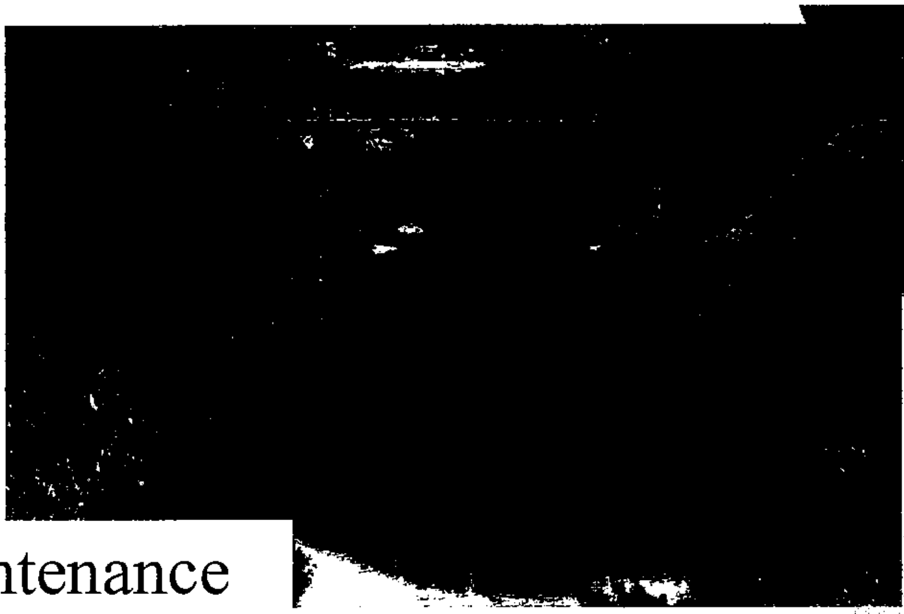
Handrail Removal of parts

Paving Loss of protective function of deck slab

Damage on main beam
Section loss
due to collision ,salt attack



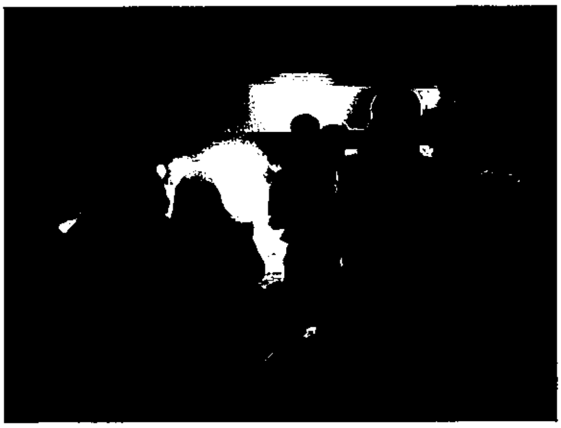
Vegetation, stagnating of water, corrosion



Bridge Maintenance

- To know the condition of bridges -- Inspection
  Based on inspection record
- To Improve the condition of bridges – Maintenance

To go and see underneath of bridge



About Bridge Management

The Project
for Capacity Development
on Bridge Management

JICA Project Team
Kazuya URANO

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Contents

1. What is "managing the bridges"?
2. Important issues on "developing the system / mechanism of bridge management"
3. Important issues on "bridge inspection"
4. Important issues on "collecting the data and information"
5. Important issues on "developing the bridge repair and maintenance plan"
6. Outlines of Bridge Management System (BMS)

1. What is "managing the bridges"?

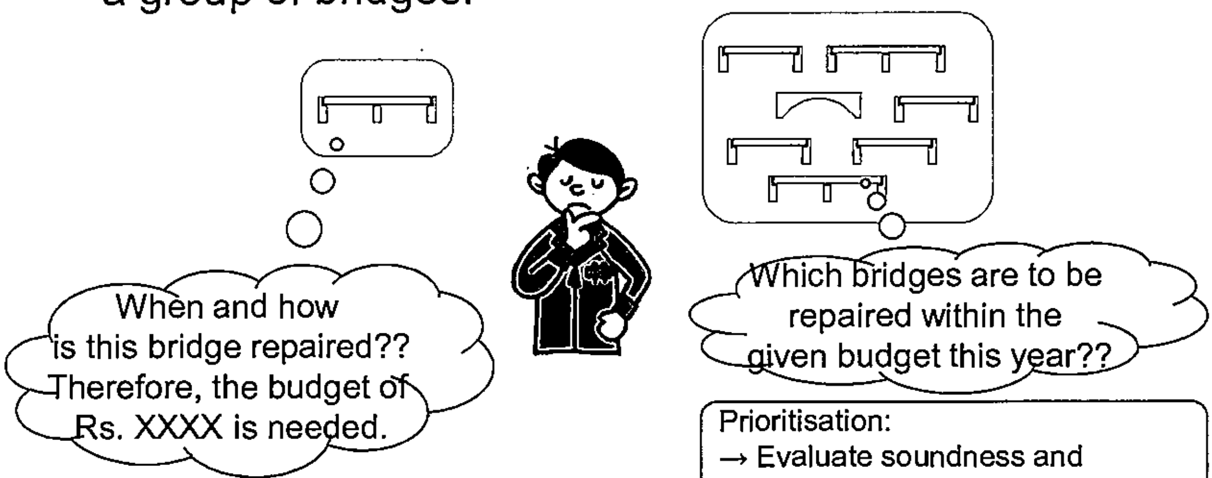
- If the bridge is considered as "a person", "managing the bridge" is to taking care of the health not to be sick or injured, to detect and treat the sick in its early stage.

Without treatment, symptoms are getting worse and worse, and doctor' s fee will increase more and more!!

Healthy	Slightly injured	Seriously injured	Critical stage	away

With early detection and treatment, the bridge can be used for a extended period of time.

- To plan how to manage the individual bridge is one of the "Bridge Management".
- However, what RDA should do is **to manage a group of bridges** under RDA's management.
- There are **unique techniques and ideas** for managing a group of bridges.



Prioritisation:
→ Evaluate soundness and importance quantitatively

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2. Important issues on "developing the system / mechanism of bridge management"

- It is more important to **determine the order of priority of repair** than to decide whether it is repaired or not.

  Based on (i) the order of priority and (ii) the budget given, it shall be determined whether the bridge is repaired or not.

- A lot of people involve in collecting a variety of information needed for determining the order of priority.

  Level of engineering knowledge and skills are different from person to person involved in data collection.

- It is more important to **sustainably implement** the bridge management than to collect detailed and accurate data / information. → **Place the primary importance on sustainability.**

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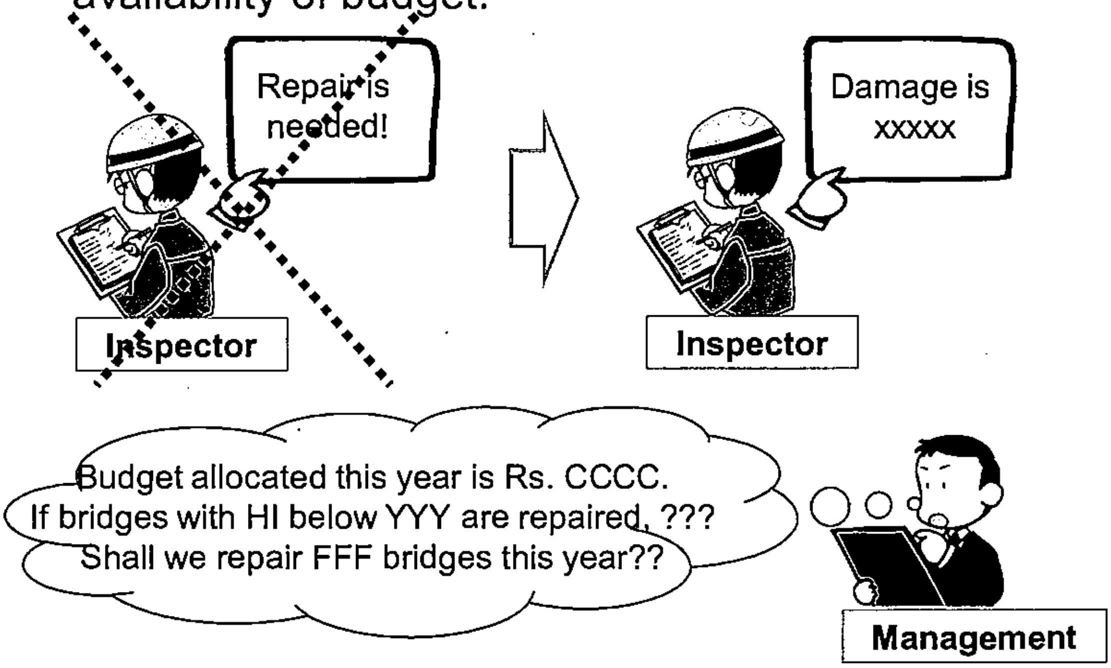
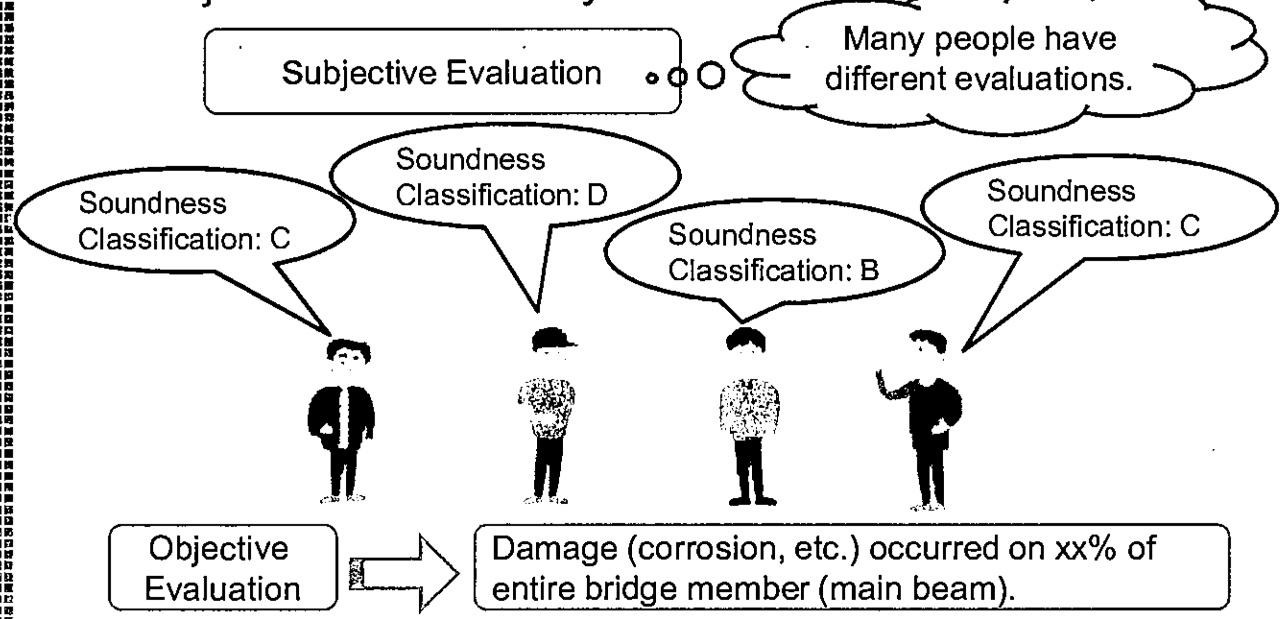
3. Important issues on "bridge inspection"

- Inspectors shall not decide whether the bridge should be repaired or not. It shall be decided based on the availability of budget.



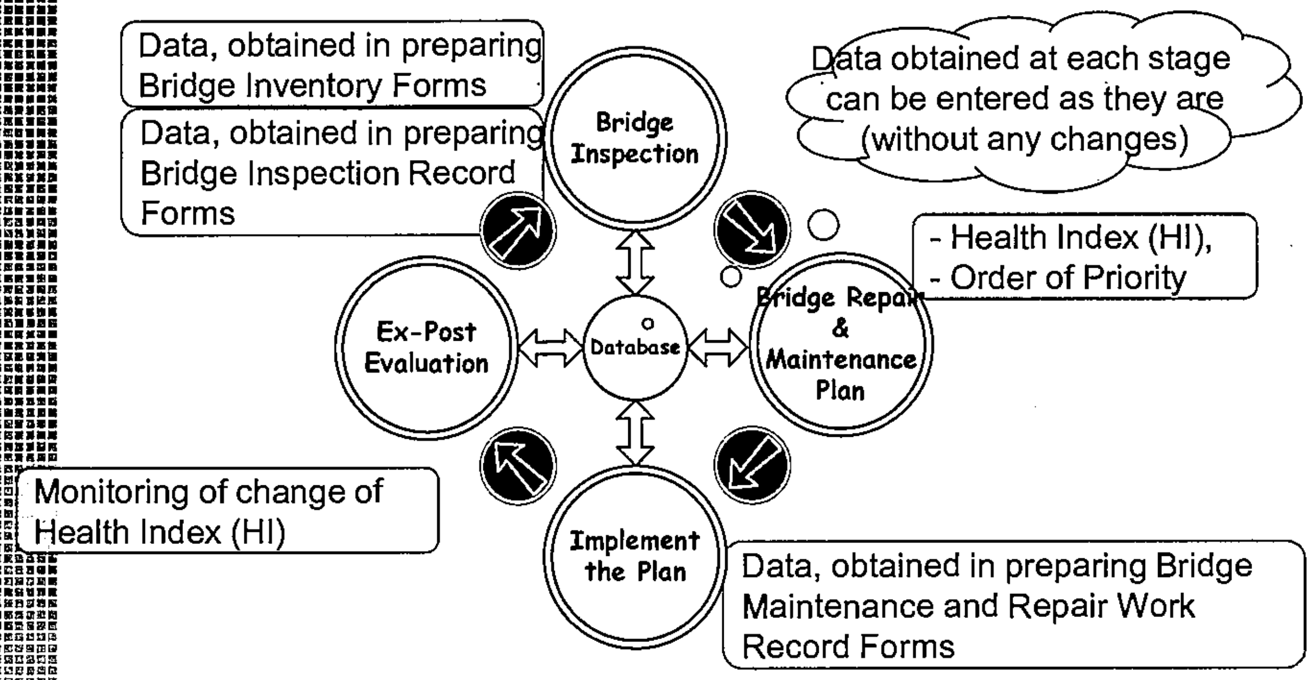
- A lot of inspectors involve in bridge inspection, with different levels of engineering knowledge and skills.
- Subjective evaluation (soundness classification) will have large variations among the results.
- Objective evaluation system shall be used.



- In order to implement the bridge inspection sustainably, consideration shall be made on efficiency and labor-saving of the inspection work.
  - → Simplify the way of evaluation and recording after all the necessary information is reviewed.
  - → Make the best use of BMS.

4. Important issues on "collecting the data and information"

- It is important that bridge inspection results and repair / maintenance history can be easily and securely stored.



- Data and information stored (needed), namely a database, will not be changed largely.
- However, methods and ideas of various actions such as collecting the data / information and monitoring will be reviewed and changed, in response to the change of social needs.
  - → Evaluation of soundness (health index) and importance of the bridge based on new findings
  - → Change from reactive maintenance to preventive maintenance (prediction of degradation introduced)
  - → Change of OS, update of general-purpose system (MS Excel, etc.)
  - → New technologies: image analysis, remote diagnosis, measurement & monitoring

- The system / mechanism shall be simple and open as much as possible, without any "black box", so that the system / mechanism can flexibly adapt to the various changes.

5. Important issues on "developing the bridge repair and maintenance plan"

- When developing the bridge repair and maintenance plan, it is required
  - → To logically explain the procedure of decision-making of the order of priority of repair works, even to the personnel who have no bridge engineering knowledge.
  - → To evaluate the soundness, importance and functional obsolescence of the bridge quantitatively.

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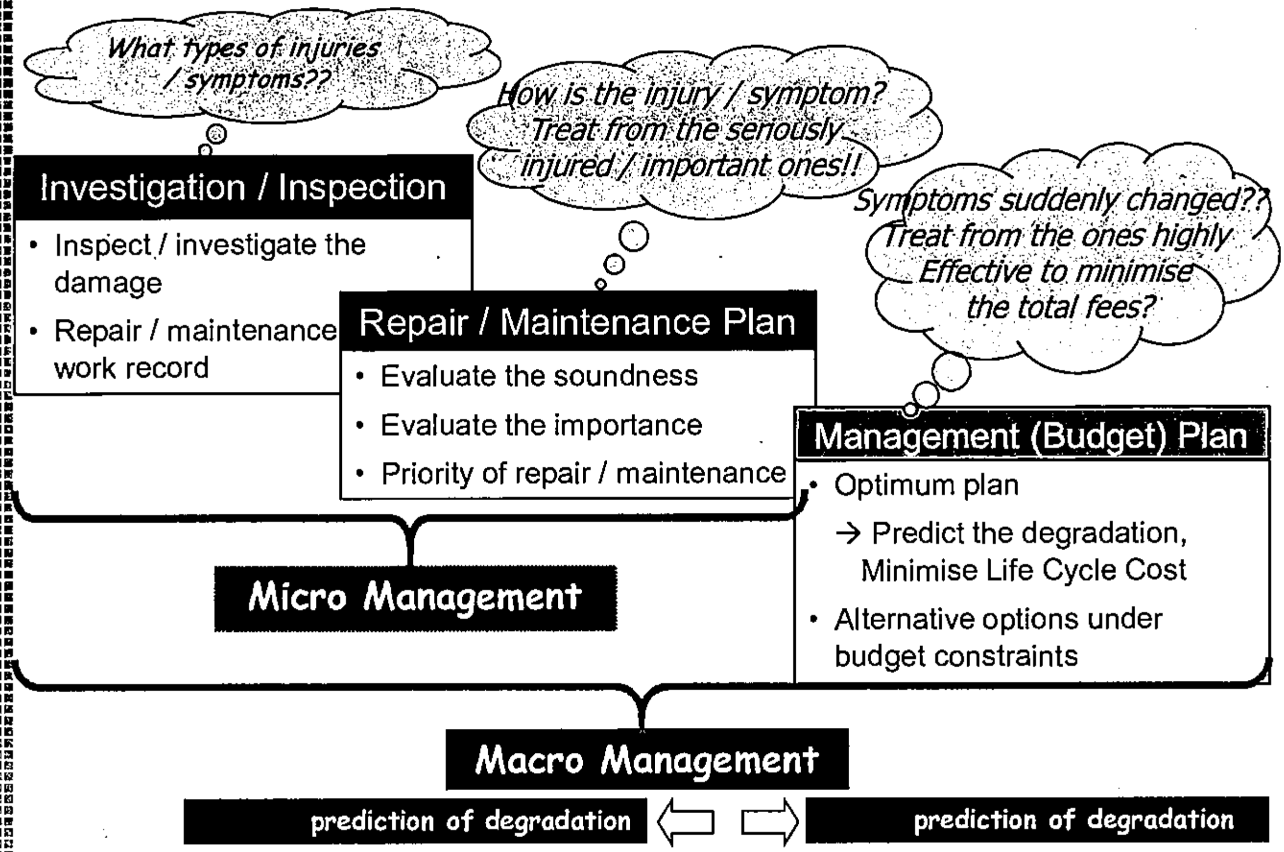
- Two points of view on bridge management:



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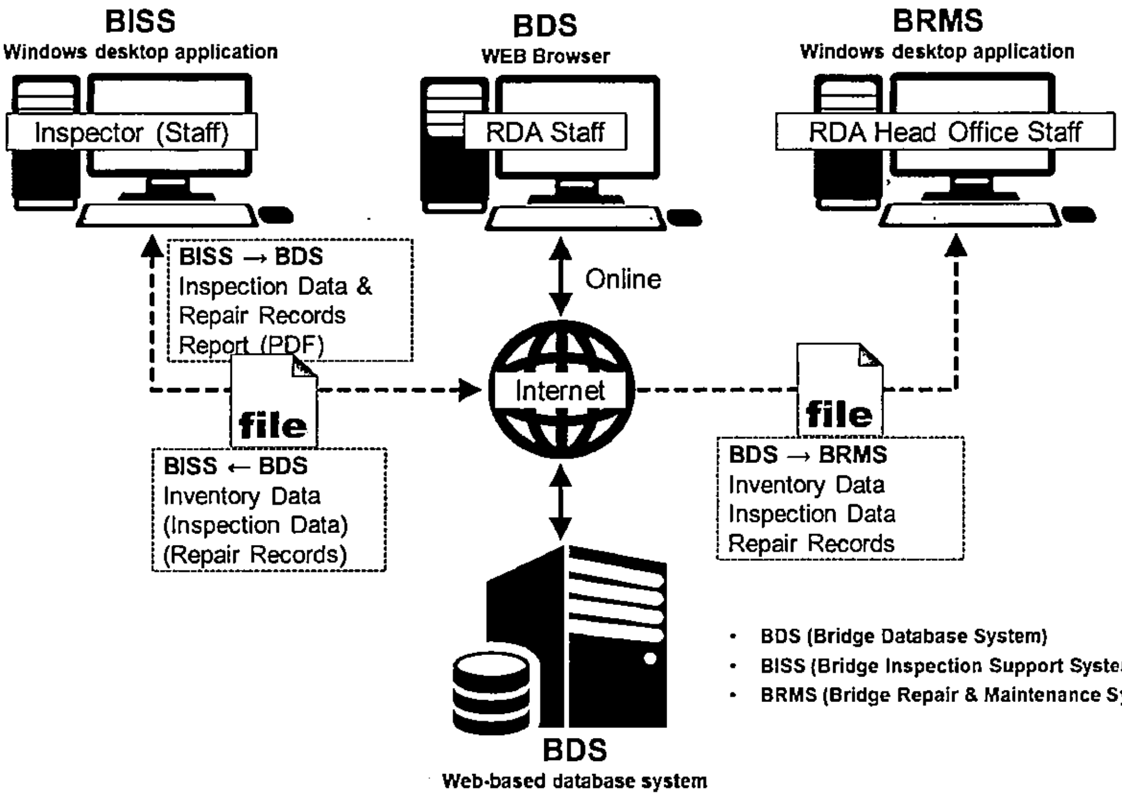
- **Micro Management**
  - Order of priority of repair (which is first, XXX-Bridge or YYY-Bridge??)
  - Which bridge member, to what extent, is damaged? (bridge deck slab, or main beam?)

  Which bridge member should be repaired first?
  → Repair Plan

- **Macro Management**
  - With annual budget of Rs. xxxx, how can the condition of a group of bridges be improved?
  - In order to maintain a group of bridges in good condition, how much / when is the budget needed?

  How should the budget be used?
  → Management (Budget) Plan

6. Outlines of Bridge Management System (BMS)



- BDS (Bridge Database System)
- BISS (Bridge Inspection Support System)
- BRMS (Bridge Repair & Maintenance System)

- Why is BMS composed of 3 sub-systems?
  - A) Divided the data / information owned by entire RDA and by regional office → possible to adapt the outsourcing of bridge inspection work in the future
  - B) Composed the system and minimise the amount of data, suitable for the purpose of use, cases of use and work descriptions.
  - C) Considered the future extension, and prevented the enlargement of the system

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- Features of BMS

A) Bridge Inspection Support System (BISS)

Considered the labor-saving and efficiency of bridge inspection works.

B) Bridge Database System (BDS)

Specialised in searching, browsing and extracting a variety of data and information.

C) Bridge Repair & Maintenance System (BRMS)

Considered the flexible response to the change of calculation conditions.

Considered the use of calculation results (outputs) freely (extract the results to MS Excel file).

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- Recording of Inspection Results (degree of damage, extent of damage to entire bridge member)

A) Record the degree of damage by type

Degree of damage = "Extent" & "Severity"

B) Extent of damage to entire bridge member is recorded with the use of "Element"

$$\frac{\sum \text{(Number of elements by degree of damage)}}{\text{Total number of elements by bridge member}}$$

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Degree of Damage

Extent of Damage to Entire Bridge Member ⇨

Location of Damage ⇨

■ Main Beam

■ Spall / Dela / Ex-Rebar

Extent of Damages						Photographs
<a>	<b>	<c>	<d>	<e>	Σ	<Distant View>
7	–	–	2	–	**9**	*jpg-01*
						<Close View>
						jpg-02

Location

	Start	Center	End
Left	□	■	■
Center	□	□	□
Right	□	□	□

【Superstructure Plane Marking】

Remarks

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- Recording of Damage (Location of Damage)
  - A) To assist in (i) confirming the damage thoroughly at site, (ii) evaluating the progress of damage (increase of number of elements), and (iii) estimating the causes of damage.
  - B) We can simply recognise (divide) “Left”, “Center” and “Right” by intuition at site. → more complicate divisions cannot be recognised by intuition.
  - C) In the longitudinal direction, left / right (near supports) elements are subject to shear / impact, and center elements are subject to flexure.
  - D) In the bridge width direction, left / right (sidewalk, railing, etc.) elements are subject to rain, salt damage, less loading with sidewalk, and center elements are subject to vehicle loadings.

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E) Divide the bridge member by 9 elements basically, and mark the locations.

- Use of Worksheets

Inspect the bridges at site with the use of prepared worksheets, in order to alleviate the burden to the bridge inspectors in preparing the bridge inspection record sheets.

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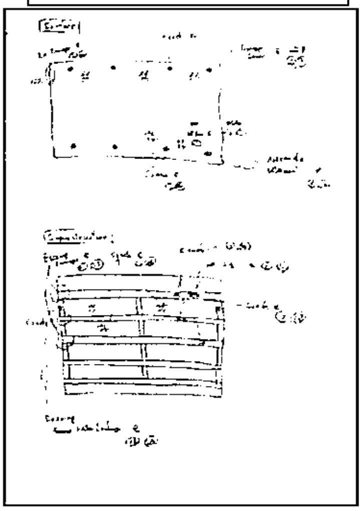
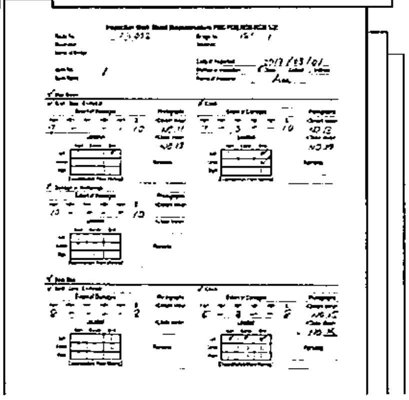
Why recording the inspection data in the worksheets?

Handwriting Sketch ← **Better to prepare both** → **Inspection Worksheet**



Same?



- All the types of damage are given in the prepared worksheets so that the inspector will not overlook the damage.
- It enables to habituate the inspector to seeing the bridge thoroughly and securely, by recording the number of element and location of damage by type of damage.
- Everyone can enter the data into the system and prepare the inspection record form / report.

- The inspector will record only the damage s/he found at site, and may overlook?.
- Other than the inspector, no one can enter the data into the system and prepare the inspection record form / report.

Bridge Management Guideline

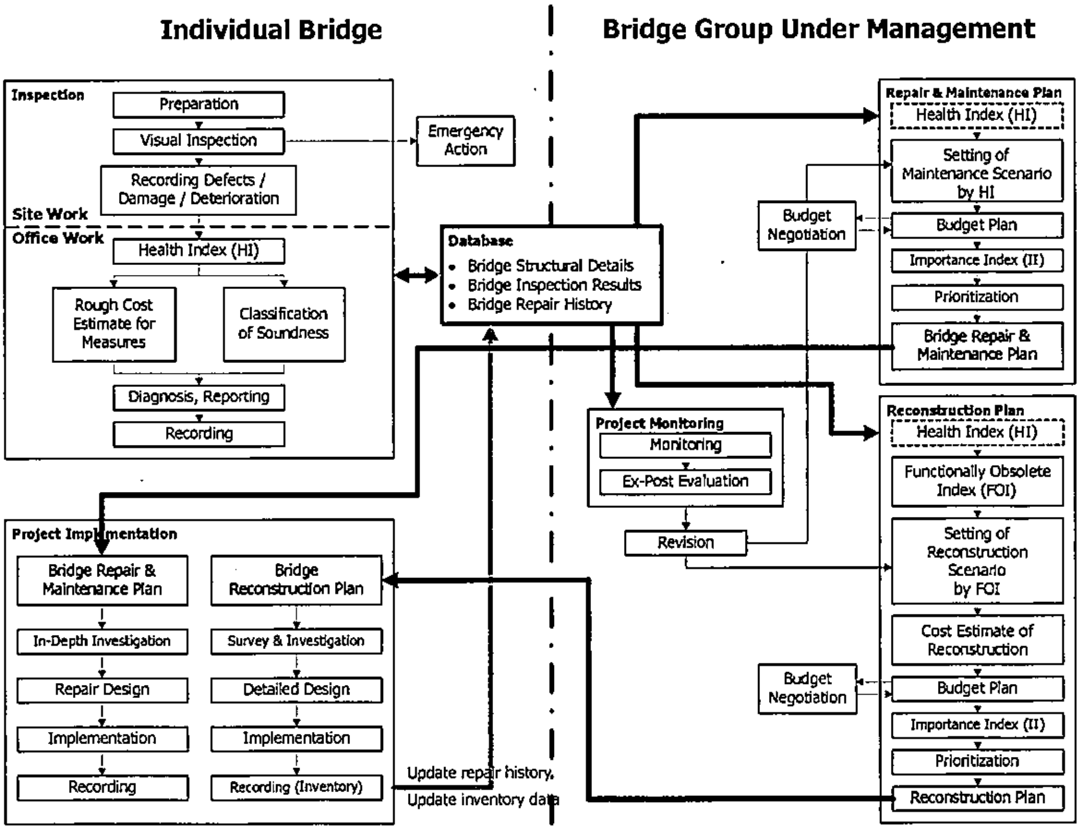
The Project
for Capacity Development
on Bridge Management

JICA Project Team
Kazuya URANO

Contents

Contents

1. Flow of Bridge Management



2. Bridge Repair & Maintenance Plan

(1) Health Index (HI)

- ❖ Based on the bridge inspection, Health Index is calculated as <u>a quantitative value of evaluation results of conditions / soundness</u> of a bridge member, component, span and entire bridge.
- ❖ HI is not the value of expressing the load carrying capacity directly; but is just the quantitative value of expressing the need of taking measures (repair, maintenance) and its scale (costs).
- ❖ HI will be used as an indicator of bridge management.

Definition of HI

Definition of HI

Required Performance / Functions
- Design speed
- Load carrying capacity
- Durability, etc.

HI = 100: New conditions (immediately after construction)

HI = 0: Not exhibit the required design performance / functions

Bridge members seriously damaged **cannot** exhibit the required performance / functions.

Damage Recorded at Site on
- Bridge Member
- Bridge Component
- Entire Bridge / Span

Assumption of Damage Situation
- Types of Damage
- Extent / Severity of Damage
- Extent of Damage to Entire Bridge Member

Proposed HI: Objectively Recorded Condition Data / Information

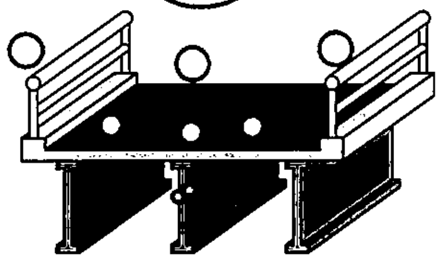
What type(s) of damage?

How many types of damage at the same time?

To what **extent / severity** ?

Degree of Required Performance(s) & Functions(s) Exhibited

Interrelated



- Identify the bridge member conditions which cannot exhibit the minimum required design performance. → **HI = 0**
- Define the type(s) and **extent** of damage for **each bridge member** <u>which need any restrictions </u>(**Definition of "HI=0 Conditions"**)

Health Index: Degree of required performance(s) / function(s) exhibited (soundness) is quantified for each member.

- Minimum level of required performance for a bridge member → **HI = 0**
- Performance of a bridge member owned at opening to traffic (new) → **HI = 100**
- **"HI"** is decreased with time (elapsed time after opening to traffic).

Image of Degradation of Performance As a Bridge

Performance	Need any restrictions / limits	Minimum performances required (design)	Performances owned at opening to traffic (new)
		HI = 0	HI = 100
Speed	Speed limit (20 km/h)	60 km/h	80 km/h
Load carrying capacity	Load limit (10 ton)	20 ton	25 ton

Allowance

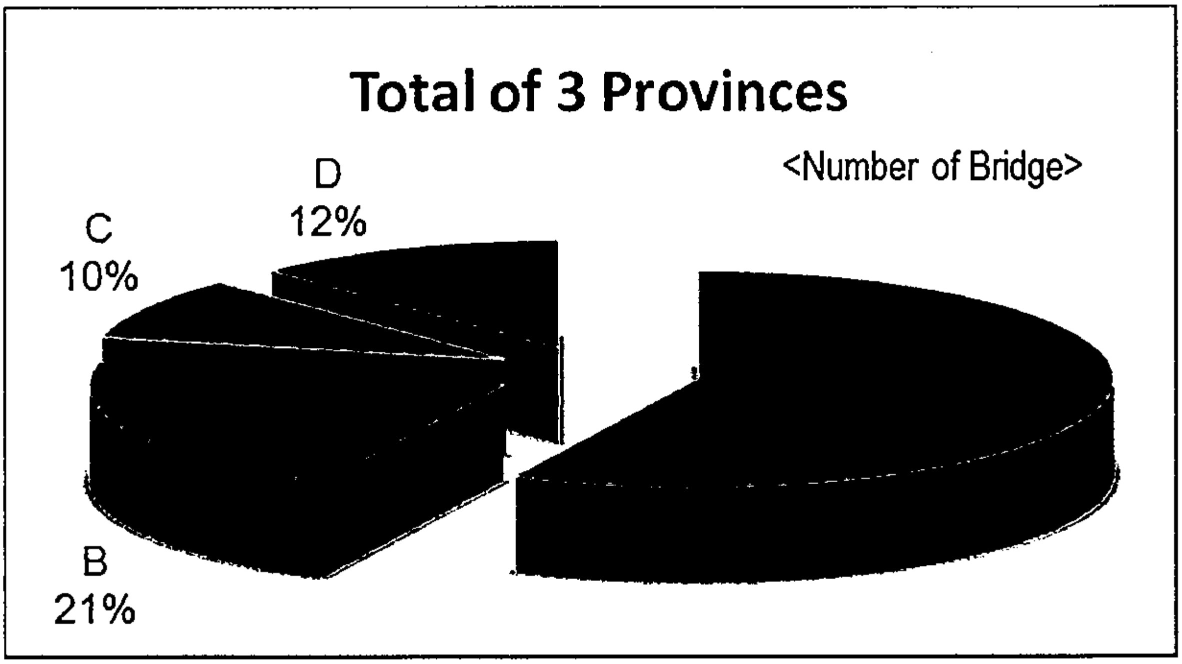
A bridge member / bridge loses its function(s)!

Decreased with time

(2) Soundness Classification

- With reference to the value of health index (HI), soundness of the bridge is categorised into four (4) classification (soundness classification).
- Why, is soundness classification set up in addition to the health index (HI)?
  - ✓ Soundness classification can be used for the road administrator (RDA) to generally understand the condition of bridges.
  - ✓ Soundness classification can be used as a convenient indicator for releasing the bridge conditions to the public.

Soundness Classification		General Conditions	HI
A	Sound	❑ Structures are well functioning.	75 – 100
B	Preventive Maintenance Stage	❑ Structures are well functioning. ❑ However, it is desirable to take necessary measures from the perspective of preventive maintenance.	50 -75
C	Reactive Maintenance Stage	❑ Functions of the structure will be possibly impaired. ❑ Necessary measures should be taken at an early stage (within 5 years)	25 – 50
D	Immediate Action Stage	❑ Functions of the structure are impaired or possibility of impairment of functions is extremely high. ❑ Necessary measures should be taken immediately (within 2 years)	0 - 25

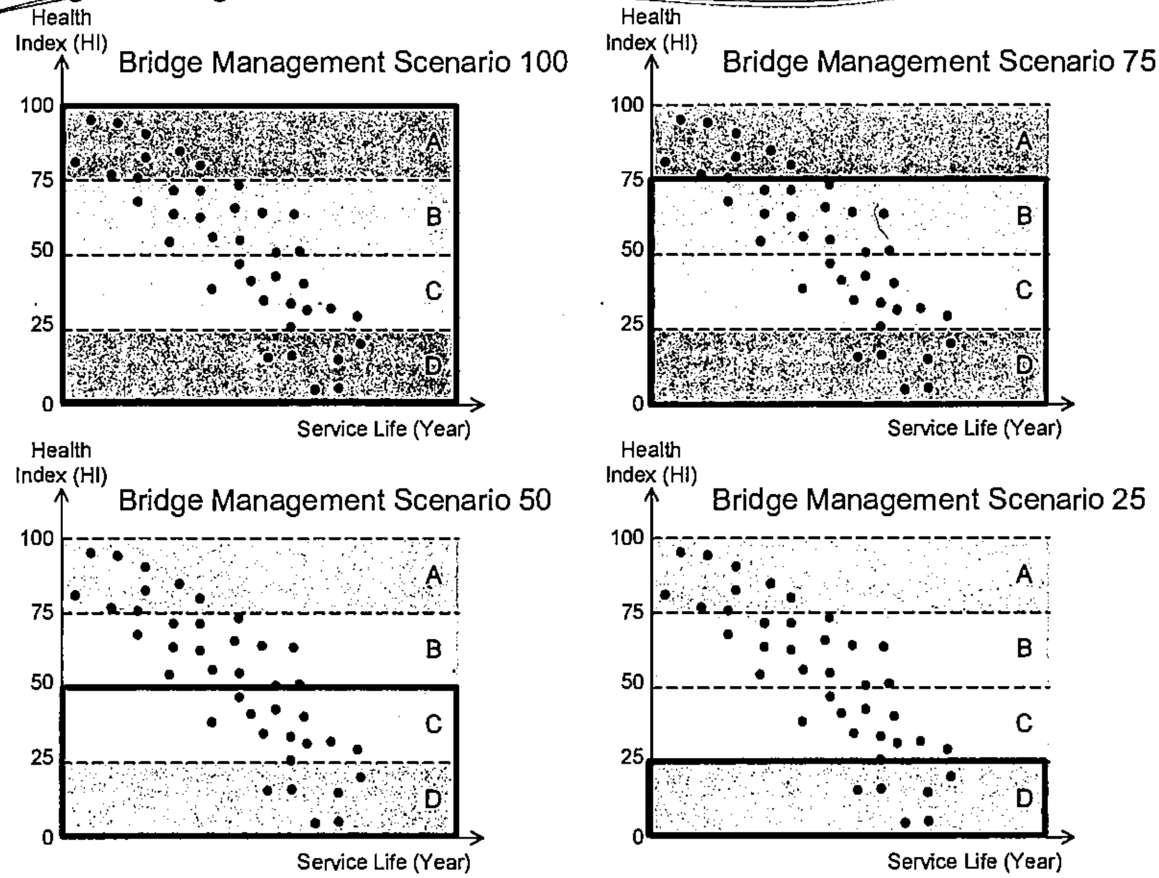


(3) Setting of Bridge Management Scenarios

- ❖ In order to develop the possible bridge repair and maintenance plan within the available budget, several bridge management scenarios will be set out for comparison, with the use of HI.
- ❖ For example,
  - ✓ **HI = 75 scenario** for an entire bridge:
    - → An entire bridge shall be always with HI = 75 or larger
    - → All the bridges with HI below 75 shall be repaired and on a list in the Bridge Repair & Maintenance Plan.

Scenario / Component / Member	HI = 75	HI = 50	HI = 25
Entire Bridge	75	50	25
Bridge Superstructure	75	50	25
Main Beam	75	50	25
Deck Slab	75	50	25
Bridge Bearing	10	10	10
Bridge Substructure	75	50	25
Bridge Surface	75	50	25
Pavement	75	50	25
Bridge Expansion Joint	10	10	10
Accessories	75	50	25
Approach Road / Riverbank	75	50	25
Costs	Rs. AAAA	Rs. BBBB	Rs. CCCC

Bridge Management Scenario

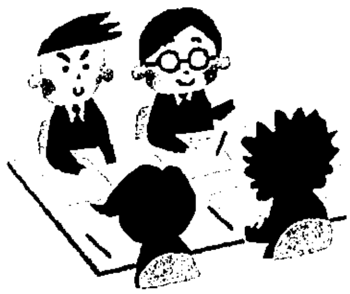


(4) Cost Estimates

- ❖ Details of method of cost estimates for repair and maintenance will be explained separately.
- ❖ For each scenario, costs for repairing all the bridges with HI below the target shall be estimated.

(5) Budget Plan & Negotiation

- ❖ Determine the target repair period for the said bridges.
  - ✓ 5 years??
- ❖ Calculate annual costs for repairing the said bridges for each scenario
  - ✓ Costs / target repair period
- ❖ Negotiation with the Ministry of Finance
  - ✓ Which scenario is feasible with given budget?



(6) Target Bridge Management Level

- ❖ Target bridge management level will include:
  - ✓ Target health indices for entire bridge, component and each bridge member
  - ✓ Annual budget
  - ✓ Target bridge repair period

(7) Prioritisation of Bridge Repairs

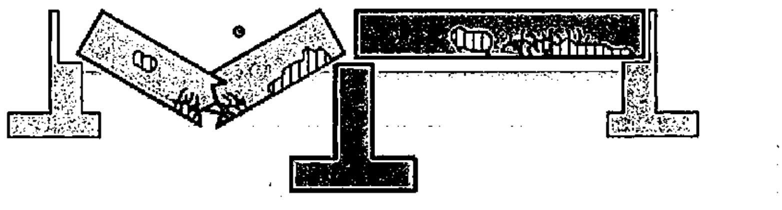
- ❖ Priority of implementing the repair and maintenance work will be evaluated comprehensively in consideration of both health index (HI) and importance index (II).
- ❖ Order of relative priority will be expressed as "Priority Point (PP)"

  $PP = \alpha \times (100\text{-}HI) + \beta \times II$

- ❖ Health index (HI) has already been mentioned.
  - → HI = 100: Good condition
  - → HI = 0: Seriously damaged

Shall we repair the bridge promptly not to be in trouble due to out-of-service?

