Government of People's Republic of Bangladesh
Ministry of Road Transport and Bridges
Roads and Highways Department

Bridge Inspection and Evaluation Manual

Final Draft

August 2018

PREFACE

It is a matter of great pleasure that the **Bridge Inspection and Evaluation Manual** has been developed by the consultants under the Bridge Management Capacity Development Project (BMCDP) of RHD with the cooperation of JICA.

The Bridge Inspection and Evaluation Manual 2018 is the updated version of the one titled "Bridge Condition Survey Manual" produced by RHD in 2014. In order to identify detailed physical condition of each element of bridge, this manual covers the detail procedure for a systematic element level inspection of bridges in RHD Road Network and provides information for effective management of RHD bridge stock.

This manual would serve as guidance on the fundamentals of bridge inspection and update the bridge database periodically and help the Bridge Management Wing of RHD in prioritizing bridge maintenance program. An intranet Bridge Management System (BMS) based on the new concept and functions for effective bridge maintenance management, is also developed under BMCDP as an integrated and accessible information system for the database of bridge inventory, inspection and maintenance work history.

Together with the systematic use of this BMS, this manual will be useful to the RHD field staff responsible for direct maintenance, the policy makers of RHD in this area and also the staff who will be involved in maintenance by contract.
We hope that this manual will assist in improving the understanding of the function of bridge structures and their long term durability and serviceability.

Finally, we would like to take this opportunity to thank the experts of JICA Consultant Team for their efforts in preparing the **Bridge Inspection and Evaluation Manual 2018**.

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APPENDICES

1. BACKGROUND

Construction of bridges in Bangladesh has been accelerated drastically after its independence in 1971, and the number of bridges and culverts increased from 1,112 to 18,356 within the period of 1971 to 2013. Meanwhile, the maintenance was inadequate due to rapid increase of the number of bridges and consequently the bridge condition was seriously deteriorated and has caused collapse of portable steel bridges (Bailey bridges).

The first nationwide Bridge Inventory/Condition Survey was carried out in 1997 by RHD staff in each Sub-Division. The data arising out from the surveys were used to form the first countrywide RHD computerized Bridge Database and data for over 9,000 bridges and culverts were printed in the 1997-98 Annual Road and Bridge Database Report.

The effort of computerizing bridge database for effective nationwide bridge management was enhanced by RHD by introducing Bridge Maintenance and Management System (BMMS) in 2005. In order to fulfill all bridge's data into BMMS, Bridge Condition Survey was carried out by the consultants in 2004-2005 based on Bridge Condition Survey Manual of RHD at that time. However, no updating of BMMS data has been carried out since 2005.

In 2013 in line with making effort to more efficient bridge maintenance by RHD, the nationwide Bridge Condition Survey for 4,563 bridges except culverts were surveyed by using Bridge Condition Survey Manual 2013 of RHD through Eastern Bangladesh Bridge Improvement Project (EBBIP). The inspected results were inputted into BMMS.

From few years ago the significance of road and bridge maintenance has become strongly influenced by bridge collapse and poor condition of roads. Therefore, RHD has now been changing the direction of bridge maintenance strategy to establish more systematic and rational bridge maintenance to secure smooth traffic and to contribute to national economic growth.

By reviewing the existing Bridge Condition Survey Manual 2014 which includes some limitations on usability for the implementation of the most efficient bridge inspection and evaluation, and by identifying required significant revision/improvement of the existing manual, this manual was developed. Closely related to this manual, the intranet based Bridge Management System (BMS) providing the new concept and functions for effective bridge maintenance management, is also developed. Both are produced through the active discussions in the Workshops among the Core Members of RHD and the JICA Experts of the Bridge Management Capacity Development Project under JICA technical cooperation.

In order to achieve the objective of efficient bridge management system RHD has to be embarked on a regular bridge inspection program to monitor the condition of the bridges and to conduct follow-up rehabilitation and replacement work.

2. INTRODUCTION

Bridge inspection is the most important first step for assessment process of the physical condition of a bridge in order to determine remedial action, such as maintenance, repair, rehabilitation, strengthening, or replacement. And the efficiency of assessment process depends on the quality of the inspection and the operation of a powerful database, which must be regularly updated with the input of current information on the assets under management.

This Bridge Inspection and Evaluation Manual describes the necessary guidelines for carrying out the bridge inspection for effective management of RHD bridge stock, which includes all structures of bridges, box culverts, arch masonry, flyovers, roadway and railway overpasses (hereinafter all of these are referred to as "Bridges").

The primary objective of bridge inspection is to find out the physical condition of the bridge and to detect any abnormality or defects of the bridges at early stage that may affect safety of the users and bridge structures and to make the traffic flow smooth and comfortable. Another objective is to monitor development of the defects on the bridge continuously so that timely remedial measures can be taken. In addition, the results collected from the inspection can be used to develop inspection and maintenance program, to carry out load capacity assessment, and to provide feedback to the design process.

This Manual provides the detail procedures and requirements for inspection and rating of defects, evaluation for the necessary remedial actions, documentation and recorded data management of RHD's bridges in service. Data collected from these inspections and evaluation will be used to update the bridge inventory and to develop inspection and maintenance program by using the Bridge Management System (BMS) for efficient bridge maintenance of the prevailing bridge structures under RHD.

Future Revisions

It is intended that parts of the guidance and information contained in this manual need to be reviewed and updated from time to time as necessary to take into account the organizational framework of RHD, the accumulated engineering experiences, and new knowledge and lessons learned.

3. BRIDGE INSPECTION PROGRAM

3.1 Types of Inspection and Frequency

For the most efficient bridge inspection with limited resource, it is necessary to inspect the bridge by appropriate methods according to the purpose and the bridge condition at the appropriate time. The type of inspection is classified in terms of purpose, frequency, major items to be inspected and method of inspection.
These various types of inspection are presented in Table 3.1 below.

Table 3.1 Type of Inspections

Type	Purpose	Frequency	Methods
Scheduled Bridge Inspection			
Surveillance Patrol	General check of bridge structure	1 month	Vehicular patrol/ Foot patrol
Routine Inspection	General check of bridge structure condition	6 months	Visual inspection
Periodic Inspection	Condition check and defects finding, and assessment of safety of all structural components and elements of bridges	Periodic at intervals of 2 years	Visual inspection
Non-scheduled Bridge Inspection			
Interim Inspection	Monitoring of a particularly known or suspected deficiency after the last periodic inspection	If recommended in Periodical Inspection	Visual inspection
Emergency Inspection	Defects finding and assessment of structural condition	As required	Visual or Mechanical inspection
Detailed Investigation	Physical test and analysis (nondestructive/destructive), Monitoring of primary structural components	If recommended in The result of periodical inspection by the evaluator	Mechanical inspection

The depth and frequency of bridge inspection will depend on several factors such as age, traffic characteristics, state of maintenance, known defects. Regarding the frequency shown in the Table 3.1, the calculated grounds for the frequency with some assumptions is referenced in the last part of this chapter. It can be revised accordingly

3.1.1 Surveillance Patrol

Purpose

- To check the general serviceability of the bridge structure, particularly for the safety of road users, and identify any emerging problem.

Scope

- To find out any visible abnormality or damage of a bridge, such as structural damages, fallen objects, and illegal occupation etc. at early stage in a routine basis.

Any defects (such as that of deck surface, railing, wheel guard, lighting post and guide sign post, expansion joint, and truss members) recognized through driving shall be confirmed on foot as needed.

