Ministry of Transportation Department of Rural Roads
The Kingdom of Thailand

A SURVEY FOR THE BRIDGE MAINTENANCE PLANNING (THE CHAO PHRAYA RIVER CROSSING BRIDGES) IN THE KINGDOM OF THAILAND

REPORT 2

"BRIDGE INSPECTION AND EVALUATION MANUAL"

March 2011

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

CHODAI CO., LTD.
METROPOLITAN EXPRESSWAY CO., LTD.

Ministry of Transportation Department of Rural Roads
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FOREWORD

As times change from responsive to preventive long-term maintenance, periodic inspection has been the most important subject and it is urgently necessary for the different countries to accomplish the corresponding development.

Although the bureaus of DRR (road maintenance, bridge construction and testing & research development) have developed different manuals for the periodic inspection, they have no consistency each other.
Additionally the issues became known that the maintenance cost over approximately 7000 bridges under the control of DRR, which cause the situation enough amount of inspectors can not be arranged and educated, and moreover the inspection results vary individually.

Since the acknowledgement and the experience regarding the similar issues in Japan offer good guidance for them, this manual is drafted based upon the two manuals, "Manual for periodic inspection on the highway bridges, national highway and risk management division, road bureau, MLIT Japan, March 2004" and "Basic data collection manual of highway bridge conditions (draft), NILIM, MLIT Japan, April 2007".

In this manual the all aspects from the scheme of the different types of inspection in the maintenance system to usual inspection and periodic inspection are demonstrated. In periodic inspection damages are evaluated objectively. The subjective evaluation how the damages should be managed in the future such as necessity of repair etc. is discussed as "classification of countermeasure" in the manual for long-term maintenance planning.

This manual is for the 12 bridges over Chao Phraya river, however, the basic parts are also applicable to the rural road bridges.

It is expected this manual will be applied in the near future and contributes to the preventive long-term maintenance of whole DRR

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I Common

1. Application

This manual is developed to assist the periodic inspection of the following 12 road bridges over the Chao Phraya river.

Rama 4, Rama 5, Rama 7, Krung Thon, Phra Pinklao, Memorial, Phra Pokklao, Taksin, Krung Thep, Rama 3, IRR (North), IRR (South)

2. Purpose of inspection

Inspection is intended for the recording of the damage data recognizing the condition of the bridges such as the existence of remarkable deterioration in the bridges so that maintenance can be realized as planed.

3. Types of inspection

It is necessary to inspect by appropriate methods according to the purpose and the condition at the appropriate time. The types of inspection are shown as follows:

(1) Routine inspection
(2) Periodic inspection
(3) Emergency inspection
(4) Advanced inspection

Besides periodic inspection there are different types of inspection and investigation in the maintenance system. This can be schematically demonstrated in the maintenance system as follows:

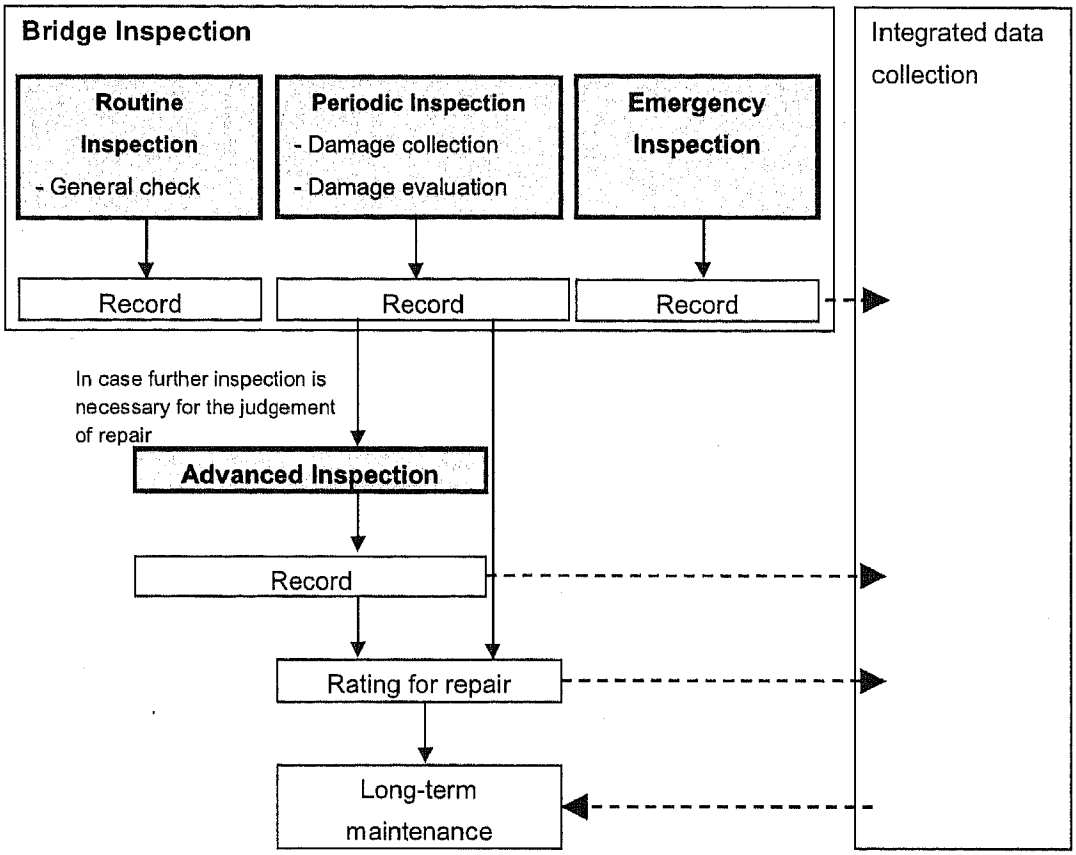


Figure 1: Scheme of inspection in the maintenance system

Table.1: Types of inspection and activities

	Inspector	Frequency	Method	Remarks
Routine Inspection	Technician	Once / Week	Visual	General check (Foot/Vehicle patrol)
Periodic Inspection	Technician Engineer	Once / 5 years	Visual (as close as possible to the structure)	Optionally supporting with high performance apparatus
Emergency Inspection	Technician Engineer	Optional	Similar to periodic or advanced inspection	In case of unexpected damages due to earthquake, typhoon, heavy rain etc.
Advanced Inspection	Consultant	Optional	Physical test(non-destructive/destructive), analysis, etc. (If it is appeared to be necessary according to the periodic inspection result)	E.g. Krung Thon, Memorial, Phra Pinklao bridge., etc.

3.1 Routine inspection

Routine inspection is accomplished by daily visual inspection combined with vehicle or foot patrol in order to check structural damages, falling objects, illegal occupation, stolen appurtenances etc..

Inspection work is performed by the technician in the maintenance offices.

3.2 Periodic inspection

This is the most important inspection in the maintenance system for the purpose of collecting records periodically for the efficient maintenance. The damage condition is grasped based upon visual inspection to the structure and evaluated finally. It can be often supported by the high performance apparatus such as a high performance digital camera, a bridge checker etc. where it is difficult to access closely.

Inspection work is performed by the engineers at head office and technicians in the maintenance offices.

3.3 Emergency inspection

This is optional inspection in order to confirm the existence of fatal damages for the structural stability in case of disasters or large accidents such as earthquake, typhoon, heavy rain etc. are detected. The method of periodic or advanced inspection is similarly applied.

Inspection work is performed by the engineers at head office and technicians in the maintenance offices.

3.4 Advanced inspection

If it appears to be difficult to judge the necessity of repair or the repair method after periodic inspection, advanced inspection is then applied. The cause and extent of damages are further inspected in detail using physical test(non-destructive or destructive), analysis, etc.. The examples are shown in III Reference. In the past DRR has already applied this type of inspection to the bridges of Krung Thon, Memorial, Phra Pinklao etc.

Inspection work is performed by consultants every time due to its specificity and specialty.

II Routine inspection

Routine inspection is accomplished by daily visual inspection combined with vehicle or foot patrol in order to check structural damages, falling objects, illegal occupation, stolen appurtenances etc.. The main purposes are to ensure safe and smooth traffic as well as to prevent the third party injury.

1. Inspection methods

In the routine inspection bridges and facilities are inspected according to the following method:

(1) Bridges
Bridges are inspected basically by foot patrol. In case such as the bridges without sidewalks, inspection in rainy conditions, etc. vehicle patrol can be also combined depending on the situation.

a) Foot patrol
The inspector inspects structural damages and checks the conditions under the bridge during foot patrol in the daytime. In rainy condition it is also important to pay attention to water leakage and standing water.

b) Vehicle patrol
The inspector inspects structural damages in the visible range from the car during vehicle patrol in the daytime, judges the condition of road surface by means of the driving comfortableness, and checks the conditions under the bridge. In rainy condition it is also important to pay attention to water leakage and standing water.

(2) Facilities
The running conditions of machine-, electric-, communication-facilities, etc. are checked not only by means of visual inspection but also measuring instruments. Planting such as trees are to be inspected whether they hinder the traffic.

2. Inspection subjects

Attention should focus on the following inspection subjects:

- On bridge
Pavements, barriers, catch basins, expansion joints, appurtenances (noise barrier, lightings, traffic signs, etc), fallen objects on the road, etc.

- Under bridge

Piers, girder exterior, deck undersides, drainage facilities, expansion joints, inspection ways, appurtenances (noise barrier, lightings, traffic signs, etc), cable pipes, etc.

3. Frequency of inspection

Frequency of inspection is defined as once per week in principle.

4. Inspection report

The inspection results need to be reported to the related sections. If any countermeasures are necessary, it is necessary to clarify the way, the responsible personnel and the completion date.

III Periodic inspection

1. Inspection work

1.1 Preparation of inspection plan

In order to accomplish an appropriate periodic inspection the inspection plan shall be prepared. It contains all the plans such as investigation for the existing documents, inspected subjects and methods, inspection personnel, preparation survey, consultation with the administrators, safety measurement, emergency network, reporting organization for the necessity of emergency solution.

1.2 Methods and subjects of inspection

(1) Inspection shall be based upon visual inspection. Where the methods shown below is difficult to be applied due to the structural reason and the bridge location, the condition of inspected element such as surface characteristics, etc., high performance apparatus are recommended.

(2) The members at the girder end, the bearings and these vicinities shall be inspected as close as possible to the structure from the nearest abutments or piers.

(3) The condition in the place it is difficult to access shall be estimated by visual inspection with a distant view and the condition of the surrounding members. Inspection and evaluation shall be applied every span regardless of number of span. Inspection subjects, evaluation criteria and inspected area etc. are given in Table 1.1.
In Figure 1.1 a conceptual scheme for inspection with a close view in case of steel bridge is shown.