- ❖ Importance Index (II) represents the extent of obstruction due to out-of-condition of bridges.
  - → When the bridge cannot be used (collapse, closure to traffic, etc.), how seriously the road users will suffer from ??



  - → II = 100: Largely affect to surrounding areas (serious obstruction)
  - → II = 0: No affect to surrounding areas (no obstruction)

❖ Evaluation Criteria of Importance Index (II)

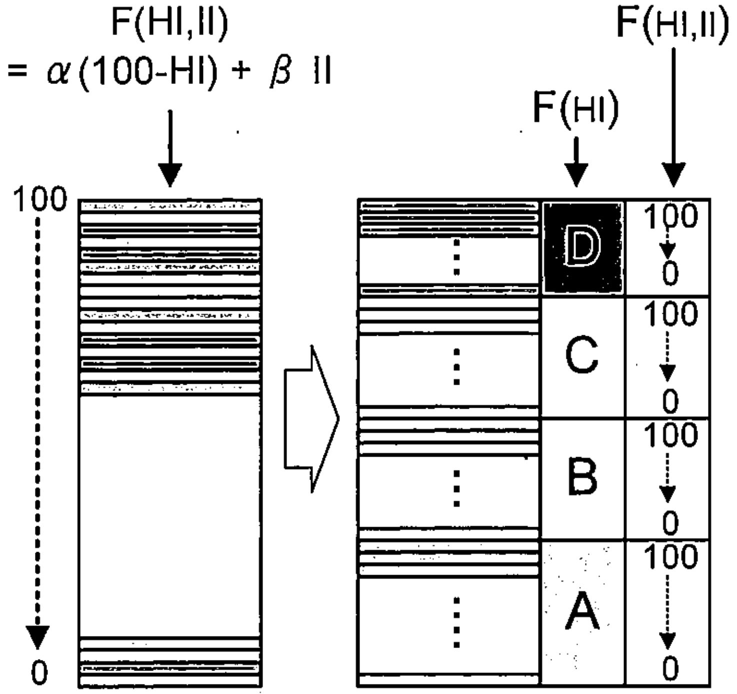
Indicators for Importance Index

- Importance of Providing Access (Region) (0.32)
  - Densely inhabited districts (0.19)
  - Connectivity to important facilities (0.26)
  - Difficulty in restoration (0.30)
  - Isolated villages / towns (0.25)
- Importance of Providing Mobility (Wide Area Network) (0.27)
  - Traffic characteristics (0.28)
  - Detour (0.33)
  - Specific important route (0.39)
- Third Party Effects (0.41)
  - Crossings (0.50)
  - Utilities attached (0.28)
  - Disturbance to water flow at flood times (0.22)

(8) Development of Bridge Repair & Maintenance Plan

- ❖ The plan includes the list of bridges under the target bridge management level, in the order of priority, with repair and maintenance costs.
- ❖ In order to ensure the minimum safety, consideration should be given not to omit the bridges with low health indices.

❖ Order of priority of bridges in the Plan



❖ Details of the Bridge Repair & Maintenance Plan

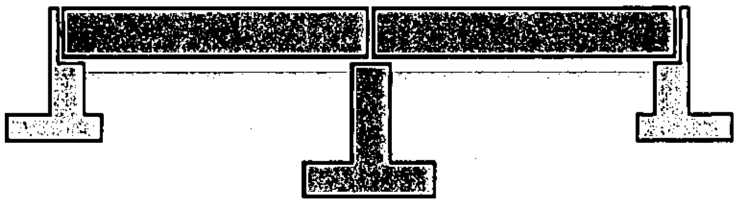
Priority of Bridge Repair	Bridge ID	Bridge No.		Name of Bridge	Health Index of Bridge	Soundness Classification of Bridge	Importance Index	Repair Priority Point	Repair Cost (Unit: 1,000 SL Rupee)				
		km	No.						Bridge	Bridge Surface	Superstructure	Bridge Bearing	Substructure
1	100	14	2		0.0	D	44	83.2	210.1	1.4	76.5	0	132.2
2	801	14	1	BRIDWELL	0.0	D	44	83.2	405	1	315.8	0	88.2
3	296	17	1		0.0	D	37.6	81.3	823.8	17.4	573.9	226.9	5.6
4	120	4	2	Nuga Ela B	0.0	D	37	81.1	521.1	0.4	294	0	226.7
5	797	2	1		0.0	D	35.1	80.5	200.6	0	0	0	200.6
6	823	19	1	Dandugam	0.0	D	34.1	80.2	3664.1	376.6	0	2531.6	755.9
7	1024	11	5		0.0	D	29.3	78.8	299	42	169.3	87.7	0
8	24	53	3		0.0	D	28.6	78.6	1349.4	51.5	19.5	440.5	837.9
9	262	3	3		0.0	D	28.4	78.5	354.6	0.5	178.1	50.4	125.6
10	104	8	1		0.0	D	28.1	78.4	577.6	7.6	345.2	0	224.8
161	1167	4	5		25.4	D	14.7	56.6	188.3	5.5	182.8	0	0
162	1426	23	9		24.0	D	9.5	56.1	557.4	5.4	76	286.6	189.4
163	1254	1	2		25.3	D	7.6	54.6	128.8	15.2	0	12.2	101.4
164	443	92	12		25.3	D	3.8	53.4	268.2	36.9	0	0	231.3
165	208	16	2		25.8	C	42.1	64.6	247.1	41.5	0	127.3	78.3
166	743	32	3		26.8	C	29	59.9	109.1	6.1	0	0	103
167	1309	1	5	Galmulle B	27.5	C	27.7	59.1	259.4	6.2	247.7	0	5.5
168	668	61	5		28.0	C	27.4	58.6	365.2	0	365.2	0	0
169	508	1	1		26.3	C	22.3	58.3	717.1	0.7	680.8	0	35.6
170	226	7	6		25.7	C	20.4	58.1	158.1	6.7	138.5	0	12.9
171	1402	2	2		27.5	C	24.2	58	170.3	0	28.3	0	142
287	1295	42	3		50.0	C	14.7	39.4	52.3	0	0	0	52.3
288	1028	6	4		46.5	C	5.7	39.2	221.6	29.5	8.2	180.7	3.2
289	1140	58	1		49.0	C	11.4	39.1	1245.4	0	744.6	500.8	0
290	66	13	1		48.7	C	7.6	38.2	49.1	0	0	0	49.1
291	47	34	4		49.9	C	5.7	36.8	897.6	124.8	0	764.2	8.6
292	1398	4	3		52.9	B	41.4	45.4	813.8	41.5	661.3	78.8	32.2
293	859	2	1	Palam Thu	50.9	B	29.4	43.2	1002	87.4	78.5	718.5	117.6
294	835	2	1		51.1	B	29	42.9	399.9	41.9	0	342.1	15.9
295	328	2	2	GALA JUN	51.3	B	29	42.8	81.5	21.2	25.9	0	34.4
296	1364	4	4		58.7	B	44	42.1	272.2	20.5	0	226.9	24.8
297	335	1	5		51.0	B	25.5	42	426	59.8	0	366.2	0

3. Bridge Reconstruction Plan

Shall we promptly reconstruct the bridge because we are in trouble due to functional obsolescence?

(1) Functionally Obsolete Index (FOI)

- Functionally Obsolete Index (FOI) represents the extent of obstruction due to functional obsolescence of the bridge
  - → Due to the functional obsolescence of a bridge, how seriously road users / surrounding people will suffer from ??



→ FOI = 100: Largely affected from functional obsolescence

→ FOI = 0: No affect from functional obsolescence

A bridge is still in service; however,
- A bridge width is narrow,
- Alignment of a bridge is bad, resulting in accidents,
- A bridge is inundated at disaster times
- A bridge is damaged due to disaster before,

❖ Evaluation Criteria of Functionally Obsolete Index (FOI)

- Indicators for Functionally Obsolete Index
  - Structural Details (0.40)
    - Bridge Width (0.40)
    - Alignment / clearance (0.40)
    - Design loading (0.20)
  - Nature of Bridge (0.30)
    - Nature of bridge (1.00)
  - Resistance to Disaster (0.30)
    - Year-round mobility (0.40)
    - History of disaster (0.60)

(2) Classification of Functional Obsolescence

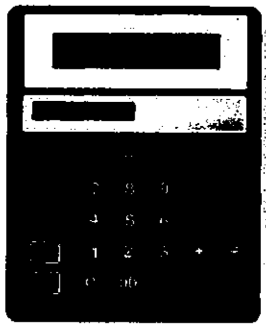
❖ With reference to the value of functionally obsolete index (FOI), functional obsolescence of the bridge is categorised into four (4) classification (classification of functional obsolescence).

Classification of Functional Obsolescence		General Conditions	FOI
A'	Satisfactorily functioning	❑ A bridge exhibits the required functions satisfactorily.	0 – 25
B'	Functionally obsolete	❑ A bridge is functionally obsolete. ❑ However, no adverse effect to socioeconomic activities is identified.	25 – 50
C'	Functionally obsolete remarkably	❑ A bridge is functionally obsolete to the extent that socioeconomic activities are adversely and remarkably affected.	50 – 75
D'	Functionally obsolete seriously	❑ A bridge is functionally obsolete to the extent that socioeconomic activities are adversely and seriously affected.	75 - 100

(3) Setting of Bridge Reconstruction Scenarios

- ❖ In order to develop the possible bridge reconstruction plan within the available budget, several bridge reconstruction scenarios will be set out for comparison, with the use of FOI.
- ❖ For example,
  - ✓ **FOI = 75 scenario**:
    - → All the bridges with FOI equal to or above 75 shall be reconstructed and on a list in the Bridge Reconstruction Plan.

(4) Cost Estimates

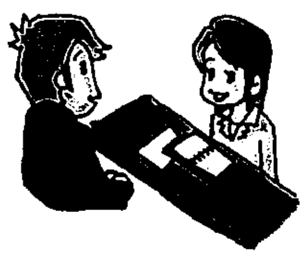


- ❖ Details of method of cost estimates for reconstruction will be explained separately.
- ❖ For each scenario, costs for reconstructing all the bridges with FOI above the target shall be estimated.

Scenario	FOI = 75	FOI = 50	FOI = 25
Costs	Rs. AAAA	Rs. BBBB	Rs. CCCC

(5) Budget Plan & Negotiation

- ❖ Determine the target reconstruction period for the said bridges.
  - ✓ 10 years??
- ❖ Calculate annual costs for reconstructing the said bridges for each scenario
  - ✓ Costs / target reconstruction period
- ❖ Negotiation with the Ministry of Finance
  - ✓ Which scenario is feasible with given budget?



(6) Target Bridge Reconstruction Level

- Target bridge reconstruction level will include:
  - ✓ Target functionally obsolete indices
  - ✓ Annual budget
  - ✓ Target bridge reconstruction period

(7) Prioritisation of Bridge Reconstruction

- Priority of implementing the reconstruction work will be evaluated comprehensively in consideration of health index (HI), importance index (II) and functionally obsolete index (FOI).
- Order of relative priority will be expressed as "Priority Point (PP)"

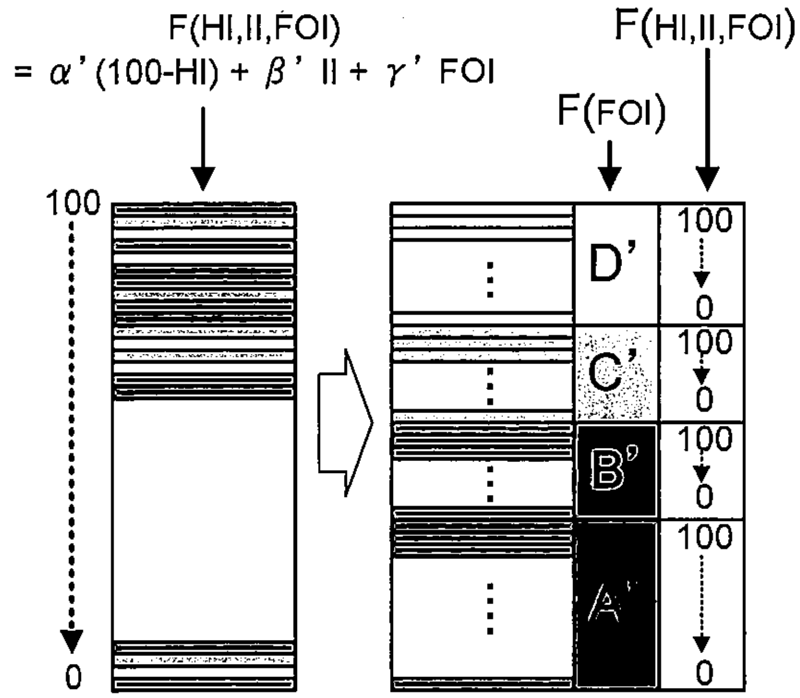
  $PP = \alpha' \times (100\text{-}HI) + \beta' \times II + \gamma' \times FOI$

- HI, II and FOI have already been mentioned.

(8) Development of Bridge Reconstruction Plan

- ❖ The plan includes the list of bridges above the target bridge reconstruction level, in the order of priority, with reconstruction costs.
- ❖ Consideration should be given not to omit the extremely functionally obsolete bridges.

- ❖ Order of priority of bridges in the Plan



❖ Details of the Bridge Reconstruction Plan

Bridge ID	Bridge No.		Name of Bridge	Health Index of Bridge	Soundness Classification of Bridge	Importance Index	Functionally Obsolute Index	FO Classification	Reconstruction Priority Point	Priority of Bridge Reconstruction	Reconstruction Cost	Repair Priority Point	Repair Cost of Bridge
	km	No.											
100	14	2		0.0	D	44.0	16.0	A'	38.4	1	5,852	83.2	210
296	17	1		0.0	D	37.6	16.0	A'	37.1	2	3,574	81.3	824
120	4	2	Nuga Ela B	0.0	D	37.0	16.0	A'	37.0	3	6,747	81.1	521
797	2	1		0.0	D	35.1	16.0	A'	36.6	4	5,016	80.5	201
823	19	1	Dandugam	0.0	D	34.1	16.0	A'	36.4	5	470,728	80.2	3,664
24	53	3		0.0	D	28.6	16.0	A'	35.3	6	65,527	78.6	1,349
262	3	3		0.0	D	28.4	16.0	A'	35.3	7	4,953	78.5	355
104	8	1		0.0	D	28.1	16.0	A'	35.2	8	5,620	78.4	578
535	62	2	Benthara B	0.0	D	28.1	16.0	A'	35.2	9	111,007	78.4	10,656
51	12	1		0.0	D	25.2	16.0	A'	34.6	10	7,644	77.6	604
1230	1	7		0.0	D	24.3	16.0	A'	34.5	11	69,877	77.3	8,290
90	1	5		0.0	D	23.3	16.0	A'	34.3	12	5,242	77.0	138
248	8	1		0.0	D	23.3	16.0	A'	34.3	13	7,900	77.0	1,006
933	11	3	Medagampi	0.0	D	23.3	16.0	A'	34.3	14	6,026	77.0	799
1330	4	6		4.5	D	27.7	16.0	A'	34.2	15	22,698	75.2	376
1282	1	2		0.0	D	22.3	16.0	A'	34.1	16	23,464	76.7	2,774
233	19	2		19.2	D	41.4	16.0	A'	34.0	17	8,470	69.0	240
228	2	2		24.6	D	45.9	16.0	A'	33.9	18	6,970	66.6	119
8	31	1		12.9	D	33.7	16.0	A'	33.8	19	60,140	71.1	717
1302	8	3		0.0	D	21.0	16.0	A'	33.8	20	18,571	76.3	125
801	14	1	BRIDWELL	0.0	D	44.0	8.0	A'	33.6	21	4,752	83.2	405
496	1	4		0.0	D	19.5	16.0	A'	33.5	22	3,036	75.9	496
434	10	5	Talathuoya	0.0	D	18.5	16.0	A'	33.3	23	31,626	75.6	3,710
690	19	1		0.0	D	18.5	16.0	A'	33.3	24	3,689	75.6	375
803	25	6		0.0	D	18.5	16.0	A'	33.3	25	5,544	75.6	394
891	4	11		0.0	D	18.5	16.0	A'	33.3	26	2,869	75.6	372
893	5	7		0.0	D	18.5	16.0	A'	33.3	27	18,371	75.6	989
208	16	2		25.8	C	42.1	16.0	A'	32.9	28	6,336	64.6	247

Bridge Inspection

THE PROJECT
FOR CAPACITY DEVELOPMENT
ON BRIDGE MANAGEMENT

Minobu AOYAMA

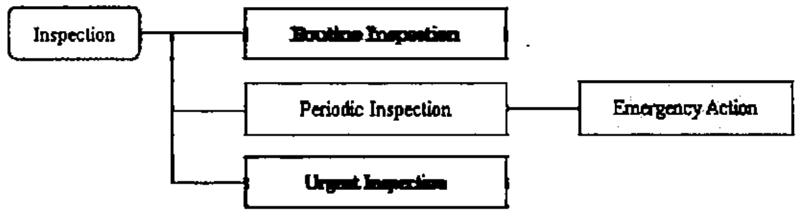
CONTENTS

1.Purpose and Method of Bridge Inspection

Purpose of Bridge Inspection

- Detect the damage early which may affect to the safety and durability of bridges, thereafter take necessary measures;
- Collect necessary data and information for managing the bridges systematically (prioritization, predict the future conditions), in order to effective maintenance.

Type of Inspection



【Periodic Inspection】
Inspection done periodically on superstructure & substructure by closed eye observation for member to prepare damage record and evaluation of soundness.

【Inspection Frequency】: Base once par 5 years.

Explain the periodic inspection from here.

Method of Bridge Inspection (1)

・Collection of basic information

Location, length, width, dimension of the structural members.
Examine construction year will be recorded as basic information.

・Visual inspection is basic of inspection, supplemented with hammer and pole camera

Visual inspection

Use of pole camera

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Method of Bridge Inspection (2)

・Bridge inspection by BIV for bridges/spans which cannot be approached;

Hammering inspection by BIV

・It is easy to find damage by BIV because it can be close inspection.

・Hammering inspection can find damages in or on concrete.

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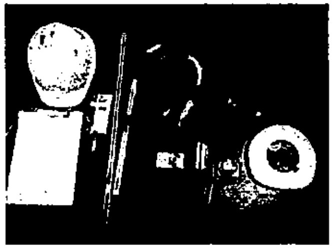
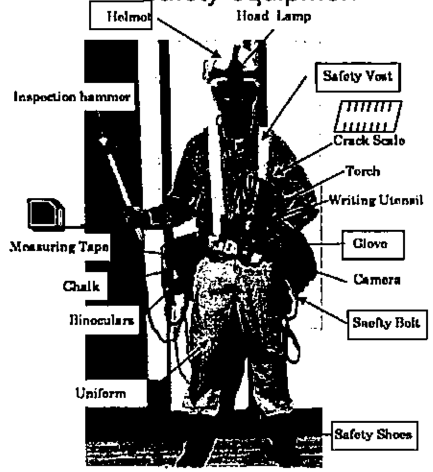
Personal Tools and Safety Equipment

Personal Tools



・Inspection hammers
・Measures
・Crack scale
・Binocular
・Camera

Safety equipmen



You should take care your safety by no one but by yourselves.

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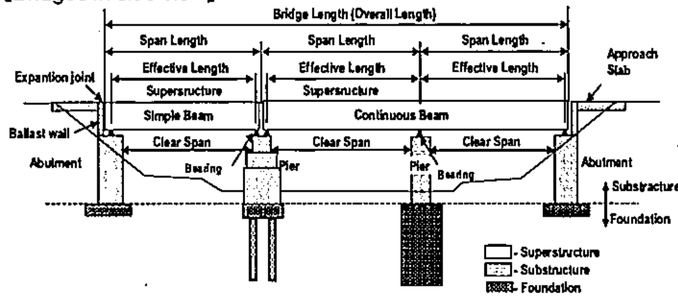
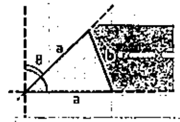
2. Basic Knowledge of Bridges

Names of Bridge Components of Bridge

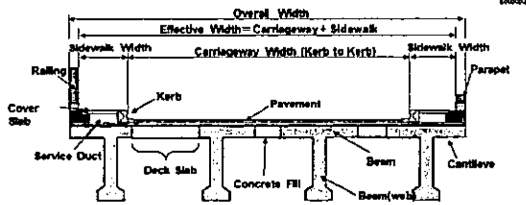
【Bridges in side view】 Bridge Length: distance between the first and the last expansion joints.



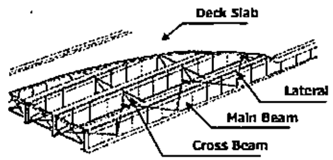
【Skew angle θ】



The skew angle can be obtained by measuring the length of two sides of a isosceles triangle.



【Cross section of concrete bridge】



【Steel bridge】

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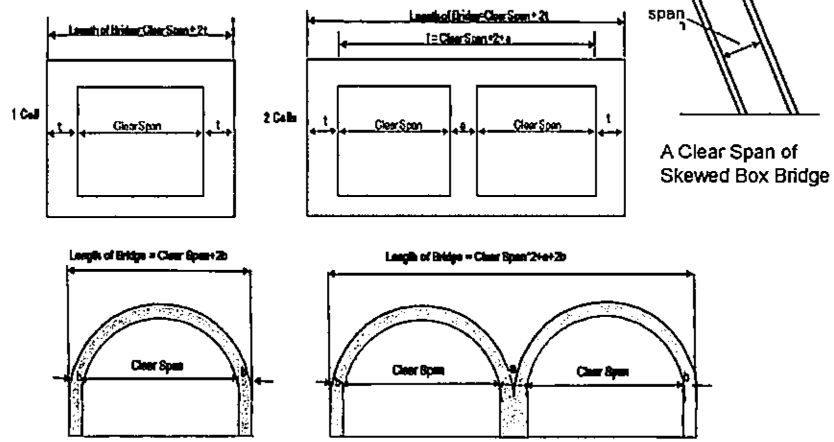
Length of Arch Bridges and Box Bridges

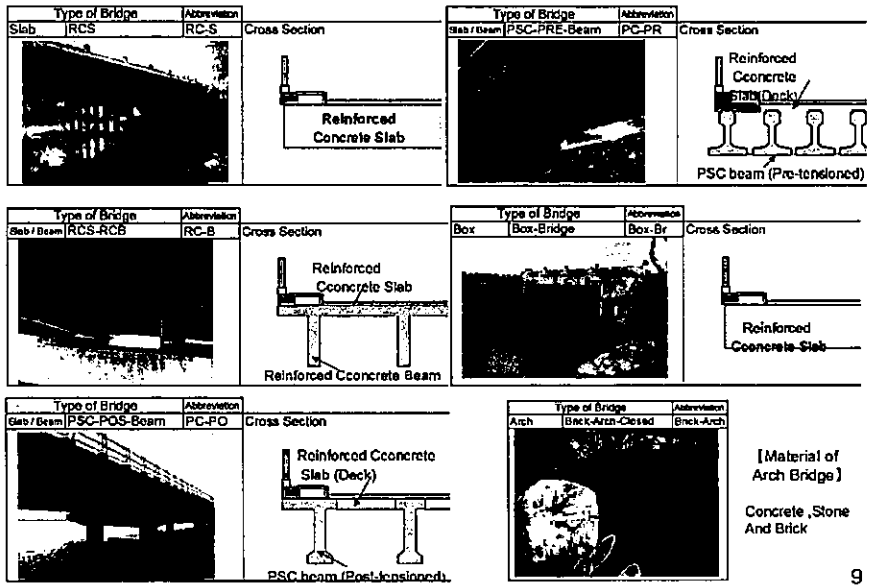
Box bridges are defined as those clear span is more than 3.0 meters.

Length of bridges are given as follow figures.



In case obtaining "a" / "b" / "t" is difficult, It may use a=1.0m, b=0.5m and, t=0.35m,

Type of Bridges(Concrete & Arch Bridge)

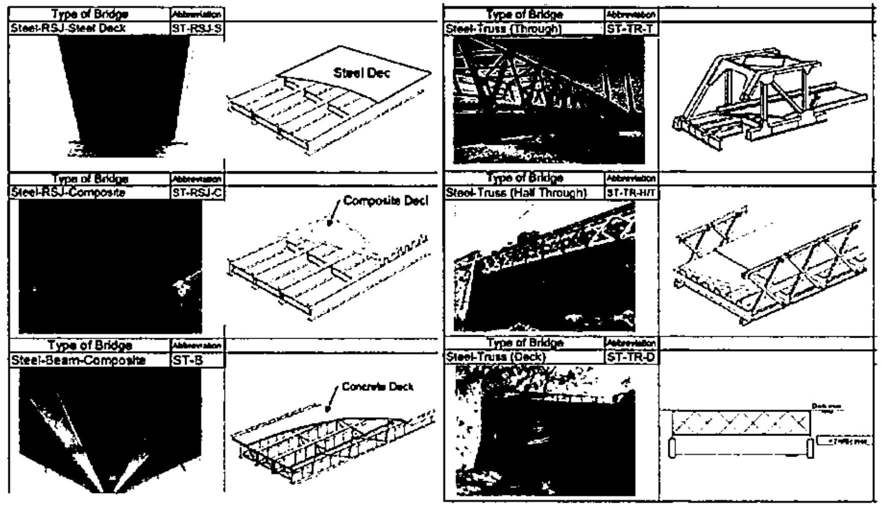


【Material of Arch Bridge】

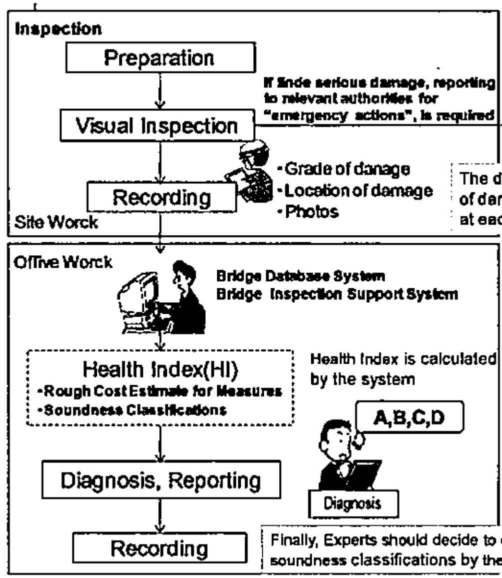
Concrete ,Stone And Brick

Type of Bridges(Steel Bridge)

Truss bridge are classified by the deck slab position



3. Flow of Periodic Bridge Inspection



The damage is found at site, the status progress of damaged shall be graded (a, b, c, d and e) at each element of member

Soundness Classifications(A,B,C,D)

A	Sound, no measure required minor damage
B	Need miner repair for damage needed for preventive maintenance purpose recommended for structural safety points of view at early stage
C	Need repair promptly for structural safety points of view
D	Need replacement of member / strengthening / reconstruction of entire bridge

Finally, Experts should decide to diagnosis of soundness classifications by the observations.

4. Details of Bridge Inspection

Target Type of Bridge

Standard bridge types are 7 types, based on the study results of existing bridge type in Sri Lanka.

The target type bridge (7 types bridges)

No.	Type of Bridge
1	Bridge Structure (PSC-PRE)
2	Bridge Structure (RC-S)
3	Bridge Structure (PSC-POS,RCS RCB)
4	Bridge Structure (Box Bridge)
5	Bridge Structure (Truss Bridge)
6	Bridge Structure (Steel Bridge)
7	Bridge Structure (Arch Bridge)

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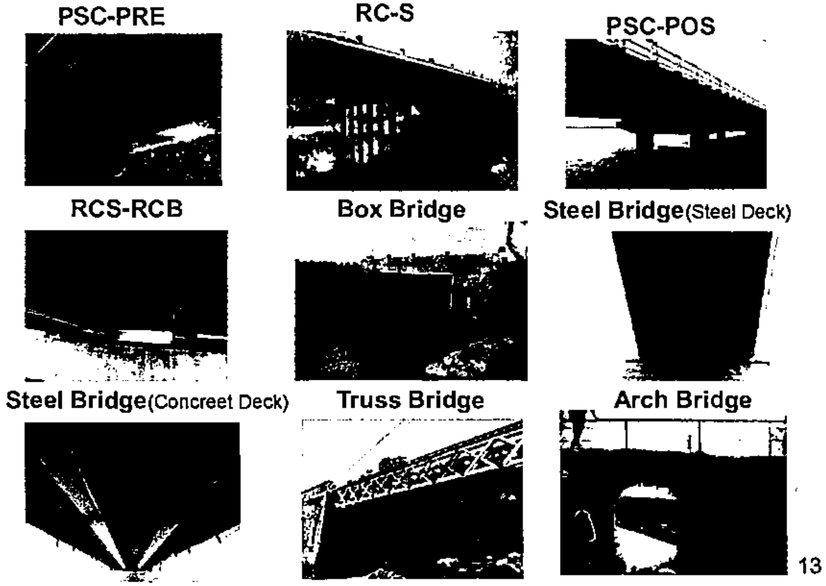
Target Type of Bridge



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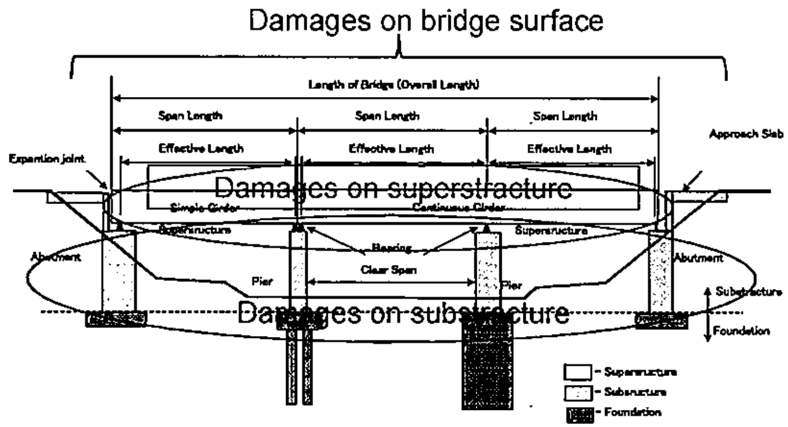
Type of Damage

Side view of the typical bridge structure



· Damages are often appeared in particular part of bridge surface, superstructure and substructure.

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Type of Damage

11 types for bridge surface,14 types for bridge structure

Bridge Surface

No	Member	Type of Damage
1	Pavement	Pothole
2		Pavement Crack
3		Rutting
4		Waving
5	Expansio Joint	Oamage on Expansion joint
6		Difference in Levels
7	Accessories	Damage on Drainage
8		Damages on Service Duct
9		Damages on Railing / Parapet
10	Approaches	Settlement of Surface
11		Approach Bank / River Bank

Bridge Structure

No	Member	Type of Damage
12	Concret Bridge/ Member	Spall / Dela / Ex-Rebar
13		Crack
14		Damage on Anchorage
15	Bridge Bearing	Water Leakage from Expansion Joint
16		Damage on Bridge Bearing
17	Sub Structure	Scour
18		Mud Deposition / Vegetation
19		Paint Degradation
20	Steel/Truss Bridge	Corrosion
21		Damage (Rivet / HSFG)
22		Damage of Deck Slab
23	Arch Bridge	Arch Line (Displacement)
24		Deteriorated (Loose)
25		Others

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Standard Grade of Damage

The evaluation of damage is classified in to 5 grades for each type of damage at each element of member.

Grade of Damage	Status	Status progress of damage Severity/Extent
a	Sound	There is no damage on bridge member.
b	Almost sound	Damage on bridge member is small.
c	Slight	There is a certain degree of damage on bridge member.
d	Remarkable	Damage on bridge member is remarkable.
e	Serious	Damage on bridge member serious.

- Some damaga, only"a", "c"and"e" , or only "a"and"e".
- Appendix is given classified grades for each type of damage.

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Grading for Each Type of Damage(1)

A. Bridge Surface

No.1 Pothole

Grade of Damage	General Condition
a	Not Exist
b	–
c	Depth < 50mm Deck is not exposed
d	–
e	Depth >=50mm Deck is exposed

Sample "e"

No.2 Pavement Crack

Grade of Damage	**General Condition**
a	Not Exist
b	–
c	Crack width < 5 mm
d	–
e	Crack width >=5 mm

Sample "c"

Sample "e"

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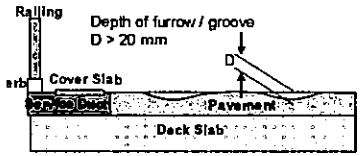
Grading for Each Type of Damage(2)

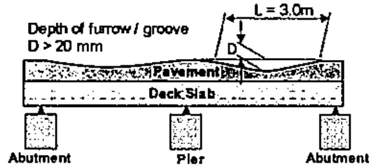
No.3 Rutting

Grade of Damage	General Condition
a	Not Exist
b	
c	凹凸: About 20 mm< D < about 30 mm
d	
e	凹凸: D >= about 30 mm



No.4 Waving

Grade of Damage	**General Condition**
a	Not Exist
b	
c	凹凸: D< about 20 mm
d	
e	凹凸: D>= about 20 mm



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Grading for Each Type of Damage(3)

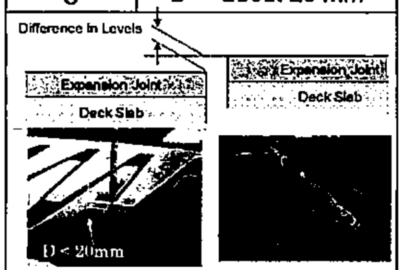
No.5 Damage on Expansion Joint

Grade of Damage	General Condition
a	Not Exist
b	
c	
d	
e	Expansion joint is damaged.

Sample "e"

No.6 Difference in Levels

Grade of Damage	General Condition
a	Not Exist
b	
c	D< about 20 mm
d	
e	D>= about 20 mm



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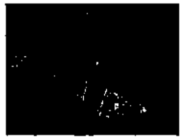
Grading for Each Type of Damage (4)

No.7 Damage of Drainage

Grade of Damage	General Condition
a	Not Exist
b	-
c	-
d	-
e	Catch basin or drainage pipe is plugged with soil and other debris.

Sample "e"



No.8 Damage on Service Duct

Grade of Damage	General Condition
a	Not Exist
b	-
c	-
d	-
e	Service duct is damaged.

Sample "e"

Grading for Each Type of Damage (5)

No.9 Damage on Railing / Parapet

Grade of Damage	General Condition
a	Not Exist
b	-
c	-
d	-
e	Railing/ Parapet is broke.

Sample "e"

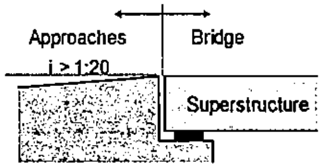
Sample "a"

Function of railing is kept.

No.10 Settlement of Surface at Approaches

Grade of Damage	General Condition
a	Not Exist
b	-
c	-
d	-
e	Approach is settled. Inline i ≥ about 1/20 .

Sample

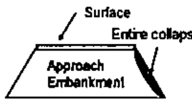


Grading for Each Type of Damage(6)

No.11 Approach Bank / River Bank

Grade of Damage	General Condition
a	Not Exist
b	-
c	-
d	-
e	Approach embankment is collapsed or out-flown.

Sample "e"



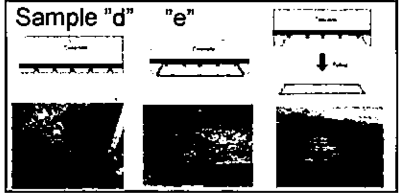
B. Bridge Structure

No.12 Spall / Dela / Exposed-Reber

These damage are major damage on concrete bridges in Sri Lanka.

Grade of Damage	General Condition
a	Not Exist
b	
c	Spall without ex-rebar.
d	Ex-rebar with corrosion
e	Spall / Dela /broken rebar.

Sample "d" "e"



[Note]: In case, this damage is found, the same grade shall be given to the element in crack although the crack is not found.

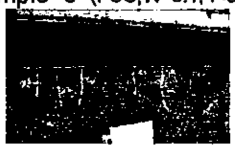
Grading for Each Type of Damage(7)

No.13 Concrete Crack

Grade of Damage	General Condition		
	RC, Box, Sub.	PSC-PRE / POS	Arch
a	Not Exist		
b	W< 0.2 & l > 50	W< 0.1 & l > 50	W< 10 & l > 50
c	W<=0.2 & l <= 50 0.2< =W< 0.3 & l >50	W<=0.1 & l <= 50 0.1< =W< 0.2 & l >50	W<=10 & l <= 50 10< =W< 30 & l >50
d	0.2< =W< 0.3 & l <=50 W>=0.3 & l >50	0.1< =W< 0.2 & l <=50 W>=0.2 & l >50	10< =W< 30 & l <=50 W>=30 & l >50
e	W>= 0.3 & l <=50	W>= 0.2 & l <=50	W>= 30 & l <=50

W: With of crack (about mm), l: Interval of crack (cm)

Sample "c" (PSC,W=0.1, l<50)



"d"(Sub. W>0.3, l>50)

"d"(Arch. W>30, l>50)

Grading for Each Type of Damage(8)

No.14 Damage on Bridge Anchorage

Grade of Damage	General Condition
a	Not Exist
b	-
c	Crack on plug concrete.
d	-
e	Trace of rust. or Broken plug concrete or remarkable damage on anchorage part.

Sample "c"

Sample "e"

No.15 Water Leakage from Expansion Joint

Grade of Damage	General Condition
a	Not Exist
b	-
c	Water leakage is existed.
d	
e	Extreme water leakage from expansion joint and/or there is pond at bearing seat.

Sample "c"

Sample "e"

Grading for Each Type of Damage(9)

No.16 Damage on Bridge Bearing

Grade of Damage	General Condition
a	Not Exist
b	-
c	Slight damage, such as corrosion of bearing, crack on bearing seat.
d	-
e	There is lack of bearing function such as broken bearing.

Sample "c"

Sample "e"

No.17 Scour

Grade of Damage	General Condition
a	Not Exist
b	
c	Surrounding of pier/ abutment is scoured. Caisson: Slight scour (less than width of caisson).
d	
e	Under footing of pier/ abutment is scoured. Caisson: Serious scour. (more than width of caisson).

Sample "c"

Sample "e"

Grading for Each Type of Damage(10)

No.18 Mud Deposition / Vegetation

Grade of Damage	General Condition
a	Not Exist
b	
c	
d	
e	Damage exists at substructure, truss girder, steel girder, arch rib and spandrel.

Sample "e"

No.19 Paint Degradation

This damage is major damage on steel bridges in Sri Lanka.

Grade of Damage	General Condition
a	Not Exist
b	
c	Discoloring on top coat or partial deterioration of paint film.
d	
e	Loss of paint film is degraded with large(>1/2) surface area of element and dot rust exists in element.

Sample "c"

Sample "e"

Grading for Each Type of Damage(11)

No.20 Corrosion

This damage is major damage on steel bridges in Sri Lanka.

Grade of Damage	General Condition
a	Not Exist
b	Rust and Area < 1/2 of element
c	Rust and Area >= 1/2 of element
d	Loss of section and Area < 1/2 of element
e	Loss section and Area >= 1/ 2 of element. break of steel or crack of steel

Sample

"b"

"d"

"c"

"e"

No.21 Damage (Rivet / HSFG)

Grade of Damage	General Condition
a	Not Exist
b	
c	Nos of loose or lost bolt < 5% of bolt group.
d	
e	Nos of loose or lost bolt ≥ 5% of bolt group.

Sample "c"

Sample "e"

Grading for Each Type of Damage(11)

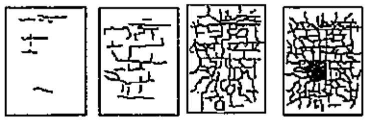
No.22 Damage of Deck Slab

22-1 Deck Slab by RC

Grade of Damage	General Condition
a	Not Exist
b	Refer to the manual (22-1 Deck Slab on RC Bridge, Attachment 1: Guidelines for development of bridge inspection record sheets (example))
c	
d	
e	Broken slab

Sample (Refer).

"b" "c" "d" "e"



-When grading is difficult, it is OK to refer this sample figure.

22-2 Deck Slab by Steel

Grade of Damage	General Condition
a	Not Exist
b	Surface rust and no water leak
c	Surface rust and water leak
d	Loss of section and slight water leak
e	Loss of section and remarkable water leak. or other serious damage such as crack of steel

Sample "b"

Sample "e"

Grading for Each Type of Damage(13)

No.23 Arch Line (Displacement)

Grade of Damage	General Condition
a	Not Exist
b	–
c	–
d	–
e	Deformation at Arch line (rib)

Sample "e"

No.24 Deteriorated (Loose)

Grade of Damage	General Condition
a	Not Exist
b	–
c	–
d	–
e	Loose or missing material of arch rib and spandrel

Sample "e"

Grading for Each Type of Damage(14)

No.25 Others

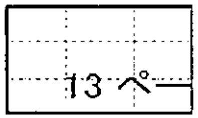
Grade of Damage	General Condition
a	Not Exist
b	–
c	–
d	–
e	Other damages shown below shall also be checked

- Abnormal sound and vibration
- Abnormal deflection
- Deformation and lack of structural members
- Settlement, movement and inclination of substructures

Divide the Bridge Member into Element

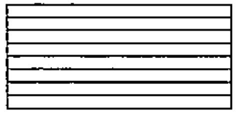
- There are 4 types of elements to divide.