<Inspection Items>

- Pavement or deck slab	: Existence of crack and exposure of rebar, or check of traveling condition.
- Curbs and railing	: Existence of crack, spalling due to impact damage from vehicles and other deterioration of concrete or steel
- Expansion joint	: Existence of abnormal sound, difference in level and check of the traveling condition.
- Drainage	: Observation of drainage function on the bridge surface
- Railing, wheel guard, lighting post and guide sign post	: Existence of any abnormalities
- Illegal occupation	

Procedures and Inspector

It is mainly carried out by means of visual observation combined with vehicle patrol.

Any adverse condition during such inspection should be properly recorded and reported to the organization in charge.

It is carried out by a team of road maintenance personnel who have a good practical knowledge of defect of bridge structures but not necessarily trained in bridge inspection.

Frequency

Minimum frequency is generally one inspection per 1 month.

3.1.2 Routine Inspection

Purpose

- To check level of safety and ensure appropriate serviceability on and under the bridge.

Scope

- To find out any visible abnormality or damage on and under the bridge.
- Inspection items are all visible elements of a structure that can be inspected without the need for special access equipment or traffic management arrangements.

Procedures and Inspector

Observations are carried out with a prepared inventory sheet and check lists.

Prior to undertaking Routine Inspection, the inspector should review the record of the structure to familiarize themselves with the characteristics of the structure, condition of the bridge at the time of last inspection and any significant maintenance/modifications since the last inspection.

When Routine Inspection coincides with Periodic Inspection only the latter is undertaken.

Routine Inspection work is performed by the Sub-Assistant Engineer.

Frequency

Minimum frequency is generally one inspection per 6 months.

3.1.3 Periodic Inspection

Purpose

- To assess the physical and functional condition of every components and elements of the entire bridge with close visual observation,
- To evaluate the necessity for remedial measures by rating the defects that cause deterioration, and
- To ensure that the structure continues to remain in good serviceable conditions.

Periodic inspections are undertaken to detect defects at early stage. This will prevent possible further deterioration or failure and will provide information for the planning of further inspection, detailed investigation and remedial measures.

Scope

- Reviewing the existing inventory of the bridge structure.
- Visual inspection of all bridge elements (including measurement of crack widths, etc.) and assessment of defects using a standard condition rating system as defined in the reference of "Types of Defects and Rating" in the Chapter 3 and Appendix-6 of the Manual.
- Reporting the rating of defects of the bridge elements

Procedures and Inspector

Periodic Inspection is carried out with close visual observation of all external surfaces and features, and where appropriate, all internal surfaces by Senior Inspector (inspection team leader), Inspector and Assistant Inspector and other technical staff of the Sub-Division Office.

Frequency

Minimum frequency is generally one inspection in no longer than 2 years.

The first periodic inspection (Inventory Inspection) is carried out visually and systematically to collect inventory data to be recorded into the inventory record, to obtain bridge condition data and to assess condition of the bridge structure. Dimensions, general drawings, general photographs are recorded into the inventory form of each bridge, based on the latest available construction drawings.

The first periodic inspection is to be implemented within 2 years after the commencement of operation of the bridge. It is reported that initial defects such as the defects due to poor construction work (concrete crack of deck slab or girders), insufficient design (insufficient drainage system) and/or unexpected factors (defects due to abnormal vibration) are generally risen within these years. A sample bridge inventory sheet is shown in Appendix-9.1.

3.1.4 Interim Inspection

Purpose

- To monitor a particularly known or suspected deficiency between the periodic inspections and serves as a supplement of the periodic inspection.

Scope

- To monitor a particularly known or suspected deficiency discovered during periodic inspection, such as foundation settlement or scour, significant member deterioration, or the public's use of a load-posted bridge

  Example: Bridges posted for a weight limit less than the legal weight limit.
  The sign of rapid deterioration of a particular bridge element.
  Bridges with potential foundation problems such as scour.

Procedure and Inspector

Interim Inspection is carried out by means of visual observation. Senior Inspector should observe and monitor this condition to determine the effect on the bridge. The inspection interval may vary depending on the type of defects being inspected.

3.1.5 Emergency Inspection

Emergency Inspection is carried out whenever there is a natural disaster such as flooding, heavy rain, earthquake, landslide, or large accidents such as collision by vehicle/ship or fire or serious accidents on the bridge.

Purpose

- To confirm that the bridges remain safe for use or to determine the necessary urgent remedial action required to either ensure the safety of the bridge or to restore the function of the bridge.

Scope

The following measures should be taken in addition to collecting the additional information.

- To judge the severity of the defect, design documents, as built drawings and a history of maintenance works carried out earlier should be reviewed.
- Following investigation and measurement of the defects to the bridges needs to be carried out on site.

  Identify any fractured members.

  Determine any loss of foundation support.

  Compute the amount of any sectional loss.

  Measure the amount of any member is out of alignment.

  Inform the higher authority to take charge bridge maintenance that an updated load rating may be necessary.

With this information a decision will be required whether the bridge will needed to be closed to ensure the safety of public traffic.

Procedure and Inspector

Emergency Inspection is performed by the Senior Inspector (The inspection team leader), Inspector and Assistant Inspector and other technical staff of the Sub-Division Office.

The Senior Inspector should prepare an emergency inspection report and choose one of the following categories:

- Collision	Damage typically caused by over height vehicles or ship collision to piers
- Flooding	Damage as a result of scour to the channel beneath the structure
- Earthquake	Damage caused by seismic events
- Fire	Damages due to fire
- Reported by others	

<Example: Flood>

The bridge should be visited immediately after the flood to assess any damage to the bridge and to provide information about the actual impact of the flood. Senior Inspector should assess the impact of any of the following:

- Streambed scour around underwater bridge elements.
- Bank erosion.
- Lateral migrations of the channel.
- Sediment transport or accumulation (especially around piers).

After an emergency inspection report shall be prepared, descriptions and comments on the damage shall be added.

3.1.6 Detailed Investigation

Purpose

- To investigate defect causes or structural condition, behavior or to assess damaged structural components for repair/rehabilitation.

Scope

The following objectives are covered by detailed investigation.

- To grasp detailed behavior and actions of defect
- To monitor the progress of any defect
- To investigate the cause of defect
- To test and evaluate material quality or strength
- To evaluate structural strength

Procedure and Inspector

This is a very specialized job and it often requires use of nondestructive and minute destructive testing equipment in the inspection exercise. Based on it's result, recommendations will then be made on the most feasible rehabilitation methods.

Detailed investigation work is performed under the following circumstances by the professional engineers with expertise. (In case of necessity, Consultants carry out.)

- If recommended in the periodic inspection as a consequence of serious defects identified by the inspector
- If a load capacity assessment is required, and previous periodic inspection records do not contain sufficient information to allow an assessment of structural conditions.

3.2 Composition of Inspection Team and Requirement for Inspectors

Inspections shall be conducted by trained personnel who also have sufficient knowledge and extensive practical experience in material and structural behavior, bridge design, typical construction practices and capacities of carrying out visual observations by using special instruments. In addition, they shall be competent to have capacities of evaluating condition of the bridge correctly and proposing appropriate countermeasures optimal to the defects.

Furthermore, the inspector should have experience and awareness on safety for bridge inspection because a bridge inspection always involves safety risks.

RHD should have opportunities to train its engineers so as to be good inspectors at regular basis to make the bridge inspection initiative sustainable. (Bridge Inspection Manual 2012)

The inspection personnel consists of the Evaluator and the Inspectors (Senior Inspector, Inspector, Assistant inspector) as follows;

- Evaluator The role is;
  To evaluate the conditions of the bridge correctly and proposing appropriate remedial actions for the defects.
  The personnel who shall have extensive practical experience in material and structural behavior, bridge design, typical construction practices, and having the capacities of review of inspected results and make the appropriate recommendation of corrective actions.
- Inspectors The role is;
  To carry out visual observations by using special instruments, to judge the condition of bridge structures and the importance of the visual defects, and to prepare accurate inspection records, documents, and recommendation of corrective actions.
  The personnel, who shall have the ability to correctly identify and interpret the severity and nature of structural and material defects, assess their criticality.