Note : "inspection with a close view" is defined as inspection where the inspector is close enough to touch the area being inspected.

Table 1.1: Inspection subjects, evaluation methods and location

	Damage	Evaluation classification	Inspected area	Distant view	Close view	Remarks
Steel	(1) Corrosion	a – e	Girder end, vicinity of truss node		✓	
	(2) Cracking	a – e	Girder end, vicinity of truss node		✓	
	(3) Missing bolts	a – e	Whole	✓		
	(4) Fracture	a – e	Whole	✓		
	(5) Deformation & loss	a – e	Whole	✓		
Concrete	(6) Cracking, water leakage and free lime	a – e	Whole		✓	
	(7) Rebar exposure	a – e	Whole	✓		
	(8) Pop-outs	a – e	Whole	✓		
	(9) Deck cracking	a – e	Girder end*		✓	
	(10) Damages at the anchorages of prestressing tendons	a – e	Whole	✓		
Others	(11) Unevenness of road surface	a – e	Whole		✓	
	(12) Functional damage of bearings	a – e	Whole		✓	
	(13) Damages in substructures	a – e	Whole	✓		Settlement, movement, inclination, scour, errosion
	(14) Damages in pavements	a – e	Whole		✓	
	(15) Damages in barriers	a – e	Whole		✓	
	(16) Damages in expansion joints	a – e	Whole		✓	
	(17) Damages in cables	a – e	Whole	✓		

* The Area is accessible from abutments and piers without scaffoldings so that damages can be recognized closely. It is preferable to inspect approximately 2 panels from the end.

In case unprecedented damages such as fire signs or unusual condition related to the safety or harmful to a third person are found in the inspection according to this manual, it is important to take a appropriate countermeasure such as advanced inspection etc.

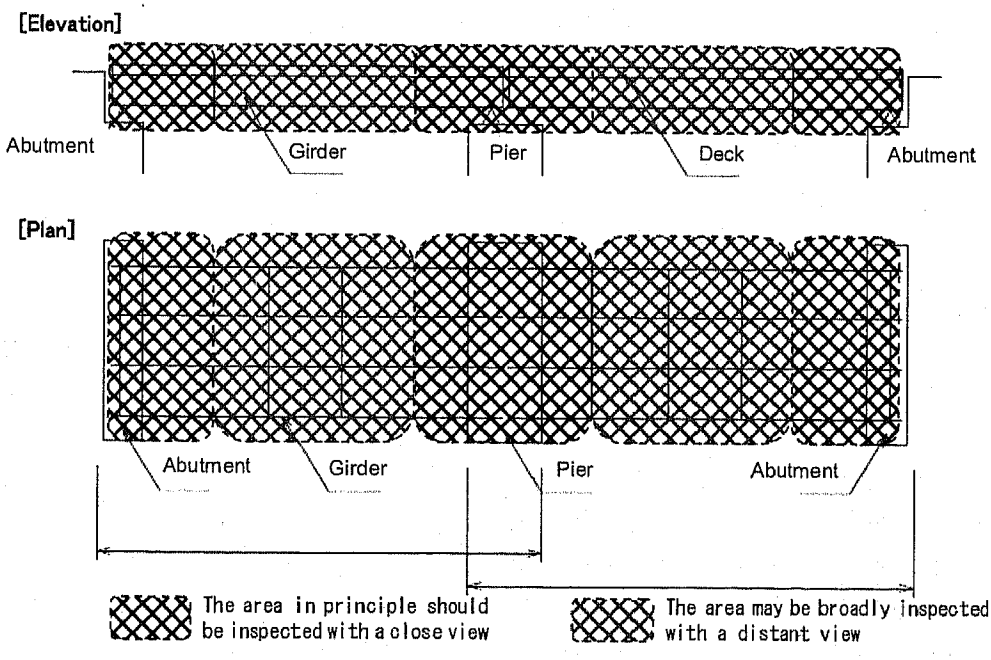


Figure 1.1: Conceptual scheme for inspection with a close view in case of steel bridge