< Elements as divided into 9 or 6 >



【Apply to】
Bridge surface
RC-S
Box — Superstructure
Arch
Substructure

< Elements as each main beam >



【Apply to】
PSC-PRE

e.g. Number of elements: 8

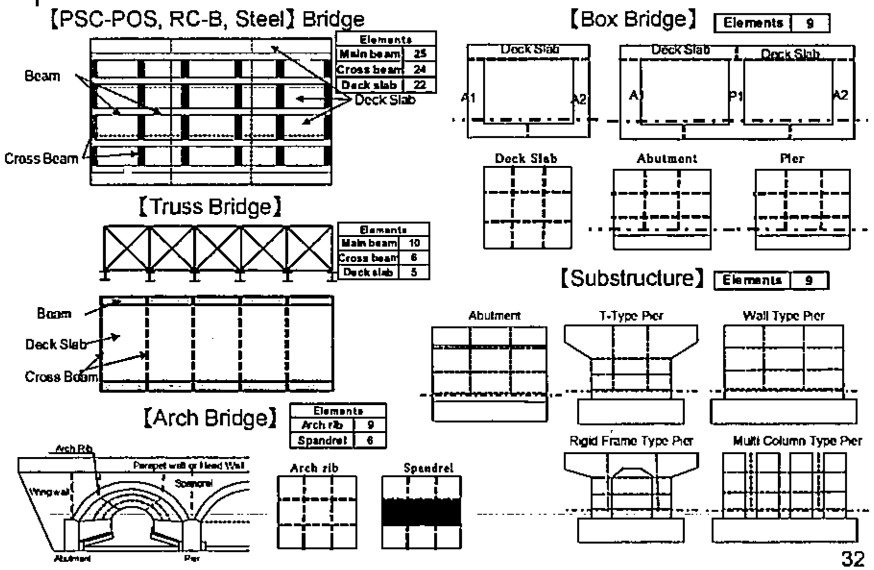
< Elements as section of main beam divided by diaphragm/cross beam >

【Apply to】
PSC-POS
RCS-RCB
Truss
Steel

e.g. Number of elements:
Main beam 20
Cross Beam 20
Deck slab 16

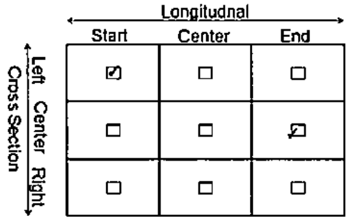
<Not element: damage evaluation percentage in length/numbers >
【Apply to】 Expansion Joint, Accessories, Bridge Bearing.

Example of Elements to Divide



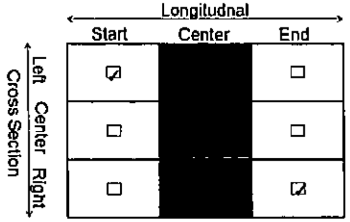
Record Method of Location the Damage

Record the locations of damage in 9 / 6 divides.

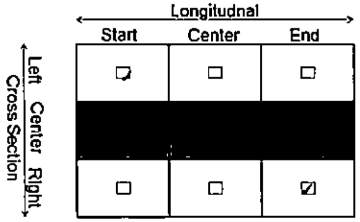


Check the element(s) "✓" where the damage with the worst category is detected.

【Expansion Joint & Approaches】



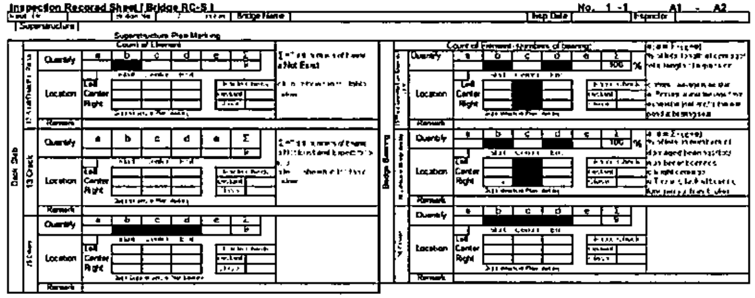
【Accessories & Spandrel of arch bridge】

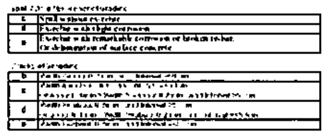


5. Record of Damage on Bridge

Example of on-site memo for recording damage (RC-S)

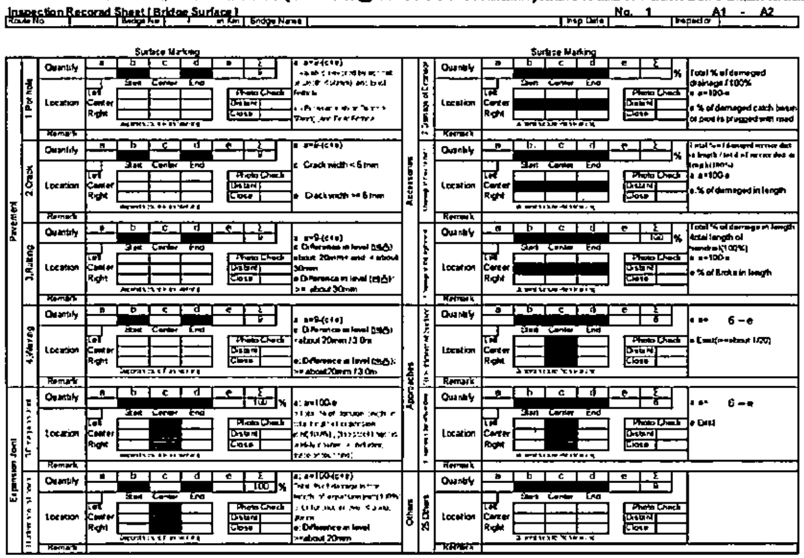
This sheet prepare to print out in advance . Moreover, it record on-site, the quantity of elements in total, quantity of each damage grade and locations of damage with the worst category is detected, etc.



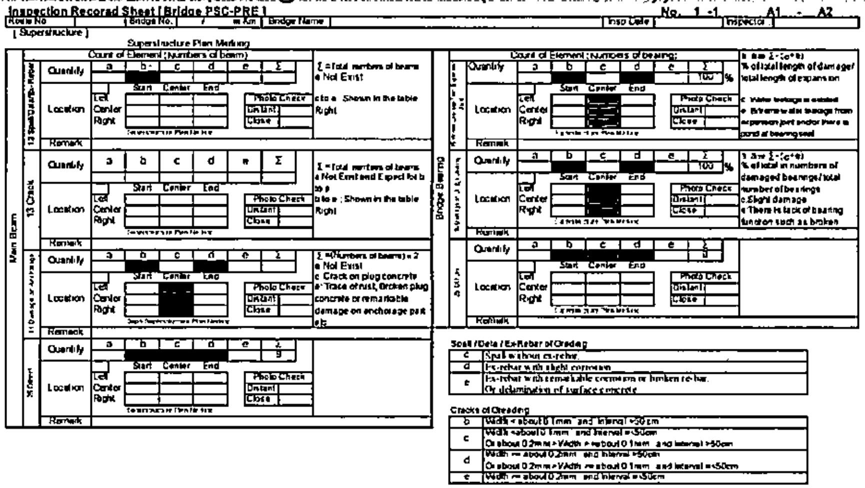


These sheets make it possible to record on 1 page for each target type of bridge, bridge surface and substructure. Therefore, the forms are slightly different from the input form of the database system. Beforehand, to input the bridge number and the span number to the excel sheet for each bridge type.

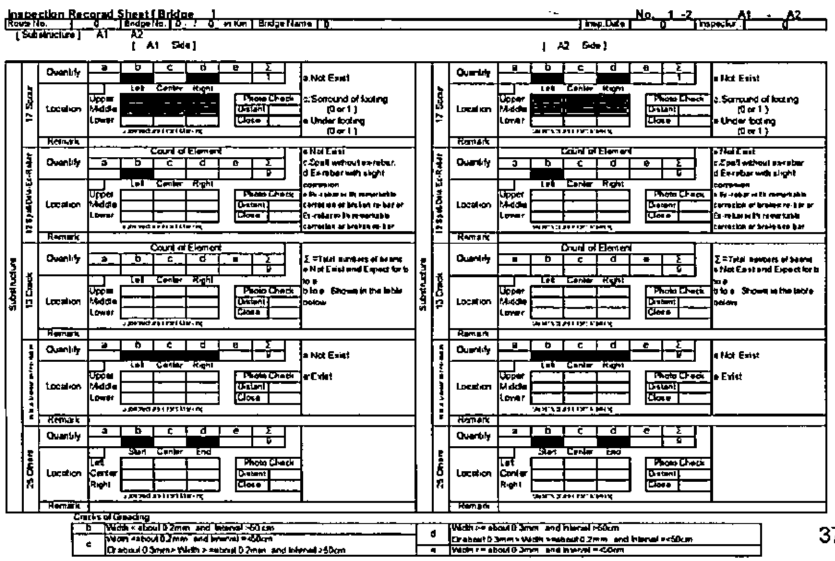
Example of On-site Memo for Recording Damage (2) (Bridge Surface)



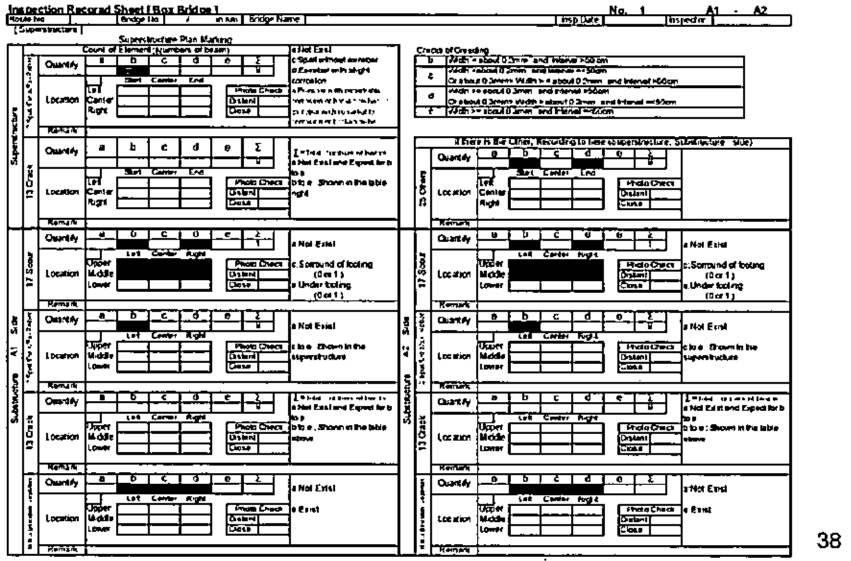
Example of On-site Memo for Recording Damage(3) (Bridge Structure(PSC-PRE))


Inspection Recorad Sheet [Bridge PSC-PRE]

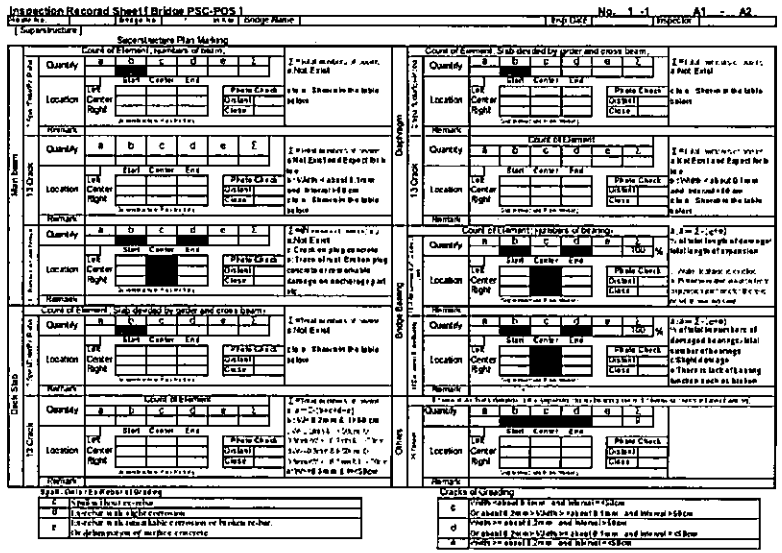
Example of On-site Memo for Recording Damage(4) (Bridge Structure(Sub structure))


Inspection Recorad Sheet [Bridge 1]

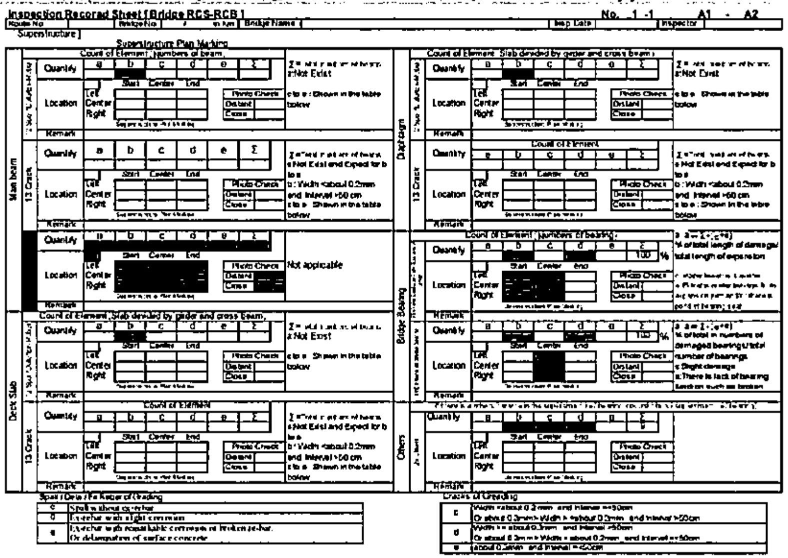
Example of On-site Memo for Recording Damage(5) (Bridge Structure(Box Bridge))


Inspection Recorad Sheet [Box Bridge]

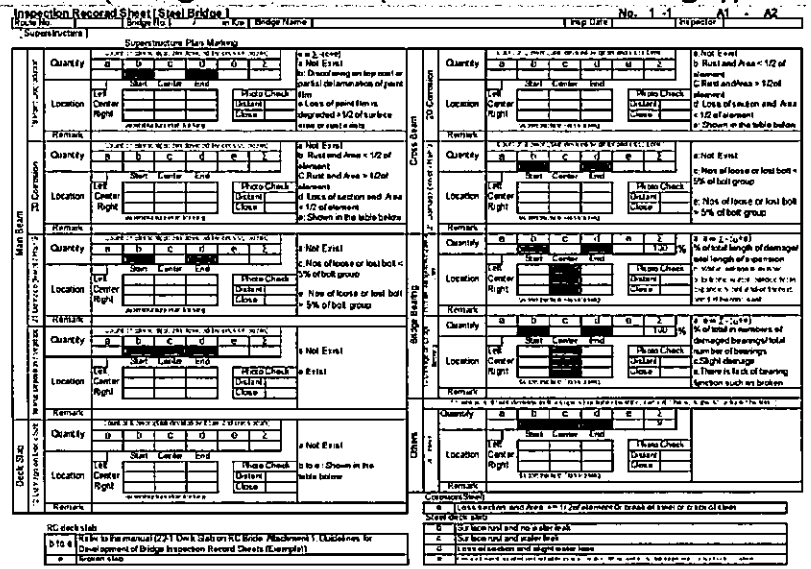
Example of On-site Memo for Recording Damage(6) (Bridge Structure(PSC-POS))


Inspection Recorad Sheet [Bridge PSC-POS]

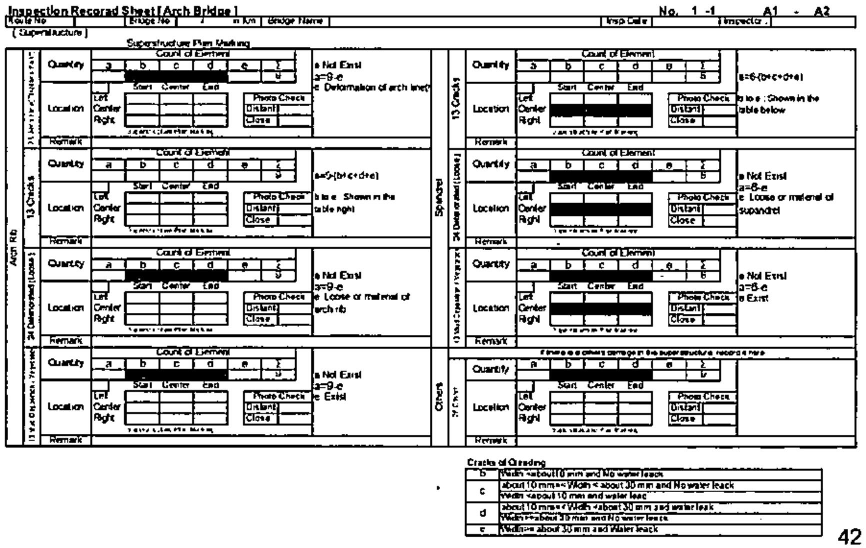
Example of On-site Memo for Recording Damage(7) (Bridge Structure(RC-RCB))



Example of On-site Memo for Recording Damage(8) (Bridge Structure(Truss & Steel Bridge))



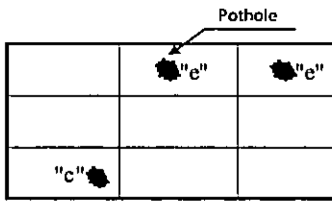
Example of On-site Memo for Recording Damage(9) (Bridge Structure(Arch Bridge))



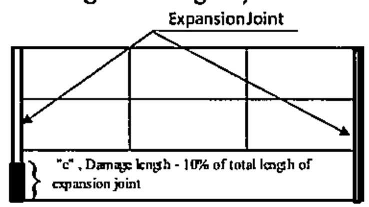
Recording Method of Damage on Bridge (1)

Example of recoding method for damage on surface.

Damage on "Pavement" for Surface(9 elements)



Damage on "Expansion Joint" for Surface (damage evaluation percentage in length)



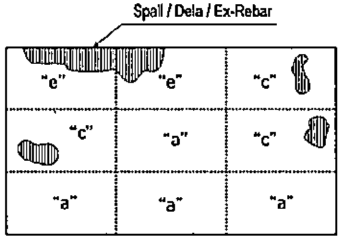
1.Pot hole								
Quantity	a 6	b	c 1	d	e 2	Σ 9		
Location	Left ✓ / Center / Right	Start	Center ✓	End ✓		Photo Check / Distant / Close		
		Superstructure Plan Marking						
Remark								

5 Dmage on Joint								
Quantity	a 90	b	c	d	e 10	Σ 100	%	
Location	Left ✓ / Center / Right ✓	Start	Center	End		Photo Check / Distant / Close		
		Superstructure Plan Marking						
Remark								

Recording Method of Damage on Bridge (2)

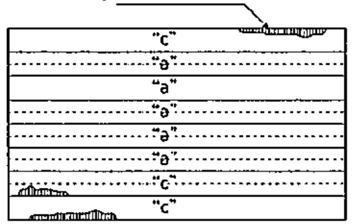
Example of recoding method for damage with each type of bridge.

Damage on "slab" for RC-S(9 elements)



12 Spall/Dela/Ex-Rebar		Count of Element					
Quantity		a	b	c	d	e	Σ
		4		3	0	2	9
Location	✓	Start	Center	End		Photo Check	
	Left	✓	✓			Distant	
	Center					Close	
	Right						
		Superstructure Plan Marking					
Remark							

Damage on "beam" for PSC-PRE(number of beams = 8)



12 Spall/Dela/Ex-Rebar		Count of Element (Numbers of beams)					
Quantity		a	b	c	d	e	Σ
		5		3	0	0	8
Location	✓	Start	Center	End		Photo Check	
	Left			✓		Distant	
	Center					Close	
	Right	✓					
		Superstructure Plan Marking					
Remark							

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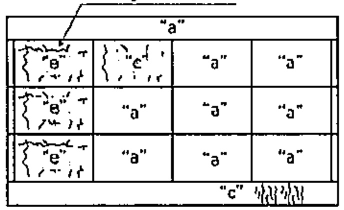
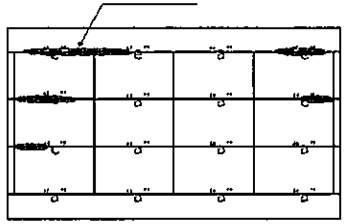
Recording Method of Damage on Bridge (3)

Damage on "deck slab" for Steel bridge
(Number of areas enclosed by beam and cross beam = 14)



12 Damage on Deck Slab		Count of Element(Slab devided by beam and cross beam)					
Quantity		a	b	c	d	e	Σ
		9	0	2	0	3	14
Location	✓	Start	Center	End		Photo Check	
	Left	✓				Distant	
	Center	✓				Close	
	Right	✓					
		Superstructure Plan Marking					
Remark							

Damage on "main beam" for steel beam bridge (number of beam elements divided by cross beam = 16)



20 Corrosion		Count of Element(Beam devided by crosss beam)					
Quantity		a	b	c	d	e	Σ
		10	0	2	0	4	16
Location	✓	Start	Center	End		Photo Check	
	Left	✓		✓		Distant	
	Center	✓		✓		Close	
	Right						
		Superstructure Plan Marking					
Remark							

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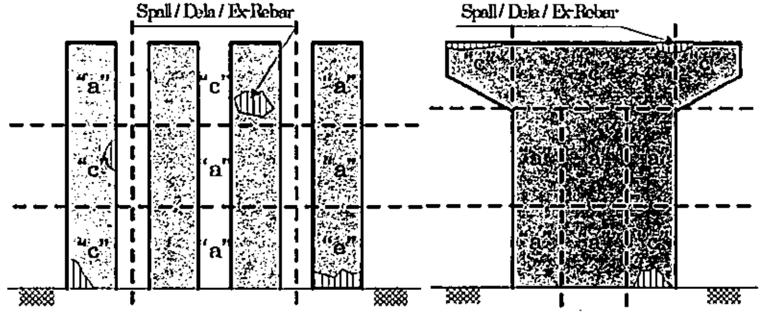
Recording Method of Damage on Bridge (4)

Damage on "pier" for substructure(9 elements)



12 Spall/Dela/Ex-Rebar		Count of Element					
Quantity		a	b	c	d	e	Σ
		5		3	0	1	9
Location	✓	Left	Center	Right		Photo Check	
	Upper					Distant	
	Middle					Close	
	Lower			✓			
		Substructure Front Marking					
Remark							

12 Spall/Dela/Ex-Rebar		Count of Element					
Quantity		a	b	c	d	e	Σ
		5		4	0	0	9
Location	✓	Left	Center	Right		Photo Check	
	Upper	✓	✓	✓		Distant	
	Middle					Close	
	Lower			✓			
		Substructure Front Marking					
Remark							

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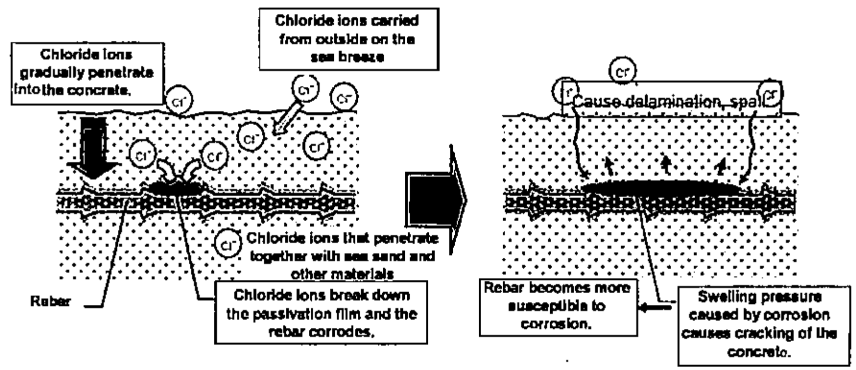
6. Major Damage Example with Those Mechanisms of Bridges

Damage Caused by Rebar Corrosion of Concrete Members
(Corroded Rebar by Salt in Coastal Areas))



Mechanism of Salt damage

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Damage Caused by Rebar Corrosion of Concrete Members (Corroded Rebar by Carbonation)

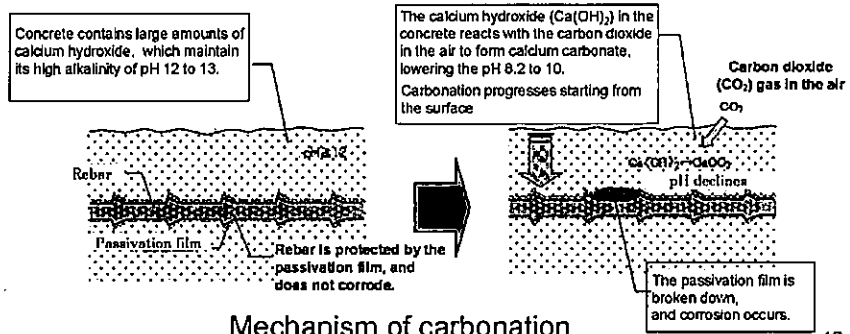
Carbonation

PH of Concrete: 12~13
Effect of carbon dioxide
PH 8.2 to 10

$Ca(OH)_2+CO_2 \Rightarrow CaO_3+H_2O$

Depth of Carbonation

it is not discolored after spraying solution of phenolphthalein



Mechanism of carbonation

Relationship Between Rebar Corrosion and Cracking Pattern

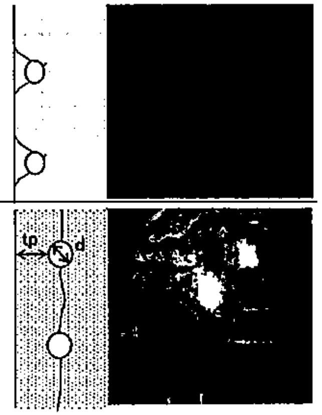
Cover Concrete is thin

the cracks occur on the surface

When: $(2tp+d)/d<3.0$

Space between rebar is small

Cracks internally between the rebar



- In most cases, cracks occur internally between rebar.
- This cracks are not visible from outside in earlier stage.

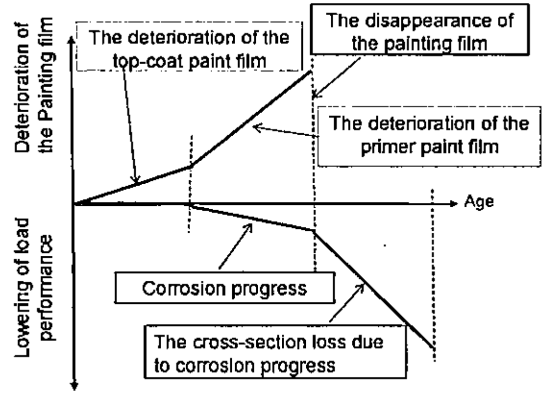
Characteristics of Rebar Corrosion

Characteristics of rebar corrosion by salt damage and carbonation

	Chloride ion penetration	Carbonation of concrete
Regions	Coastal areas	All regions
Corrosion cause	Chloride ion	Carbon dioxide
Time corrosion occurs	After 20 - 40 years	After 50 years or more
Speed of corrosion	Rapid	Slow
Example Photo		

Steel Bridge Corrosion

【Relationship between deterioration of paint film and lowering of load-carrying performance】



- Steel members is very susceptible to corrosion
- A paint film is very important.

Steel Bridge Corrosion

Locations of severe corrosion on a steel bridge are the bottom flanges and the web of exterior beams

Process of corrosion on web cross section.

Photo 1: Initial stage of web cross section reduction

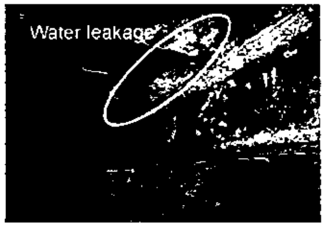
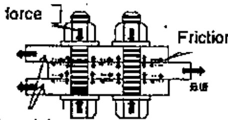


Photo 2: Expanding loss of web cross section

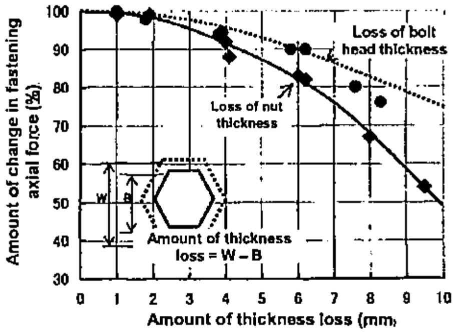
It is important to repair in initial stage for decrease of repair cost and safety.

Loss of Strength in High-Strength Bolts

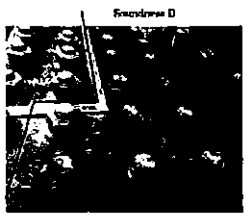


A high-strength bolt transmits working force by the friction force to produce axial force.

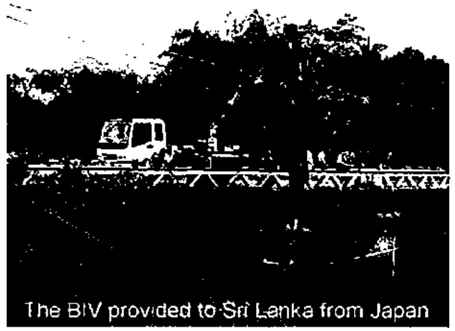
Change in fastening axial force resulting from decrease in high-strength bolt thickness



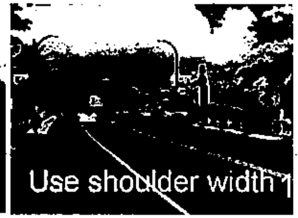
When the bolt is corroded, the safety of the bolt connection decreases.

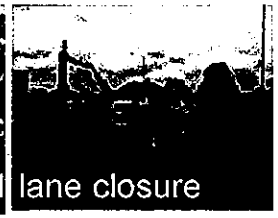


7. Bridge Inspection by BIV

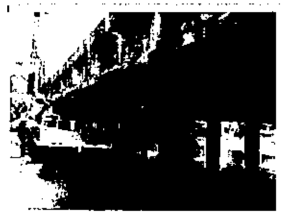


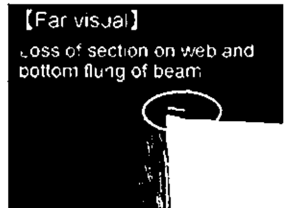
Traffic Cotrol



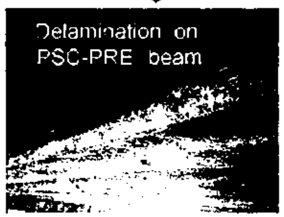


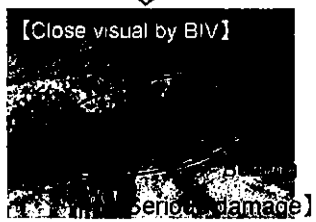
Inspection Result by BIV in OJT





Removal of large tree root





- By inspecting with BIV, it is easy to find invisible damage by far visual.
- Inspectors can know easily the details of damage.
- The large tree root can remove using BIV.

Thank you for your attention

END

Agenda of Additional Bridge Inspection Seminar

19 Sept 2017 (Western)

22 Sept 2017 (Southern)

29 Sept 2017 (Central)

- Outline of the Project
- Bridge inspection
- Bridge diagnosis & emergency action
- Desk bridge inspection
- On-site inspection/ inspection results review
- System data input

Bridge Inspection

THE PROJECT
FOR CAPACITY DEVELOPMENT
ON BRIDGE MANAGEMENT

Minobu AOYAMA

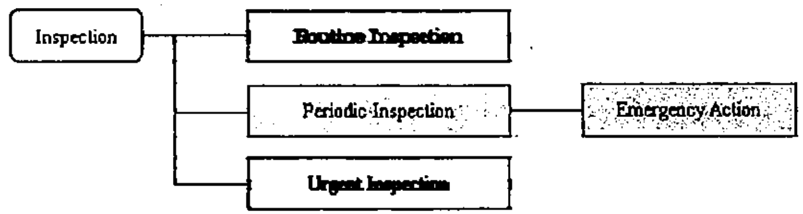
CONTENTS

1.Purpose and Method of Bridge Inspection

Purpose of Bridge Inspection

- Detect the damage early which may affect to the safety and durability of bridges, thereafter take necessary measures;
- Collect necessary data and information for managing the bridges systematically (prioritization, predict the future conditions), in order to effective maintenance.

Type of Inspection



【Periodic Inspection】
Inspection done periodically on superstructure & substructure by closed eye observation for member to prepare damage record and evaluation of soundness.

【Inspection Frequency】: Base once par 5 years.

Explain the periodic inspection from here.

Method of Bridge Inspection (1)

- Collection of basic information

Location, length, width, dimension of the structural members.
Examine construction year will be recorded as basic information.

- Visual inspection is basic of inspection, supplemented with hammer and pole camera

Visual inspection

Use of pole camera

Method of Bridge Inspection (2)

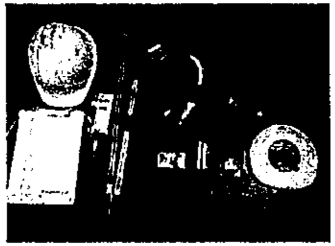
- Bridge inspection by BIV for bridges/spans which cannot be approached;

Hammering inspection by BIV

- It is easy to find damage by BIV because it can be close inspection.
- Hammering inspection can find damages in or on concrete.

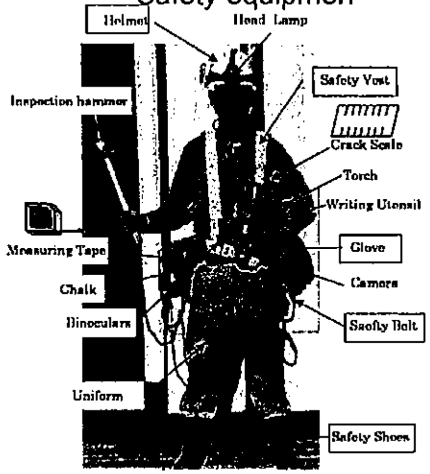
Personal Tools and Safety Equipment

Personal Tools



- Inspection hammers
- Measures
- Crack scale
- Binocular
- Camera

Safety equipmen

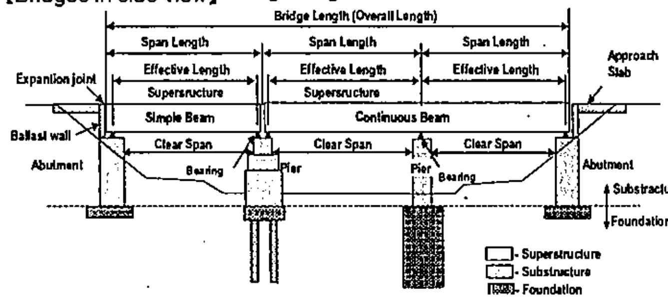


You should take care your safety by no one but by yourselves.

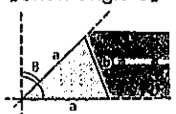
2. Basic Knowledge of Bridges

Names of Bridge Components of Bridge

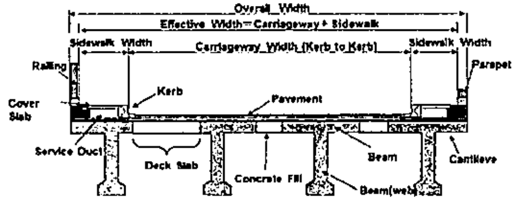
【Bridges in side view】 Bridge Length: distance between the first and the last expansion joints.



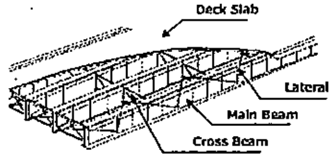
【Skew angle θ】



The skew angle can be obtained by measuring the length of two sides of a isosceles triangle.



【Cross section of concrete bridge】

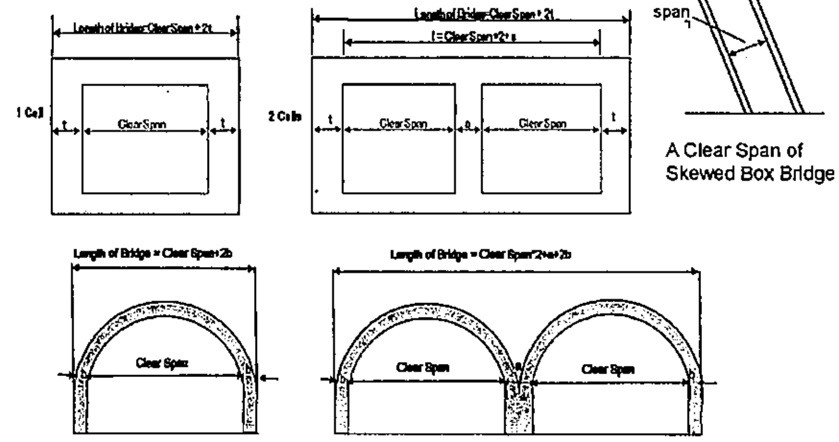


【Steel bridge】

Length of Arch Bridges and Box Bridges

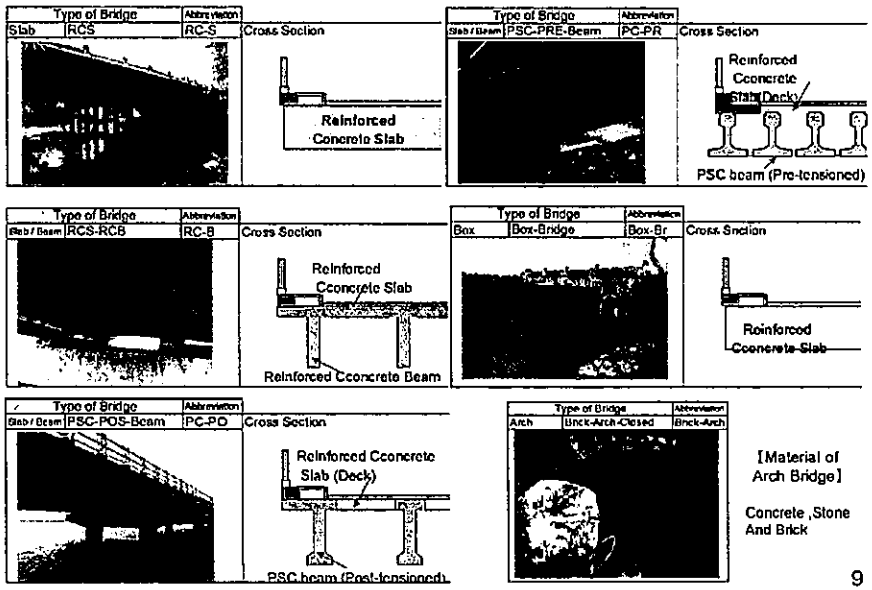
Box bridges are defined as those clear span is more than 3.0 meters.

Length of bridges are given as follow figures.



In case obtaining "a" / "b" / "t" is difficult, It may use a=1.0m, b=0.5m and, t=0.35m,

Type of Bridges(Concrete & Arch Bridge)

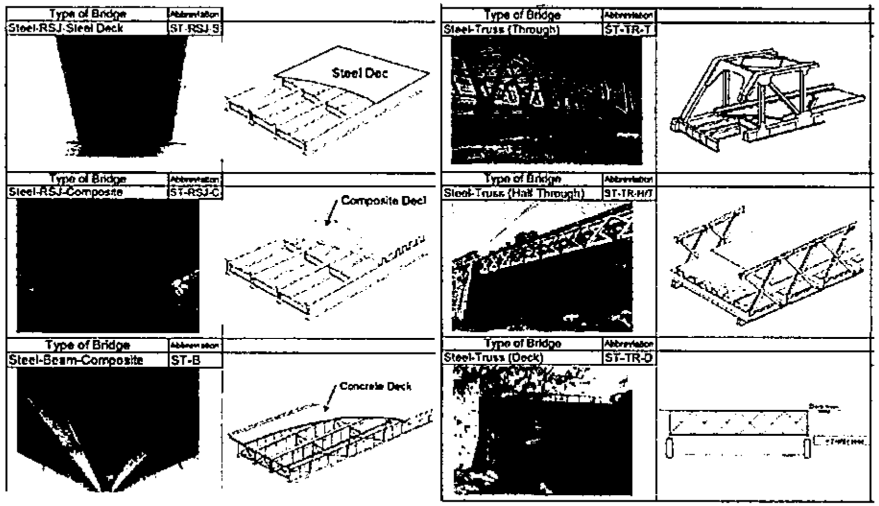


【Material of Arch Bridge】

Concrete ,Stone And Brick

Type of Bridges(Steel Bridge)

Truss bridge are classified by the deck slab position



3. Flow of Periodic Bridge Inspection

Inspection

Preparation → Visual Inspection → Recording

If finds serious damage, reporting to relevant authorities for "emergency actions", is required → Emergency Action

- Grade of damage
- Location of damage
- Photos

Site Worck

The damage is found at site, the status progress of damaged shall be graded (a, b, c, d and e) at each element of member

Office Worck

Bridge Database System
Bridge Inspection Support System

Health Index(HI)
- **Rough Cost Estimate for Measures**
- **Soundness Classifications**

Health Index is calculated by the system

A,B,C,D

Diagnosis

Diagnosis, Reporting → Recording

Finally, Experts should decide to diagnosis of soundness classifications by the observations.