The composition of inspection personnel is shown in Figure 3.1.
Each inspector's roles are described below.

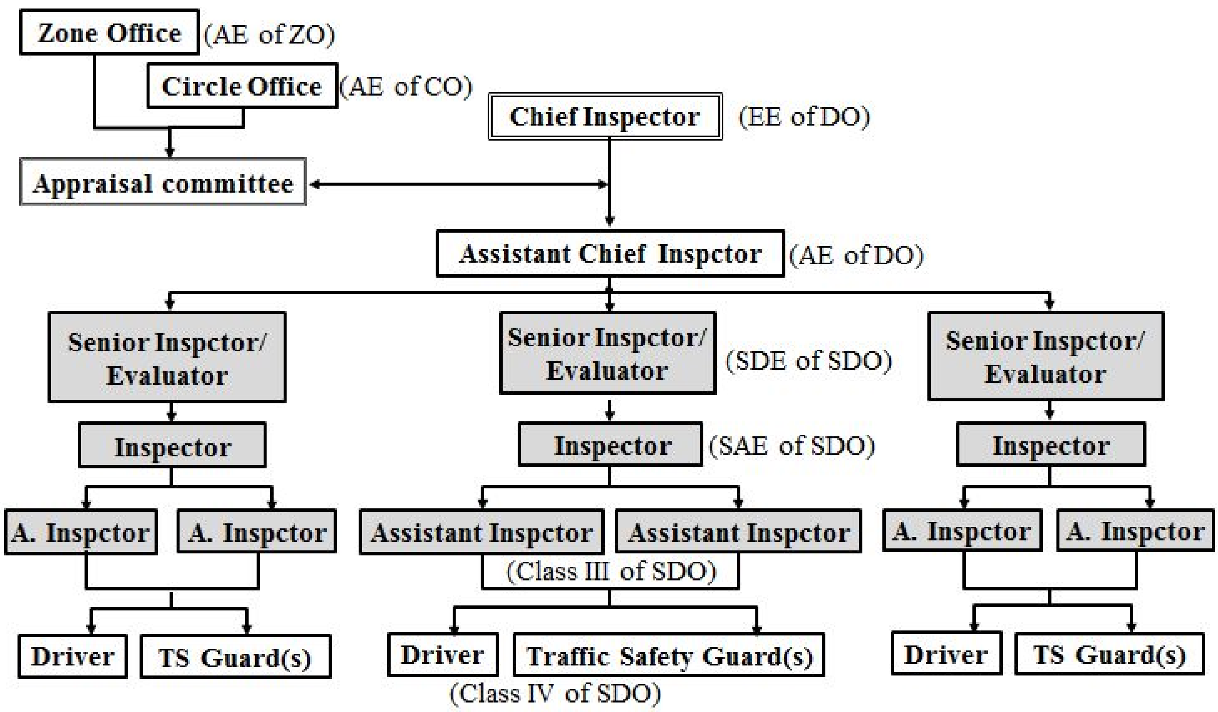

Figure 3.1 Composition of Inspection personnel

Chief Inspector

The Chief Inspector will take responsibility for all bridge inspection works and management program. The major roles of Chief Inspector are as follows;

1) To approve organization of bridge inspection team proposed by Sub-Division Offices
2) To approve bridge inspection plan proposed by Sub-Division Offices
3) To supervise bridge inspection works

Qualifications for Chief Inspector shall possess the following minimum qualifications:

1) Have successfully completed an RHD approved comprehensive bridge inspection training course based on the "Bridge Inspection and Evaluation Manual"

Assistant Chief Inspector (AE)

The Assistant Chief Inspector will assist the inspection work under Senior Inspector.
The major roles of Assistant Chief Inspector are as follows;

1) To check submitted document/data
2)To supervise inspection works on sites

Qualifications for Assistant Chief Inspector shall possess the following minimum qualifications:

1) Have successfully completed an RHD approved comprehensive bridge inspection training course based on the "Bridge Inspection and Evaluation Manual"

Senior Inspector (SDE) (Inspection Team Leader)

The Senior Inspector will control the inspection team, with due attention paid on the safety control, and understands the activities of each personnel while keeping close contact with the assistant inspector during inspection and investigation. The major responsible roles for field inspection work are as follows;

1) To establish the bridge inspection plan
   Past inspection data, location, schedule, tool and instrument list, vehicle & traffic safety guards list,
2) To conduct bridge inspection works on site.
3) To evaluate rating of remedial action of all bridges **as Evaluator**

Qualifications for Senior Inspector shall possess the following minimum qualifications:

1) Have successfully completed an RHD approved comprehensive bridge inspection training course based on the "Bridge Inspection and Evaluation Manual"

Inspector (SAE)

The Inspector will assist the inspection work under Senior Inspector.
On detection any defects or abnormality he will take record of the measurement result and practical defect/abnormality state using tools in compliance with the bridge

inspection procedure. He will also take photographs and draw a field sketch of the defect. The major rolls are as follows;

1) To confirm tool and equipment, vehicle and manpower prepared by Assistant Inspector
2) To instruct driver on planning of traveling routes
3) To implement bridge inspection works on site
4) To record inspection results on Inspection Recording Forms
5) To take photographs of the bridge and defects and to sketch defects if necessary
6) To assist Senior Inspector summarizing Inspection Recording Forms and making fair copy of Inspection Recording Forms including photos and sketches
7) To assist Senior Inspector inputting work of inspected results data into BMS

Qualifications for Inspector shall possess the following minimum qualifications:

1) Have successfully completed an RHD approved comprehensive bridge inspection training course based on the "Bridge Inspection and Evaluation Manual"

Assistant Inspector (Class III)

The Assistant Inspector will assist the inspection work under Inspector. The major rolls are as follows;

1) To assist daily preparation of bridge inspection works
   - Preparing necessary tool, equipment and material
   - Loading/unloading tool, equipment and material on/off the vehicle
2) To assist implementation of bridge inspection works
   - Inspection and taking photographs at narrow or high place
   - Measuring
   - Supporting scaffolding
   - Cleaning bridges, if necessary
   - Removing obstructions, if there

Qualifications for Assistant Inspector shall possess the following minimum qualifications:

1) Have successfully completed an RHD approved comprehensive bridge inspection training course based on the "Bridge Inspection and Evaluation Manual"

Traffic Safety Guard (Class IV)

The traffic safety guard will prevent traffic disturbance and ensure the safety of the inspection personnel during inspection. The major rolls are as follows;

1) To prepare necessary tool, equipment and material for traffic safety measures at inspection sites
2) To place necessary traffic control material on inspection sites
3) To watch and control traffic at inspection sites

Driver (Class IV)

The major rolls are as follows;

1) To confirm driving routes to inspection sites where instructed by the Inspector and get approval from the Inspector one day before inspection
2) To take the inspection team to the inspection sites according to approved routes with **Safety First Policy**
3) To find adequate space for parking during inspection works near inspection sites

Composition of Inspection Team

For the various types of inspections described in the section 3.1, the personnel of the field inspection team will be determined as shown in Table 3.2.