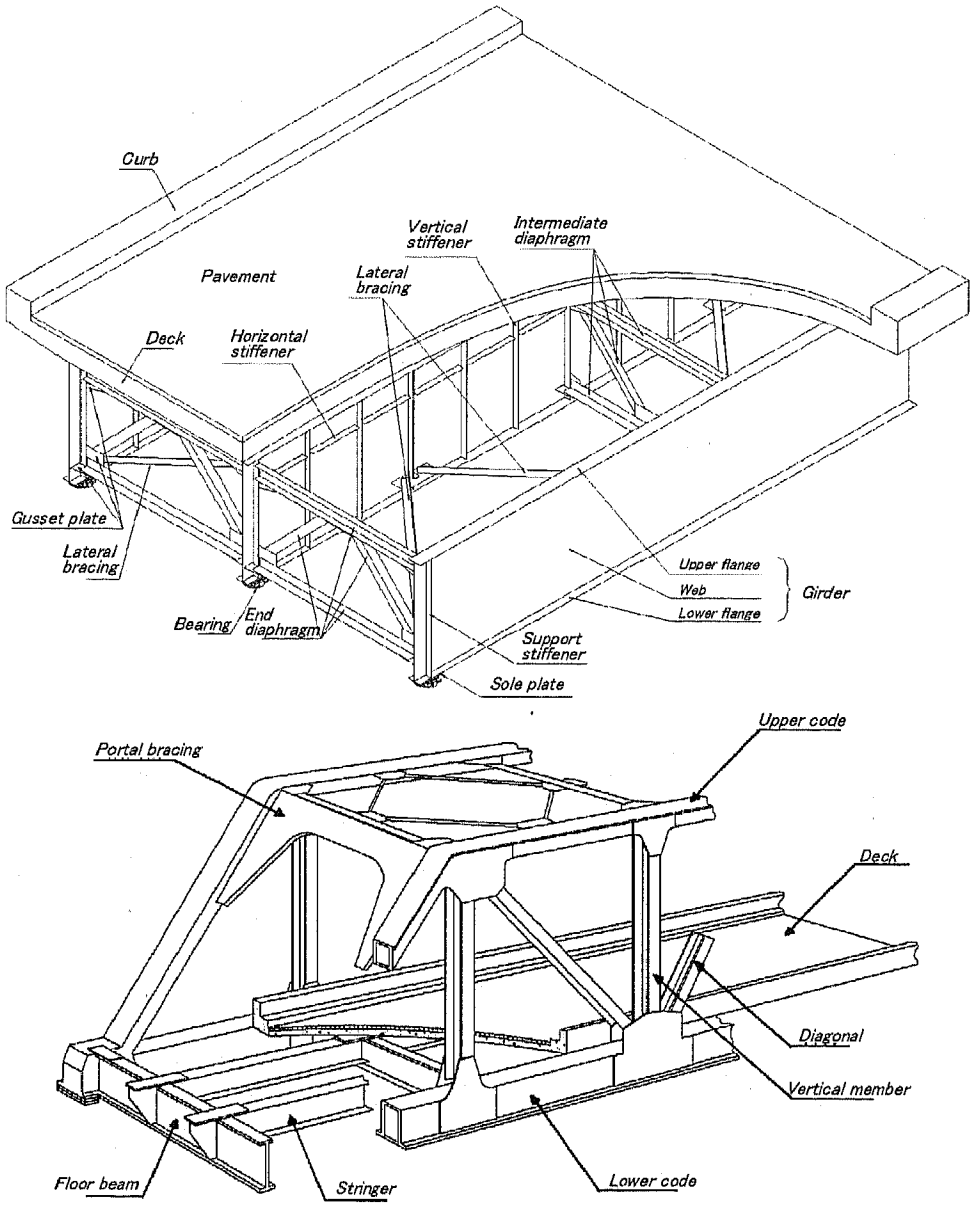


Figure 1.2: Typical members of steel bridge (above:steel girder bridge, below:truss bridge)

Figure 1.2 shows typical members of steel bridge. In case of simple supported girders remarkable damages tend to occur at the girder end area although the location can not be generally specified. According to circumstances the damages at the girder end area is a supporting point may give a great influence on the bridge health. Therefore it is preferable to inspect the condition at the girder end as close as possible.

There is a great potential of local corrosion or crack damages in the cross point of the support stiffeners and the girder lower flanges, the connecting areas of gusset plates, the nodes of the truss bridges etc. are influenced by water or soil leakage through a expansion joint, on the other hand it should be taken into consideration it can be difficult to check the member condition visually due to the existence of water leakage or accumulated soil and dirt.