Soundness Classifications(A,B,C,D)

A	Sound, no measure required minor damage
B	Need miner repair for damage needed for preventive maintenance purpose recommended for structural safety points of view at early stage
C	Need repair promptly for structural safety points of view
D	Need replacement of member / strengthening / reconstruction of entire bridge

4. Details of Bridge Inspection

Target Type of Bridge

Standard bridge types are 7 types, based on the study results of existing bridge type in Sri Lanka.

The target type bridge (7 types bridges)

No.	Type of Bridge
1	Bridge Structure (PSC-PRE)
2	Bridge Structure (RC-S)
3	Bridge Structure (PSC-POS,RCS RCB)
4	Bridge Structure (Box Bridge)
5	Bridge Structure (Truss Bridge)
6	Bridge Structure (Steel Bridge)
7	Bridge Structure (Arch Bridge)

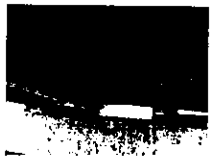
Target Type of Bridge

PSC-PRE

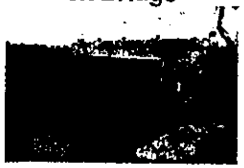
RC-S

PSC-POS

RCS-RCB



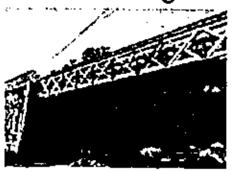
Box Bridge



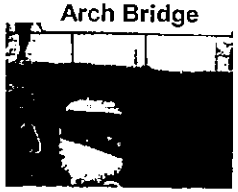
Steel Bridge(Steel Deck)

Steel Bridge(Concreet Deck)

Truss Bridge

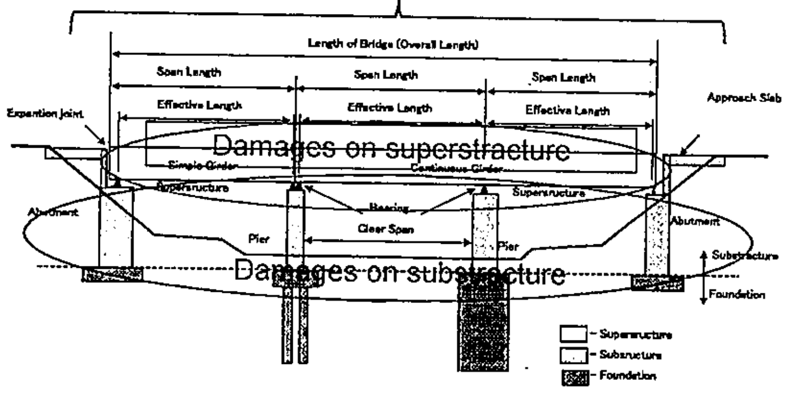


Arch Bridge



Type of Damage

Side view of the typical bridge structure



·Damages are often appeared in particular part of bridge surface, superstructure and substructure.

Type of Damage

11 types for bridge surface,14 types for bridge structure

Bridge Surface		
No	**Member**	**Type of Damage**
1	Pavement	Pothole
2		Pavement Crack
3		Rutting
4		Waving
5	Expansio Joint	Damage on Expansion joint
6		Difference in Levels
7	Accessories	Damage on Drainage
8		Damages on Service Duct
9		Damages on Railing / Parapet
10	Approaches	Settlement of Surface
11		Approach Bank / River Bank

Bridge Structure		
No	**Member**	**Type of Damage**
12	Concret Bridge/ Member	Spall / Dela / Ex-Rebar
13		Crack
14		Damage on Anchorage
15	Bridge Bearing	Water Leakage from Expansion Joint
16		Damage on Bridge Bearing
17	Sub Structure	Scour
18		Mud Deposition / Vegetation
19		Paint Degradation
20	Steel/Truss Bridge	Corrosion
21		Damage (Rivet / HSFG)
22		Damage of Deck Slab
23	Arch Bridge	Arch Line (Displacement)
24		Deteriorated (Loose)
25		Others

Standard Grade of Damage

The evaluation of damage is classified in to 5 grades for each type of damage at each element of member.

Grade of Damage	Status	Status progress of damage Severity/Extent
a	Sound	There is no damage on bridge member.
b	Almost sound	Damage on bridge member is small.
c	Slight	There is a certain degree of damage on bridge member.
d	Remarkable	Damage on bridge member is remarkable.
e	Serious	Damage on bridge member serious.

- Some damage, only"a", "c"and"e" , or only "a"and"e".
- Appendix is given classified grades for each type of damage.

Grading for Each Type of Damage(1)

A. Bridge Surface

No.1 Pothole

Grade of Damage	General Condition
a	Not Exist
b	–
c	Depth < 50mm Deck is not exposed
d	–
e	Depth >=50mm Deck is exposed

Sample "e"

No.2 Pavement Crack

Grade of Damage	**General Condition**
a	Not Exist
b	–
c	Crack width < 5 mm
d	–
e	Crack width >=5 mm

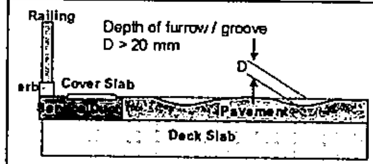
Sample "c"

Sample "e"

Grading for Each Type of Damage(2)

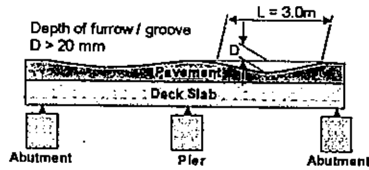
No.3 Rutting

Grade of Damage	General Condition
a	Not Exist
b	
c	凹凸: About 20 mm< D < about 30 mm
d	
e	凹凸: D >= about 30 mm



No.4 Waving

Grade of Damage	**General Condition**
a	Not Exist
b	
c	凹凸: D< about 20 mm
d	
e	凹凸: D>= about 20 mm



Grading for Each Type of Damage(3)

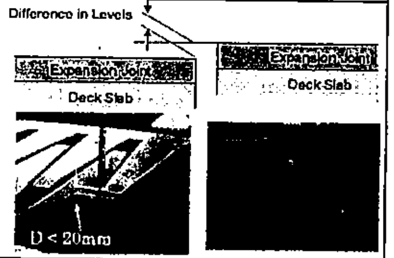
No.5 Damage on Expansion Joint

Grade of Damage	General Condition
a	Not Exist
b	
c	
d	
e	Expansion joint is damaged.

Sample "e"

No.6 Difference in Levels

Grade of Damage	General Condition
a	Not Exist
b	
c	D< about 20 mm
d	
e	D>= about 20 mm



Grading for Each Type of Damage (4)

No.7 Damage of Drainage

Grade of Damage	General Condition
a	Not Exist
b	-
c	-
d	-
e	Catch basin or drainage pipe is plugged with soil and other debris.

Sample "e"


No.8 Damage on Service Duct

Grade of Damage	General Condition
a	Not Exist
b	
c	
d	
e	Service duct is damaged.

Sample "e"

Grading for Each Type of Damage (5)

No.9 Damage on Railing / Parapet

Grade of Damage	General Condition
a	Not Exist
b	-
c	-
d	-
e	Railing/ Parapet is broke.

Sample "e"

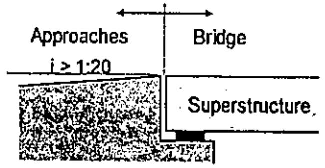
Sample "a"

Function of railing is kept.

No.10 Settlement of Surface at Approaches

Grade of Damage	General Condition
a	Not Exist
b	
c	-
d	
e	Approach is settled. Inline i > about 1/20 .

Sample

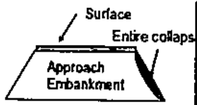


Grading for Each Type of Damage(6)

No.11 Approach Bank / River Bank

Grade of Damage	General Condition
a	Not Exist
b	
c	
d	
e	Approach embankment is collapsed or out-flown.

Sample "e"



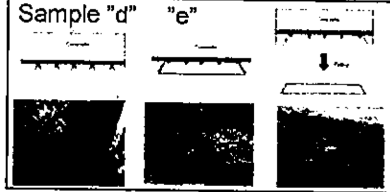
B. Bridge Structure

No.12 Spall / Dela / Exposed-Reber

These damage are major damage on concrete bridges in Sri Lanka.

Grade of Damage	General Condition
a	Not Exist
b	
c	Spall without ex-rebar.
d	Ex-rebar with corrosion
e	Spall / Dela /broken rebar.

Sample "d" "e"



【Note】: In case, this damage is found, the same grade shall be given to the element in crack although the crack is not found.

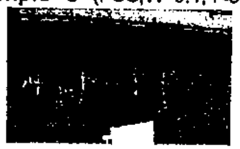
Grading for Each Type of Damage(7)

No.13 Concrete Crack

Grade of Damage	General Condition		
	RC, Box, Sub.	PSC-PRE / POS	Arch
a	Not Exist		
b	W< 0.2 & I > 50	W< 0.1 & I > 50	W< 10 & I > 50
c	W<=0.2 & I <= 50 0.2< =W< 0.3 & I >50	W<=0.1 & I <= 50 0.1< =W< 0.2 & I >50	W<=10 & I <= 50 10< =W< 30 & I >50
d	0.2< =W< 0.3 & I <=50 W>=0.3 & I >50	0.1< =W< 0.2 & I <=50 W>=0.2 & I >50	10< =W< 30 & I <=50 W>=30 & I >50
e	W>= 0.3 & I <=50	W>= 0.2 & I <=50	W>= 30 & I <=50

W: With of crack (about mm), I: Interval of crack (cm)

Sample "c" (PSC,W=0.1, I<50)



"d"(Sub. W>0.3, I>50)

"d"(Arch. W>30, I>50)

Grading for Each Type of Damage(8)

No.14 Damage on Bridge Anchorage

Grade of Damage	General Condition
a	Not Exist
b	-
c	Crack on plug concrete.
d	-
e	Trace of rust. or Broken plug concrete or remarkable damage on anchorage part.

Sample "c" Sample "e"


No.15 Water Leakage from Expansion Joint

Grade of Damage	General Condition
a	Not Exist
b	-
c	Water leakage is existed.
d	
e	Extreme water leakage from expansion joint and/or there is pond at bearing seat.

Sample "c" Sample "e"


Grading for Each Type of Damage(9)

No.16 Damage on Bridge Bearing

Grade of Damage	General Condition
a	Not Exist
b	-
c	Slight damage, such as corrosion of bearing, crack on bearing seat.
d	-
e	There is lack of bearing function such as broken bearing.

Sample "c" Sample "e"


No.17 Scour

Grade of Damage	General Condition
a	Not Exist
b	
c	Surrounding of pier/ abutment is scoured. Caisson: Slight scour (less than width of caisson).
d	
e	Under footing of pier/ abutment is scoured. Caisson: Serious scour. (more than width of caisson).

Sample "c" Sample "e"


Grading for Each Type of Damage(10)

No.18 Mud Deposition / Vegetation

Grade of Damage	General Condition
a	Not Exist
b	
c	
d	
e	Damage exists at substructure, truss girder, steel girder, arch rib and spandrel.

Sample "e"


No.19 Paint Degradation

This damage is major damage on steel bridges in Sri Lanka.

Grade of Damage	General Condition
a	Not Exist
b	
c	Discoloring on top coat or partial deterioration of paint film.
d	
e	Loss of paint film is degraded with large(>1/2) surface area of element and dot rust exists in element.

Sample "c" Sample "e"


Grading for Each Type of Damage(11)

No.20 Corrosion

This damage is major damage on steel bridges in Sri Lanka.

Grade of Damage	General Condition
a	Not Exist
b	Rust and Area < 1/2 of element
c	Rust and Area >= 1/2 of element
d	Loss of section and Area < 1/2 of element
e	Loss section and Area >= 1/2 of element. break of steel or crack of steel

Sample

"b"

"d"

"c"

"e"

No.21 Damage (Rivet / HSFG)

Grade of Damage	General Condition
a	Not Exist
b	
c	Nos of loose or lost bolt < 5% of bolt group.
d	
e	Nos of loose or lost bolt ≥ 5% of bolt group.

Sample "c" Sample "e"


Grading for Each Type of Damage(11)

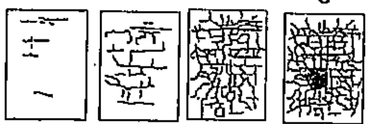
No.22 Damage of Deck Slab

22-1 Deck Slab by RC

Grade of Damage	General Condition
a	Not Exist
b	Refer to the manual (22-1 Deck Slab on RC Bridge, Attachment 1: Guidelines for development of bridge inspection record sheets (example))
c	
d	
e	Broken slab

Sample (Refer).

"b" "c" "d" "e"



- When grading is difficult, it is OK to refer this sample figure.

22-2 Deck Slab by Steel

Grade of Damage	General Condition
a	Not Exist
b	Surface rust and no water leak
c	Surface rust and water leak
d	Loss of section and slight water leak
e	Loss of section and remarkable water leak. or other serious damage such as crack of steel

Sample "b"

Sample "e"

Grading for Each Type of Damage(13)

No.23 Arch Line (Displacement)

Grade of Damage	General Condition
a	Not Exist
b	—
c	—
d	—
e	Deformation at Arch line (rib)

Sample "e"

No.24 Deteriorated (Loose)

Grade of Damage	General Condition
a	Not Exist
b	—
c	—
d	—
e	Loose or missing material of arch rib and spandrel

Sample "e"

Grading for Each Type of Damage(14)

No.25 Others

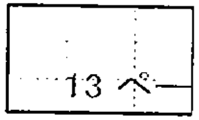
Grade of Damage	General Condition
a	Not Exist
b	—
c	—
d	—
e	Other damages shown below shall also be checked

- Abnormal sound and vibration
- Abnormal deflection
- Deformation and lack of structural members
- Settlement, movement and inclination of substructures

Divide the Bridge Member into Element

- There are 4 types of elements to divide.

< Elements as divided into 9 or 6 >



【Apply to】
Bridge surface
RC-S, Box, Arch — Superstructure
Substructure

< Elements as each main beam >

【Apply to】
PSC-PRE

e.g. Number of elements: 8

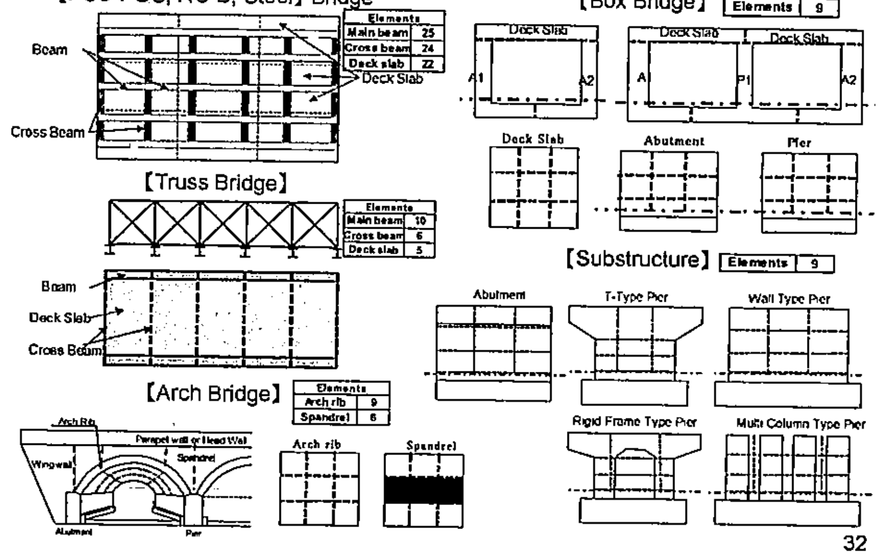
< Elements as section of main beam divided by diaphragm/cross beam >

【Apply to】
PSC-POS
RCS-RCB
Truss
Steel

e.g. Number of elements:
Main beam 20
Cross Beam 20
Deck slab 16

<Not element: damage evaluation percentage in length/numbers >
【Apply to】 Expansion Joint, Accessories, Bridge Bearing.

Example of Elements to Divide



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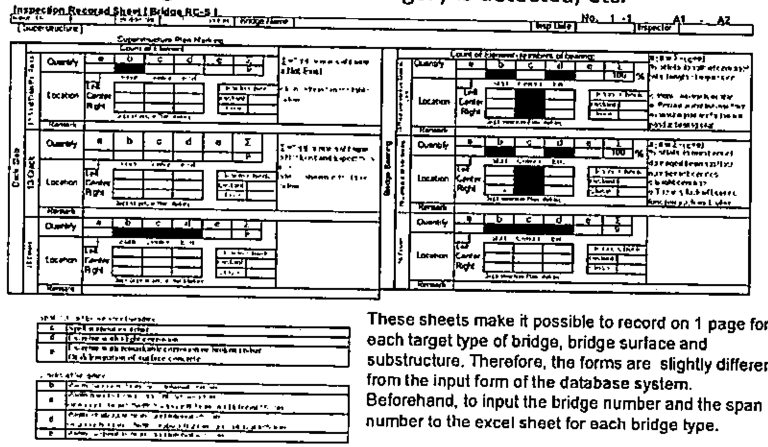
5. Record of Damage on Bridge

Example of on-site memo for recording damage (RC-S)

This sheet prepare to print out in advance . Moreover, it record on-site, the quantity of elements in total, quantity of each damage grade and locations of damage with the worst category is detected, etc.



These sheets make it possible to record on 1 page for each target type of bridge, bridge surface and substructure. Therefore, the forms are slightly different from the input form of the database system. Beforehand, to input the bridge number and the span number to the excel sheet for each bridge type.

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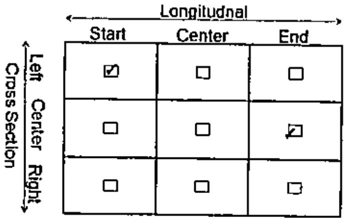
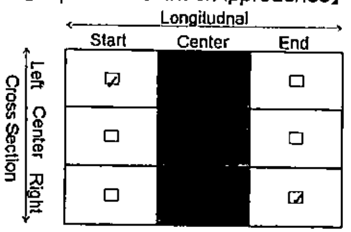
Record Method of Location the Damage

Record the locations of damage in 9 / 6 divides.

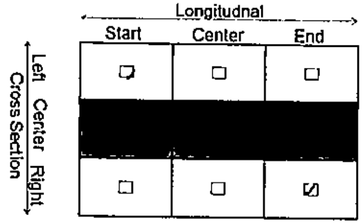


Check the element(s) "✓" where the damage with the worst category is detected.

【Expansion Joint & Approaches】



【Accessories & Spandrel of arch bridge】



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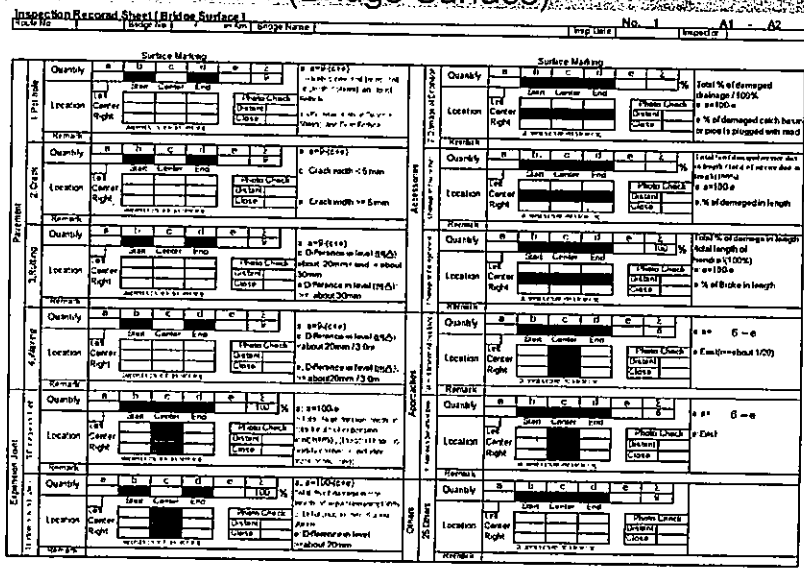
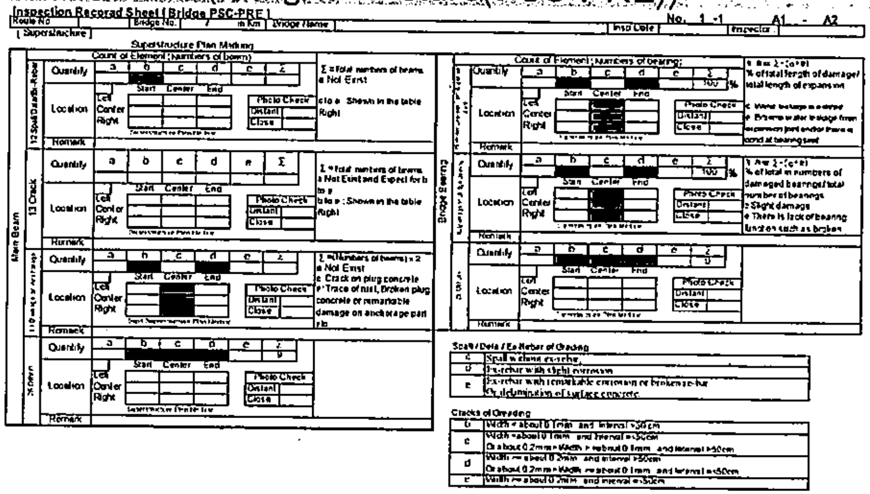
Example of On-site Memo for Recording Damage (2) (Bridge Surface)

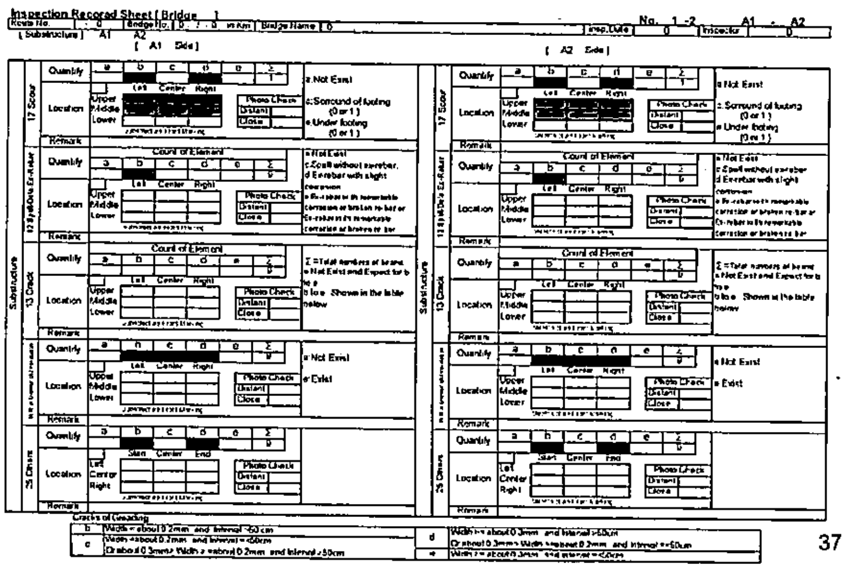


35

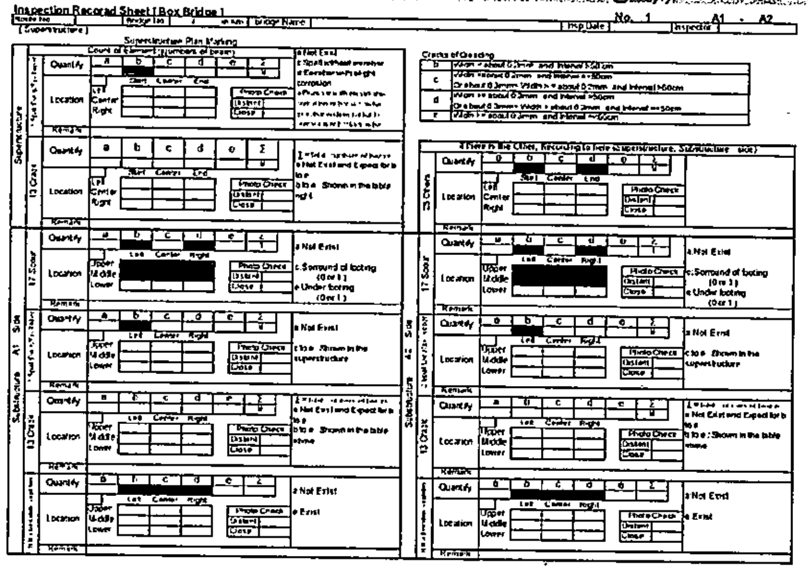
Example of On-site Memo for Recording Damage(3) (Bridge Structure(PSC-PRE))



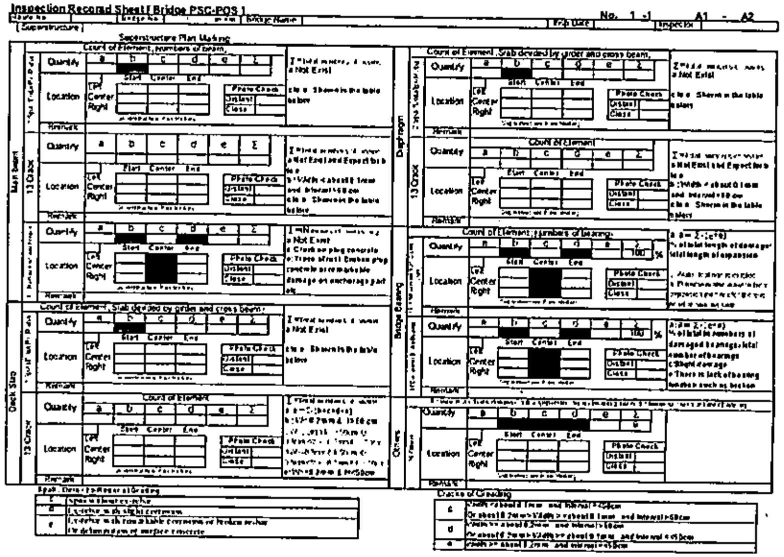
Example of On-site Memo for Recording Damage(4) (Bridge Structure(Sub structure))



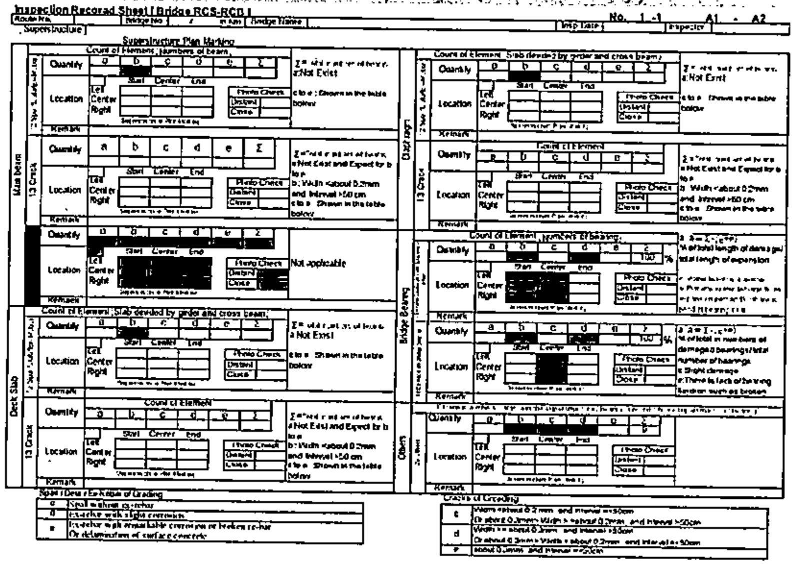
Example of On-site Memo for Recording Damage(5) (Bridge Structure(Box Bridge))



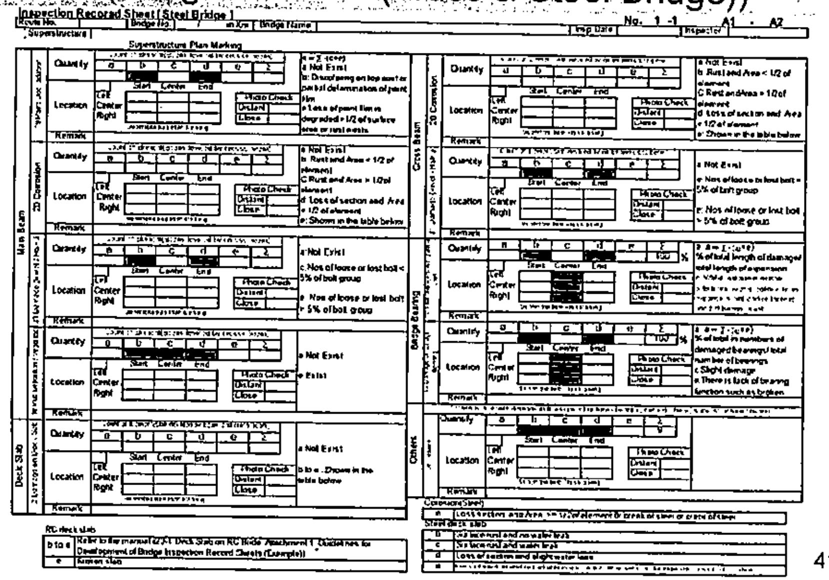
Example of On-site Memo for Recording Damage(6) (Bridge Structure(PSC-POS))



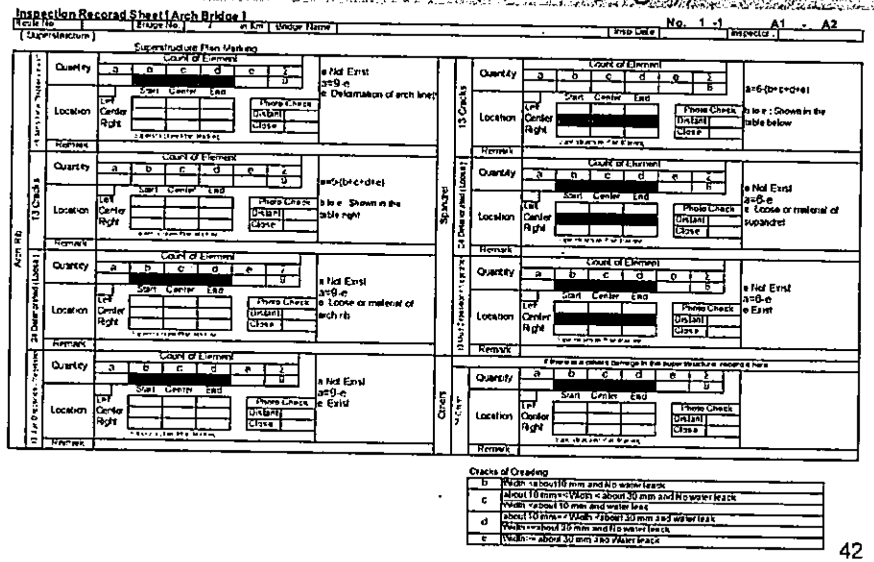
Example of On-site Memo for Recording Damage(7) (Bridge Structure(RC-RCB))



Example of On-site Memo for Recording Damage(8) (Bridge Structure(Truss & Steel Bridge))



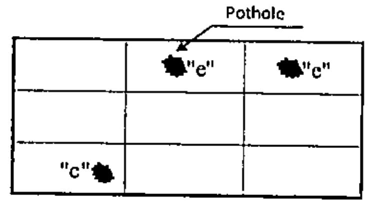
Example of On-site Memo for Recording Damage(9) (Bridge Structure(Arch Bridge))



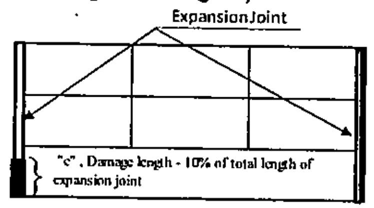
Recording Method of Damage on Bridge(1)

Example of recoding method for damage on surface.

Damage on "Pavement" for Surface(9 elements)



Damage on "Expansion Joint" for Surface (damage evaluation percentage in length)



1.Pot hole

Quantity	a	b	c	d	e	Σ
	6		1		2	9

Location		Start	Center	End	Photo Check
	Left ✓				Distant
	Center		✓	✓	Close
	Right				
		Superstructure Plan Marking			
Remark					

5 Damage on Joint

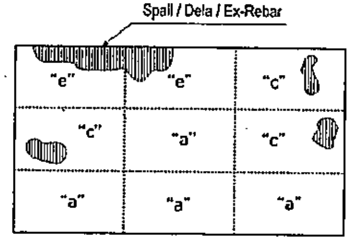
Quantity	a	b	c	d	e	Σ	
	90				10	100	%

Location		Start	Center	End	Photo Check
	Left ✓				Distant
	Center				Close
	Right	✓			
		Superstructure Plan Marking			
Remark					

Recording Method of Damage on Bridge (2)

Example of recoding method for damage with each type of bridge.

Damage on "slab" for RC-S(9 elements)



12 Spall/Dela/Ex-Rebar

	Count of Element					
Quantity	a	b	c	d	e	Σ
	4		3	0	2	9

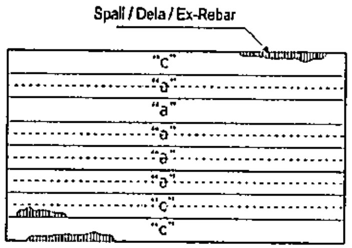
Location	Start	Center	End
✓ Left	✓	✓	
Center			
Right			

Superstructure Plan Marking

Photo Check: Distant / Close

Remark

Damage on "beam" for PSC-PRE(number of beams = 8)



12 Spall/Dela/Ex-Rebar

	Count of Element (Numbers of beams)					
Quantity	a	b	c	d	e	Σ
	5		3	0	0	8

Location	Start	Center	End
✓ Left			✓
Center			
Right	✓		

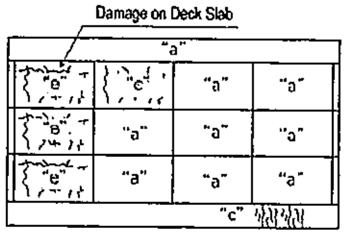
Superstructure Plan Marking

Photo Check: Distant / Close

Remark

Recording Method of Damage on Bridge (3)

Damage on "deck slab" for Steel bridge
(Number of areas enclosed by beam and cross beam = 14)



12 Damage on Deck Slab

	Count of Element(Slab devided by beam and cross beam)					
Quantity	a	b	c	d	e	Σ
	9	0	2	0	3	14

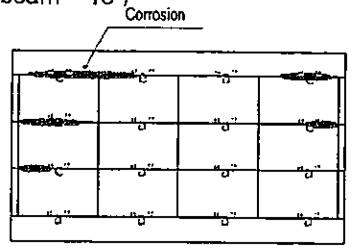
Location	Start	Center	End
✓ Left	✓		
Center	✓		
Right	✓		

Superstructure Plan Marking

Photo Check: Distant / Close

Remark

Damage on "main beam" for steel beam bridge (number of beam elements divided by cross beam = 16)



20 Corrosion

	Count of Element(Beam devided by cross beam)					
Quantity	a	b	c	d	e	Σ
	10	0	2	0	4	16

Location	Start	Center	End
✓ Left	✓		✓
Center	✓		✓
Right			

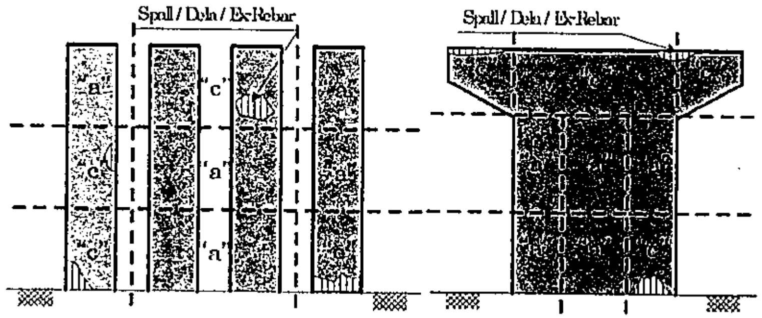
Superstructure Plan Marking

Photo Check: Distant / Close

Remark

Recording Method of Damage on Bridge (4)

Damage on "pier" for substructure(9 elements)



12 Spall/Dela/Ex-Rebar

	Count of Element					
Quantity	a	b	c	d	e	Σ
	5		3	0	1	9

Location	Left	Center	Right
✓ Upper			
Middle			
Lower			✓

Substructure Front Marking

Photo Check: Distant / Close

Remark

12 Spall/Dela/Ex-Rebar

	Count of Element					
Quantity	a	b	c	d	e	Σ
	5		4	0	0	9

Location	Left	Center	Right
✓ Upper	✓	✓	✓
Middle			
Lower			✓

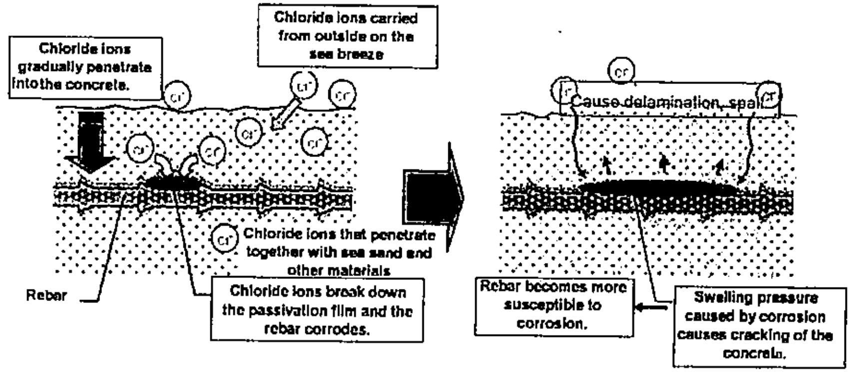
Substructure Front Marking

Photo Check: Distant / Close

Remark

6. Major Damage Example with Those Mechanisms of Bridges

Damage Caused by Rebar Corrosion of Concrete Members (Corroded Rebar by Salt in Coastal Areas))

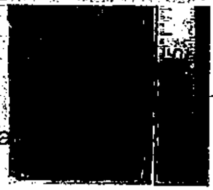


Mechanism of Salt damage

Damage Caused by Rebar Corrosion of Concrete Members (Corroded Rebar by Carbonation)

Carbonation

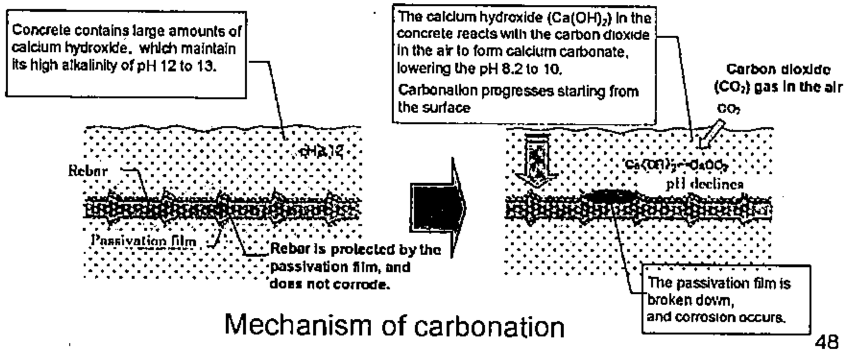
PH of Concrete: 12∼13
Effect of carbon dioxide
PH 8.2 to 10



$Ca(OH)_2+CO_2 \Rightarrow CaO_3+H_2O$

Depth of Carbonation

it is not discolored after spraying solution of phenolphthalein



Mechanism of carbonation

Relationship Between Rebar Corrosion and Cracking Pattern

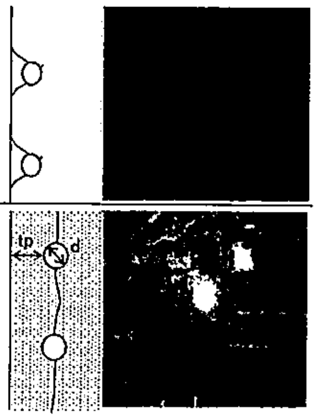
Cover Concrete is thin

the cracks occur on the surface

When: $(2tp+d)/d<3.0$

Space between rebar is small

Cracks internally between the rebar



- In most cases, cracks occur internally between rebar.
- This cracks are not visible from outside in earlier stage.

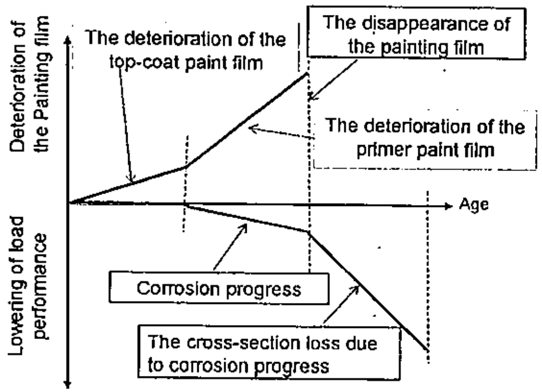
Characteristics of Rebar Corrosion

Characteristics of rebar corrosion by salt damage and carbonation

	Chloride ion penetration	Carbonation of concrete
Regions	Coastal areas	All regions
Corrosion cause	Chloride ion	Carbon dioxide
Time corrosion occurs	After 20 - 40 years	After 50 years or more
Speed of corrosion	Rapid	Slow
Example Photo		

Steel Bridge Corrosion

【Relationship between deterioration of paint film and lowering of load-carrying performance】



- Steel members is very susceptible to corrosion
- A paint film is very important.

Steel Bridge Corrosion

Locations of severe corrosion on a steel bridge are the bottom flanges and the web of exterior beams

Process of corrosion on web cross section.