Table 3.2 Members of the Inspection Team

	Position	Number of Personnel		
		Surveillance Patrol	**Routine Inspection**	**Periodic Inspection**
Evaluator/Senior Inspector	SDE	---	---	1
Inspector	SAE	1	1	1
Assistant Inspector	Class III	As required	1 or 2	2
Driver	Class IV	1	1	1
Traffic Controller	Class IV	---	---	1

3.3 Inspection Tools and Access Equipment

In order to carry out the inspection properly the bridge inspector must be properly equipped with inspection tools and instruments. This is needed for measurement, recording, safety and access. Bridge location and type are two of the main factors in determining tools, instruments and access equipment. A set of recommended list of standard instrument is given below.

For more specialized inspection non-destructive testing (NDT) equipment may sometimes needed.

Table 3.3 Recommended list of Inspection tools

Measurement Tools

No.	Tools	Purposes
1	2m measuring tape	For measuring short dimensions
2	30m measuring tape	For measuring span length, width and other longer dimension
3	Plum bob	For measuring degree of tilting at pier
4	Crack scale	For measuring crack width
5	Vernier or jaw-type caliper	For measuring steel thickness
6	Spirit levels	For measuring perpendicular distance to any structural member and tilting of pier
7	Ranging rods	For probing and measuring scour under culverts, piers and abutments
8	GPS	To identify the location of the bridge
9	Laser Range Finder	To determine the distance of an object
10	Others if required	

Recording Tools

No.	Tools	Purposes
1	Digital camera	To take photographs of defects of the structures, and for bridge identification
2	Blackboard	To record bridge number/name while taking photographs for bridge identification; should be supplied with chalk and duster.
3	Clipboard	As a hard surface to write on when filing forms
4	Writing paper	For drawing sketches
5	Markers, pens and pencils	For marking and writing
6	Others if required	

Safety Tools

No.	Tools	Purposes
1	Safety vest	To be worn at all times during inspection
2	Helmet	To be worn at all times during inspection
3	Safety boots	To be worn at all times during inspection
4	Safety belt	To be used when climbing the structure
5	Life jacket	To be worn when inspecting over waterways
6	Goggles	To protect the eyes while looking under deck
7	First-aid kit	For first-aid treatment of any injuries
8	Traffic sign boards/cones	To be installed for traffic control

Access Tools

No.	Tools	Purposes
1	Ladder	For access to soffit, bearing, walls etc.
2	Binoculars	To be used when there is no access to the structure
3	Boats or barges	For access to river piers and spans
4	Tapping hammer	For tapping the concrete surface in order to determine the soundness of the structure Especially sounding by hammer can be used to detect delaminated areas.
5	Flash light/Head light	For lighting dark areas
6	Inspection mirrors	For identifying the defects which can't be seen directly
7	Wire brush	
8	Carrying bag	For holding equipment

Method of Access

The two primary methods of gaining access to a bridge are access facilities and access vehicles. All transportation and access facilities/vehicles should be inspected and maintained regularly.

a) Access facilities

The purpose of access facilities is to position the inspector close enough to the bridge element so that a close inspection can be performed. Common access facilities are as follows:

Ladders: Ladders can be used for inspecting the underside of a bridge or inspecting substructure units, and also be used only for those portions of the bridge that can be reached comfortably without undue leaning.

Scaffolds: Scaffolds provide an efficient access alternative for bridges narrow under clearance and over level ground.

Boats or Barges: Boats or barges may be used for bridges over water.

b) Access Vehicles

Most of smaller bridges can be accessed from below by ladders or small boat without great effort since this eliminates the need for traffic control on the bridge. But major and high-level bridges need the assistance of access vehicles.

Typical access vehicles are:

Manlift,

Bucket Truck,

Under-bridge inspection vehicle.

Whenever an inspection access vehicle is to be placed on a bridge deck, the strength and geometry of the deck and framing should be reviewed to ascertain the safe and effective use of the equipment.

The use of the under-bridge inspection vehicle may cause traffic control that may create several problems, such as inconvenience to the public, inspection cost, and safety of the public and inspectors.

Cautions for inspection with an under-bridge inspection vehicle are as follows;

- A trained operator must operate the bucket/platform and keep contact with an inspector on the bucket/platform.
- For setting up traffic control it is necessary to submit the work plan to a local police authority for approval beforehand.

Reference: Questions to apply heavy access vehicles

Source: Fundamentals of Bridge Inspection USA

In most cases, even the most sluggish lift device will be quicker than using a ladder or rigging to inspect a structure. The time saved, however, must offset the higher costs associated with obtaining and operating the vehicle.

In assessing the time-saving effectiveness of a lift device, the following questions should be answered:

- Can the bridge be inspected by other reasonable methods?
- What types of access vehicle or access equipment are available?
- How much of the bridge can be inspected using the access vehicle?
- How much of the bridge can be inspected from one setup of the access vehicle?
- How much time does it take to inspect at each setup?
- How much time does it take to move from one setup to the next?
- Does the vehicle require an independent operator or driver other than the inspector?
- Will the use of the access vehicle require special traffic control?
- Can the bridge carry the weight of an inspection vehicle?

The inspection time and vehicle costs can then be compared to costs associated with using standard access equipment.

Reference: Bridge Inspection/Evaluation Work Period and Frequency
-By Inspection Team of Staff of Sub-Division-

Approved at Workshop 14 on April 10, 2016

1. Condition

- Inspection work for all bridges and culverts is carried out by <u>one team</u> of the staff of each Sub-Division Office.
  (No consideration of 1) Exclusive staff of Division Office and 2) Outsourcing)
- Inspection work includes field inspection work, making report and data input of inspected results at office.

2. Calculation of No.of bridges to be inspected / evaluated for Periodic Inspection

1) Number of bridges to be inspected/evaluated

3 bridges /day = 6 bridges /*<u>2 days*(1 week)</u>*

(* Inspection Work **2 hours/bridge** * 3 bridges = 6 hours
Traveling time = 1 hour/day)

Work of Sub-Division Engineer, Inspection Team Leader

Field inspection: 2 days

Evaluation for D-rated bridge: 1 day

	Av. No. of Bridges	Progress		Necessary Months	Deployed Teams	Remarks
		Weekly	Monthly			
Sub-Division Office Staff	138	6	26	5.3	1 team/SDO (133 teams)	Dry season only 2 days(6 bridges) /week

Other 2 days: **other work**

2) Monthly progress

= **6 (bridges /week)** * <u>30.5 (days/month) / 7 (days/week)</u>= **26 (bridges/month)**

= 4.4 week/month

3. Summary

Dry season= 8 month (October ~ May) **only**

✓ Inspection work including field work and making report for defect rating and evaluation for remedial actions at office require **5.3 months average** within dry season. It is possible to implement periodic inspection with **the frequency of 1 year as a minimum** for all bridges and culverts managed by each Sub-Division Office.

✓ It is recommended to implement inspection effectively with the combination of the following types of inspection.

Types of Inspection	Expected Frequency
1) Superficial Inspection/Patrol	2 weeks
2) Routine Inspection	**6 Months** (at the beginning and the end of dry season)
3) Periodic Inspection	**No longer than 2 years**

Points to be considered comprehensively:

- Practical training for new inspectors
- Technology succession of Inspectors due to personnel change — As short period as possible
- To grasp the state of severity and progress of various defects — As short period as possible
- Data check and active use for maintenance plan of BMS by BMW — Minimum 2 years preferable

✓ In Sub-Division Office with more than average number of bridges (142 bridges)

More than one team can be implemented?

Not only dry season but other seasons inspection is possible or not.