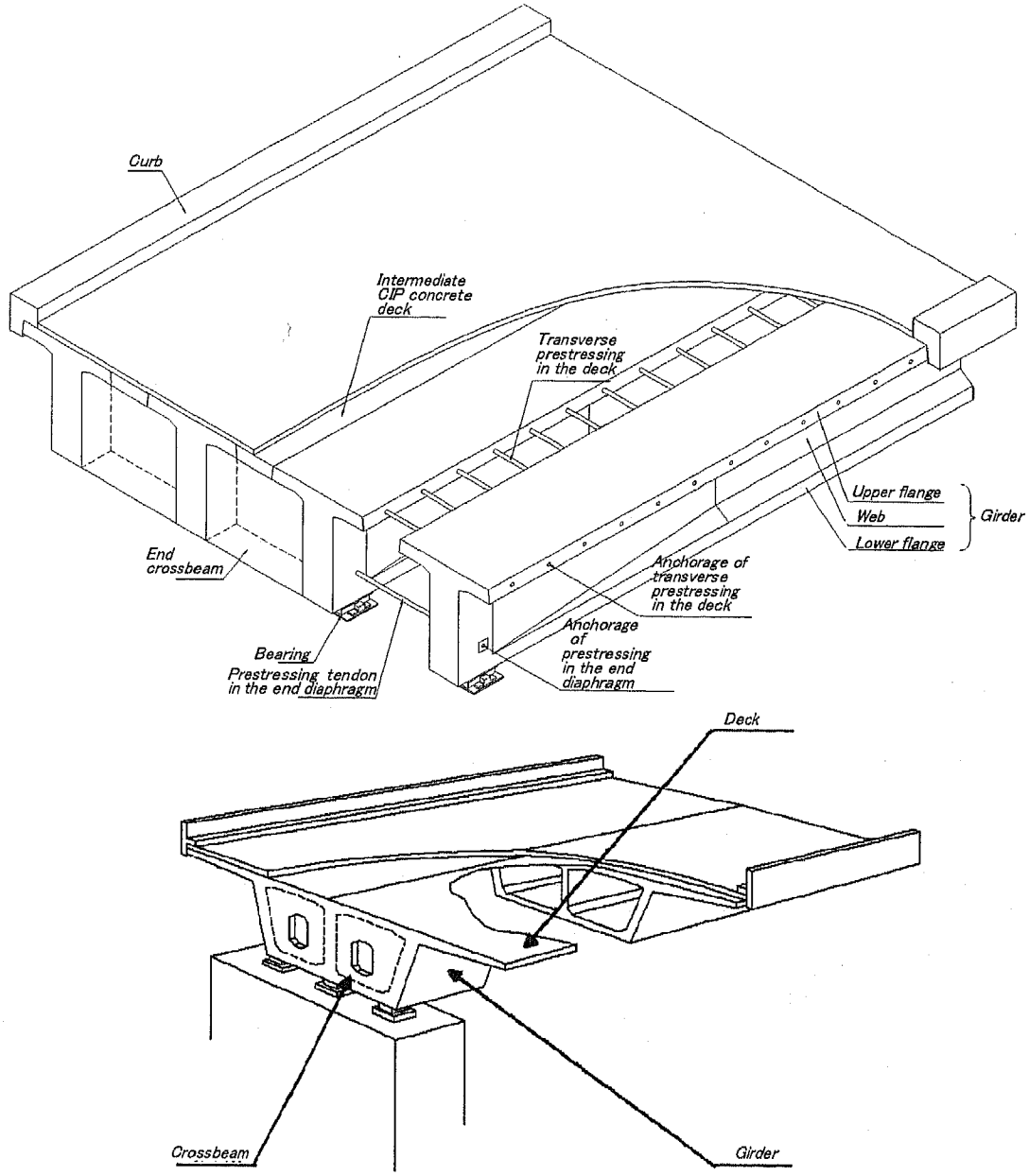


Figure 1.3: Typical members of concrete bridge (above: PC-T shaped girder, below PC box girder)

Figure 1.3 shows typical members of concrete bridge. Damages in a concrete girder vary in crack direction, characteristics and also its location depending upon the causes. It is necessary to confirm the whole cracking area as close as possible, since cracks such as shear cracks may give a great influence on the bridge health.

In case of prestressed concrete girder the state of prestressing gives a great influence on the bridge health. Therefore it is preferable to confirm every anchorage zone where indicates the existence of the damage in a prestressing tendon such as the anchorage zone of transverse tendon in the end crossbeam and the deck nevertheless the inspection intends to grasp the rough health.

1.3 Inspection personnel

Periodic inspection shall be performed by personnel with enough acknowledgement and practical skill regarding bridge.
It is preferable to determine the arrangement of inspection personnel considering the inspection contents and the site condition referring to the following. :

- Bridge inspector : 1 person
- Assistant inspector : 1 or 2 persons
  In case of using supporting apparatus such as a bridge checker, additional personnel are provided appropriately.
- Traffic controller : The number of personnel is determined appropriately according to the traffic condition.

The personnel above shall possess the following responsibilities:

a) Bridge inspector
The bridge inspector provides overall supervision of the inspection team and controls the work considering the safety and maintaining close contact with the supporting inspector.
b) Assistant inspector
The assistant inspector supports inspection work following the instruction of the bridge inspector. He also operates the supplementary apparatus and contacts with the traffic controller for the coordination.
c) Traffic controller
The traffic controller prevents traffic disturbance during inspection and ensures the safety of the inspectors.

1.4 Equipments for inspection

For reference general carrying tools and apparatuses are shown as follows:
(1) Inspection tools
Binocular, inspection hammer, tape measure, pole, etc
(2) Recording tools
Camera, video camera, chalk, blackboard, magic marker, scale, recording form
(3) Supplementary inspection tools
Lighting equipments, flashlight, cleaning tools, traffic regulators, rope, packaging tape
(4) Approaching tools
Chair, ladder
(5) Lifesaver
Life ring (for operation on board or water), ropes, etc.

An example of general dressing with equipments for periodic inspection is shown as follows:

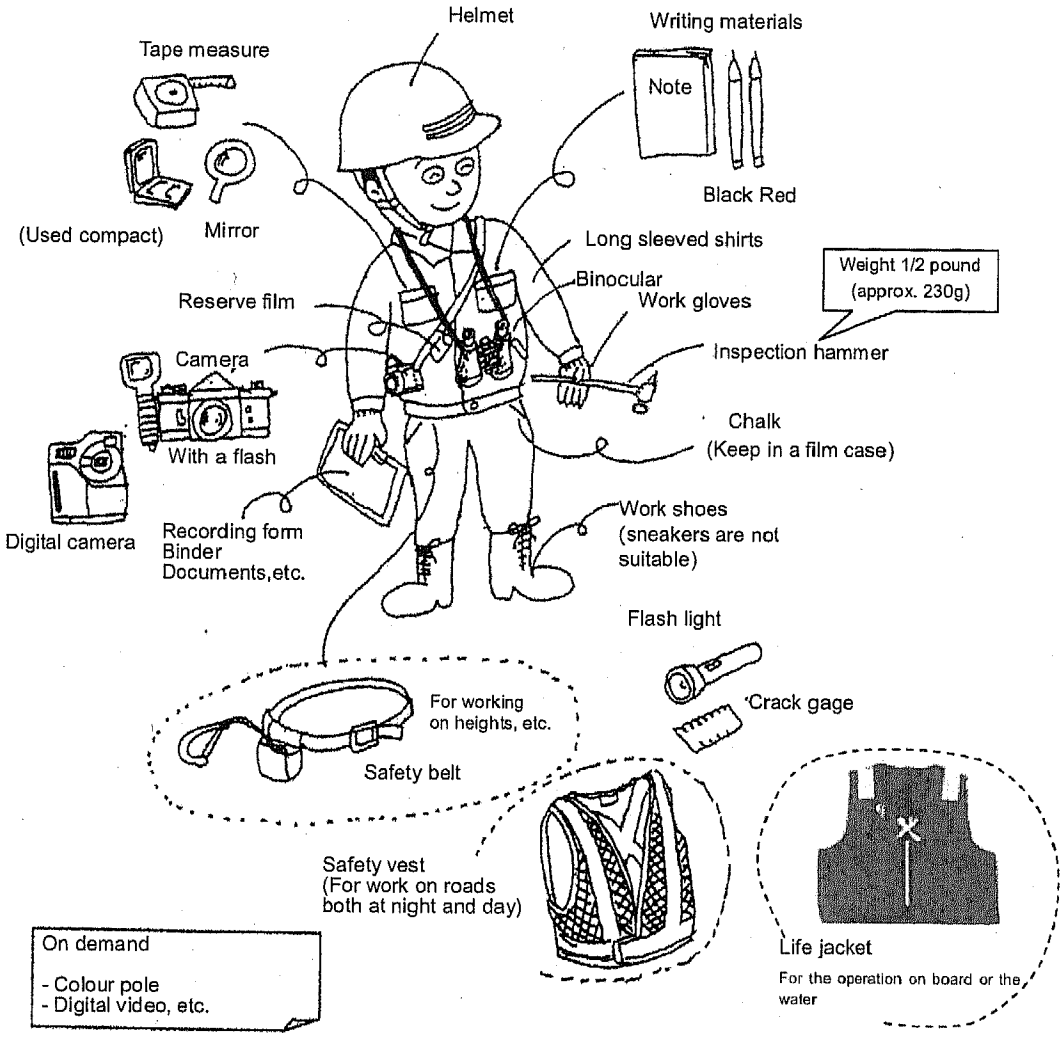


Figure 1.4: An example of general dressing equipments for periodic inspection

1.5 Frequency of inspection

In many example cases in different countries the frequency is defined as once per 5 years except that of 2 years in U.S.. In this manual it is defined as once per 5 years initially.

This frequency can be reconsidered in the PDCA cycle consistently with the realities of Thailand after a few year of trial practice.

2. Grasp of damage condition and evaluation of damage

2.1 Grasp of damage condition

When damages are confirmed in periodic inspection, damage condition shall be grasped in every classification in order to obtain necessary information for the efficient maintenance.

The grasped damages classified in Section 1.2 shall be recorded in the forms shown in Section 3 according to the rules of Section 2.2.

2.2 Evaluation of damage

In this manual the condition of members is evaluated into one of several levels of classification as data according to the type of damage and member in order to grasp the influence upon the bridge health.

2.2.1 Steel structures

(1) Corrosion

(a) General description and damage characteristics

Corrosion is defined as intensive or extremely developed rust which leads to the sectional reduction or corrosion in case of normal steel protected with paint or galvanization. In case of weathering steel it is defined as extraordinary rust without the development of stable rust or remarkable sectional reduction due to the extraordinary rust.

The areas likely to be corroded are the girder end which are often influenced by water leakage, the upper side of the horizontal members which tends to be undrained, the vicinity of bearing supports, the connection area where ventilation and drain are poor, the upper side of the lower flange where dirt and dust tend to be accumulated, the welding parts, etc..

(b) Relation to the other damages

- The other damages such as cracks, breakage etc. besides corrosion shall be also evaluated in the related subjects if exist.
- Rebar corrosion shall not be evaluated in this subject.

(c) Inspection area

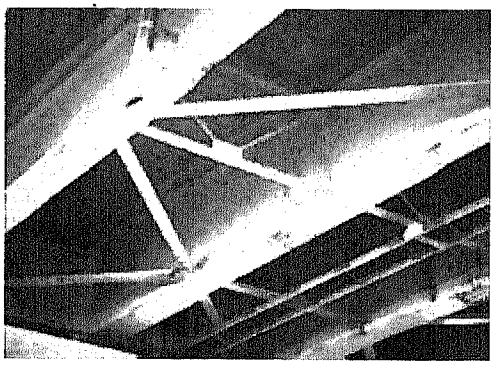
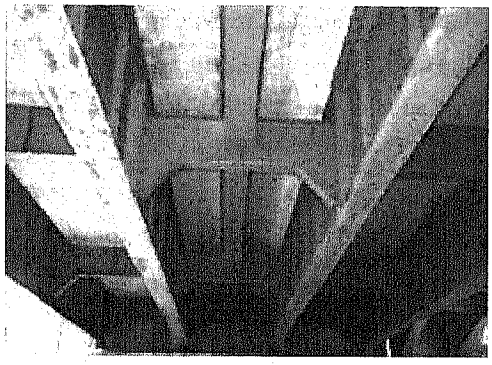
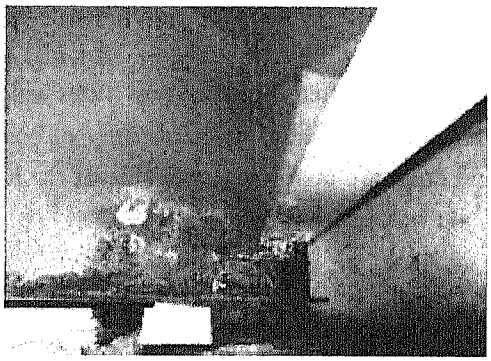
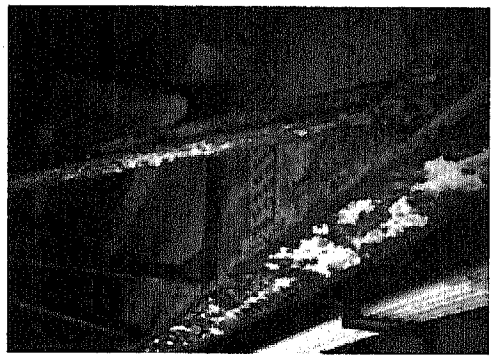
The condition of corrosion in the main members (girder, lateral bracing, end diaphragm, etc.) within visually perceptible area shall be inspected approaching close to the girder end area. Here the end diaphragm area may be considered as one panel (devided area with next diaphragm, etc. from the girder end) of a girder or the area of 5m from the girder end.