Photo 1: Initial stage of web cross section reduction

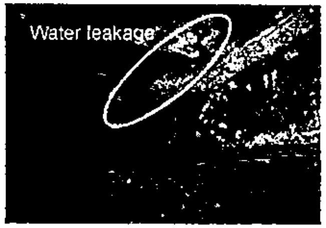
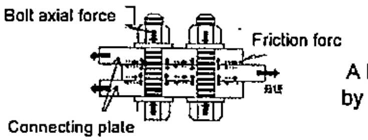


Photo 2: Expanding loss of web cross section

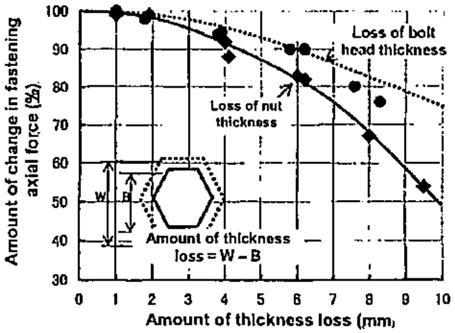
It is important to repair in initial stage for decrease of repair cost and safety.

Loss of Strength in High-Strength Bolts

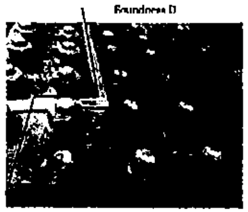


A high-strength bolt transmits working force by the friction force to produce axial force.

Change in fastening axial force resulting from decrease in high-strength bolt thickness

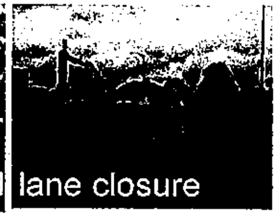


When the bolt is corroded, the safety of the bolt connection decreases.

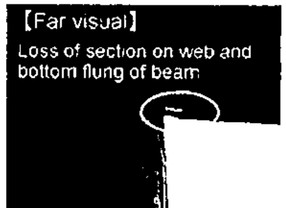


7. Bridge Inspection by BIV

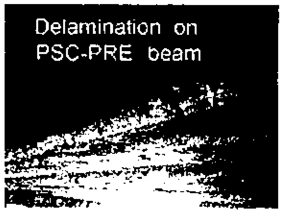
Traffic Cotrol

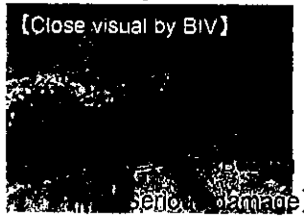


Inspection Result by BIV in OJT



Removal of large tree root





- By inspecting with BIV, it is easy to find invisible damage by far visual.
- Inspectors can know easily the details of damage.
- The large tree root can remove using BIV.

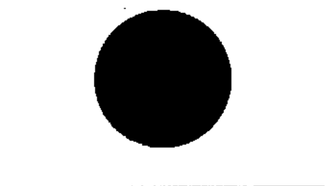
Road Development Authority

THE PROJECT FOR CAPACITY DEVELOPMENT ON BRIDGE MANAGEMENT IN THE SOCIALIST REPUBLIC OF SRI LANKA

JICA
Japan International Corporation Agency

OUTLINE OF THE PROJECT
&
BRIDGE INSPECTION

W.J.P.R.P.P.Jayasuriya
BM & AU
Road Development Authority



THIS PROJECT IS A GIFT FROM GOVERNMENT OF JAPAN TO GOVERNMENT OF SRI LANKA

Under this project Japan granted followings to Srilanka as requested by RDA

1. **Technical Corporation**
2. **Bridge Inspection vehicle**
3. **Pole camera**

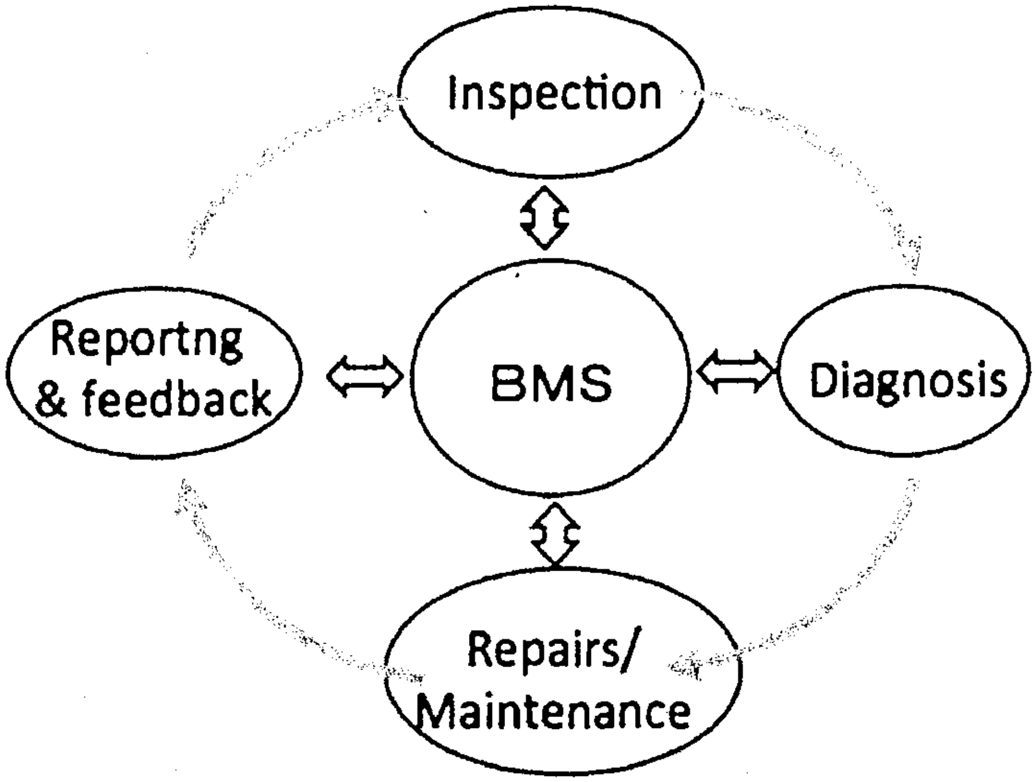
This is not a project to find out weak bridges in Srilanka. It has very broad meaning and very useful in future

Duty of RDA

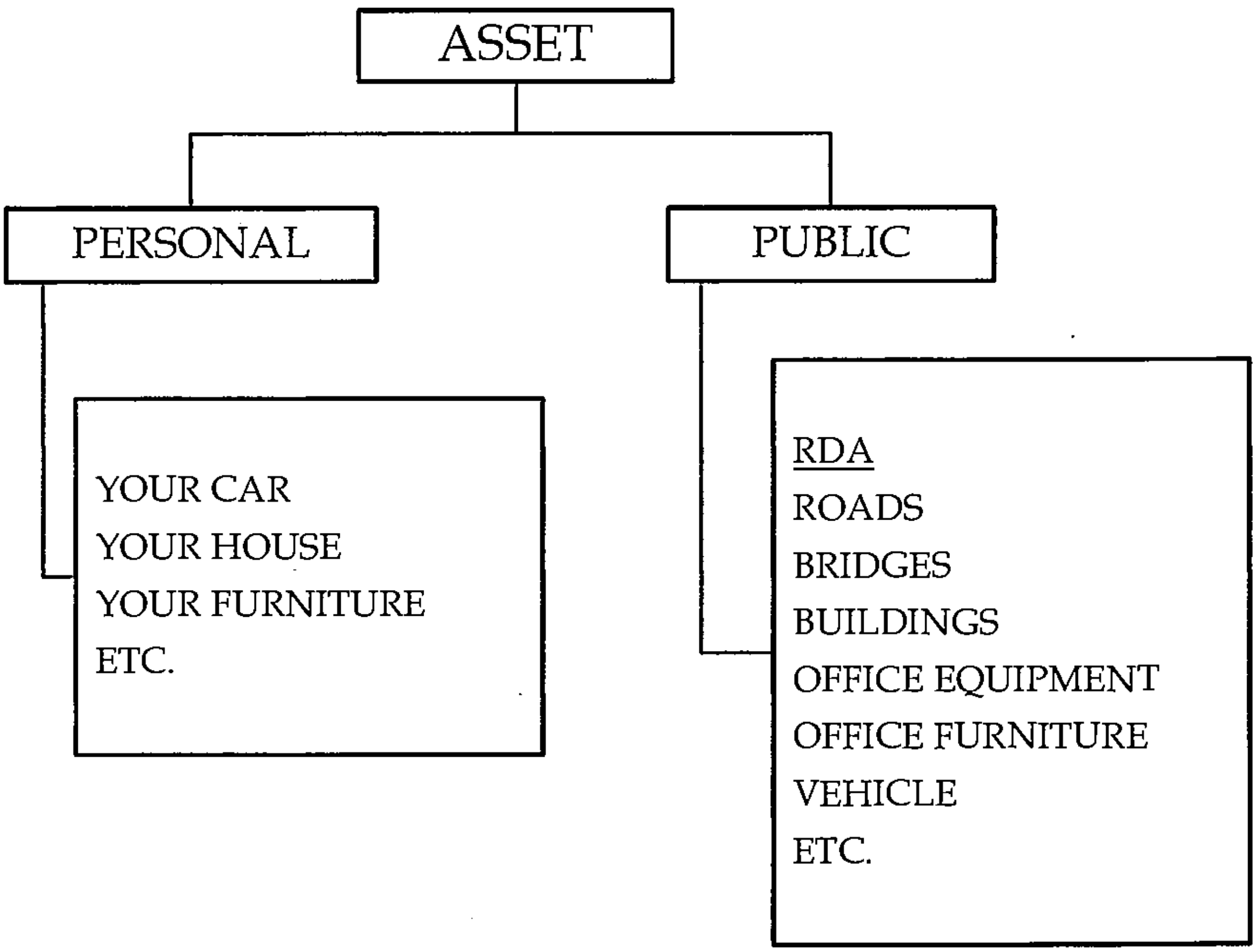
1. Class "A" - 4,217.42Km
2. Class "B" - 7,992.24 Km
3. Class "E" - 169.13 Km
4. Bridges - around 4800

Maintain & rehabilitate above roads & bridges and construct new "A", "B", "E" class roads and bridge on those roads

Project Cycle



ASSET MANAGEMENT

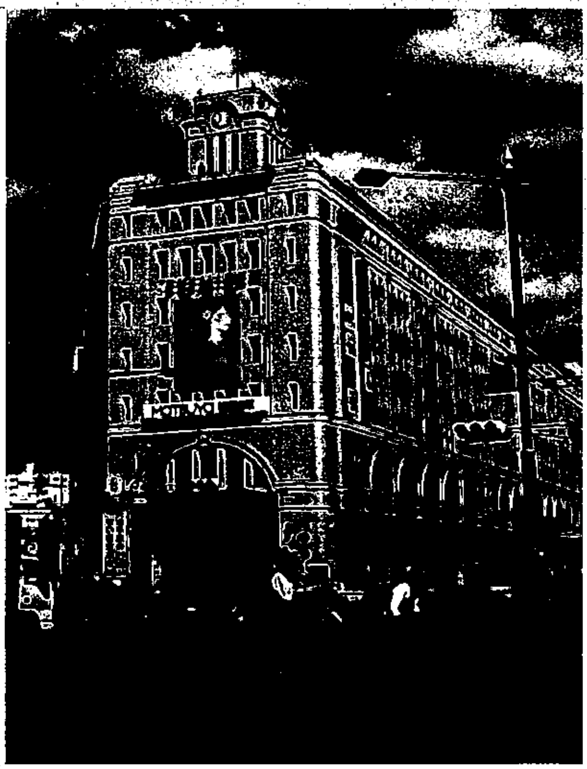


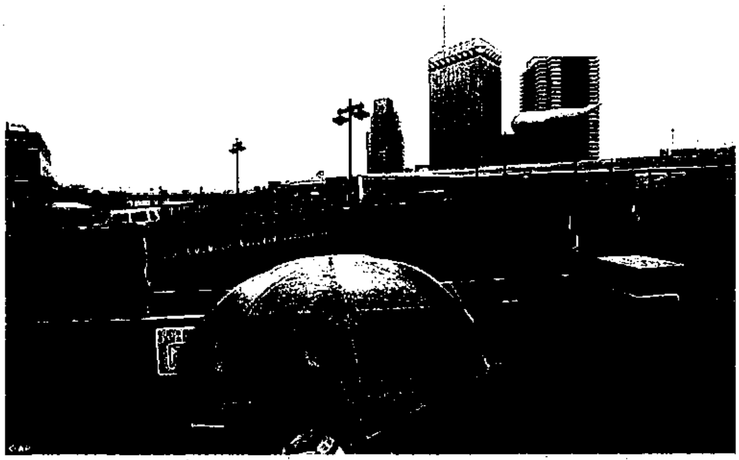
OBJECTIVES OF ASSET MANAGEMENT

- Reduction of O & M cost
- Get maximum benefit of limited budget
- Priority for most required events
- Cut down unnecessary things
- Can start from EE level

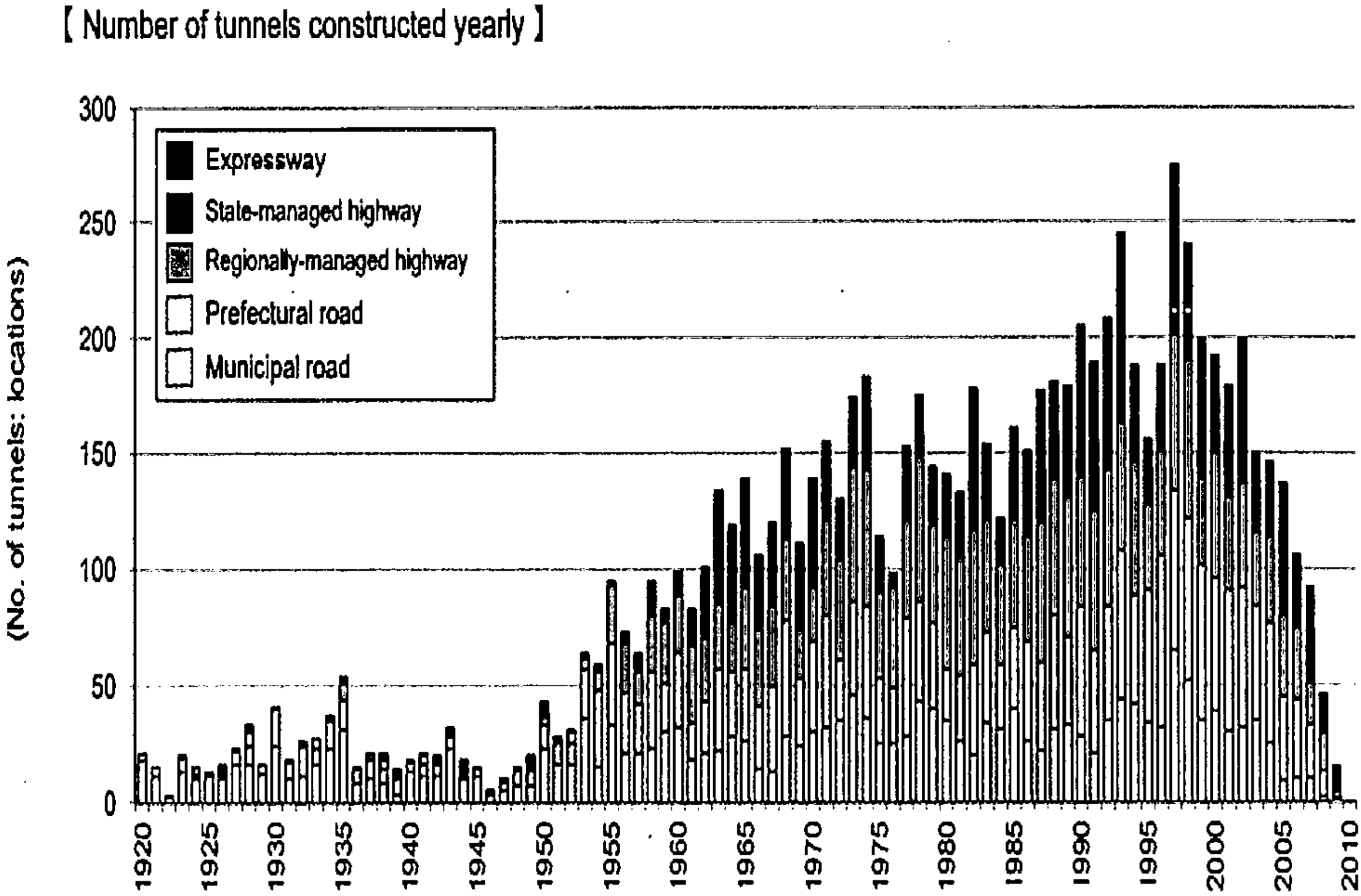
LESSON LEARN FROM JAPAN

Japan is a very poor country after world war

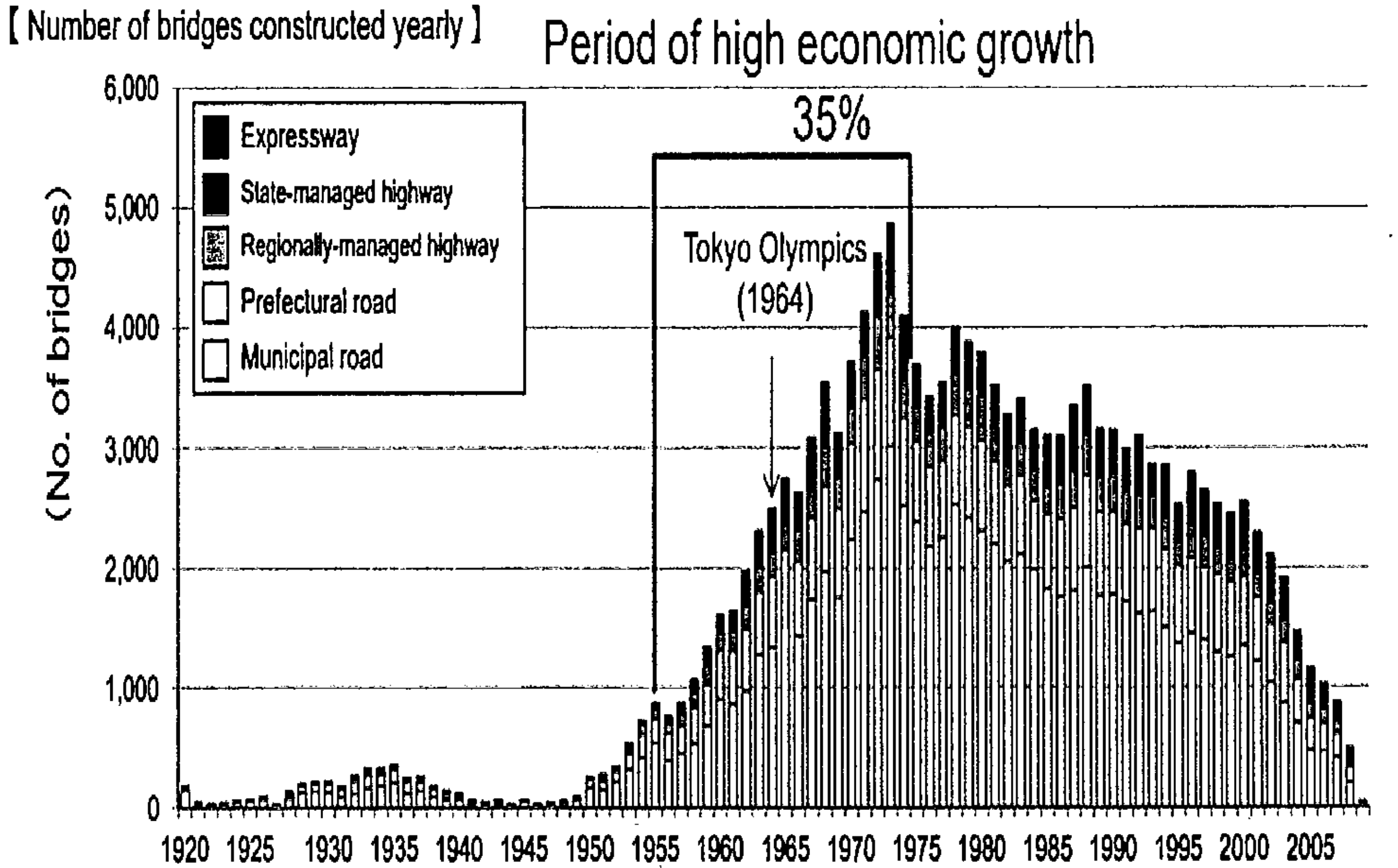




Tunnel stock

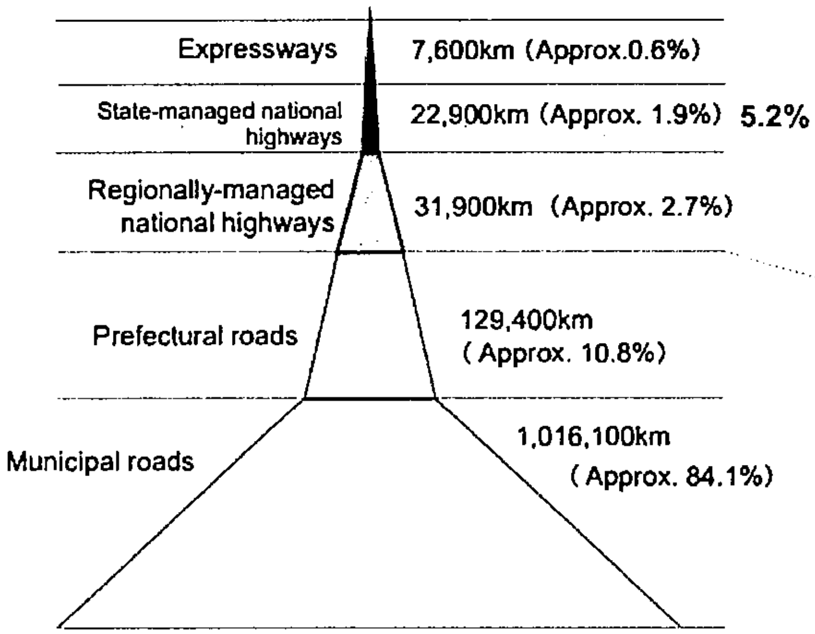


Road bridge stock



- Population - 341 inhabitants per sq. km(Srilanka - 333)

Classification of roads and total length of the road network

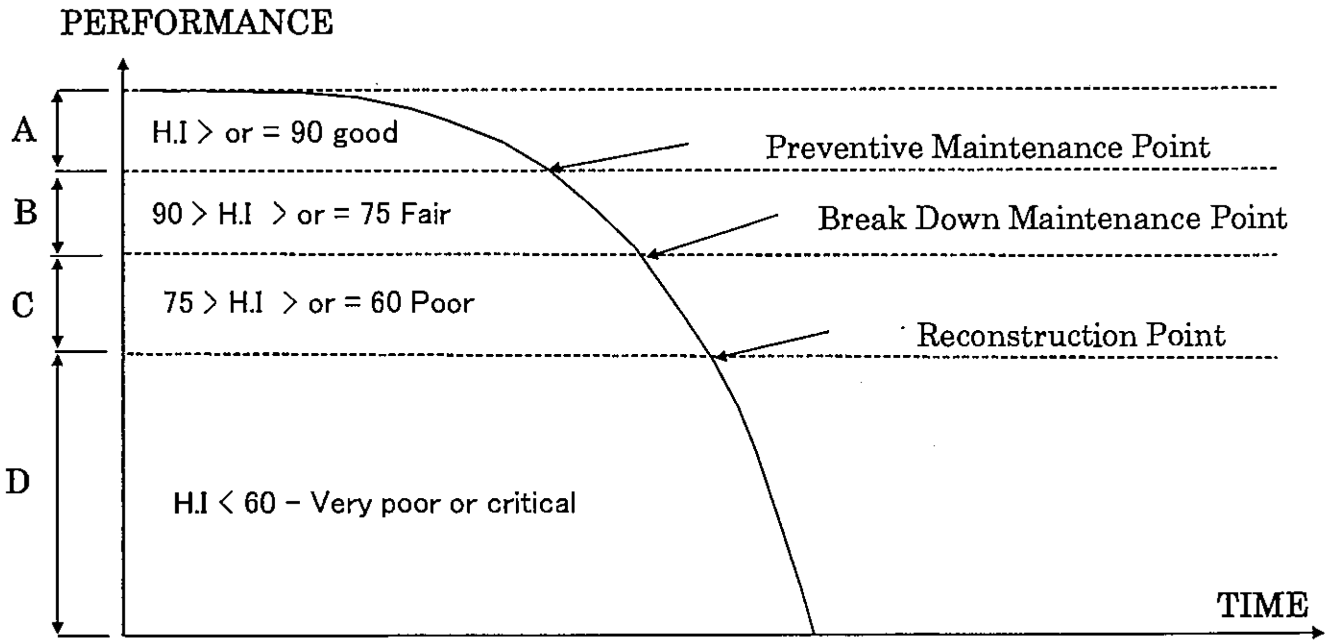


Total Approx. 1,201,000km

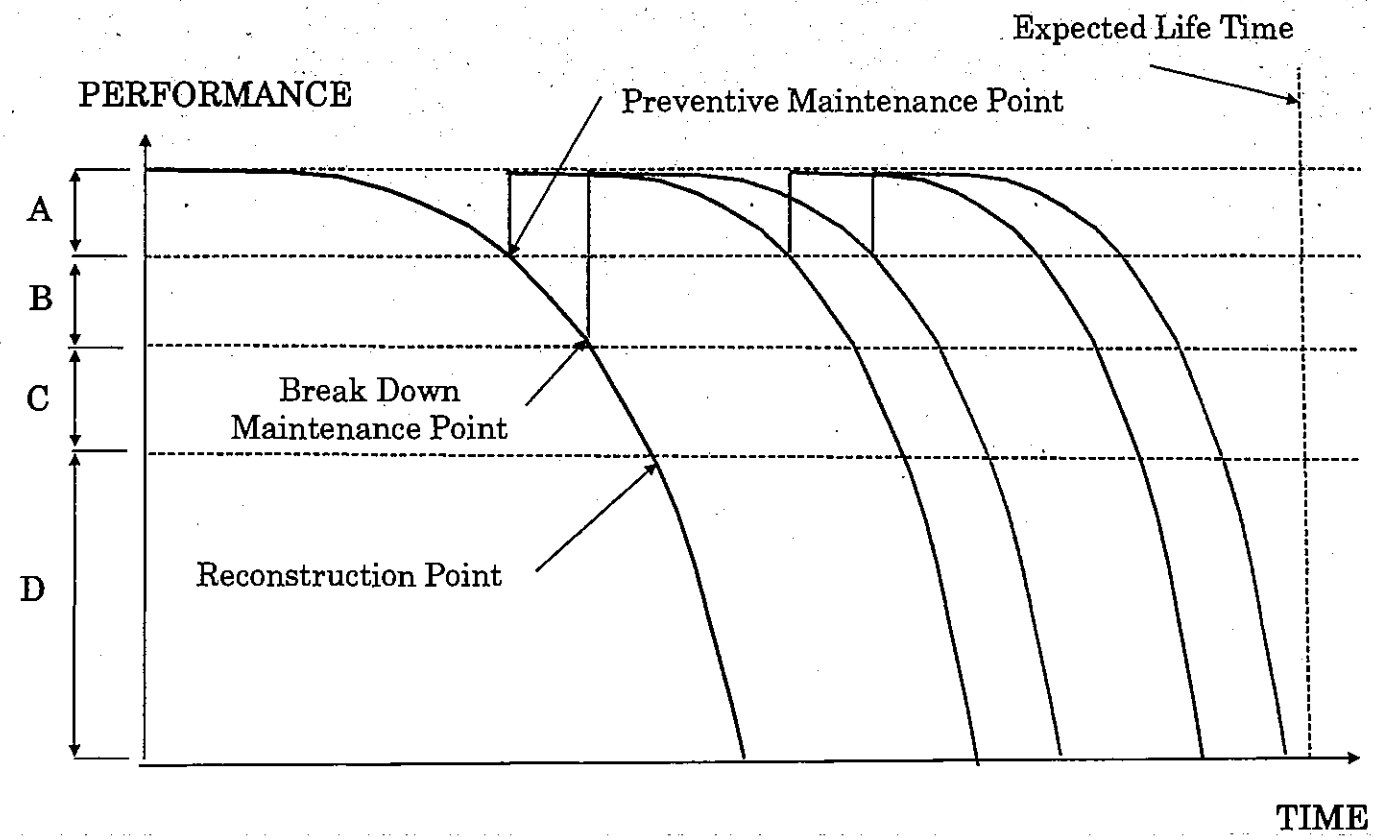
Historical value is very important

PREVENTIVE MAINTENANCE

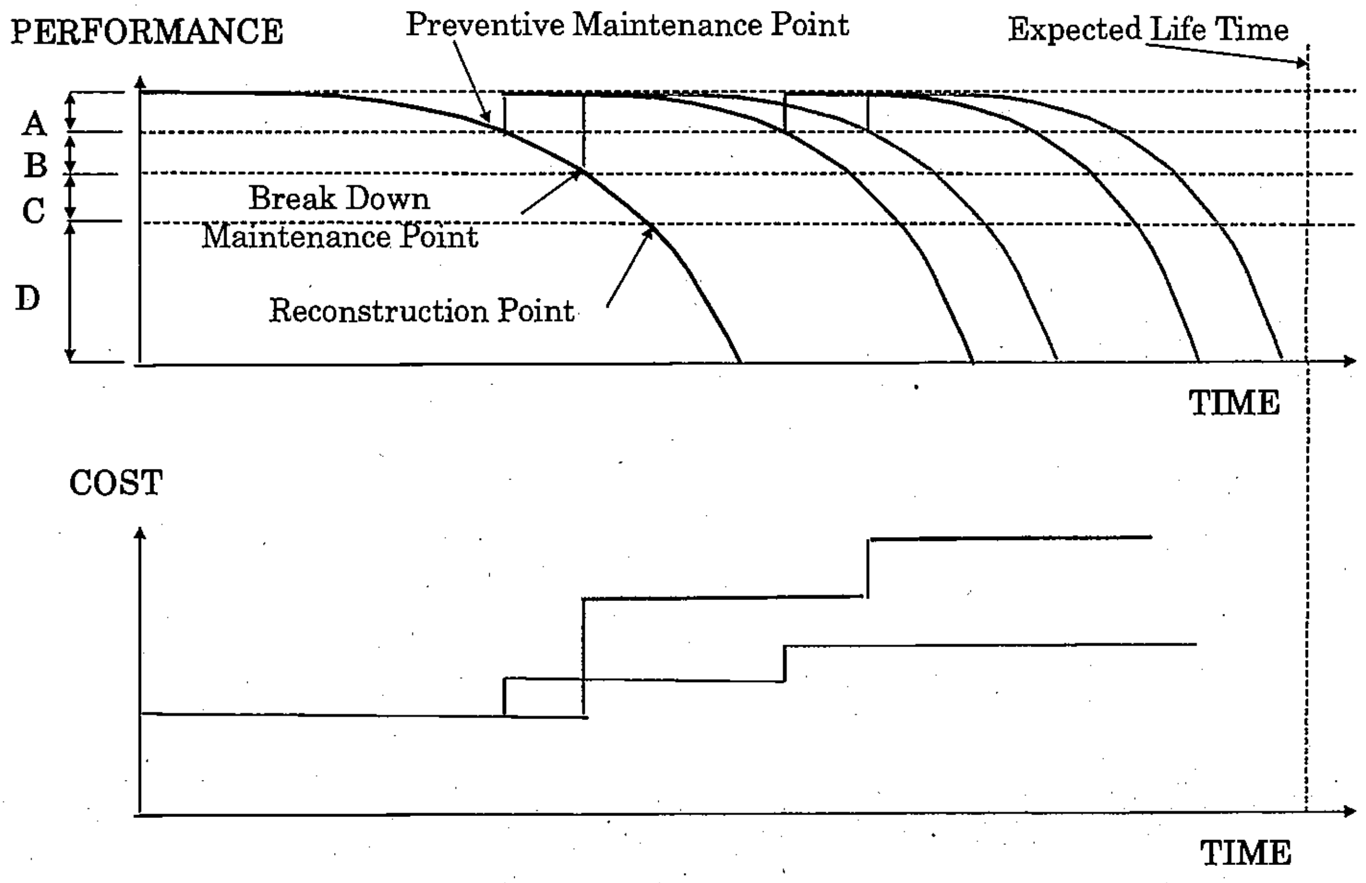
RELATION BETWEEN LIFETIME AND PERFORMANCE



RELATION BETWEEN LIFETIME AND PERFORMANCE OF A BRIDGE WITH MAINTANANCE



LIFETIME AND COST



AIM OF PREVENTIVE MAINTENENCE

1. Prevent, delay or reduce deterioration of bridges or bridge elements.

2. Keep the bridges in good condition.

3. Extend their life.

4. Reduce Maintenance cost

1.BACKGROUND OF THE PROJECT

- There are 4,800 bridges in A, B class National Highway in Sri Lanka.
- It seems that bridge the maintenance & management has been neglected for long time.
- Since 2015 the Japan International Cooperation Agency (JICA)has been working with Road Development Authority(RDA) for The Project for Capacity Development on Bridge Management.

2.GOAL OF THE PROJECT

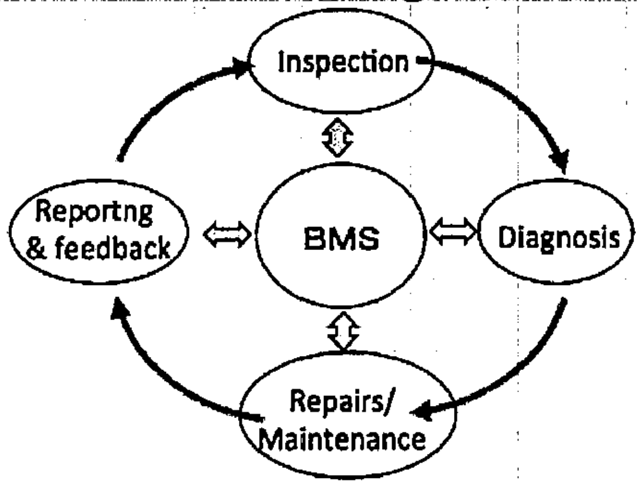
Overall Goal	RDA conducts bridge management in a systematic manner throughout the country in accordance to the Bridge Management Cycle
Project Purpose	Institutional capacity of RDA on bridge management is provided

3.OUTPUT OF THE PROJECT

(i) Bridge management strategy/ plan.
(ii) Institutional framework of RDA head office and regional offices (PD,CE,EE) on bridge management
(i) Bridge inspection and diagnosis manuals are revised and developed.
(i) Bridge management data system is established.
(v) Basic engineering knowledge of staff of RDA head office and regional offices in Sample Provinces is enhanced through seminars and OJTs.

4.BRIDGE MAINTANANCE CYCLE

- Bridge maintenance work consisted with bridge inspection, bridge repair and so on.
- A series of maintenance work is called Bridge Maintenance Cycle.



5.BRIDGE MAINANANCE WORK IN EE OFFICE

- BRIDGE MAINTENANCE is a VITAL ACTIVITY
- Inspection: Accurate observation and record
- Proper emergency action
- Frequent cleaning and minor repair work
- Cooperation with BM&AU and other divisions in RDA

BRIDGE INSPECTION

Bridge Inspection

THE PROJECT
FOR CAPACITY DEVELOPMENT
ON BRIDGE MANAGEMENT

Minobu AOYAMA

CONTENTS

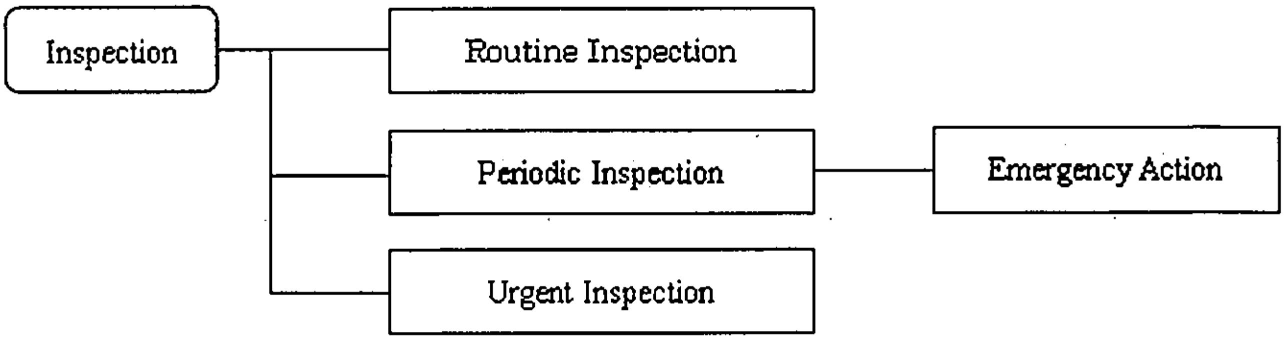
1.Purpose and Method of Bridge Inspection

Purpose of Bridge Inspection

- Detect the damage early which may affect to the safety and durability of bridges, thereafter take necessary measures;

- Collect necessary data and information for managing the bridges systematically (prioritization, predict the future conditions), in order to effective maintenance.

Type of Inspection



【Periodic Inspection】

Inspection done periodically on superstructure & substructure by closed eye observation for member to prepare damage record and evaluation of soundness.

【Inspection Frequency】: Base once par 5 years.

Explain the periodic inspection from here.

Method of Bridge Inspection (1)

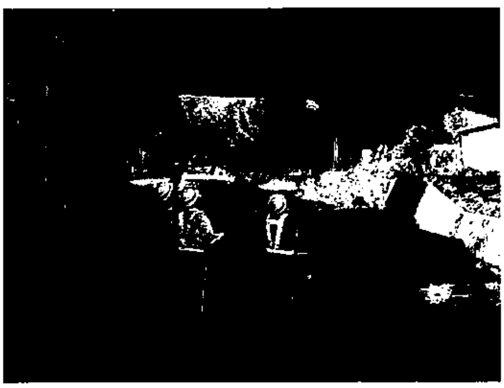
・Collection of basic information

Location, length, width, dimension of the structural members.

Examine construction year will be recorded as basic information.

・Visual inspection is basic of inspection, supplemented with hammer and pole camera

Visual inspection



Use of pole camera

Method of Bridge Inspection (2)

・Bridge inspection by BIV for bridges/spans which cannot be approached;

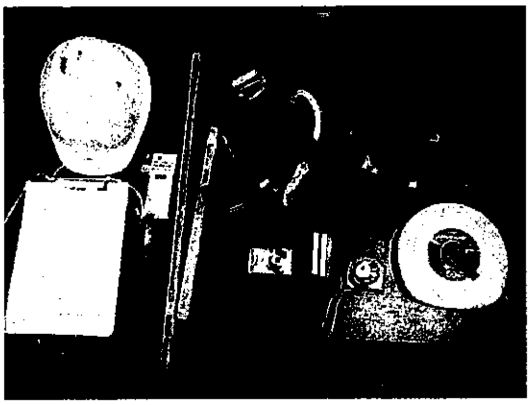
Hammering inspection by BIV

・It is easy to find damage by BIV because it can be close inspection.

・Hammering inspection can find damages in or on concrete.

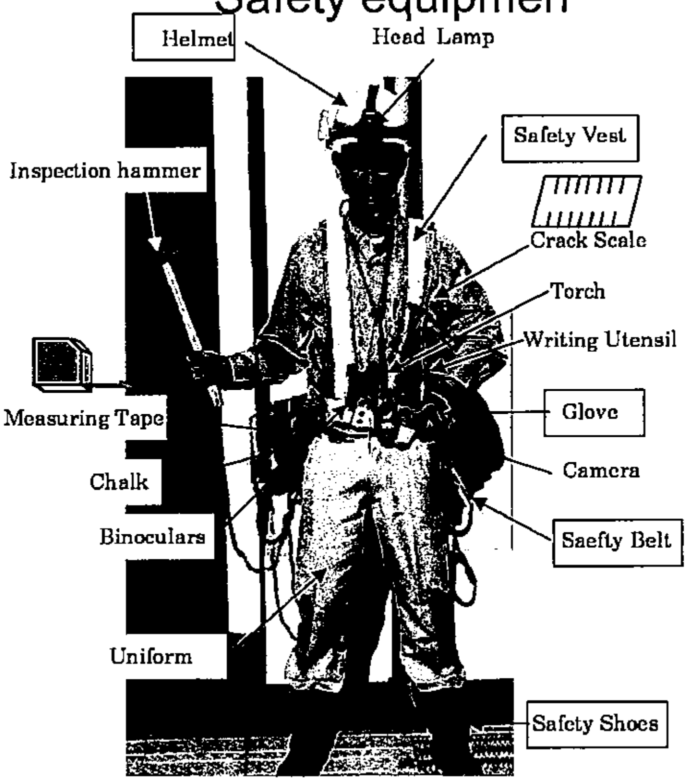
Personal Tools and Safety Equipment

Personal Tools



・Inspection hammers
・Measures
・Crack scale
・Binocular
・Camera

Safety equipmen

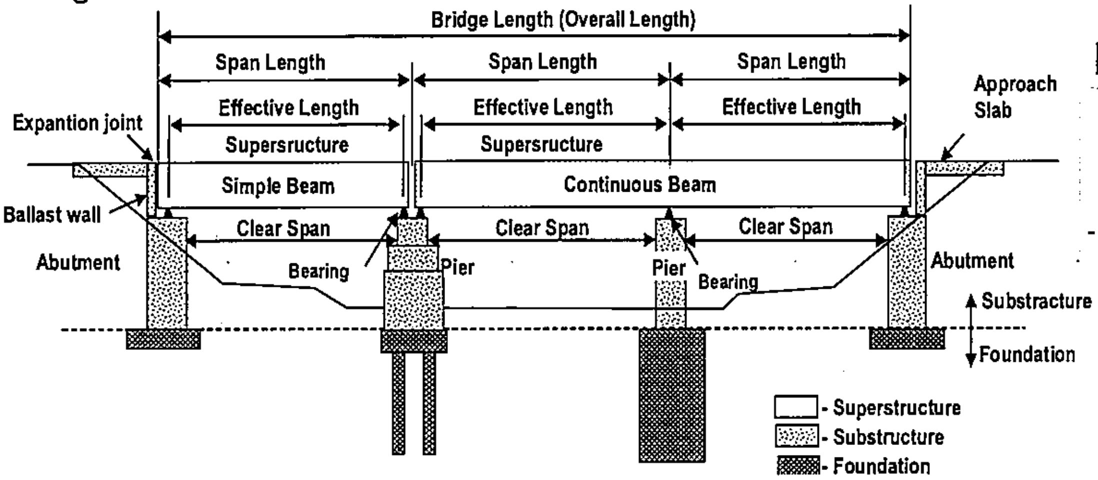


You should take care your safety by no one but by yourselves.