Possible Options: for More than 300 bridges in one Sub-Division

- Increase of inspection team
- Extension of inspection work period available
- Cooperation with the team in the adjacent Sub-Division
- Outsourcing controlled by the central authority

Basic Information

		A	B	C	D	Total	
No. of Bridges		12,401	2,352	2,834	768	18,355	
Rate (%)		68	13	15	4	100	
Average No. of Bridges							
Zone	10 Zones	1,240	235	283	77	1,836	
Division Office	6.5 Dos/Zone	191	36	44	12	282	
Sub-Division Office	2 SDOs/DO	96	18	22	6	138	average
=133 Sub-Divisions/65Divisions							
6 bridges/week = 3 bridges/day*2 days/week		4.06	0.77	0.92	0.25	6	average

4. Routine Inspection

1)Field Inspection — 10 bridges/day — including box culvert

Items to be considered — 1 hour travelling

1) Past performance by EBBIP (bridges only) 180 bridges/month

2) Past experience

2)Team arrangement

Inspector	1
Assistant Inspector	1 or 2
Driver	1

3)Inspection and making report

Field Inspection : 3 days 30 bridges/week

Making report : 2 days

4)Period for 133 bridges in Sub-division

133 bridges/30 bridges /week = 4.5 week =**1.2 months**

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4. INSPECTION PROCEDURE

4.1 Planning of Inspection

An inspection always begins with good planning.
To implement the inspection orderly and systematically, the Senior Inspector should develop appropriate programs in advance, which are necessary for an efficient, cost-effective effort which will also result in an accurate, thorough and complete inspection. Main activities are as follows:

- Listing of all the bridges to be inspected
- Determination of the type of inspection
- Establishment of a time schedule of an inspection work
- Arrangement of the inspection team staff
- Arrangement of available tools and equipment requirements
- Seasonal restrictions

It is important to keep a schedule flexible taking account for delays caused by weather, shutting down traffic lanes and working over railroads, equipment breakdown, and personnel absence.

4.2 Preparation for the Inspection

Prior to commencing inspections the inspector shall ensure that he has all relevant documentation, inspection and safety tools and equipment and has made the appropriate arrangements with the relevant road, railway or other authorities for temporary access to carry out the inspection. No structure should be inspected without some measure of preparation.
Main activities are as follows:

- ➢ Reviewing the bridge inventory file
    - Previous inspection reports
    - Maintenance and repair records
    - Hydrologic data

      Shape and location of the channel, the presence of protection device, flood frequencies, and water elevations for various flood intervals

- Identifying the components and elements

  Establishment of the structure orientation and a system for identifying the various components/elements of the bridge

  The route direction based on the chainage: to identify the beginning and the end of the bridge

  Details of element numbering system are shown in the Appendix-4.
- Developing an inspection sequence
- Preparing and organizing note, forms, and sketches
  - To eliminate unnecessary work in the field, copies of the standard inspection form should be obtained for use in recordkeeping and as a checklist to ensure that the condition of all elements is noted.
  - A copy of previous inspection report including photographs and any other relevant information shall be taken to the bridge site.
- Arranging for traffic control
  - When working in an area exposed to traffic, the bridge inspector should check and follow the governing standards.
  - Schedules may have to be adjusted to accommodate traffic control needs.
- Reviewing the safety precautions
  - The importance of taking safety precautions cannot be overlooked.
  - The inspection team must follow the general guidelines for safety precautions.
- Organizing tools and equipment

  Bridge location and the type are the main factors to determine the required tools and equipment.
- Information to authorities
  - If lane closure is required, particularly on heavily trafficked roads, it may be necessary to inform the local police.
  - Working on or over railroads usually requires special procedures. The owner should always be informed when entering his property. Be sure to follow the owner's procedures and never foul the track with the equipment without prior approval.
- Contingency planning

  It includes knowing where to go or whom to notify in case of emergency, and having the office and home phone numbers of the involved in the inspection.

If the inspector is not familiar with the site and possible external factors, then a familiarization visit (Pre-inspection Investigation) will be beneficial.

It is recommended to clear the bridge and areas surrounding the bridge from undergrowth and vegetation.

4.3 Performing the Inspection

At the bridge site the inspector shall carry out the inspection in a systematic manner starting at the deck surface and approaches, proceeding from the start of the bridge down through the superstructure and substructure. Inspector shall complete the following activities;

1) Site Orientation

   The orientation should include the compass directions, the direction of waterway flow, and the direction of the inventory route. Also record inspection team, air temperature, weather conditions, and time.

2) Coordination Meeting

   A coordination meeting should be held among all of the inspection team members for clear understanding of what is to be accomplished and how to do it safely to the completion of the inspection in addition to the possible safety risks.

3) On-site Inspection

- The followings should be checked to avoid mistake in identifying the bridge:
  - Bridge number, if any
  - Bridge name/River name, if any
  - Road section number and distance to the bridge
  - Other identification mark if none of the above is available

  Marking components and elements of the structure is carried out, in order to keep track of the inspector's location and to guard against overlooking any portion of the structure.
- Inspect and assess the condition of each standard component and element and the extent of them to which the rating applies.
  - Observations should be careful and attentive to the work at hand, and when problems are found, the location, size, and severity of the deterioration or distress and its probable cause should be noted. Refer to the guide on types of defects for severity rating and material condition rating to determine the types of defects and the rating of them.
  - Every point should be noted as soon as the observation is made. No portion should be overlooked.

Photographs and sketches are the most effective ways of describing a defect or the condition of structural elements. An appropriate photographic and sketch record must be compiled for Periodic Inspection Report by the Senior Inspector.

- Mandatory inventory photographs

  Elevation of structure (both sides)

  General view of carriageway over deck (both directions)

  View from approach road, with the bridge number or other identification written on a blackboard

- Deficient components and major defects.
  - Must be taken for the worst condition for each span of bridges
  - Must include any information in terms of defects
  - Must show measurement if possible by placing ribbon rod/measuring tape beside damage points
- Undefined Components.

Detailed work procedure and the work flow (Figure 4.1 and Figure 4.2) of periodic inspection and emergency inspection are described in the following pages:

Detailed Work Procedure of **Periodic Inspection**

Actual work procedures for periodic inspection are presented as follows:

1) Annual Plan	To implement periodic inspection effectively and to ensure an even work load throughout the year, Sub-Division Engineer in consultation with Executive Engineer shall first prepare annual plan for periodic inspections. The following items shall be taken into account when planning. - Selection of appropriate season for each bridge to properly understand their condition (such as during periods of rain to continue the adequacy of the drainage system) - An equal distribution of manpower throughout the year to execute work. - The availability of inspection equipment. - Preparation of a time schedule to carry out repairs based on the inspection result.
2) Execution Plan	A monthly or weekly execution plan shall be made for manpower allocation, and for organizing inspection teams and routes.
3) Defect?	Prior to inspection work, inspectors shall prepare visual inspection data sheets to record their observations of defects. Previous inspections shall be reviewed to understand the nature of previously recorded defects. This shall be checked together with any new defect to the bridge elements. If identified the inspector shall determine if further measurements are needed.
4) Rating by Inspectors	When inspector identify defect, the inspector shall describe the condition of the defect and rate it according to the Manual. A photographic record of the inspection should also be appended to the report.
5) Urgent Repair? [Evaluation]	Serious defect to primary elements that support vehicle loads directly may require urgent remedial measures to secure the safety of vehicular traffic and to avoid the progress of defect. Therefore, inspectors shall judge whether or not urgent remedial measures are necessary as quickly as possible for both safety and cost efficiency.
6) Further Inspection?	When an inspector cannot decide the rating of defect and/or cause of defect by visual inspection only, the inspector shall decide whether further inspections such as a special inspection, re-inspection or monitoring are necessary.
7) Further Inspection	When further inspections such as monitoring or detail investigation are necessary, an inspection plan shall be drawn up.
8) Detail Investigation	Detail Investigation will be carried out considering inspection methods based on the characteristics of the bridge and its defect.
9) Repair Need?	The final decision for remedial measures to damaged elements shall be made by the Evaluator (Sub-Division Engineer).