(d) Classification of damages

The inspected results shall be evaluated with the following classification:

Evaluation criteria			Classification
Existence of rust	Depth of rust	Extent of rust	
Yes	-	-	a
No	Surface only	Local	b
		Global	c
	Reduction in thickness, Remarkable expansion of steel surface	Local	d
		Global	e

(Examples)

Damage level b	Damage level c
	
Local rust on the girder surface	Global rust on the lower flange surface
Damage level d	**Damage level e**
	
Local rust with thickness reduction at the girder end	Global remarkable rust with thickness reduction on the whole girder

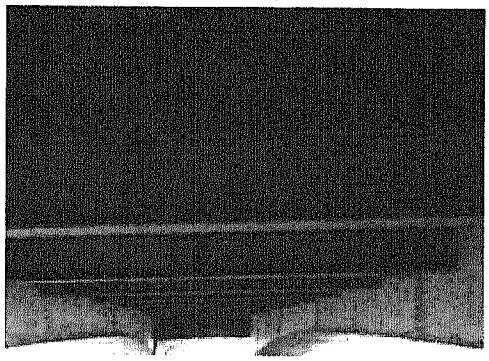
Bridges in "weathering steel" shall be evaluated with the following classification:

Evaluation criteria		Classification
Condition of rust	Extent of rust	
Uniform rust*	-	a
Scaly rust	-	c
Laminated separation, reduction in thickness	Local	d
	Global	e

* Fine rust developed on the surface of weathering steel in the appropriate environment. It includes the general irregular rust constructed after several years (Slightly irregular and disappearing with time).

(Examples)

Damage level a

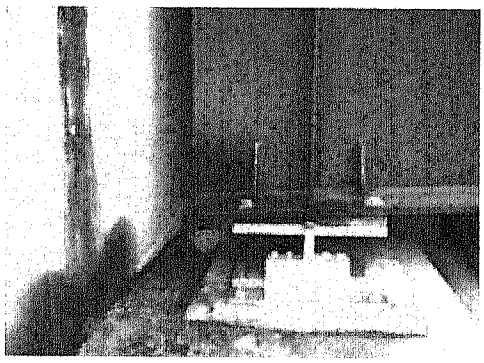


Globally uniform rust

Damage level c

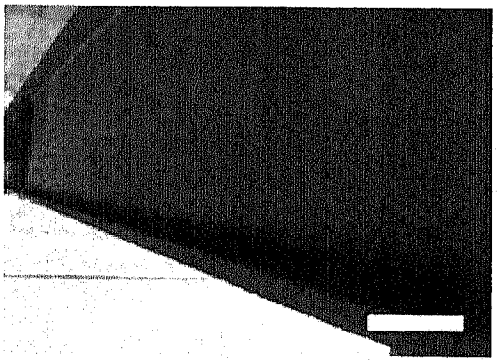
Scaly rust

Damage level d



Locally remarkable rust

Damage level e



Globally laminated separation

(2) Cracking in steel

(a) General description and damage characteristics

Cracks appear often at the sudden sectional change, welding connection etc. where stress concentration tends to occur.

It is not perceptible only by visual inspection as it may occur also inside of steel.

Most of extremely small cracks on the rough surface such as vicinity of welding line often can not be distinguished from the surface scratch or the shade of rough rust. Crack appearing on the painted surface often occurs being accompanied by the painting crack.

(b) Relation to the other damages

- The cause of cracking in steel can not be often identified by visual characteristics so that all the cracks on the steel surface shall be considered as "Cracking in steel" regardless of its location and size.
- The cracking which developed the fracture shall be evaluated as "Fracture".

(c) Inspection area

The existence of cracks in all the members within visually perceptible area shall be inspected approaching close to the girder end area.