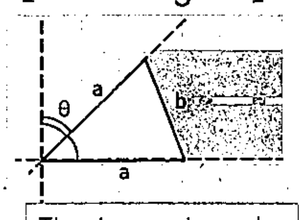
2. Basic Knowledge of Bridges

Names of Bridge Components of Bridge

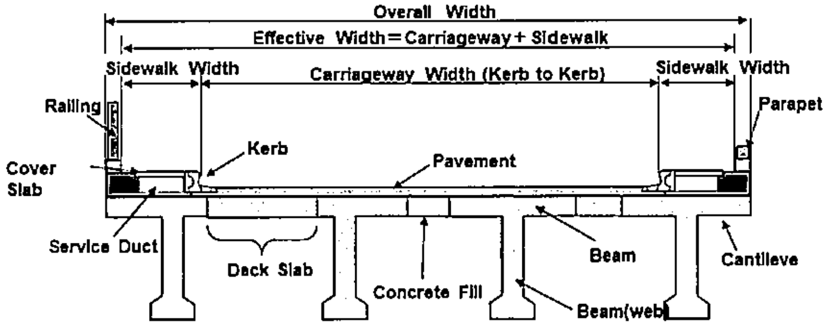
【Bridges in side view】 Bridge Length: distance between the first and the last expansion joints.



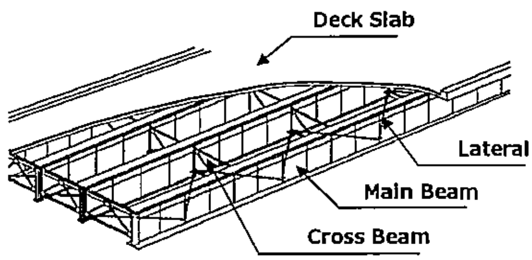
【Skew angle θ】



The skew angle can be obtained by measuring the length of two sides of a isosceles triangle.



【Cross section of concrete bridge】

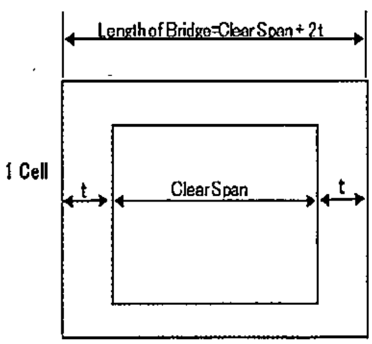


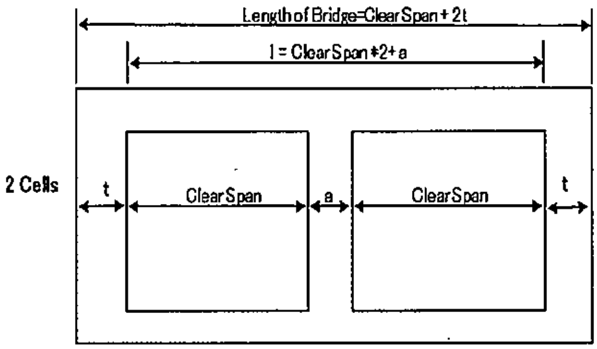
【Steel bridge】

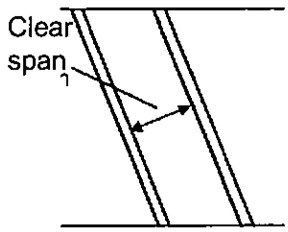
Length of Arch Bridges and Box Bridges

Box bridges are defined as those clear span is more than 3.0 meters.

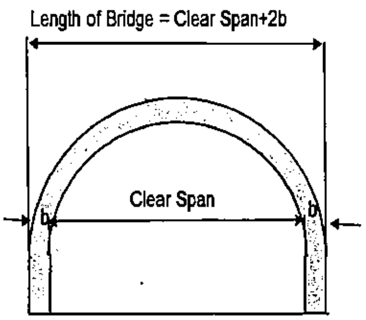
Length of bridges are given as follow figures.

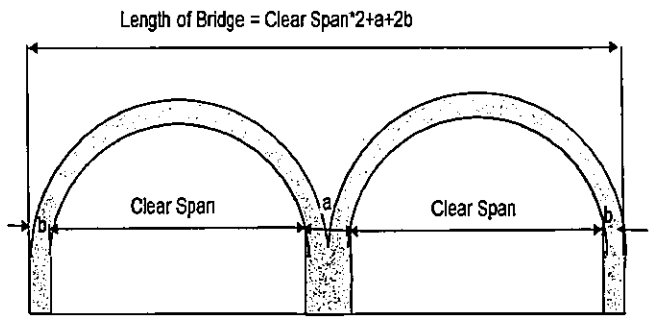






A·Clear Span of Skewed Box Bridge



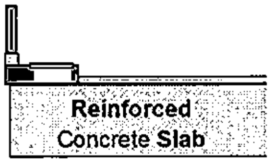


In case obtaining "a" / "b" / "t" is difficult, It may use a=1.0m, b=0.5m and, t=0.35m,

Type of Bridges(Concrete & Arch Bridge)

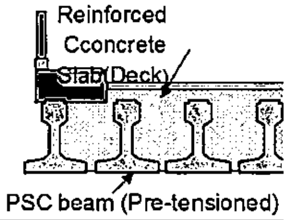
Type of Bridge		Abbreviation
Slab	RCS	RC-S.

Cross Section



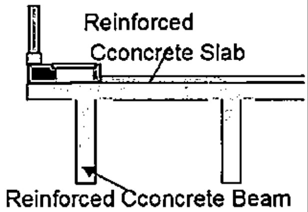
Type of Bridge		Abbreviation
Slab / Beam	PSC-PRE-Beam	PC-PR

Cross Section

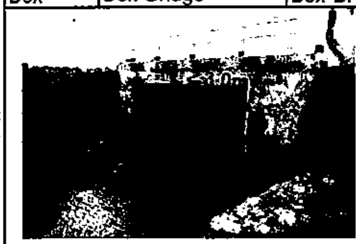


Type of Bridge		Abbreviation
Slab / Beam	RCS-RCB	RC-B

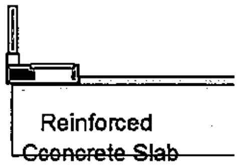
Cross Section



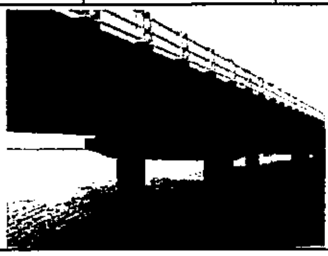
Type of Bridge		Abbreviation
Box	Box-Bridge	Box-Br



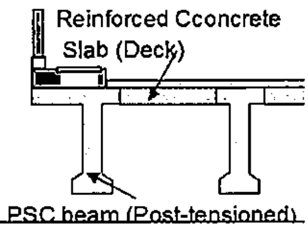
Cross Section



Type of Bridge		Abbreviation
Slab / Beam	PSC-POS-Beam	PC-PO



Cross Section



Type of Bridge		Abbreviation
Arch	Brick-Arch-Closed	Brick-Arch

【Material of Arch Bridge】

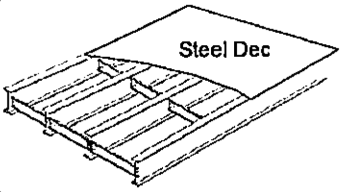
Concrete ,Stone And Brick

9

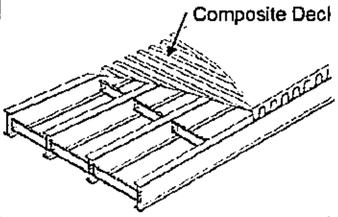
Type of Bridges(Steel Bridge)

Truss bridge are classified by the deck slab position

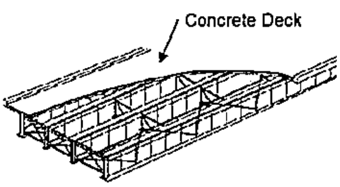
Type of Bridge	Abbreviation
Steel-RSJ-Steel Deck	ST-RSJ-S



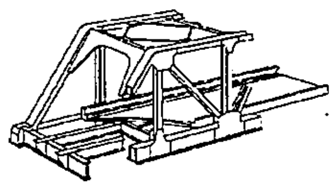
Type of Bridge	Abbreviation
Steel-RSJ-Composite	ST-RSJ-C



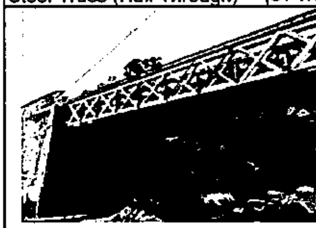
Type of Bridge	Abbreviation
Steel-Beam-Composite	ST-B

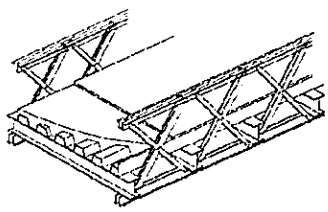


Type of Bridge	Abbreviation
Steel-Truss (Through)	ST-TR-T

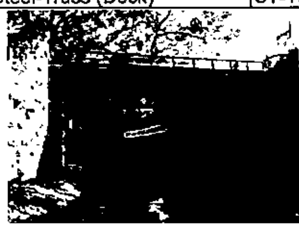


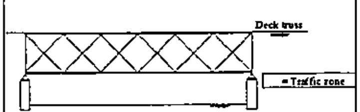
Type of Bridge	Abbreviation
Steel-Truss (Half Through)	ST-TR-H/T



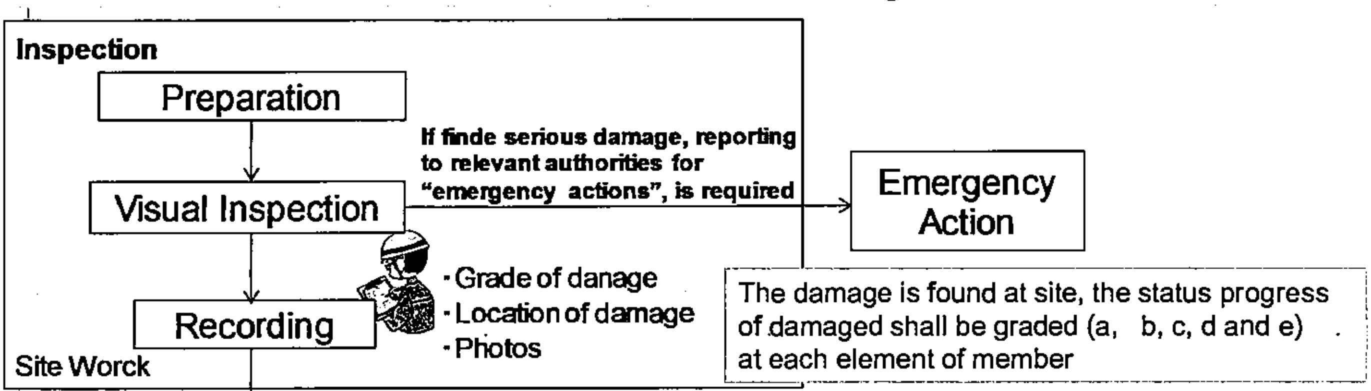


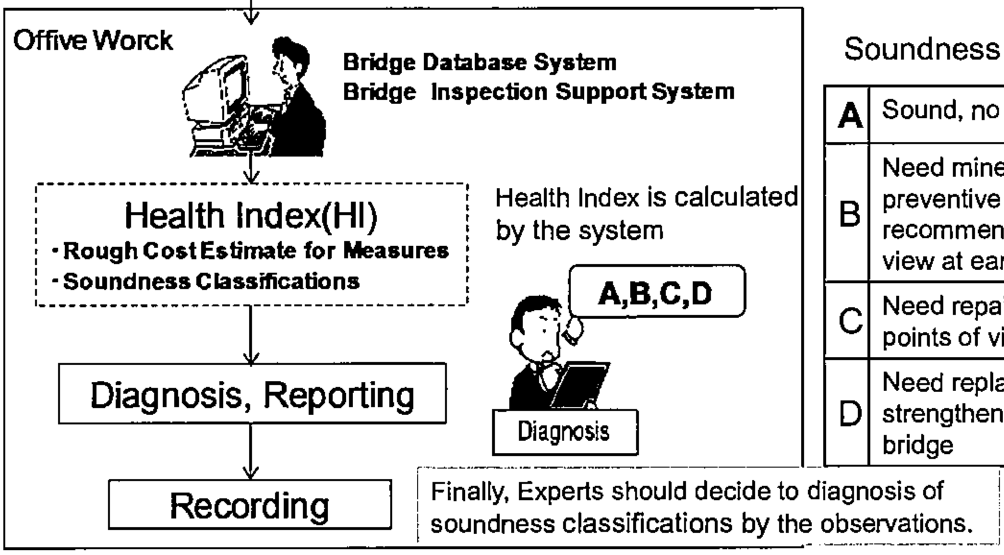
Type of Bridge	Abbreviation
Steel-Truss (Deck)	ST-TR-D





3. Flow of Periodic Bridge Inspection





Soundness Classifications(A,B,C,D)

A	Sound, no measure required minor damage
B	Need miner repair for damage needed for preventive maintenance purpose recommended for structural safety points of view at early stage
C	Need repair promptly for structural safety points of view
D	Need replacement of member / strengthening / reconstruction of entire bridge

4. Details of Bridge Inspection

Target Type of Bridge

Standard bridge types are 7 types, based on the study results of existing bridge type in Sri Lanka.

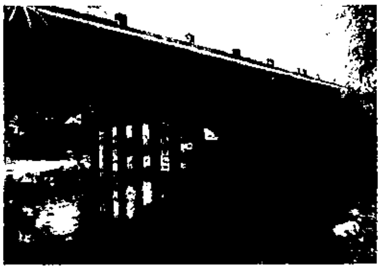
The target type bridge (7 types bridges)

No.	Type of Bridge
1	Bridge Structure (PSC-PRE)
2	Bridge Structure (RC-S)
3	Bridge Structure (PSC-POS,RCS RCB)
4	Bridge Structure (Box Bridge)
5	Bridge Structure (Truss Bridge)
6	Bridge Structure (Steel Bridge)
7	Bridge Structure (Arch Bridge)

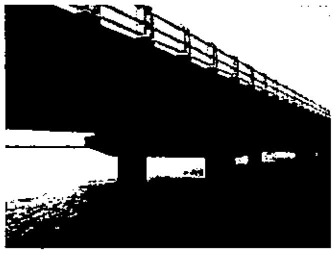
Target Type of Bridge

PSC-PRE

RC-S

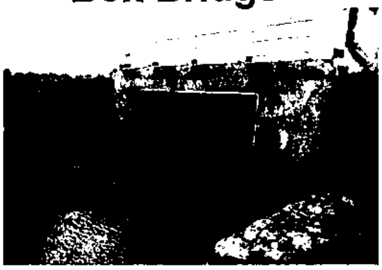


PSC-POS

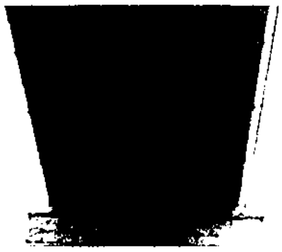


RCS-RCB

Box Bridge

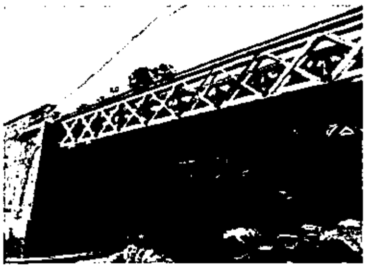


Steel Bridge(Steel Deck)

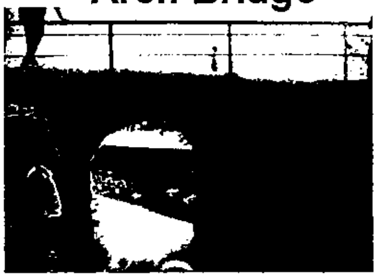


Steel Bridge(Concreet Deck)

Truss Bridge



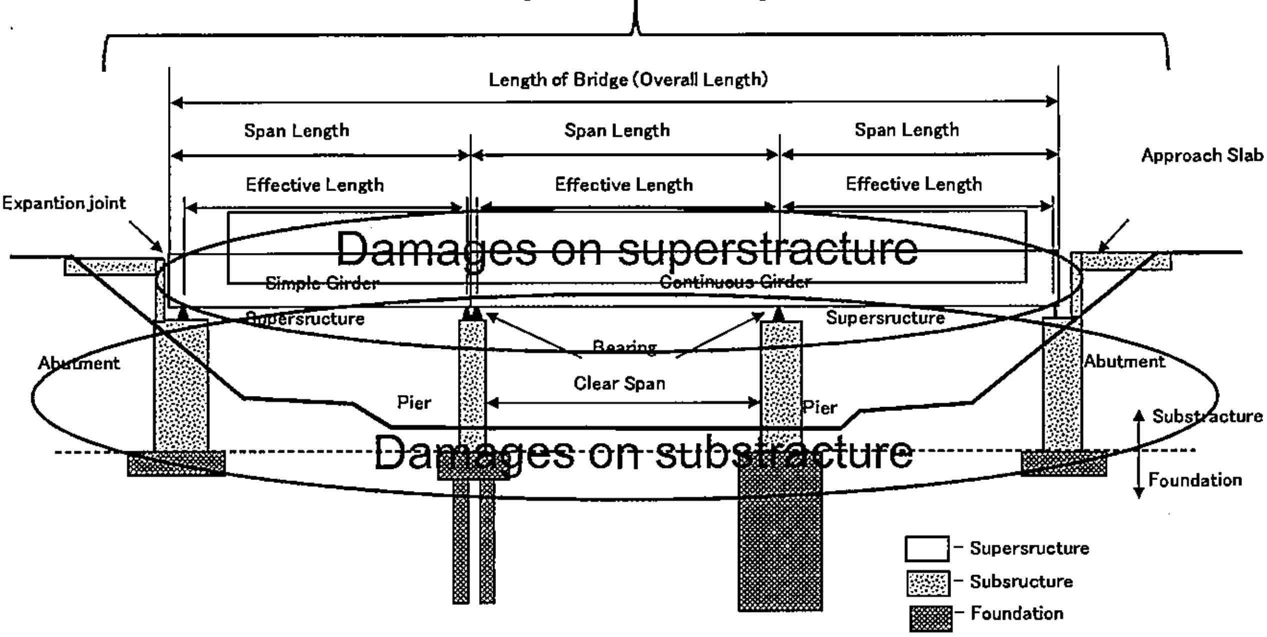
Arch Bridge



Type of Damage

Side view of the typical bridge structure

Damages on bridge surface



・Damages are often appeared in particular part of bridge surface, superstructure and substructure.

Type of Damage

11 types for bridge surface,14 types for bridge structure

Bridge Surface

No	Member	Type of Damage
1	Pavement	Pothole
2		Pavement Crack
3		Rutting
4		Waving
5	Expansio Joint	Damage on Expansion joint
6		Difference in Levels
7	Accessories	Damage on Drainage
8		Damages on Service Duct
9		Damages on Railing / Parapet
10	Approaches	Settlement of Surface
11		Approach Bank / River Bank

Bridge Structure

No	Member	Type of Damage
12	Concrete Bridge/ Member	Spall / Dela / Ex-Rebar
13		Crack
14		Damage on Anchorage
15	Bridge Bearing	Water Leakage from Expansion Joint
16		Damage on Bridge Bearing
17	Sub Structure	Scour
18		Mud Deposition / Vegetation
19	Steel/Truss Bridge	Paint Degradation
20		Corrosion
21		Damage (Rivet / HSFG)
22		Damage of Deck Slab
23	Arch Bridge	Arch Line (Displacement)
24		Deteriorated (Loose)
25		Others

Standard Grade of Damage

The evaluation of damage is classified in to 5 grades for each type of damage at each element of member.

Grade of Damage	Status	Status progress of damage Severity/Extent
a	Sound	There is no damage on bridge member.
b	Almost sound	Damage on bridge member is small.
c	Slight	There is a certain degree of damage on bridge member.
d	Remarkable	Damage on bridge member is remarkable.
e	Serious	Damage on bridge member serious.

・Some damage, only"a", "c"and"e" , or only "a"and"e".
・Appendix is given classified grades for each type of damage.

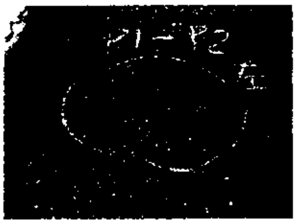
Grading for Each Type of Damage(1)

A. Bridge Surface

No.1 Pothole

Grade of Damage	General Condition
a	Not Exist
b	-
c	Depth < 50mm Deck is not exposed
d	-
e	Depth >=50mm Deck is exposed

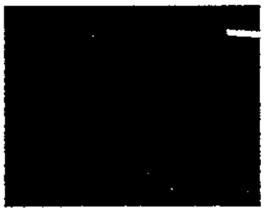
Sample "e"



No.2 Pavement Crack

Grade of Damage	**General Condition**
a	Not Exist
b	-
c	Crack width < 5 mm
d	-
e	Crack width >=5 mm

Sample "c"

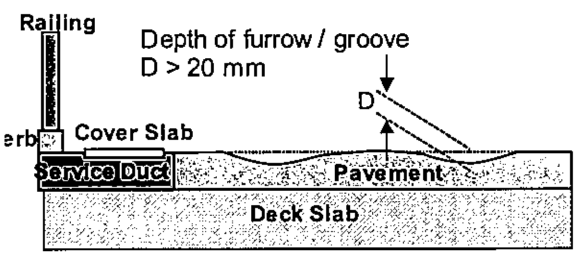


Sample "e"

Grading for Each Type of Damage(2)

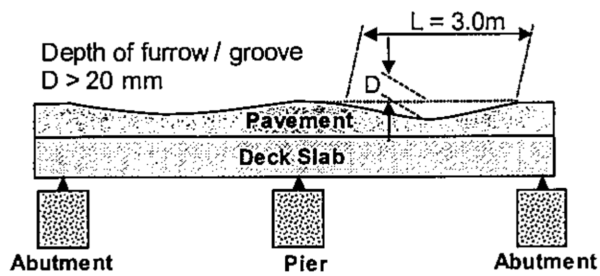
No.3 Rutting

Grade of Damage	General Condition
a	Not Exist
b	-
c	凹凸: About 20 mm< D < about 30 mm
d	-
e	凹凸: D >= about 30 mm



No.4 Waving

Grade of Damage	**General Condition**
a	Not Exist
b	-
c	凹凸: D< about 20 mm
d	-
e	凹凸: D>= about 20 mm



Grading for Each Type of Damage(3)

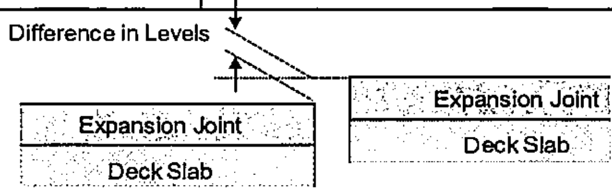
No.5 Damage on Expansion Joint

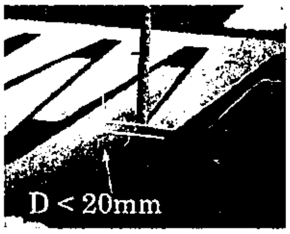
Grade of Damage	General Condition
a	Not Exist
b	[redacted]
c	[redacted]
d	[redacted]
e	Expansion joint is damaged.

Sample "e"

No.6 Difference in Levels

Grade of Damage	General Condition
a	Not Exist
b	[redacted]
c	D< about 20 mm
d	[redacted]
e	D>= about 20 mm





Grading for Each Type of Damage (4)

No.7 Damage of Drainage

Grade of Damage	General Condition
a	Not Exist
b	[redacted]
c	[redacted]
d	[redacted]
e	Catch basin or drainage pipe is plugged with soil and other debris.

Sample "e"

No.8 Damage on Service Duct

Grade of Damage	General Condition
a	Not Exist
b	[redacted]
c	[redacted]
d	[redacted]
e	Service duct is damaged.

Sample "e"

Grading for Each Type of Damage (5)

No.9 Damage on Railing / Parapet

Grade of Damage	General Condition
a	Not Exist
b	[redacted]
c	[redacted]
d	[redacted]
e	Railing/ Parapet is broke.

Sample "e"

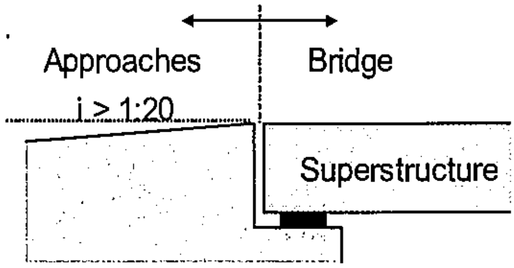
Sample "a"

Function of railing is kept.

No.10 Settlement of Surface at Approaches

Grade of Damage	General Condition
a	Not Exist
b	[redacted]
c	[redacted]
d	[redacted]
e	Approach is settled. Inline i ≥ about 1/20 .

Sample

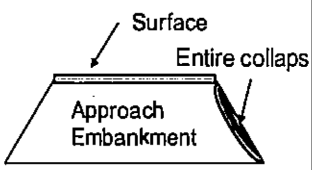


Grading for Each Type of Damage(6)

No.11 Approach Bank / River Bank

Grade of Damage	General Condition
a	Not Exist
b	[redacted]
c	[redacted]
d	[redacted]
e	Approach embankment is collapsed or out-flown.

Sample "e"



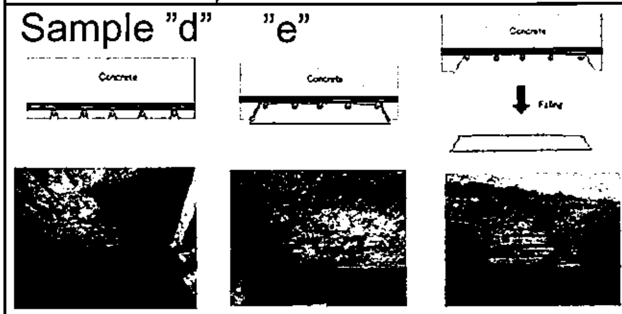
B. Bridge Structure

No.12 Spall / Dela / Exposed-Reber

These damage are major damage on concrete bridges in Sri Lanka.

Grade of Damage	General Condition
a	Not Exist
b	[redacted]
c	Spall without ex-rebar.
d	Ex-rebar with corrosion
e	Spall / Dela /broken rebar.

Sample "d" "e"



【Note】: In case, this damage is found, the same grade shall be given to the element in crack although the crack is not found.

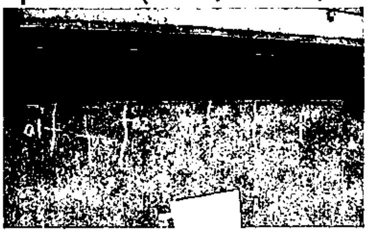
Grading for Each Type of Damage(7)

No.13 Concrete Crack

Grade of Damage	General Condition		
	RC, Box, Sub.	PSC-PRE / POS	Arch
a	Not Exist		
b	W< 0.2 & I > 50	W< 0.1 & I > 50	W< 10 & I > 50
c	W<=0.2 & I <= 50 0.2< =W< 0.3 & I >50	W<=0.1 & I <= 50 0.1< =W< 0.2 & I >50	W<=10 & I <= 50 10< =W< 30 & I >50
d	0.2< =W< 0.3 & I <=50 W>=0.3 & I >50	0.1< =W< 0.2 & I <=50 W>=0.2 & I >50	10< =W< 30 & I <=50 W>=30 & I >50
e	W>= 0.3 & I <=50	W>= 0.2 & I <=50	W>= 30 & I <=50

W: With of crack (about mm), I: Interval of crack (cm)

Sample "c" (PSC,W=0.1, I<50)



"d"(Sub. W>0.3, I>50)

"d"(Arch. W>30, I>50)

Grading for Each Type of Damage(8)

No.14 Damage on Bridge Anchorage

Grade of Damage	General Condition
a	Not Exist
b	-
c	Crack on plug concrete.
d	-
e	Trace of rust. or Broken plug concrete or remarkable damage on anchorage part.

Sample "c"

Sample "e"

No.15 Water Leakage from Expansion Joint

Grade of Damage	General Condition
a	Not Exist
b	-
c	Water leakage is existed.
d	-
e	Extreme water leakage from expansion joint and/or there is pond at bearing seat.

Sample "c"

Sample "e"

Grading for Each Type of Damage(9)

No.16 Damage on Bridge Bearing

Grade of Damage	General Condition
a	Not Exist
b	
c	Slight damage, such as corrosion of bearing, crack on bearing seat.
d	
e	There is lack of bearing function such as broken bearing.

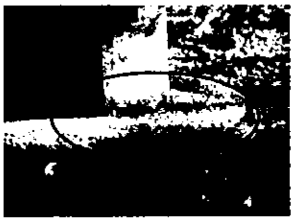
Sample "c"

Sample "e"

No.17 Scour

Grade of Damage	General Condition
a	Not Exist
b	
c	Surrounding of pier/ abutment is scoured. Caisson: Slight scour (less than width of caisson).
d	
e	Under footing of pier/ abutment is scoured. Caisson: Serious scour. (more than width of caisson).

Sample "c"



Sample "e"

Grading for Each Type of Damage(10)

No.18 Mud Deposition / Vegetation

Grade of Damage	General Condition
a	Not Exist
b	
c	
d	
e	Damage exists at substructure, truss girder, steel girder, arch rib and spandrel.

Sample "e"

No.19 Paint Degradation

This damage is major damage on steel bridges in Sri Lanka.

Grade of Damage	General Condition
a	Not Exist
b	
c	Discoloring on top coat or partial deterioration of paint film.
d	
e	Loss of paint film is degraded with large(>1/2) surface area of element and dot rust exists in element.

Sample "c"

Sample "e"

Grading for Each Type of Damage(11)

No.20 Corrosion

This damage is major damage on steel bridges in Sri Lanka.

Grade of Damage	General Condition
a	Not Exist
b	Rust and Area < 1/2 of element
c	Rust and Area >= 1/2 of element
d	Loss of section and Area < 1/2 of element
e	Loss section and Area >= 1/ 2 of element. break of steel or crack of steel

Sample

"b"

"d"

"c"

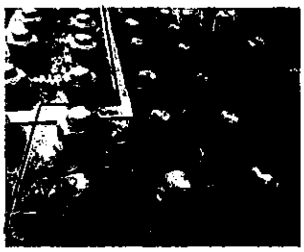
"e"

No.21 Damage (Rivet / HSFG)

Grade of Damage	General Condition
a	Not Exist
b	[redacted]
c	Nos of loose or lost bolt < 5% of bolt group.
d	[redacted]
e	Nos of loose or lost bolt $\geq$ 5% of bolt group.

Sample "c"

Sample "e"



Grading for Each Type of Damage(11)

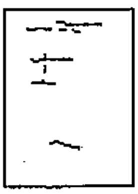
No.22 Damage of Deck Slab

22-1 Deck Slab by RC

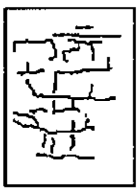
Grade of Damage	General Condition
a	Not Exist
b	Refer to the manual (22-1 Deck Slab on RC Bridge, Attachment 1: Guidelines for development of bridge inspection record sheets (example))
c	
d	
e	Broken slab

Sample (Refer).

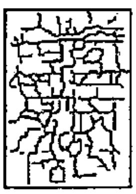
"b"



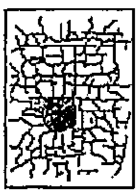
"c"



"d"



"e"

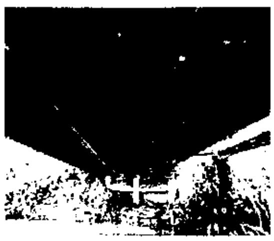


When grading is difficult, it is OK to refer this sample figure.

22-2 Deck Slab by Steel

Grade of Damage	General Condition
a	Not Exist
b	Surface rust and no water leak
c	Surface rust and water leak
d	Loss of section and slight water leak
e	Loss of section and remarkable water leak. or other serious damage such as crack of steel

Sample "b"



Sample "e"

Grading for Each Type of Damage(13)

No.23 Arch Line (Displacement)

Grade of Damage	General Condition
a	Not Exist
b	–
c	–
d	–
e	Deformation at Arch line (rib)

Sample "e"

No.24 Deteriorated (Loose)

Grade of Damage	General Condition
a	Not Exist
b	–
c	–
d	–
e	Loose or missing material of arch rib and spandrel

Sample "e"

Grading for Each Type of Damage(14)

No.25 Others

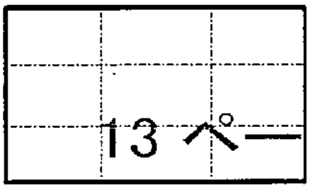
Grade of Damage	General Condition
a	Not Exist
b	–
c	–
d	–
e	Other damages shown below shall also be checked

- Abnormal sound and vibration
- Abnormal deflection
- Deformation and lack of structural members
- Settlement, movement and inclination of substructures

Divide the Bridge Member into Element

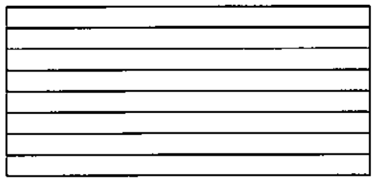
- There are 4 types of elements to divide.

< Elements as divided into 9 or 6 >



【Apply to】
Bridge surface
RC-S, Box, Arch – Superstructure
Substructure

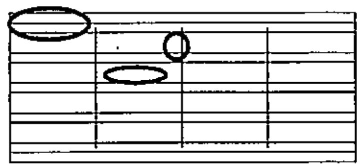
< Elements as each main beam >



【Apply to】
PSC-PRE

e.g. Number of elements: 8

< Elements as section of main beam divided by diaphragm/cross beam >



【Apply to】
PSC-POS
RCS-RCB
Truss
Steel

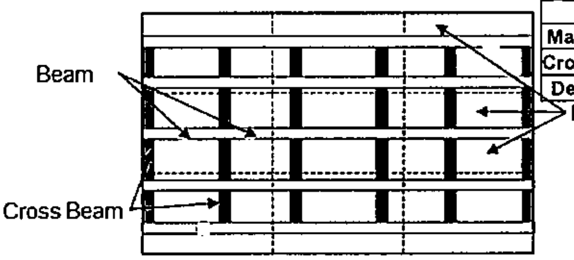
e.g. Number of elements:

Main beam	20
Cross Beam	20
Deck slab	16

<Not element: damage evaluation percentage in length/numbers >
【Apply to】 Expansion Joint, Accessories, Bridge Bearing.

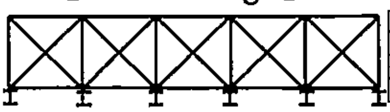
Example of Elements to Divide

【PSC-POS, RC-B, Steel】Bridge

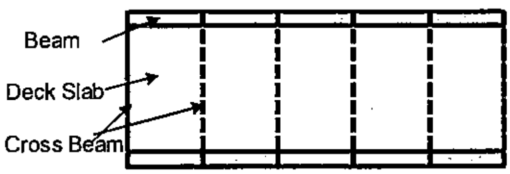


Elements	
Main beam	25
Cross beam	24
Deck slab	22

【Truss Bridge】

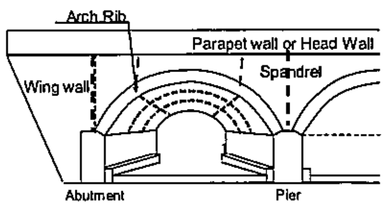


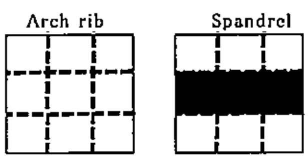
Elements	
Main beam	10
Cross beam	6
Deck slab	5



【Arch Bridge】

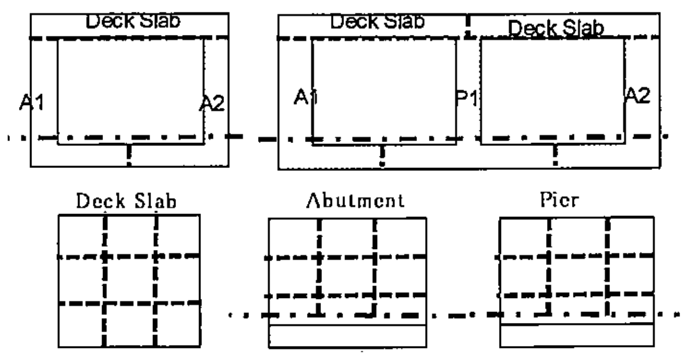
Elements	
Arch rib	9
Spandrel	6





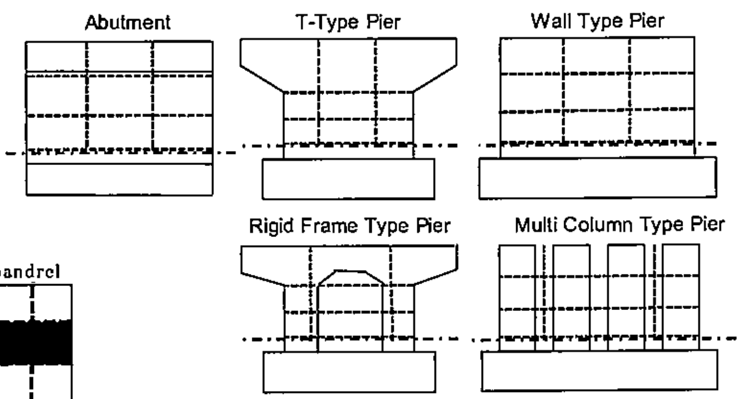
【Box Bridge】

Elements	9



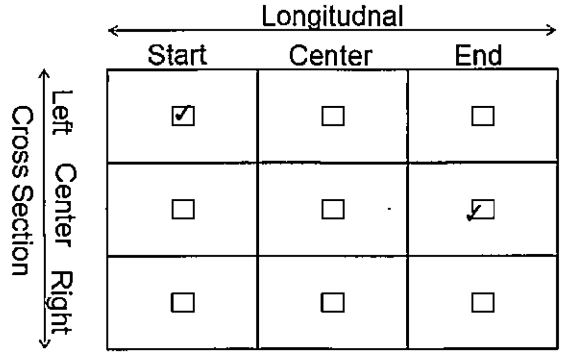
【Substructure】

Elements	9



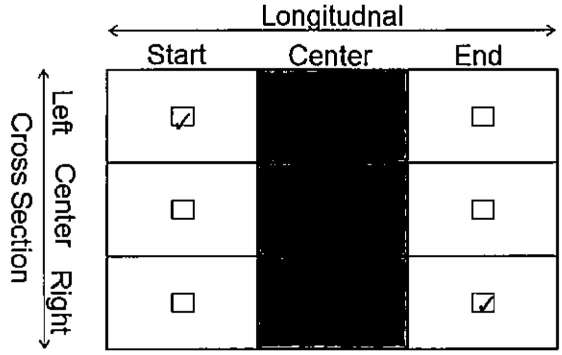
Record Method of Location the Damage

Record the locations of damage in 9 / 6 divides.

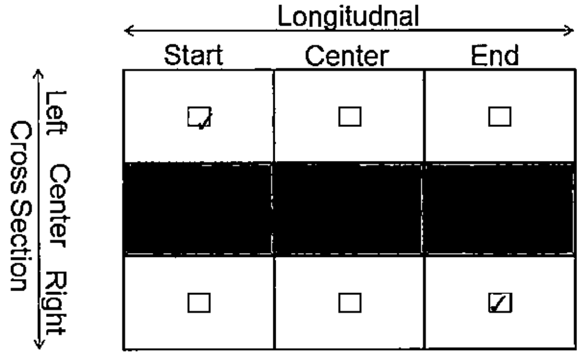


Check the element(s) "✓" where the damage with the worst category is detected.