10) Input into Database	Inspected results on the above issues shall be input into the inspection database file by an operator as soon as possible.
11) Output from Database	The periodic inspection report form shall be in the form of official report. In addition, checks for input errors shall be made immediately after outputting. Photographs can be attached to the report form.
12) Periodic Inspection Report	Periodic Inspection Report shall be kept on file, and referred to or photocopied for any official reason.
13) Repair Plan	A repair plan shall be formulated by Sub-Division Engineer in consultation with Executive Engineer concerning the repair method and design, the date of completion, person in charge, and the budget allocation.

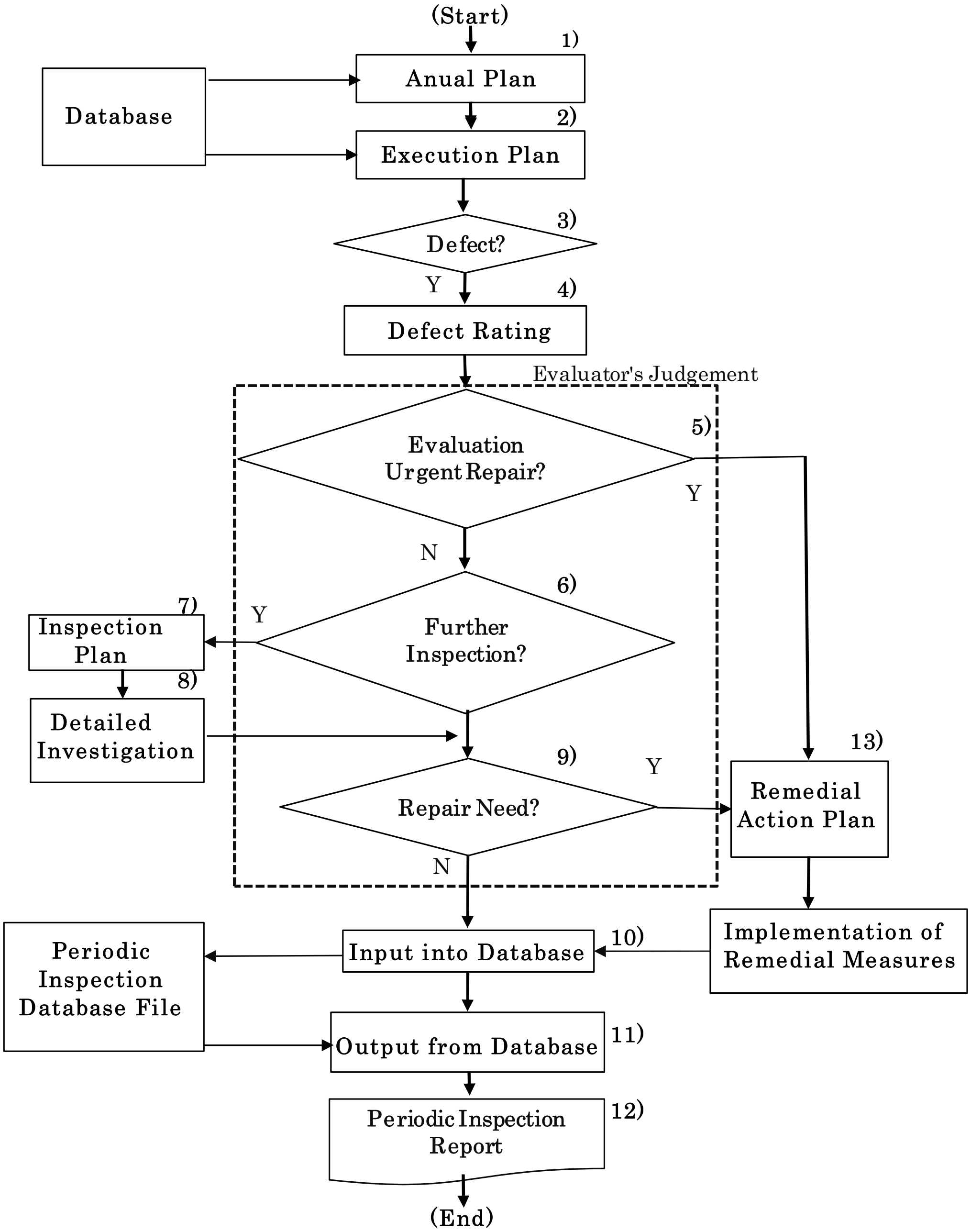


Fig. 4.1 Flow Chart of Periodic Inspection

Detailed Work Procedure of **Emergency Inspection**

Actual work procedures for periodic inspection are presented as follows:

1) Defect?	Prior to inspection work, inspectors shall prepare visual inspection data sheets to record their observations of defects.
2) Emergency Measures Required?	When inspectors identify serious obstacles to vehicular traffic due to damage to the bridge element, the Inspector/Evaluator shall determine whether or not emergency measures are necessary to ensure public safety and to avoid further accidents.
3) Emergency Measures	Inspectors shall convey information to Executive Engineer of Division to secure traffic safety and to avoid further accidents with appropriate emergency measures.
4) Rating by Inspectors	When an inspector identify defect, the inspector shall describe the condition of the defect and rate it according to the Manual. Inspectors shall also take photographs of any serious defects to show to Evaluator (Sub-Division Engineer).
5) Urgent Repair? [Evaluation]	Serious defect to primary element that support vehicle loads directly may require urgent remedial measures to secure the safety of vehicular traffic and to avoid the progress of defect. Therefore, Evaluator shall judge whether or not urgent remedial measures are necessary as quickly as possible for both safety and cost efficiency.
6) Further Inspection	When an inspection cannot decide the rating of defect and/or cause of defect by visual inspection only, the inspector shall decide whether further inspections such as Detailed Investigation, re-inspection or monitoring are necessary.
7) Inspection Plan	When further inspections such as monitoring or detail inspection is necessary, an inspection plan shall be drawn up.
8) Detail Investigation	Detail Investigation will be carried out considering inspection methods based on the characteristics of the bridge and its defect.
9) Repair Need?	The final decision for remedial measures to damaged elements shall be made by the Evaluator.
10) Input into Database	Inspected results on the above issues shall be input into the inspection database file by an operator as soon as possible.
11) Output from Database	The emergency inspection report form shall be in the form of official report. In addition, checks for input errors shall be made immediately after outputting. Photographs can be attached to the report form.
12) Emergency Inspection Report	Emergency Inspection Report shall be kept on file, and referred to or photocopied for any official reason.
13) Repair Plan	A repair plan shall be formulated by Executive Engineer of Division concerning the repair method and design, the date of completion, personnel in charge, and the budget allocation.