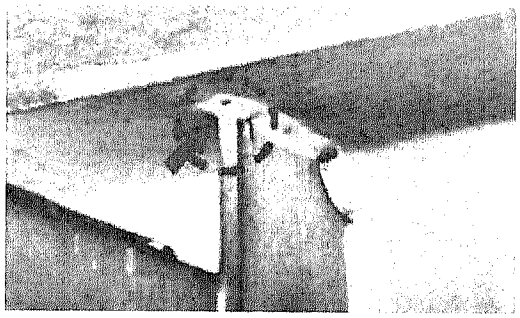
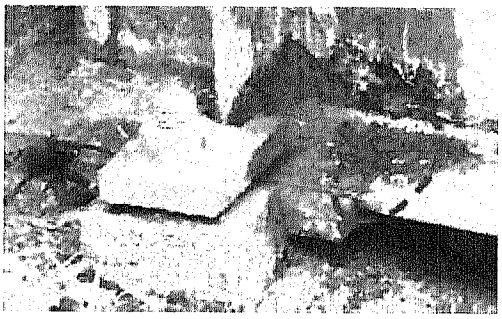
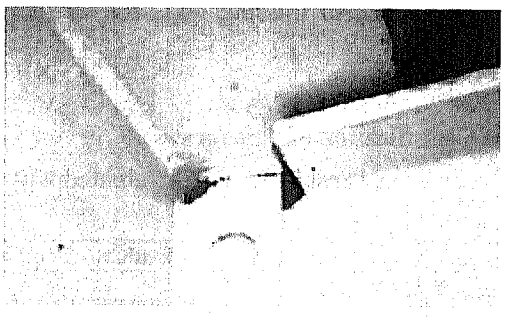
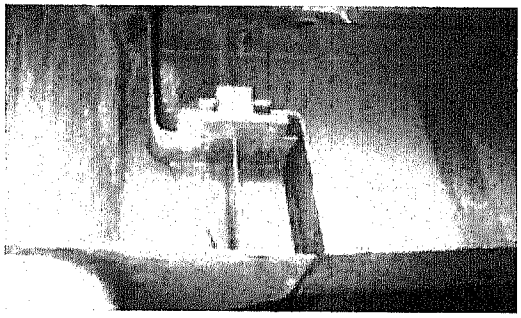
As the development of cracks at the welding zone in vicinity of supports, Gerber supports etc. can lead to dangerous condition of bridges, this should be kept in mind.

(d) Classification of damages

The inspected results shall be evaluated with the following classification:

Evaluation criteria	Classification
No damage	a
Paint cracks in the sudden sectional change or welding connection / Cracks not in a line shape, or a few line cracks with short length	c
Paint cracks potentially to be cracking in steel / Line cracks	e

(Examples)

Damage level c	Damage level c
	
Extremely short crack	Crack likely to be paint crack
Damage level e	**Damage level e**
	
Obvious linear crack in the vicinity of the bearing	Paint crack undoubtedly to be cracking on the vertical stiffner
Damage level e	**Damage level e**
	
Crack at the girder end	Crack at the Gerber support

(3) Missing bolts

(a) General description and damage characteristics

This subject indicates missing of bolts, nuts, etc. including fractured bolts. It includes all bolts and rivets regardless of the types such as normal bolt, high tensile strength bolt, rivet, etc.

(b) Relation to the other damages

- Missing of the bearing roller shall be evaluated as "functional damage of bearing".
- Missing of the anchor bolt of bearing and the setting bolt of expansion joint are included in this subject, these functional damages shall be also evaluated in the related subjects.

(c) Inspection area

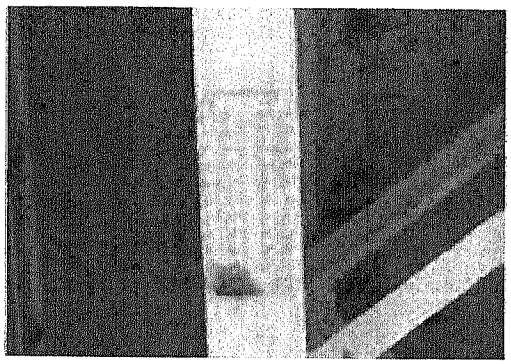
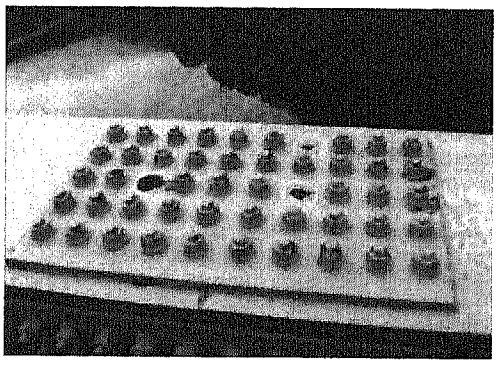
The existence of missing bolts for all the members within visually perceptible area shall be inspected.

(d) Classification of damages

The inspected results shall be evaluated with the following classification:

Evaluation criteria	Classification
No damage	a
Missing bolts (regardless of number of bolts)	e

(Examples)

Damage level e	Damage level e
	
Missing bolts	Fracture and missing of bolts

(4) Fracture

(a) General description and damage characteristics

Fracture is the condition of steel members in which the members are ruptured completely or cracked so much as to be considered as fracture. It is often found in the deck member, the secondary members such as diaphragms or lateral bracings, railings, guard rails, utilities and these supporting members.

(b) Relation to the other damages

- The other damages such as cracking or corrosion besides fracture shall be also evaluated in the related subjects if exist.
- The fracture of bolt and rivet shall be evaluated as "Missing bolts".

(c) Inspection area

The existence of fracture for all the members within visually perceptible area shall be inspected.

(d) Classification of damages

The inspected results shall be evaluated with the following classification:

Evaluation criteria	Classification
No damage	a
Fracture (evaluated as cracking if the member still continuous)	e