【Expansion Joint & Approaches】



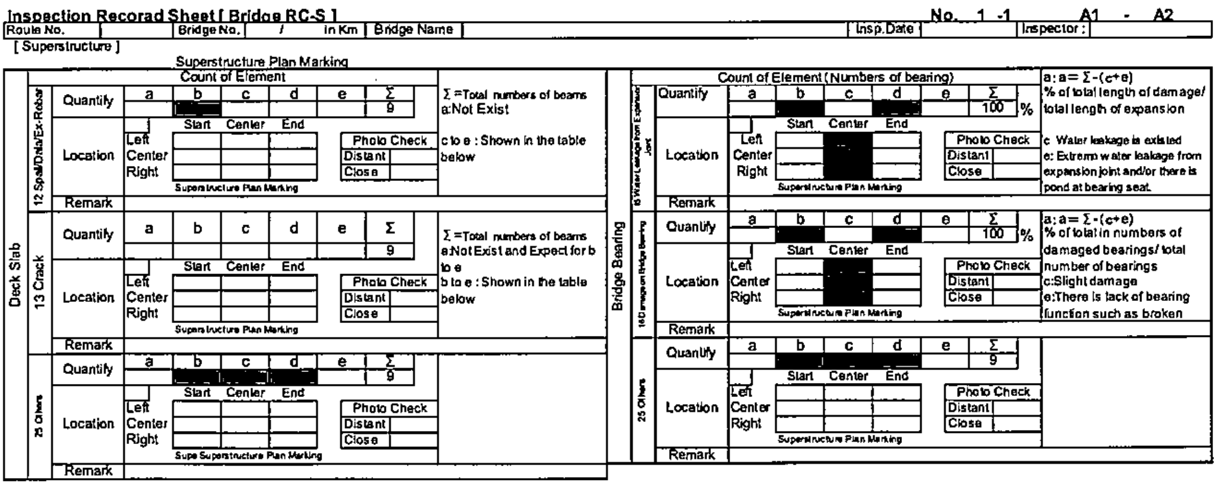
【Accessories & Spandrel of arch bridge】



5. Record of Damage on Bridge

Example of on-site memo for recording damage (RC-S)

This sheet prepare to print out in advance . Moreover, it record on-site, the quantity of elements in total, quantity of each damage grade and locations of damage with the worst category is detected, etc.



Inspection Recorad Sheet [Bridge RC-S]

No. 1 -1 A1 - A2

Route No. | Bridge No. / in Km | Bridge Name | Insp.Date | Inspector :

[Superstructure]

Superstructure Plan Marking

Deck Slab — Count of Element

12 Spall/Dela/Ex-Rebar — Quantify: a b c d e Σ 9; Location: Start Center End, Left Center Right, Superstructure Plan Marking; Photo Check: Distant, Close; Remark
Σ =Total numbers of beams
a:Not Exist
c to e : Shown in the table below

13 Crack — Quantify: a b c d e Σ 9; Location: Start Center End, Left Center Right, Superstructure Plan Marking; Photo Check: Distant, Close; Remark
Σ =Total numbers of beams
e:Not Exist and Expect for b to e
b to e : Shown in the table below

25 Others — Quantify: a b c d e Σ 9; Location: Start Center End, Left Center Right, Supe Superstructure Plan Marking; Photo Check: Distant, Close; Remark

Bridge Bearing — Count of Element (Numbers of bearing)

Water Leakage from Expansion Joint — Quantify: a b c d e Σ 100 %; Location: Start Center End, Left Center Right, Superstructure Plan Marking; Photo Check: Distant, Close; Remark
a: a= Σ-(c+e)
% of total length of damage/ total length of expansion
c: Water leakage is existed
e: Extrem water leakage from expansion joint and/or there is pond at bearing seat.

16 Damage on Bridge Bearing — Quantify: a b c d e Σ 100 %; Location: Start Center End, Left Center Right, Superstructure Plan Marking; Photo Check: Distant, Close; Remark
a: a= Σ-(c+e)
% of total in numbers of damaged bearings/ total number of bearings
c:Slight damage
e:There is lack of bearing function such as broken

25 Others — Quantify: a b c d e Σ 9; Location: Start Center End, Left Center Right, Superstructure Plan Marking; Photo Check: Distant, Close; Remark

Spall / Dele / Ex-Rebar of Grading

c	Spall without ex-rebar.
d	Ex-rebar with slight corrosion
e	Ex-rebar with remarkable corrosion or broken re-bar. Or delamination of surface concrete.

Cracks of Greading

b	Width <about 0.2mm and Interval >50 cm
c	Width about<0.2mm and Interval =<50cm Or about 0.3mm> Width > =about 0.2mm and Interval >50cm
d	Width >= about 0.3mm and Interval >50cm Or about 0.3mm> Width >=about 0.2mm and Interval =<50cm
e	Width >=about 0.3mm and Interval =<50cm

These sheets make it possible to record on 1 page for each target type of bridge, bridge surface and substructure. Therefore, the forms are slightly different from the input form of the database system. Beforehand, to input the bridge number and the span number to the excel sheet for each bridge type.

Example of On-site Memo for Recording Damage (2) (Bridge Surface)

Inspection Recorad Sheet [Bridge Surface] No. 1 A1 - A2

Route No.		Bridge No.	/	in Km	Bridge Name		Insp.Date		Inspector :	

Surface Marking

Pavement

1.Pot hole	a	b	c	d	e	Σ	
Quantify						9	a: a=9-(c+e) c: (Slab is covered by asphalt or Depth < 50mm), and Exist Pothole
Location	Left / Center / Right	Start	Center	End	Photo Check: Distant / Close		e: (Exposed slab or Depth >= 50mm), and Exist Pothoal
	Superstructure Plan Marking						
Remark							

2.Crack	a	b	c	d	e	Σ	
Quantify						9	a: a=9-(c+e)
Location	Left / Center / Right	Start	Center	End	Photo Check: Distant / Close		c: Crack width < 5 mm e: Crack width >= 5 mm
	Superstructure Plan Marking						
Remark							

3.Rutting	a	b	c	d	e	Σ	
Quantify						9	a: a=9-(c+e)
Location	Left / Center / Right	Start	Center	End	Photo Check: Distant / Close		c: Difference in level (凹凸) about: 20mm< and < about 30mm e: Difference in level (凹凸): >= about 30mm
	Superstructure Plan Marking						
Remark							

4.Waving	a	b	c	d	e	Σ	
Quantify						9	a: a=9-(c+e)
Location	Left / Center / Right	Start	Center	End	Photo Check: Distant / Close		c: Difference in level (凹凸): <about 20mm / 3.0m e: Difference in level (凹凸): >= about 20mm / 3.0m
	Superstructure Plan Marking						
Remark							

Expansion Joint

5.Dmage on Joint	a	b	c	d	e	Σ	
Quantify						100 %	a: a=100-e
Location	Left / Center / Right	Start	Center	End	Photo Check: Distant / Close		e: Total % of damage length in total length of expansion joint(100%), (the steel finger is widely opened / including trace of touching)
	Superstructure Plan Marking						
Remark							

6.Difference in Leavel	a	b	c	d	e	Σ	
Quantify						100 %	a: a=100-(c+e) Total % of damage in total length of expansion joint(100%)
Location	Left / Center / Right	Start	Center	End	Photo Check: Distant / Close		c: Difference in level < about 20mm e: Difference in level : >=about 20mm
	Superstructure Plan Marking						
Remark							

Accessories

7.Damage of Drainage	a	b	c	d	e	Σ	
Quantify						%	Total % of damaged drainage / 100% a: a=100-e
Location	Left / Center / Right	Start	Center	End	Photo Check: Distant / Close		e: % of damaged catch basin or pipe is plugged with mad
	Superstructure Plan Marking						
Remark							

8.Damage on Service Duct	a	b	c	d	e	Σ	
Quantify						%	Total % of damaged service duct in length / total of service duct in length(100%) a: a=100-e
Location	Left / Center / Right	Start	Center	End	Photo Check: Distant / Close		e: % of damaged in length
	Superstructure Plan Marking						
Remark							

9.Damage on Railing/Parapet	a	b	c	d	e	Σ	
Quantify						100 %	Total % of damage in length /total length of handrail(100%) a: a=100-e
Location	Left / Center / Right	Start	Center	End	Photo Check: Distant / Close		e: % of Broke in length
	Superstructure Plan Marking						
Remark							

Approaches

10.Setlment of Surface	a	b	c	d	e	Σ	
Quantify						6	a: a= 6 − e
Location	Left / Center / Right	Start	Center	End	Photo Check: Distant / Close		e: Exist(i>=about 1/20)
	Superstructure Plan Marking						
Remark							

11.Approach Bank/River Bank Joint	a	b	c	d	e	Σ	
Quantify						6	a: a= 6 − e
Location	Left / Center / Right	Start	Center	End	Photo Check: Distant / Close		e: Exist
	Superstructure Plan Marking						
Remark							

Others

25 Others	a	b	c	d	e	Σ
Quantify						9
Location	Left / Center / Right	Start	Center	End	Photo Check: Distant / Close	
	Superstructure Plan Marking					
Remark						

35

Example of On-site Memo for Recording Damage(3) (Bridge Structure(PSC-PRE))

Inspection Recorad Sheet [Bridge PSC-PRE] No. 1 -1 A1 - A2

Route No.		Bridge No.	/	in Km	Bridge Name		Insp.Date		Inspector :	

[Superstructure]

Superstructure Plan Marking

Main Beam — Count of Element (Numbers of beam)

12 Spall/Dela/Ex-Rebar	a	b	c	d	e	Σ	
Quantify							Σ =Total numbers of beams a: Not Exist
Location	Left / Center / Right	Start	Center	End	Photo Check: Distant / Close		c to e : Shown in the table Right
	Superstructure Plan Marking						
Remark							

13 Crack	a	b	c	d	e	Σ	
Quantify							Σ =Total numbers of beams a: Not Exist and Expect for b to e
Location	Left / Center / Right	Start	Center	End	Photo Check: Distant / Close		b to e : Shown in the table Right
	Superstructure Plan Marking						
Remark							

14 Damage on Anchorage	a	b	c	d	e	Σ	
Quantify							Σ =(Numbers of beams)×2 a: Not Exist
Location	Left / Center / Right	Start	Center	End	Photo Check: Distant / Close		c: Crack on plug concrete e: Trace of rust, Broken plug concrete or remarkable damage on anchorage part etc.
	Supe Superstructure Plan Marking						
Remaek							

25 Others	a	b	c	d	e	Σ
Quantify						9
Location	Left / Center / Right	Start	Center	End	Photo Check: Distant / Close	
	Superstructure Plan Marking					
Remark						

Bridge Bearing — Count of Element (Numbers of bearing)

15 Water Leakage from Expansion Joint	a	b	c	d	e	Σ	
Quantify						100 %	a: a= Σ-(c+e) % of total length of damage/ total length of expansion
Location	Left / Center / Right	Start	Center	End	Photo Check: Distant / Close		c: Water leakage is existed e: Extreme water leakage from expansion joint and/or there is pond at bearing seat.
	Superstructure Plan Marking						
Remark							

16 Damage on Bridge Bearing	a	b	c	d	e	Σ	
Quantify						100 %	a: a= Σ-(c+e) % of total in numbers of damaged bearings/ total number of bearings
Location	Left / Center / Right	Start	Center	End	Photo Check: Distant / Close		c: Slight damage e: There is lack of bearing function such as broken
	Superstructure Plan Marking						
Remark							

25 Others	a	b	c	d	e	Σ
Quantify						9
Location	Left / Center / Right	Start	Center	End	Photo Check: Distant / Close	
	Superstructure Plan Marking					
Remark						

Spall / Dela / Ex-Rebar of Grading

c	Spall without ex-rebar.
d	Ex-rebar with slight corrosion
e	Ex-rebar with remarkable corrosion or broken re-bar. Or delamination of surface concrete.

Cracks of Greading

b	Width < about 0.1mm and Interval >50 cm
c	Width <about 0.1mm and Interval =<50cm Or about 0.2mm> Width > =about 0.1mm and Interval >50cm
d	Width >= about 0.2mm and Interval >50cm Or about 0.2mm> Width >= about 0.1mm and Interval =<50cm
e	Width >= about 0.2mm and Interval =<50cm

Example of On-site Memo for Recording Damage(4) (Bridge Structure(Sub structure))

Inspection Recorad Sheet [Bridge] No. 1 -2 A1 - A2

Route No.	0	Bridge No.	0 . / 0 .	in Km	Bridge Name	0	Insp.Date	0	Inspector :	0

[Substructure] A1, A2

[A1 Side]

Substructure											
17 Scour	Quantify		a	b	c	d	e	Σ		a:Not Exist
								1		
	Location		Left	Center	Right		Photo Check			c:Sorround of footing (0 or 1)
		Upper					Distant			e:Under footing (0 or 1)
		Middle					Close			
		Lower	Substructure Front Marking							
	Remark									
12 Spall/Dela/Ex-Rebar	Quantify	Count of Element	a	b	c	d	e	Σ		a:Not Exist c:Spall without ex-rebar. d:Ex-rebar with slight corrosion e:Ex-rebar with remarkable corrosion or broken re-bar or Ex-rebar with remarkable corrosion or broken re-bar.
								9		
	Location		Left	Center	Right		Photo Check			
		Upper					Distant			
		Middle					Close			
		Lower	Substructure Front Marking							
	Remark									
13 Crack	Quantify	Count of Element	a	b	c	d	e	Σ		Σ=Total numbers of beams a:Not Exist and Expect for b to e b to e : Shown in the table bolow
								9		
	Location		Left	Center	Right		Photo Check			
		Upper					Distant			
		Middle					Close			
		Lower	Substructure Front Marking							
	Remark									
18 Mud Deposition / Vegetation	Quantify		a	b	c	d	e	Σ		a:Not Exist
								9		e:Exist
	Location		Left	Center	Right		Photo Check			
		Upper					Distant			
		Middle					Close			
		Lower	Substructure Front Marking							
	Remark									
25 Others	Quantify		a	b	c	d	e	Σ		
								9		
	Location		Start	Center	End		Photo Check			
		Left					Distant			
		Center					Close			
		Right	Substructure Front Marking							
	Remark									

[A2 Side]

Substructure											
17 Scour	Quantify		a	b	c	d	e	Σ		a:Not Exist
								1		
	Location		Left	Center	Right		Photo Check			c:Sorround of footing (0 or 1)
		Upper					Distant			e:Under footing (0 or 1)
		Middle					Close			
		Lower	Substructure Front Marking							
	Remark									
12 Spall/Dela/Ex-Rebar	Quantify	Count of Element	a	b	c	d	e	Σ		a:Not Exist c:Spall without ex-rebar. d:Ex-rebar with slight corrosion e:Ex-rebar with remarkable corrosion or broken re-bar or Ex-rebar with remarkable corrosion or broken re-bar.
								9		
	Location		Left	Center	Right		Photo Check			
		Upper					Distant			
		Middle					Close			
		Lower	Substructure Front Marking							
	Remark									
13 Crack	Quantify	Count of Element	a	b	c	d	e	Σ		Σ=Total numbers of beams a:Not Exist and Expect for b to e b to e : Shown in the table bolow
								9		
	Location		Left	Center	Right		Photo Check			
		Upper					Distant			
		Middle					Close			
		Lower	Substructure Front Marking							
	Remark									
18 Mud Deposition / Vegetation	Quantify		a	b	c	d	e	Σ		a:Not Exist
								9		e:Exist
	Location		Left	Center	Right		Photo Check			
		Upper					Distant			
		Middle					Close			
		Lower	Substructure Front Marking							
	Remark									
25 Others	Quantify		a	b	c	d	e	Σ		
								9		
	Location		Start	Center	End		Photo Check			
		Left					Distant			
		Center					Close			
		Right	Substructure Front Marking							
	Remark									

Cracks of Greading

b	Width < about 0.2mm and Interval >50 cm
c	Width <about 0.2mm and Interval =<50cm Or about 0.3mm> Width > =about 0.2mm and Interval >50cm
d	Width >= about 0.3mm and Interval >50cm Or about 0.3mm> Width >=about 0.2mm and Interval =<50cm
e	Width >= about 0.3mm and Interval =<50cm

Example of On-site Memo for Recording Damage(5) (Bridge Structure(Box Bridge))

Inspection Recorad Sheet [Box Bridge] No. 1 A1 - A2

Route No.		Bridge No.	/	in Km	Bridge Name		Insp.Date		Inspector :	

[Superstructure]

Superstructure Plan Marking

Superstructure											
12 Spall/Dela/Ex-Rebar	Quantify	Count of Element (Numbers of beam)	a	b	c	d	e	Σ		a:Not Exist c:Spall without ex-rebar. d:Ex-rebar with slight corrosion e:Ex-rebar with remarkable corrosion or broken re-bar or Ex-rebar with remarkable corrosion or broken re-bar.
								9		
	Location		Start	Center	End		Photo Check			
		Left					Distant			
		Center					Close			
		Right								
	Remark									
13 Crack	Quantify		a	b	c	d	e	Σ		Σ=Total numbers of beams a:Not Exist and Expect for b to e b to e : Shown in the table right
								9		
	Location		Start	Center	End		Photo Check			
		Left					Distant			
		Center					Close			
		Right								
	Remark									

Cracks of Greading

b	Width < about 0.2mm and Interval >50 cm
c	Width <about 0.2mm and Interval =<50cm Or about 0.3mm> Width > = about 0.2mm and Interval >50cm
d	Width >= about 0.3mm and Interval >50cm Or about 0.3mm> Width > about 0.2mm and Interval =<50cm
e	Width >= about 0.3mm and Interval =<50cm

If there is the Other, Recording to here (Superstructure, Substructure side)

25 Others									
	Quantify		a	b	c	d	e	Σ
								9
	Location		Start	Center	End		Photo Check	
		Left					Distant	
		Center					Close	
		Right						
	Remark							

Substructure A1 Side

17 Scour	Quantify		a	b	c	d	e	Σ	a:Not Exist
								1	
	Location		Left	Center	Right		Photo Check		c:Sorround of footing (0 or 1)
		Upper					Distant		e:Under footing (0 or 1)
		Middle					Close		
		Lower							
	Remark								
12 Spall/Dela/Ex-Rebar	Quantify		a	b	c	d	e	Σ	a:Not Exist
								9	
	Location		Left	Center	Right		Photo Check		c to e : Shown in the superstructure
		Upper					Distant		
		Middle					Close		
		Lower							
	Remark								
13 Crack	Quantify		a	b	c	d	e	Σ	Σ=Total numbers of beams a:Not Exist and Expect for b to e b to e : Shown in the table above
								9	
	Location		Left	Center	Right		Photo Check		
		Upper					Distant		
		Middle					Close		
		Lower							
	Remark								
18 Mud Deposition / Vegetation	Quantify		a	b	c	d	e	Σ	a:Not Exist
	Location		Left	Center	Right		Photo Check		e:Exist
		Upper					Distant		
		Middle					Close		
		Lower							
	Remark								

Substructure A2 Side

17 Scour	Quantify		a	b	c	d	e	Σ	a:Not Exist
								1	
	Location		Left	Center	Right		Photo Check		c:Sorround of footing (0 or 1)
		Upper					Distant		e:Under footing (0 or 1)
		Middle					Close		
		Lower							
	Remark								
12 Spall/Dela/Ex-Rebar	Quantify		a	b	c	d	e	Σ	a:Not Exist
								9	
	Location		Left	Center	Right		Photo Check		c to e : Shown in the superstructure
		Upper					Distant		
		Middle					Close		
		Lower							
	Remark								
13 Crack	Quantify		a	b	c	d	e	Σ	Σ=Total numbers of beams a:Not Exist and Expect for b to e b to e : Shown in the table above
								9	
	Location		Left	Center	Right		Photo Check		
		Upper					Distant		
		Middle					Close		
		Lower							
	Remark								
18 Mud Deposition / Vegetation	Quantify		a	b	c	d	e	Σ	a:Not Exist
	Location		Left	Center	Right		Photo Check		e:Exist
		Upper					Distant		
		Middle					Close		
		Lower							
	Remark								

Example of On-site Memo for Recording Damage(6) (Bridge Structure(PSC-POS))

Inspection Recorad Sheet [Bridge PSC-POS] No. 1 -1 A1 - A2

Route No.		Bridge No.	/	in Km	Bridge Name		Insp.Date		Inspector :

[Superstructure]

Superstructure Plan Marking

Main beam

12 Spall/Dela/Ex-Rebar — Count of Element (Numbers of beam)

Quantity	a	b	c	d	e	Σ

Location: Start / Center / End; Left / Center / Right; Superstructure Plan Marking; Photo Check: Distant / Close

Σ=Total numbers of beams
a:Not Exist
c to e : Shown in the table bolow

Remark

13 Crack

Quantity	a	b	c	d	e	Σ

Location: Start / Center / End; Left / Center / Right; Superstructure Plan Marking; Photo Check: Distant / Close

Σ=Total numbers of beams
a:Not Exist and Expect for b to e
b : Width < about 0.1mm and Interval >50 cm
c to e : Shown in the table bolow

Remark

14 Damage on Anchorage

Quantity	a	b	c	d	e	Σ

Location: Start / Center / End; Left / Center / Right; Superstructure Plan Marking; Photo Check: Distant / Close

Σ=(Numbers of beams)×2
a:Not Exist
c: Crack on plug concrete
e: Trace of rust, Broken plug concrete or remarkable damage on anchorage part etc.

Remaek

Deck Slab

12 Spall/Dela/Ex-Rebar — Count of Element (Slab devided by girder and cross beam)

Quantity	a	b	c	d	e	Σ

Location: Start / Center / End; Left / Center / Right; Superstructure Plan Marking; Photo Check: Distant / Close

Σ=Total numbers of beams
a:Not Exist
c to e : Shown in the table bolow

Remark

13 Crack — Count of Element

Quantity	a	b	c	d	e	Σ

Location: Start / Center / End; Left / Center / Right; Superstructure Plan Marking; Photo Check: Distant / Close

Σ=Total numbers of beams
a: a=Σ-(b+c+d+e)
b : W< 0.2mm & I>50 cm
c:W<0.2mm & I=<50cm, Or 0.3mm>W>=0.2mm & I>50cm
d:W>=0.3mm & I>50cm, Or 0.3mm>W>=0.2mm & I=<50cm
e: W>=0.3mm & I=<50cm

Remark

Diaphragm

12 Spall/Dela/Ex-Rebar — Count of Element (Slab devided by girder and cross beam)

Quantity	a	b	c	d	e	Σ

Location: Start / Center / End; Left / Center / Right; Superstructure Plan Marking; Photo Check: Distant / Close

Σ=Total numbers of beams
a:Not Exist
c to e : Shown in the table bolow

Remark

13 Crack — Count of Element

Quantity	a	b	c	d	e	Σ

Location: Start / Center / End; Left / Center / Right; Superstructure Plan Marking; Photo Check: Distant / Close

Σ=Total numbers of beams
a:Not Exist and Expect for b to e
b : Width < about 0.1mm and Interval >50 cm
c to e : Shown in the table bolow

Remark

Bridge Bearing

15 Water Leakage from Expansion Joint — Count of Element (Numbers of bearing)

Quantity	a	b	c	d	e	Σ	
						100	%

Location: Start / Center / End; Left / Center / Right; Superstructure Plan Marking; Photo Check: Distant / Close

a: a= Σ-(c+e)
% of total length of damage/ total length of expansion
c: Water leakage is existed
e: Extreme water leakage from expansion joint and/or there is pond at bearing seat.

Remark

16 Damage on Bridge Bearing

Quantity	a	b	c	d	e	Σ	
						100	%

Location: Start / Center / End; Left / Center / Right; Superstructure Plan Marking; Photo Check: Distant / Close

a: a= Σ-(c+e)
% of total in numbers of damaged bearings/ total number of bearings
c:Slight damage
e:There is lack of bearing function such as broken

Remark

Others

If there is a others damage in the superstructure / bearing, record it here(superstructure / bearing)

25 Others

Quantity	a	b	c	d	e	Σ
						9

Location: Start / Center / End; Left / Center / Right; Superstructure Plan Marking; Photo Check: Distant / Close

Remark

Spall / Dela / Ex-Rebar of Grading

c	Spall without ex-rebar.
d	Ex-rebar with slight corrosion
e	Ex-rebar with remarkable corrosion or broken re-bar. Or delamination of surface concrete.

Cracks of Greading

c	Width <about 0.1mm and Interval =<50cm Or about 0.2mm> Width > =about 0.1mm and Interval >50cm
d	Width >= about 0.2mm and Interval >50cm Or about 0.2mm> Width >= about 0.1mm and Interval =<50cm
e	Width >= about 0.2mm and Interval =<50cm

Example of On-site Memo for Recording Damage(7) (Bridge Structure(RC-RCB))

Inspection Recorad Sheet [Bridge RCS-RCB] No. 1 -1 A1 - A2

Route No.		Bridge No.	/	in Km	Bridge Name		Insp.Date		Inspector :

[Superstructure]

Superstructure Plan Marking

Main beam

12 Spall/Dela/Ex-Rebar — Count of Element (Numbers of beam)

Quantity	a	b	c	d	e	Σ

Location: Start / Center / End; Left / Center / Right; Superstructure Plan Marking; Photo Check: Distant / Close

Σ=Total numbers of beams
a:Not Exist
c to e : Shown in the table bolow

Remark

13 Crack

Quantity	a	b	c	d	e	Σ

Location: Start / Center / End; Left / Center / Right; Superstructure Plan Marking; Photo Check: Distant / Close

Σ=Total numbers of beams
a:Not Exist and Expect for b to e
b : Width <about 0.2mm and Interval >50 cm
c to e : Shown in the table bolow

Remark

Quantity	a	b	c	d	e	Σ

Location: Start / Center / End; Left / Center / Right; Superstructure Plan Marking; Photo Check: Distant / Close

Not applicable

Remaek

Deck Slab

12 Spall/Dela/Ex-Rebar — Count of Element (Slab devided by girder and cross beam)

Quantity	a	b	c	d	e	Σ

Location: Start / Center / End; Left / Center / Right; Superstructure Plan Marking; Photo Check: Distant / Close

Σ=Total numbers of beams
a:Not Exist
c to e : Shown in the table bolow

Remark

13 Crack — Count of Element

Quantity	a	b	c	d	e	Σ

Location: Start / Center / End; Left / Center / Right; Superstructure Plan Marking; Photo Check: Distant / Close

Σ=Total numbers of beams
a:Not Exist and Expect for b to e
b : Width <about 0.2mm and Interval >50 cm
c to e : Shown in the table bolow

Remark

Diaphragm

12 Spall/Dela/Ex-Rebar — Count of Element (Slab devided by girder and cross beam)

Quantity	a	b	c	d	e	Σ

Location: Start / Center / End; Left / Center / Right; Superstructure Plan Marking; Photo Check: Distant / Close

Σ=Total numbers of beams
a:Not Exist
c to e : Shown in the table bolow

Remark

13 Crack — Count of Element

Quantity	a	b	c	d	e	Σ

Location: Start / Center / End; Left / Center / Right; Superstructure Plan Marking; Photo Check: Distant / Close

Σ=Total numbers of beams
a:Not Exist and Expect for b to e
b : Width <about 0.2mm and Interval >50 cm
c to e : Shown in the table bolow

Remark

Bridge Bearing

15 Water Leakage from Expansion Joint — Count of Element (Numbers of bearing)

Quantity	a	b	c	d	e	Σ	
						100	%

Location: Start / Center / End; Left / Center / Right; Superstructure Plan Marking; Photo Check: Distant / Close

a: a= Σ-(c+e)
% of total length of damage/ total length of expansion
c: Water leakage is existed
e: Extreme water leakage from expansion joint and/or there is pond at bearing seat.

Remark

16 Damage on Bridge Bearing

Quantity	a	b	c	d	e	Σ	
						100	%

Location: Start / Center / End; Left / Center / Right; Superstructure Plan Marking; Photo Check: Distant / Close

a: a= Σ-(c+e)
% of total in numbers of damaged bearings/ total number of bearings
c:Slight damage
e:There is lack of bearing function such as broken

Remark

Others

If there is a others damage in the superstructure / bearing, record it here(superstructure / bearing)

25 Others

Quantity	a	b	c	d	e	Σ
						9

Location: Start / Center / End; Left / Center / Right; Superstructure Plan Marking; Photo Check: Distant / Close

Remark

Spall / Dela / Ex-Rebar of Grading

c	Spall without ex-rebar.
d	Ex-rebar with slight corrosion
e	Ex-rebar with remarkable corrosion or broken re-bar. Or delamination of surface concrete.

Cracks of Greading

c	Width <about 0.2 mm and Interval =<50cm Or about 0.3mm> Width > =about 0.2mm and Interval >50cm
d	Width >= about 0.3mm and Interval >50cm Or about 0.3mm> Width > about 0.2mm and Interval =<50cm
e	about 0.3mm and Interval =<50cm

Example of On-site Memo for Recording Damage(8) (Bridge Structure(Truss & Steel Bridge))

Inspection Recorad Sheet [Steel Bridge] No. 1 -1 A1 - A2

Route No.		Bridge No.	/ in Km	Bridge Name		Insp.Date		Inspector :	

[Superstructure]

Superstructure Plan Marking

Main Beam — 19 Paint Degradation

Count of Element(Beam devided by crosss beam)

Quantity	a	b	c	d	e	Σ

Location	Start	Center	End	Photo Check	
Left				Distant	
Center				Close	
Right					

Superstructure Plan Marking

a= Σ-(c+e)
a:Not Exist
b: Discoloring on top coat or partial delamination of paint film
e:Loss of paint film is degraded >1/2 of surface area or rust exists

Remark

Main Beam — 20 Corrosion

Count of Element(Beam devided by crosss beam)

Quantity	a	b	c	d	e	Σ

Location	Start	Center	End	Photo Check	
Left				Distant	
Center				Close	
Right					

Superstructure Plan Marking

a:Not Exist
b :Rust and Area < 1/2 of element
C:Rust and Area > 1/2of element
d: Loss of section and Area < 1/2 of element
e: Shown in the table below

Remark

Main Beam — 21 Damage (Rivet / HSFG

Count of Element(Beam devided by crosss beam)

Quantity	a	b	c	d	e	Σ

Location	Start	Center	End	Photo Check	
Left				Distant	
Center				Close	
Right					

Superstructure Plan Marking

a:Not Exist
c;Nos of loose or lost bolt < 5% of bolt group
e: Nos of loose or lost bolt > 5% of bolt group

Remark

Main Beam — 18 Mud Deposition / Vegetation

Count of Element(Beam devided by crosss beam)

Quantity	a	b	c	d	e	Σ

Location	Start	Center	End	Photo Check	
Left				Distant	
Center				Close	
Right					

a:Not Exist
e:Exist

Remark

Deck Slab — 12 Damage on Deck Sab

Count of Element(Slab devided by beam and cross beam)

Quantity	a	b	c	d	e	Σ

Location	Start	Center	End	Photo Check	
Left				Distant	
Center				Close	
Right					

Superstructure Plan Marking

a:Not Exist
b to e ; Shown in the table bolow

Remark

RC deck slab

b to e	Refer to the manual (22-1 Deck Slab on RC Bride, Attachment 1; Guidelines for Development of Bridge Inspection Record Sheels (Example))
e	Broken slab

Cross Beam — 20 Corrosion

Count of Element(Slab devided by girder and cross beam)

Quantity	a	b	c	d	e	Σ

Location	Start	Center	End	Photo Check	
Left				Distant	
Center				Close	
Right					

Superstructure Plan Marking

a:Not Exist
b :Rust and Area < 1/2 of element
C:Rust and Area > 1/2of element
d; Loss of section and Area < 1/2 of element
e: Shown in the table below

Remark

Cross Beam — 21 Damage (Rivet / HSFG

Count of Element(Slab devided by girder and cross beam)

Quantity	a	b	c	d	e	Σ

Location	Start	Center	End	Photo Check	
Left				Distant	
Center				Close	
Right					

Superstructure Plan Marking

a:Not Exist
c;Nos of loose or lost bolt < 5% of bolt group
e: Nos of loose or lost bolt > 5% of bolt group

Remark

Bridge Bearing — 15 Water Leakage from Expansion Joint

Quantify	a	b	c	d	e	Σ	
						100	%

Location	Start	Center	End	Photo Check	
Left				Distant	
Center				Close	
Right					

Superstructure Plan Marking

a; a= Σ-(c+e)
% of total length of damage/ total length of expansion
c: Water leakage is existed
e: Extreme water leakage from expansion joint and/or there is pond at bearing seat.

Remark

Bridge Bearing — 16 Damage on Bridge Bearing

Quantify	a	b	c	d	e	Σ	
						100	%

Location	Start	Center	End	Photo Check	
Left				Distant	
Center				Close	
Right					

Superstructure Plan Marking

a; a= Σ-(c+e)
% of total in numbers of damaged bearings/ total number of bearings
c:Slight damage
e:There is lack of bearing function such as broken

Remark

If there is a others damage in the superstructure / bearing, record it,here(superstructure / bearing)

Others — 25 Others

Quantify	a	b	c	d	e	Σ
						9

Location	Start	Center	End	Photo Check	
Left				Distant	
Center				Close	
Right					

Superstructure Plan Marking

Remark

Corosion(Steel)

e	Loss section and Area >= 1/ 2of element Or break of steel or crack of steel

Steel deck slab

b	Surface rust and no water leak
c	Surface rust and water leak
d	Loss of secton and slight water leak
e	Loss of secton and remarkable water leak / Other serious damage such as crack of steel

Example of On-site Memo for Recording Damage(9) (Bridge Structure(Arch Bridge))

Inspection Recorad Sheet [Arch Bridge] No. 1 -1 A1 - A2

Route No.		Bridge No.	/ in Km	Bridge Name		Insp.Date		Inspector :	

[Superstructure]

Superstructure Plan Marking

Arch Rib — 23 Arch Line(Displacement)

Count of Element

Quantity	a	b	c	d	e	Σ
						9

Location	Start	Center	End	Photo Check	
Left				Distant	
Center				Close	
Right					

Superstructure Plan Marking

a:Not Exist
a=9-e
e: Deformation of arch line(r

Remark

Arch Rib — 13 Cracks

Count of Element

Quantity	a	b	c	d	e	Σ
						9

Location	Start	Center	End	Photo Check	
Left				Distant	
Center				Close	
Right					

Superstructure Plan Marking

a=9-(b+c+d+e)
b to e : Shown in the table right

Remark

Arch Rib — 24 Deteriorated (Loose)

Count of Element

Quantity	a	b	c	d	e	Σ
						9

Location	Start	Center	End	Photo Check	
Left				Distant	
Center				Close	
Right					

Superstructure Plan Marking

a:Not Exist
a=9-e
e: Loose or material of arch rib

Remark

Arch Rib — 18 Mud Deposition / Vegetation

Count of Element

Quantity	a	b	c	d	e	Σ
						9

Location	Start	Center	End	Photo Check	
Left				Distant	
Center				Close	
Right					

Superstructure Plan Marking

a:Not Exist
a=9-e
e: Exist

Remark

Spandrel — 13 Cracks

Count of Element

Quantity	a	b	c	d	e	Σ
						6

Location	Start	Center	End	Photo Check	
Left				Distant	
Center				Close	
Right					

Superstructure Plan Marking

a=6-(b+c+d+e)
b to e : Shown in the table below

Remark

Spandrel — 24 Deteriorated (Loose)

Count of Element

Quantity	a	b	c	d	e	Σ
						6

Location	Start	Center	End	Photo Check	
Left				Distant	
Center				Close	
Right					

Superstructure Plan Marking

a:Not Exist
a=6-e
e: Loose or material of supandrel

Remark

Spandrel — 18 Mud Deposition / Vegetation

Count of Element

Quantity	a	b	c	d	e	Σ
						6

Location	Start	Center	End	Photo Check	
Left				Distant	
Center				Close	
Right					

Superstructure Plan Marking

a:Not Exist
a=6-e
e:Exist

Remark

If there is a others damage in the superstructure, record it here

Others — 25 Others

Quantify	a	b	c	d	e	Σ
						9

Location	Start	Center	End	Photo Check	
Left				Distant	
Center				Close	
Right					

Superstructure Plan Marking

Remark

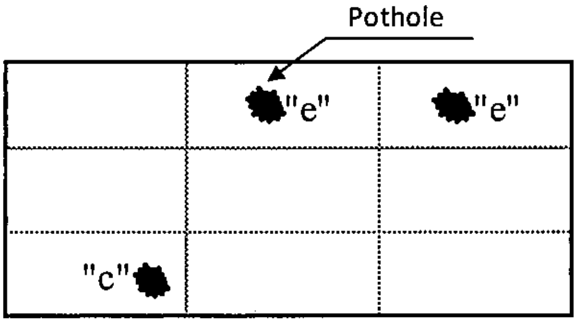
Cracks of Greading

b	Width <about10 mm and No water leack
c	about 10 mm=< Width < about 30 mm and No water leack
	Width <about 10 mm and water leac
d	about 10 mm=< Width <about 30 mm and water leak
	Width>=about 30 mm and No water leack
e	Width>= about 30 mm and Water leack

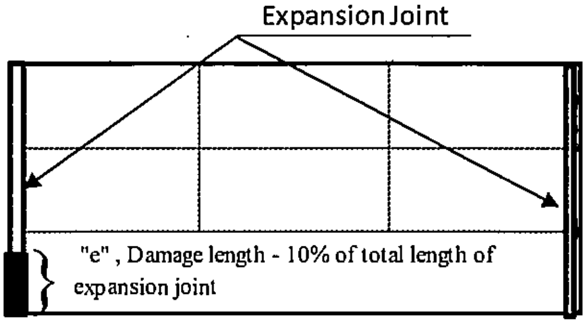
Recording Method of Damage on Bridge (1)

Example of recoding method for damage on surface.

Damage on "Pavement" for Surface(9 elements)



Damage on "Expansion Joint" for Surface (damage evaluation percentage in length)



1.Pot hole

Quantify	a	b	c	d	e	Σ
	6		1		2	9

Location	Start	Center	End
✓ Left		✓	✓
Center			
Right			

Superstructure Plan Marking

Photo Check	
Distant	
Close	

Remark

5.Dmage on Joint

Quantify	a	b	c	d	e	Σ	
	90				10	100	%

Location	Start	Center	End
✓ Left			
Center			
Right	✓		

Superstructure Plan Marking

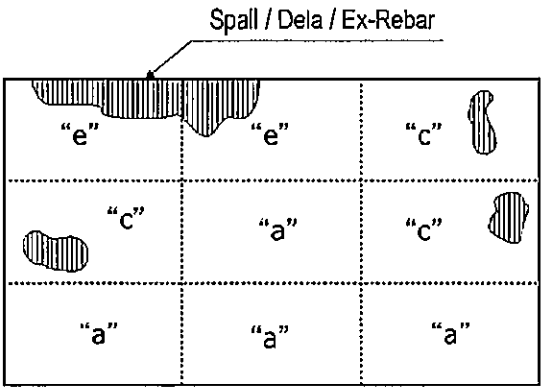
Photo Check	
Distant	
Close	

Remark

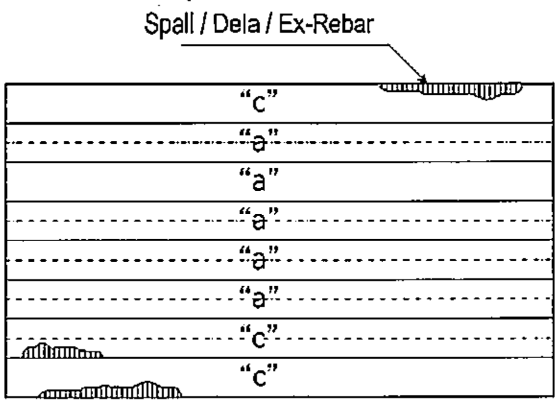
Recording Method of Damage on Bridge (2)

Example of recoding method for damage with each type of bridge.