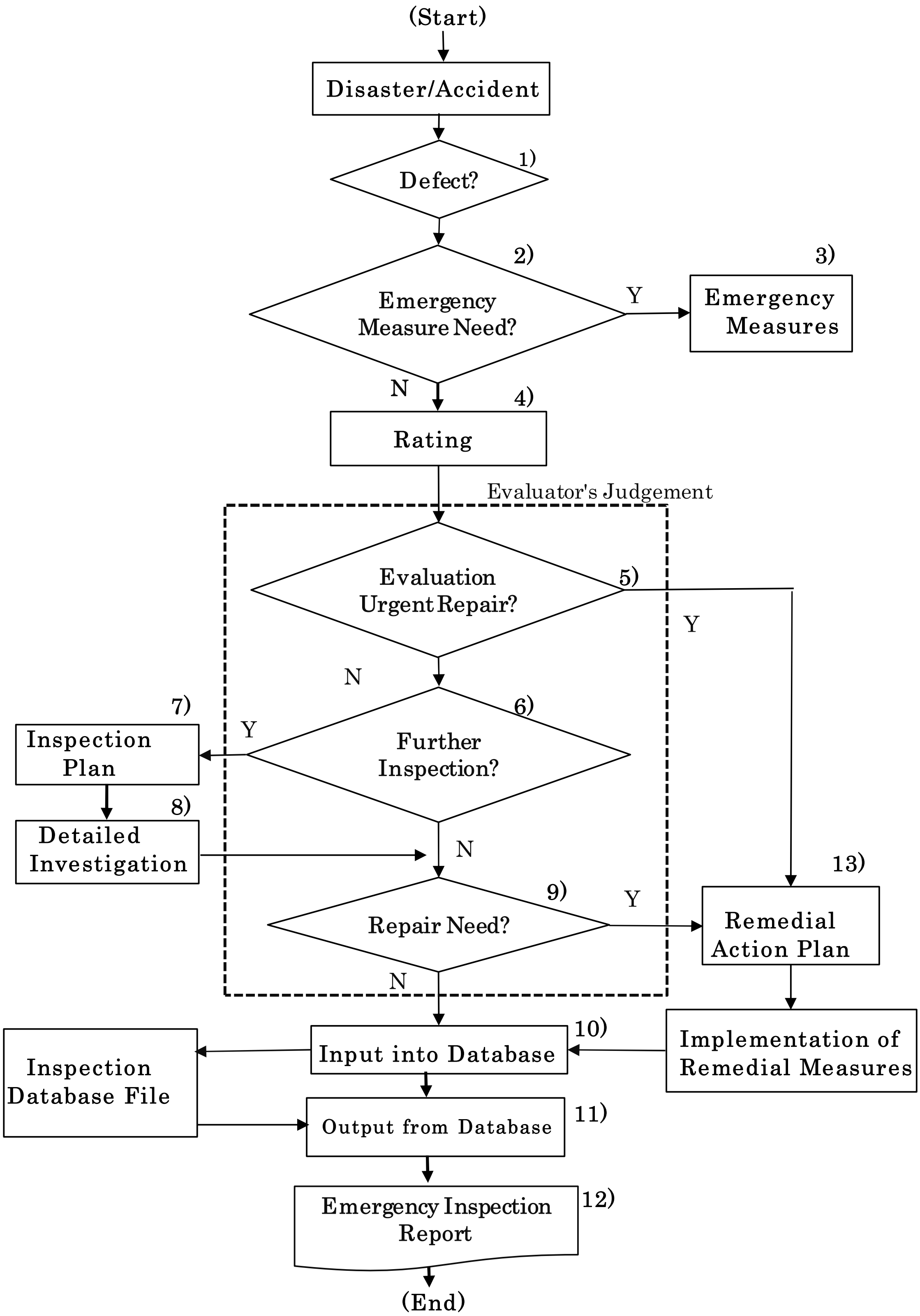


Figure 4.2 Flow Chart of Emergency Inspection

4.4 Reporting of Inspection

A Bridge Inspection Report must be prepared at the completion of each periodic inspection to record the inspection findings, provide a narrative description of conditions at the bridge site. Senior Inspector shall record and submit the findings of the periodic inspection to the Chef Inspector in Division Office.
The Bridge Inspection Report form will have the following preprinted information that will identify the bridge:

- GPS coordinates or latitude/ longitude descriptions
- Bridge Name
- Route: The number of the inventory route carried on or under the bridge.
- Chainage: The bridge's chainage on the inventory route.
- Intersecting: The feature or features which intersect with the bridge such as river, road, railway and public park

The reporting of the defects and deterioration is done according to their severity and extent. Typical faults and defects are described in Chapter 6 of this manual and the reprinting procedures together with the method for assessing the defects found are described in Chapter 7 of this manual.

Great care should be taken in filling the data sheet, as an accurate and consistent record of defects found is essential for comparison with previous sheets and in the future with subsequent sheets to show if the bridge condition is changing.

Serious defect of the primary element that support vehicle loads directly may require urgent remedial measures to secure the safety of public traffic and so avoid the progress of deficiency. Inspectors shall judge if urgent remedial measures are necessary as quick as possible for both safety and cost efficiency reasons. Critical findings that are a structural or safety related deficiency to require immediate follow up inspection or remedial measures shall be reported to the Chief Inspector as soon as possible.

4.5 Safety during Inspection

4.5.1 Basic safety Rules

During the bridge inspection, the safety of inspectors and of the public using the bridge or passing beneath the bridge should be given utmost importance. Prior to the inspection a suitable and sufficient assessment of the risks to them for the particular situation and inspection techniques involved needs to be carried out. The Senior Inspector is responsible for creating a safe environment for inspectors and the public.

During the inspection, inspectors are encouraged to follow the standard safety guidelines strictly. It is required to prepare a safety plan for the inspection. This plan should review standard bridge inspection safety procedures and then detail site-specific safety requirements such as traffic control, contact personnel, emergency telephone numbers, and the safe conduct to be used around the specific inspection equipment to be used. This plan should be distributed to all personnel and be discussed at the coordination meeting before the inspection is begun.

4.5.2 Safety Rules for Inspection Team

i) Approach to Site

Prior to approaching the inspection site arrangements will have been made to implement the appropriate traffic control measures.
Inspection team members should be aware of the layout of any traffic control measures as these may change as the inspection proceeds.

Whenever inspection team vehicles are parked so that they are not a obstruction to other users.

ii) Access

At inspection site, the inspection team members must satisfy themselves that the access facilities are adequate and safe. The inspection team must always have a communication system when entering confined spaces or areas away from the public.

iii) Precautions

Inspection team members should remain alert and safety conscious at all times.
All necessary precautions must be taken by inspection team members in advance to minimize the probability of accidents on site.
Protective clothing including helmet and safety boots should be worn. When inspection team members are on or adjacent to a trafficked carriageway they must wear a high visibility reflective waistcoat.
All inspections are carried out in well-ventilated and well-lit areas. When working in confronted spaces or using high or deep ladders inspector should ensure they have the physical and mental requirements needed to observe the inspection procedure.

iv) Tools and Instruments

Inspector must ensure that any tools and instruments carried such as cameras and tools for access, measurement and recording should be properly slung in carry bag so as to leave both hands free for using ladders and scaffolding. Tools and instruments should be handled and used in a safe manner that it does not endanger others such as dropping articles from an over-bridge.

4.5.3 Traffic Control Measures

Traffic control measures will always need to be implemented whenever the bridge inspection requires partial closure of the carriageway. This is particularly so when long term inspection work requires the use of under-bridge platforms or when equipment, such as scaffolding, needs to be erected or dismantled.

The layout illustrated in Figure 4.1 shows typical examples of lane control to provide a safe working area for the inspection work as minimum requirements. The traffic condition including speed and number of passing vehicles should be taken into account.

Use of traffic safety guard (flagmen) should be considered if this is considered advantageous. Traffic safety guard will be required to control traffic when traffic control measure is implemented.