Damage on "slab" for RC-S(9 elements)



Damage on "beam" for PSC-PRE(number of beams = 8)



12 Spall/Dala/Ex-Rebar — Count of Element

Quantify	a	b	c	d	e	Σ
	4		3	0	2	9

Location	Start	Center	End
✓ Left	✓	✓	
Center			
Right			

Superstructure Plan Marking

Photo Check	
Distant	
Close	

Remark

12 Spall/Dala/Ex-Rebar — Count of Element (Numbers of beams)

Quantify	a	b	c	d	e	Σ
	5		3	0	0	8

Location	Start	Center	End
✓ Left			✓
Center			
Right	✓		

Superstructure Plan Marking

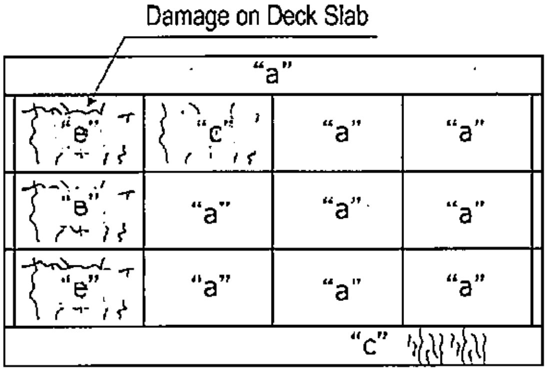
Photo Check	
Distant	
Close	

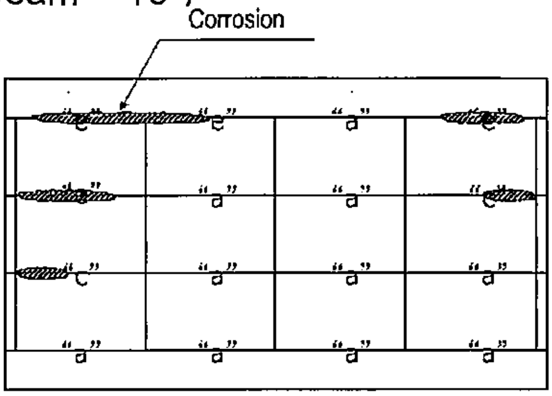
Remark

Recording Method of Damage on Bridge (3)

Damage on "deck slab" for Steel bridge
(Number of areas enclosed by beam and cross beam = 14)

Damage on "main beam" for steel beam bridge (number of beam elements divided by cross beam = 16)



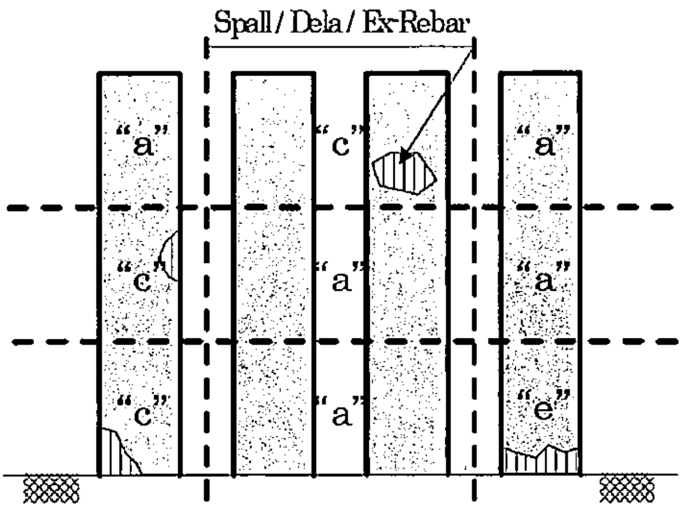


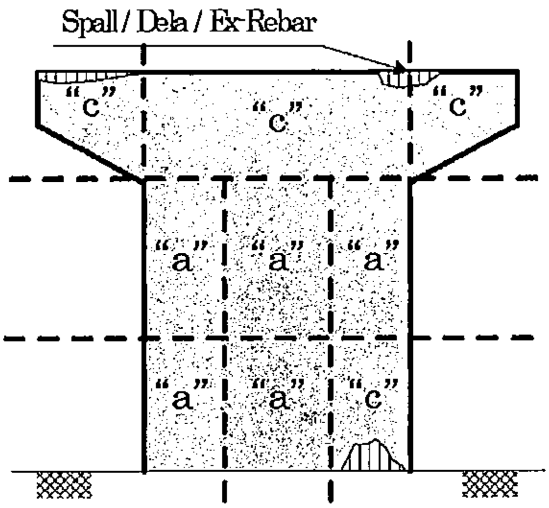
		Count of Element(Slab devided by beam and cross beam)					
12 Damage on Deck Sab	Quantity	a	b	c	d	e	Σ
		9	0	2	0	3	14
	Location	✓	Start	Center	End		
		Left	✓			Photo Check	
		Center	✓			Distant	
		Right	✓			Close	
		Superstructure Plan Marking					
	Remark						

		Count of Element(Beam devided by crosss beam)					
20 Corrosion	Quantity	a	b	c	d	e	Σ
		10	0	2	0	4	16
	Location	✓	Start	Center	End		
		Left	✓		✓	Photo Check	
		Center	✓		✓	Distant	
		Right				Close	
		Superstructure Plan Marking					
	Remark						

Recording Method of Damage on Bridge (4)

Damage on "pier" for substructure(9 elements)



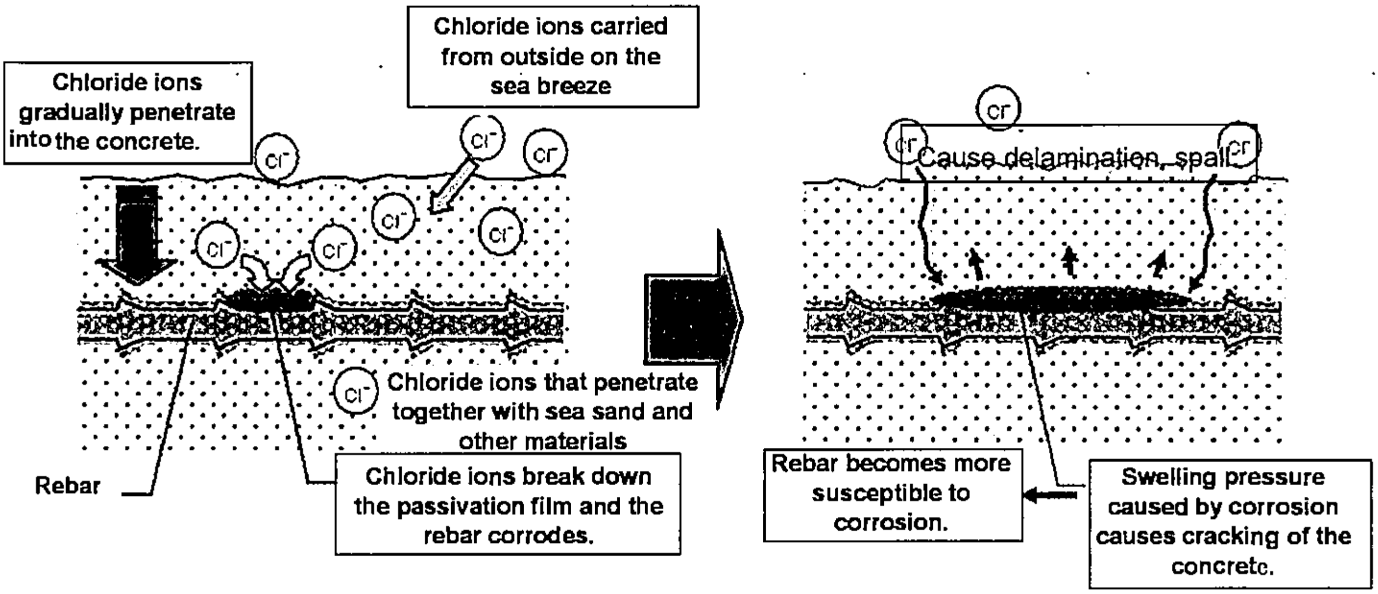


		Count of Element					
12 Spall/Dela/Ex-Rebar	Quantify	a	b	c	d	e	Σ
		5	[redacted]	3	0	1	9
	Location	✓	Left	Center	Right		
		Upper				Photo Check	
		Middle				Distant	
		Lower			✓	Close	
		Substructure Front Marking					
	Remark						

		Count of Element					
12 Spall/Dela/Ex-Rebar	Quantify	a	b	c	d	e	Σ
		5	[redacted]	4	0	0	9
	Location	✓	Left	Center	Right		
		Upper	✓	✓	✓	Photo Check	
		Middle				Distant	
		Lower			✓	Close	
		Substructure Front Marking					
	Remark						

6. Major Damage Example with Those Mechanisms of Bridges

Damage Caused by Rebar Corrosion of Concrete Members (Corroded Rebar by Salt in Coastal Areas))

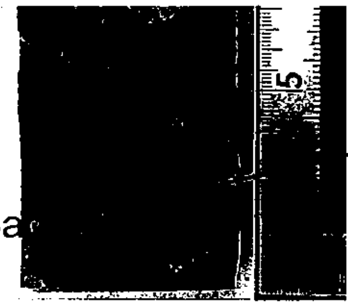


Mechanism of Salt damage

Damage Caused by Rebar Corrosion of Concrete Members (Corroded Rebar by Carbonation)

Carbonation

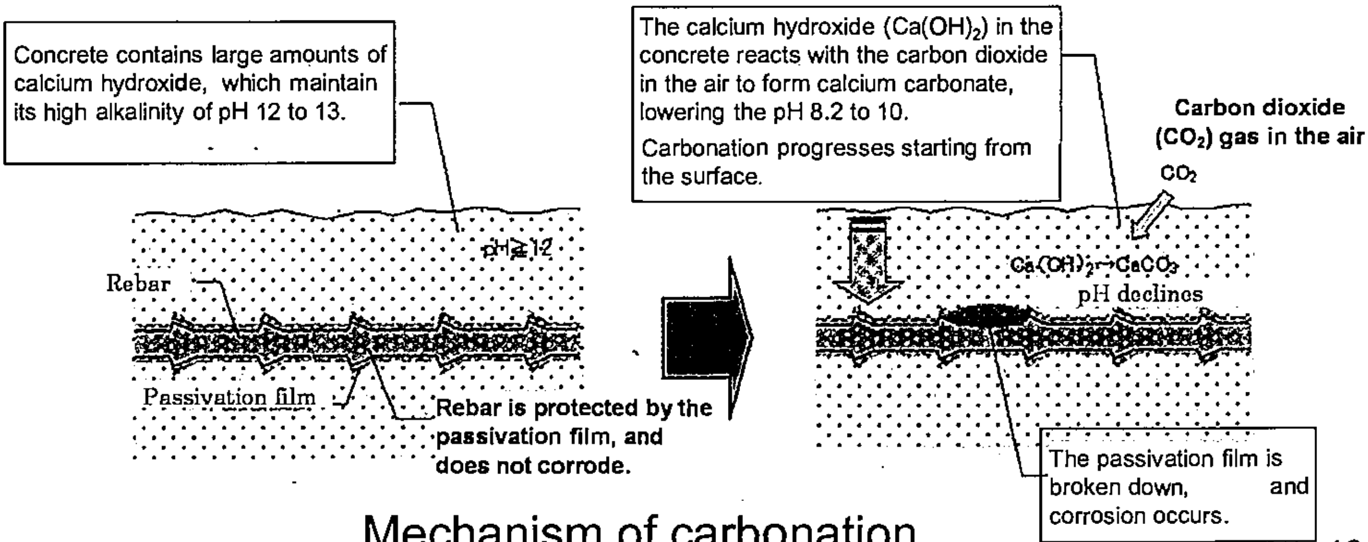
PH of Concrete : 12～13
Effect of carbon dioxide
PH 8.2 to 10



$Ca(OH)_2+CO_2 \Rightarrow CaO_3+H_2O$

Depth of Carbonation

it is not discolored after spraying solution of phenolphthalein



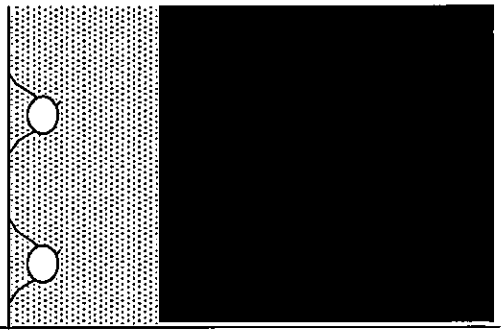
Mechanism of carbonation

Relationship Between Rebar Corrosion and Cracking Pattern

Cover Concrete is thin

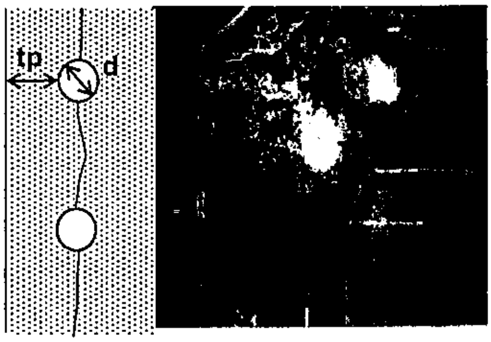
the cracks occur on the surface

When:(2tp+d)/d<3.0



Space between rebar is small

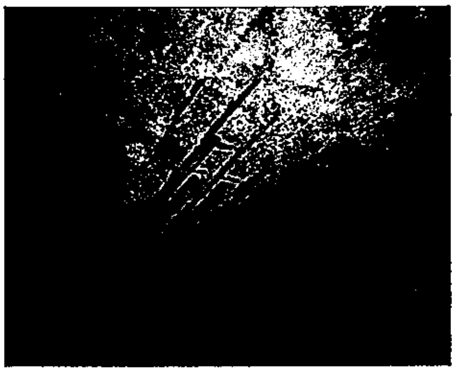
Cracks internally between the rebar



- In most cases, cracks occur internally between rebar.
- This cracks are not visible from outside in earlier stage.

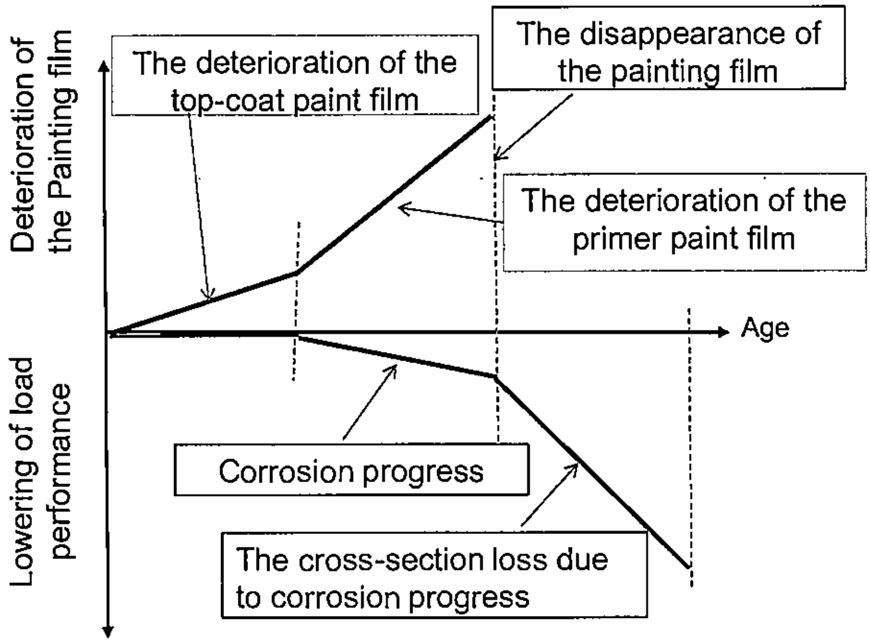
Characteristics of Rebar Corrosion

Characteristics of rebar corrosion by salt damage and carbonation

	Chloride ion penetration	Carbonation of concrete
Regions	Coastal areas	All regions
Corrosion cause	Chloride ion	Carbon dioxide
Time corrosion occurs	After 20 - 40 years	After 50 years or more
Speed of corrosion	Rapid	Slow
Example Photo		

Steel Bridge Corrosion

【Relationship between deterioration of paint film and lowering of load-carrying performance】



- Steel members is very susceptible to corrosion
- A paint film is very important.

Steel Bridge Corrosion

Locations of severe corrosion on a steel bridge are the bottom flanges and the web of exterior beams

Repetition of dry and wet , with moist silt

Process of corrosion on web cross section.

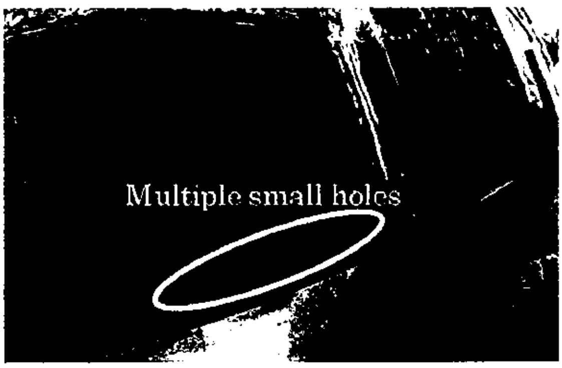


Photo 1: Initial stage of web cross section reduction

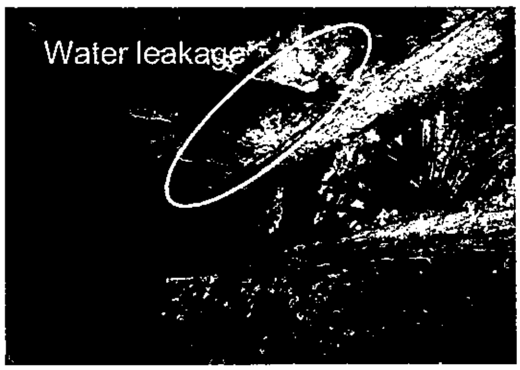
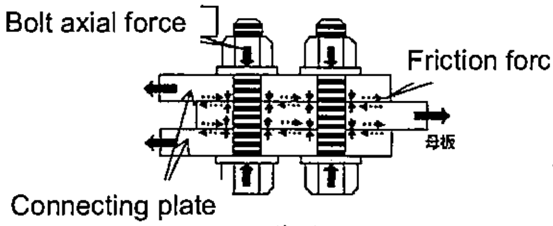


Photo 2: Expanding loss of web cross section

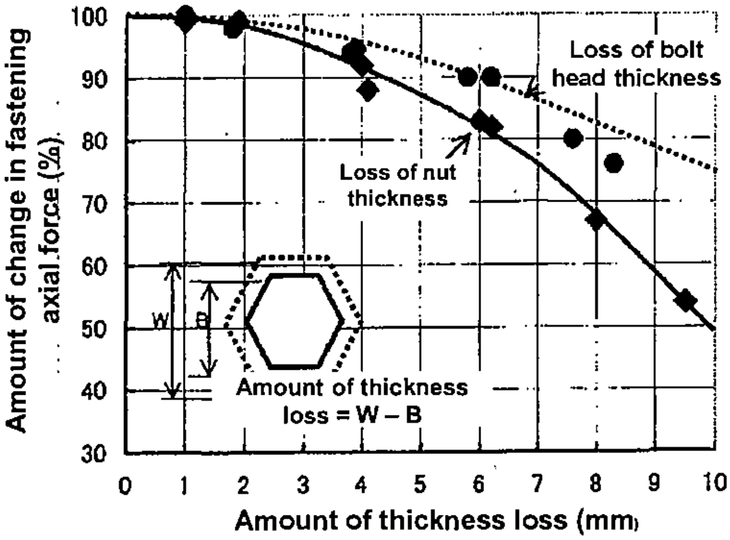
It is important to repair in initial stage for decrease of repair cost and safety.

Loss of Strength in High-Strength Bolts

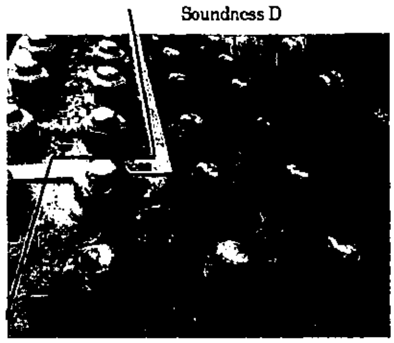


A high-strength bolt transmits working force by the friction force to produce axial force.

Change in fastening axial force resulting from decrease in high-strength bolt thickness



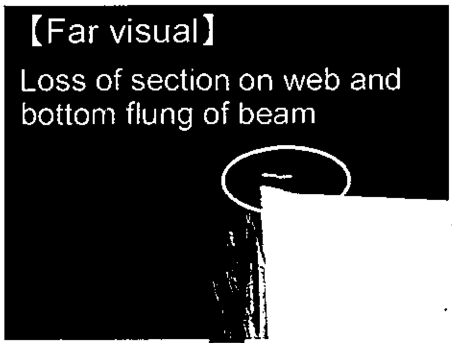
When the bolt is corroded, the safety of the bolt connection decreases.



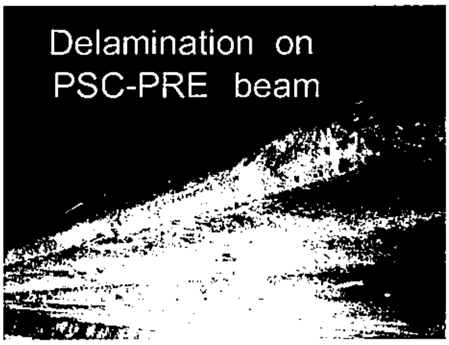
7. Bridge Inspection by BIV

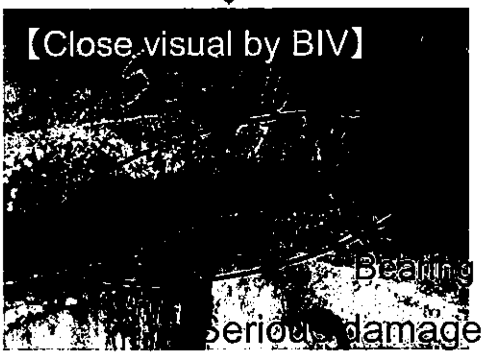
Traffic Cotrol

Inspection Result by BIV in OJT



Removal of large tree root



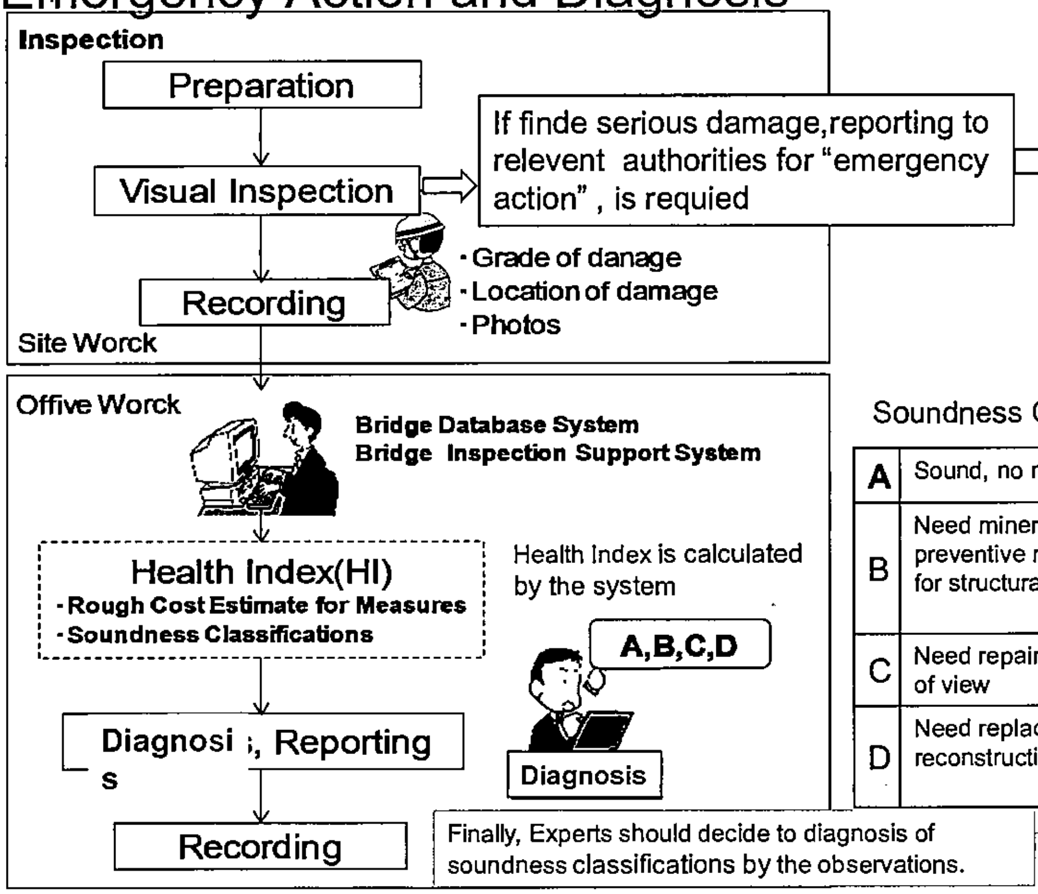


・By inspecting with BIV, it is easy to find invisible damage by far visual.
・Inspectors can know easily the details of damage.
・The large tree root can remove using BIV.

BRIDGE DIAGNOSIS & EMERGENCY ACTION

Contents

Flow of Periodic Bridge Inspection & Emergency Action and Diagnosis



Soundness Classifications(A,B,C,D)

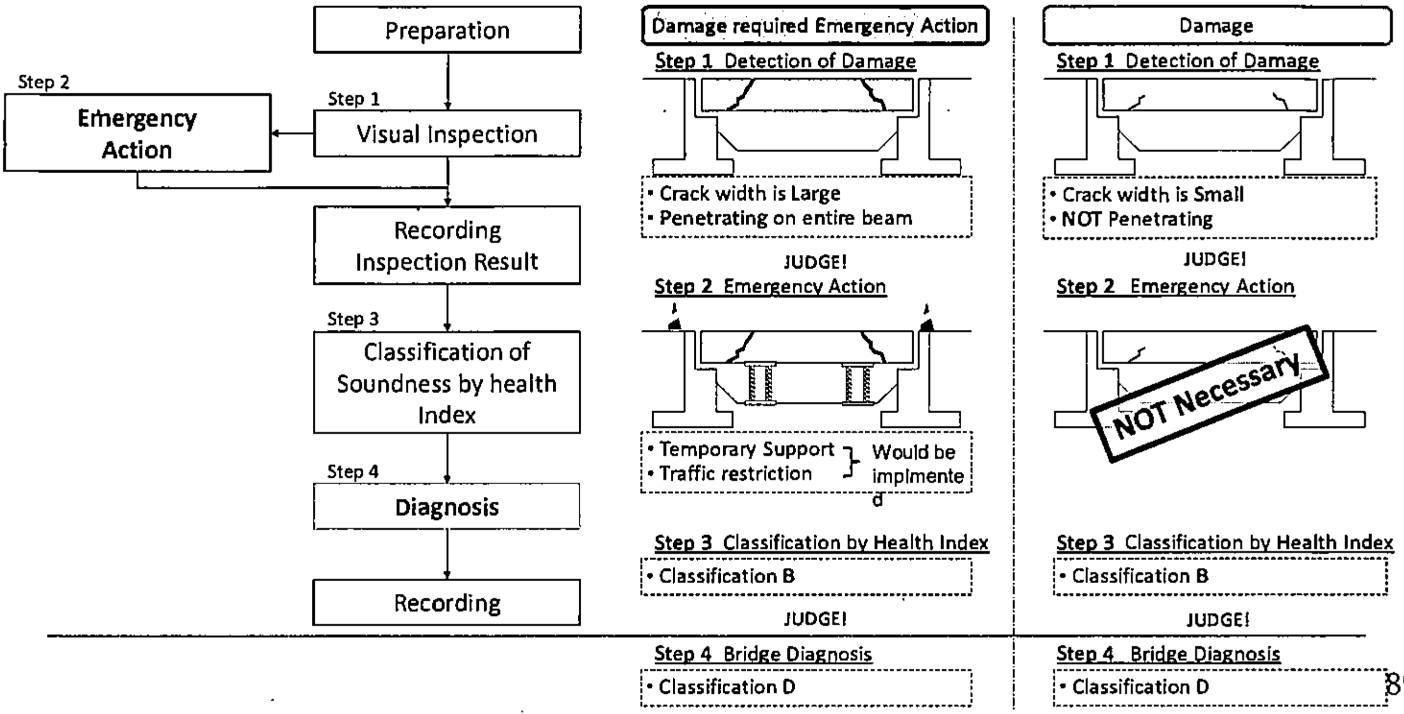
A	Sound, no measure required minor damage
B	Need miner repair for damage needed for preventive maintenance purpose recommended for structural safety points of view at early stage
C	Need repair promptly for structural safety points of view
D	Need replacement of member / strengthening / reconstruction of entire bridge

+α

1 Emergency Action and Diagnosis

1-1. Timing of Emergency Action and Diagnosis

☐ Damage shall be **judged twice during Periodic Inspection**
- During visual inspection : Whether **Emergency Action is needed**, or not
- End of periodic inspection : Whether **Soundness Classification is changed**, or not



1 Emergency Action and Diagnosis

1-2. Purpose of Emergency Action

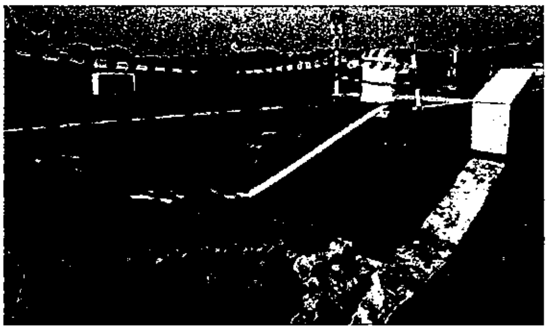
☐ In case of detection of the following situations during visual inspection, "Emergency Action" should be implemented.
- **Impairing the safety of bridge structures**
- **Third-party effects**

- **Impairing the Safety of Bridge Structures**

  Bridge structures might be **COLLAPSED** or **FALLEN DOWN** due to damage, which results in the decrease of load carrying capacity.

- **Third- Party Effects**

  When it is suspected that vehicles, trains and/or pedestrians **on/under the bridge** are **adversely affected** by the damage. thereof, emergency actions shall be taken immediately.



Collapse of a bridge

1. Emergency Action and Diagnosis

1-3-1. Purpose of Bridge Diagnosis

- ☐ Experienced experts within RDA **review Soundness Classification of Bridge at the end of Periodic Inspection**.
- ☐ **All bridges** inspected based on periodic inspection **must be reviewed**.

WHY "the bridge soundness" should be reviewed ?

✓ However, HI does **NOT** consider
- **Rate of progress** of damage - **Influence of location** of damage to the soundness

WHY all bridges ?

✓ If the serious damage is **NOT** judged appropriately,

- **NOT** repair and strengthen the serious damage

Possibility of the collapse of a bridge suddenly without warning

The serious accident occur such as the **INJURED** and the **DEAD**.

Who has Responsibility ?

In the case, **Road Administrator** has responsibility

1. Emergency Action and Diagnosis

1-3-2. Purpose of Bridge Diagnosis

- ☐ In diagnosis, soundness of an entire bridge could be changed as "D" or "C", regardless of the bridge soundness classification determined by HI.
- ☐ Change of soundness classification

Before Diagnosis(by HI)	After Diagnosis
A	C or D
B	C or D
C	D

Soundness classification by Health Index (HI)

Sound

Classification		Conditions
A	Sound	Structures are well functioning.
B	Preventive Maintenance Stage	Structures are well functioning. However, it is desirable to take necessary measures from the perspective of preventive maintenance.
C	Reactive Maintenance Stage	Functions of the structure will be possibly impaired. Necessary measures should be taken at an early stage (within 5 years).
D	Immediate Action Stage	Functions of the structure are impaired or the possibility of impairment of functions is extremely high. Necessary measures should be taken immediately (within 2 years).

Serious

2. Situation in need of Emergency Action

2-1-1. Example of Damage – Impairing safety of Bridge Structures –

Other Damage on Concrete

- Example of damage

Bearing failure near support

- Crack width is 0.3mm or more
- Impairing the bearing function

Delamination in wide area of the deck slab / main beam

- Ex-rebar with remarkable corrosion or broken re-bar, or delamination
- Damage on about 60% of its all area

with remarkable corrosion or break of rebar / PC cable.

2. Situation in need of Emergency Action

2-1-2. Example of Damage – Impairing safety of Bridge Structures –

Corrosion and Break on Steel Member

- Example of damage

Remarkable loss section of steel beam

Break of the diagonal member of truss

- Loss of web steel on its entire depth
- Loss of lower flange steel by 50% or more
- Near support

HSFG on Steel Member

- Example of damage

Damaged bolts, such as the serious corrosion is about more than 25% of one bolt group and more in number

Damage on HSFG

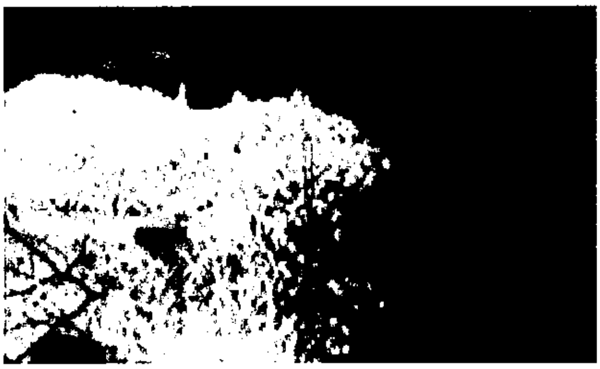
2. Situation in need of Emergency Action

2-1-3. Example of Damage – Impairing safety of Bridge Structures –

Arch Line

• Example of damage

Large deformation of the arch line



Bridge Pier / Abutment in Water

• Example of damage

Exposed foundation due to riverbed degradation and / or scour

• Scoured under footing of pier/abutment

2. Situation in need of Emergency Action

2-1-4. Example of Damage – Third-party Effects –

Railing / Parapet

• Example of damage

Missing of railing

Approach Road / River Bank

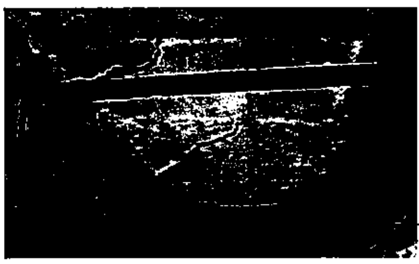
• Example of damage

Large collapse of approach road that causes the depression and crack of road surface

Damage on Deck Slab

• Example of damage

Large cracks



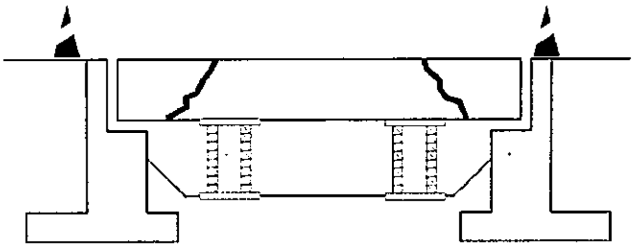
Fallen down of a concrete block from the deck slab

Severe damage of steel deck slab

These damage would cause the depression of road surface

2. Situation in need of Emergency Action

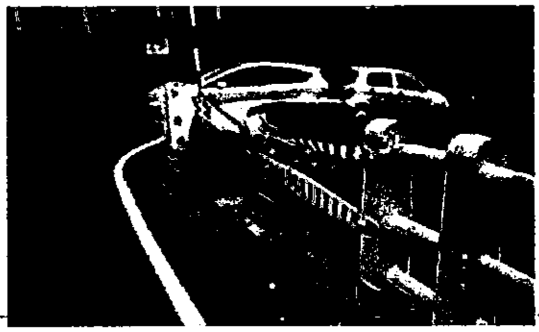
2-2. Example of Emergency Action



Temporary support with saddles & Traffic restriction

Filling with pavement mixture (Pothole)

Temporary fixing of drainage pipe



Installation Caution sign (Damage on railing/parapet)

3. Bridge Diagnosis

3-1-1. Example of Bridge Diagnosis – Concrete structure –

Classification C

Spall / Dela / Ex-rebar(No,12), Concrete Crack (No.13)

- Delamination on main concrete beam / slab to a large extent
- Large crack on main concrete beam / slab
  It is suspected that steels in concrete may be seriously corroded, resulted in the decrease of load carrying capacity.

- Crack with water leakage on concrete structure
  It is supposed that concrete will deteriorate earlier near such cracks than other areas.

3. Bridge Diagnosis

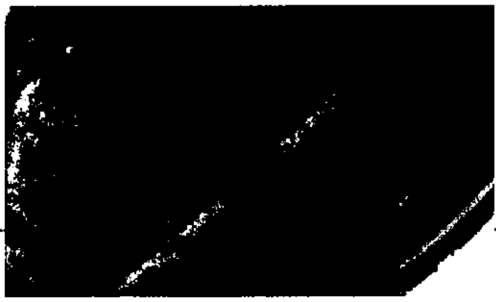
3-1-2. Example of Bridge Diagnosis – Concrete structure –

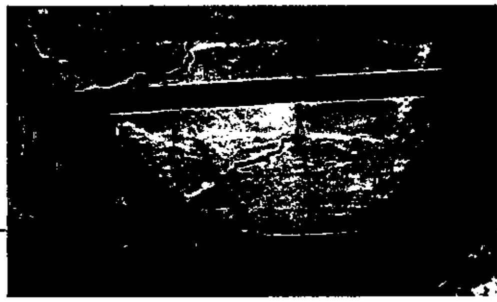
Classification C

Damage on Deck Slab (RC) (No.22-1)

- Pattern cracking on bridge deck slab
  It is suspected that excess load is delivered to a main beam due to the degradation of such load distribution function and damages the said beam. It will impair the structural safety of an entire bridge.

- Penetrating crack on concrete main beam / slab
  Load carrying capacity there will be decreased.





3. Bridge Diagnosis

3-1-3. Example of Bridge Diagnosis – Concrete structure –

Classification D

Spall / Dela / Ex-rebar(No,12), Concrete Crack (No.13)

- Delamination on main beam / slab
  The break of the steels is suspected.

3. Bridge Diagnosis

3-2-1. Example of Bridge Diagnosis – Steel structure –

Classification C

Corrosion (No.20)

- Serious extensive corrosion and local loss of structural steel
- 30% or more of the lower flange steel has been lost.
- Steel web has been lost on one-third or more of its depth.
- For the truss bridge, 20% or more of steel of its diagonal / vertical member or chord has been lost.
  Load carrying capacity will be decreased. It will impair the structural safety of an entire bridge.

- Unusual corrosion on galvanized coating with local loss of structural steel
  It is suspected that load carrying capacity might be decreased.

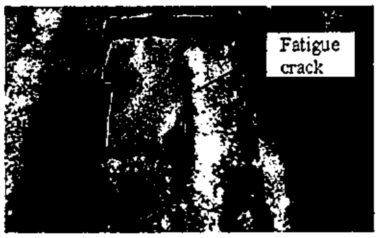
3. Bridge Diagnosis

3-2-2. Example of Bridge Diagnosis – Steel structure –

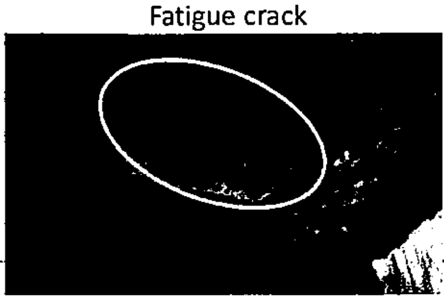
Classification C

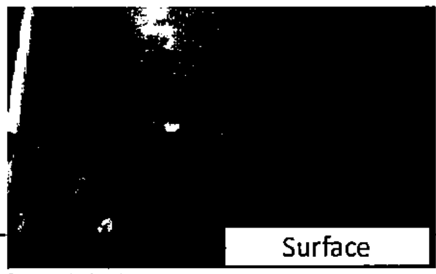
Damage on Deck Slab (Steel) (No.22-2)

- Crack on steel deck slab & Damage on steel deck slab
  It is suspected that excess load is delivered to a main beam due to the degradation of load distribution function and damages the said beam.



Fatigue crack





Large loss section of steel deck

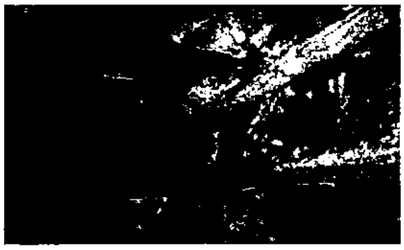
3. Bridge Diagnosis

3-2-3. Example of Bridge Diagnosis – Steel structure –

Classification D

Corrosion (No.20)

- Loss section of web steel on its entire depth
- Loss section of lower flange steel by 50% or more. Damage might cause sudden collapse of the bridge structure.



- Break of diagonal members of truss
- For the truss bridge, 40% or more of steel of its diagonal / vertical member or chord has been lost. Damage might cause sudden collapse of the bridge structure.

3. Bridge Diagnosis

3-2-4. Example of Bridge Diagnosis – Steel structure –

Classification D

Damage (HSFG) (No.21)

- 25% or more of the bolts in number in one group are seriously corroded or missed
  It is difficult to transmit the force between members due to the above damage.
  As the result, this damage might cause sudden collapse of the bridge structure.

3 Bridge Diagnosis

3-3-1. Example of Bridge Diagnosis – Others –

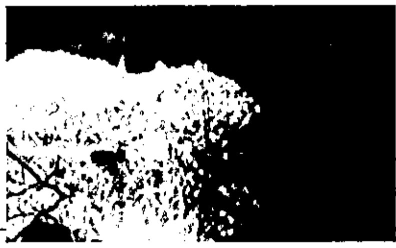
Classification D

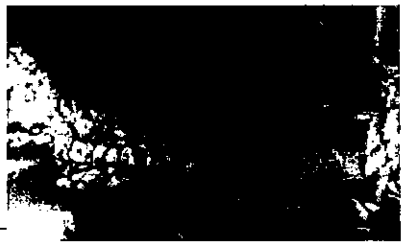
Scour (No.17)

- Exposed foundation due to riverbed degradation and/or scour
  Unusual deflection and the collapse of a bridge might occur due to riverbed degradation and scour.

Arch Line (Displacement) (No.23), Deteriorated (Loose) (No.24)

- Large deformation of arch line at its crown
  For the stone arch, it is quite important to retain the arch line as designed. Deformation of arch line will result in the entire collapse of the arch structure.





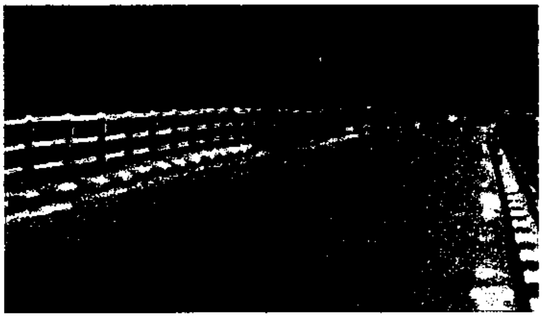
3 Bridge Diagnosis

3-3-2. Example of Bridge Diagnosis – Others –

Classification D

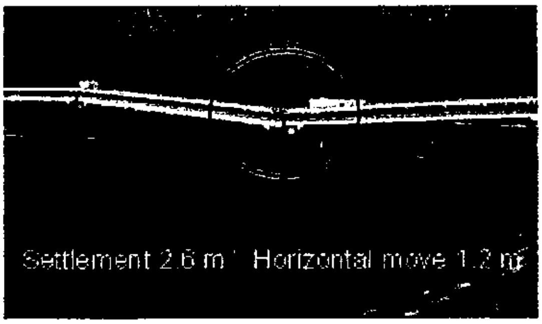
Deflection

- Unusual deflection on an entire bridge
  Unusual deflection may be the sign of settlement, movement or tilting of bridge piers and abutments, and others.



Settlement, movement and tilting of substructures

- Settlement, movement or tilting of piers / abutments
  When the settlement, movement or tilting of bridge piers and abutments are detected, emergency action shall be taken to prevent the collapse of bridge structure.



THANK YOU