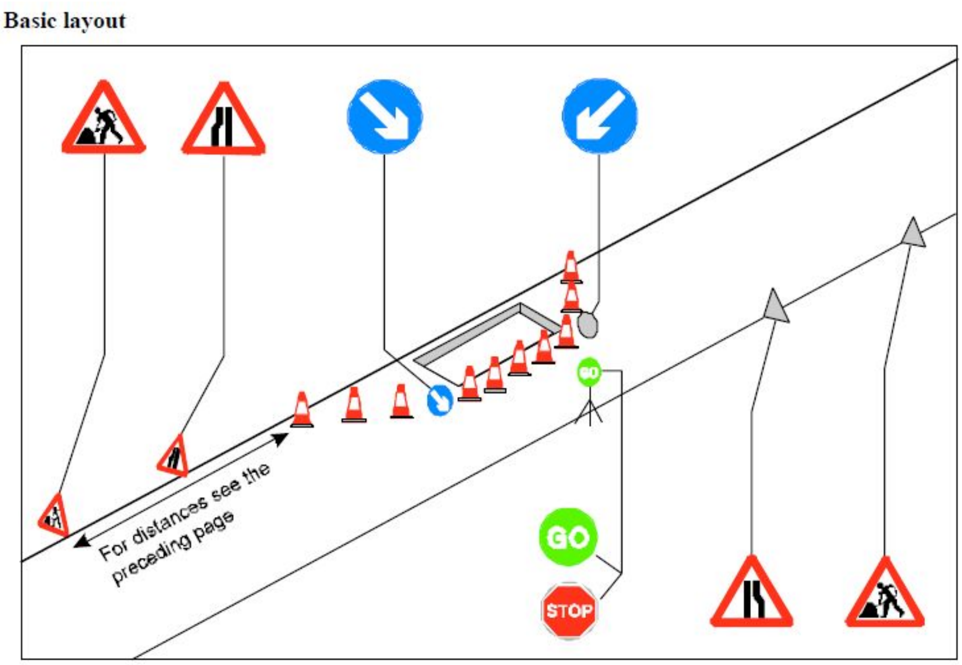


Figure 4.3 Basic Layout of Road Signs
(Safety at Road Works; Bangladesh Road Sign Manual)

5. TYPES AND CONDITIONS OF DEFECTS

5.1 Types of Bridge and Configurations

Bridges are classified according to their function, structural type, and structural material. The inspector must be aware of bridge types to properly describe a bridge for the inspection report.

Box culvert shall be considered as a bridge in this manual.

Typical types of bridges can be defined according to the basic types of structural materials (steel, concrete, timber, stone, masonry) and the type of superstructure.

They are summarized in Table 5.1 Types of Bridge and Configuration and in **Appendix-2.**

Table 5.1 Types of Bridge and Configurations

Superstructure Type	
<Concrete Bridge>	**<Steel Bridge>**
1. RC Slab Bridge	10. Steel Girder Bridge
2. RC Girder Bridge	11. Steel Box Girder Bridge
3. PC Girder Bridge	12. Steel Arch Bridge
4. PC Box Girder Bridge	13. Truss Bridge with Steel Deck
5. Concrete Arch Bridge	14. Truss Bridge with RC Slab
6. Cantilever Bridge with Hinge	15. Truss Bridge with Timber Deck
7. Rigid Frame Bridge	16. Portable Steel Bridge with Steel Deck
8. Cable-stayed Bridge	17. Portable Steel Bridge with Timber Deck
9. Small Slab Bridge	
<Masonry Arch Bridge>	18. Masonry Arch Bridge
<Culvert>	19. Box Culvert
Substructure Type	
Abutment	
Pier	
Foundation	
Bearings	

5.2 Bridge Components and Elements

In order to standardize information management and work procedures for the effective maintenance of the bridge stock, the inspection and maintenance system defines the objective bridges together with their components and the defects they may sustain. General bridge types and configurations are shown in **Appendix-2**.

Each of the bridge components has an important function to enable the structure as a whole to support live and dead loads. The bridge components/elements are classified based on structural behavior as either primary or secondary as shown in Table 5.2.
Primary structural components are composed of deck slab, girders, columns, abutments and foundations to support live and dead load directly.

Table 5.2 Bridge Components/Elements

1) Primary components:	They determine the overall condition and safety of the primary load carrying members. ▪ Superstructure including deck slab ▪ Substructure (piers, abutment and foundation) ▪ Bearings
2) Secondary components:	Other than the Primary components ▪ Deck surface ▪ Expansion joint ▪ Drainage system ▪ Approaches ▪ Other elements :railing, wheel guard, lighting post

"Approaches" is defined as the carriageway immediately behind the abutments and includes such items as wearing surface on the approach pavement, relieving slabs and drainage.
The length of approach behind abutment generally is within the equivalent length to the vertical approximate height of the abutment considering the geotechnical and structural influence range of bridge abutment.

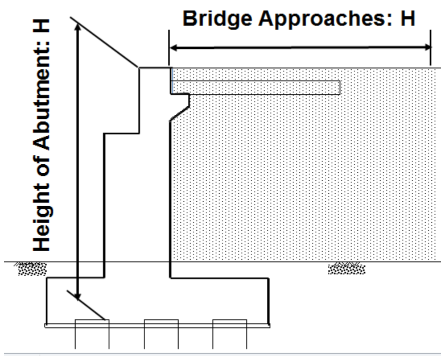


Figure 5.1 Bridge Approaches

Table 5.3 Classification of Components/Elements

Primary Components/Elements	Secondary Components/Elements
Superstructure	**Superstructure**
Main Girders	Sway Bracing
Main Girder Hinge (Gerber type)	Lateral Bracing
Cross Beam	Cable-stayed Bridge
Stringer	Horizontal Member of Tower Column
Deck Slab	Diagonal Member at Towers
Truss Structure:	**Deck Surface**
Upper/Lower Chord	Railing
Diagonal/Vertical Member	Guard Fence
Panel Point	Felloe Guard
Arch Structure:	Median
Arch Rib, Stiffening Member	Expansion Joint
Suspender/Support	(including post-cast concrete)
Panel point	Lighting Facility
Rigid Frame Structure:	Signs
Main Structure (Girder)	Curb
Main Structure (Pier)	Pavement
Cable-stayed Bridge	Approaches
Diagonal Member	**Drainage System**
Tower Columns	Drain Opening
Outer Cable	Drain Pipe
PC Anchorage	**Inspection Facilities**
Substructure	**Utilities**
Piers	**Wing Wall adjacent to Abutment**
Abutment	
Foundations	
Bearings	
Main Body of Bearings	
Anchor Bolts	
Bearing Seat Mortar	
Bearing Bed Concrete	

Inspection method must be selected carefully in line with features of the bridges, components and elements targeted for inspection, situation and environment in which the target bridge stands so that any possible defects shown in Table 5.3 can be identified.

Table 5.4 to Table 5.9 show possible defects, which are listed against the types, components and elements so as to facilitate inspectors to identify defects easily.

Table 5.4 Possible Defects for Superstructure

Component/Element		Types of Defects	
		Concrete Material	Steel Material
Superstructure :Sp			
* Main Girders :Mg		6) Crack 7) Spalling /Exposed rebar 8) Water leakage/Efflorescence 9) Fallen out of deck slab 10) Crack of deck slab 11) Delamination 12) Abnormal Spacing 17) Defects of reinforced materials for rehabilitation/strengthening 18) Abnormal anchorage 19) Discoloration/Deterioration 20) Water leakage/Puddle 21) Abnormal noise/Vibration 22) Abnormal deflection 23) Deformation/Break	1) Corrosion 2) Crack in steel 3) Loose connection/Missing bolts 4) Fracture 5) Deterioration of protective function 12) Abnormal Spacing 17) Defects of reinforced materials for rehabilitation/strengthening 18) Abnormal Anchorage 20) Water Leakage/Puddle 21) Abnormal Noise/Vibration 22) Abnormal deflection 23) Deformation/Break
* Main Girder Hinge (Gerber Type) :Gb			
* Cross Beam :Cr			
* Stringer :St			
* Deck Slab :Ds			
Cross Frame :Cf			
Lateral Bracing	Upper Lateral Bracing :Lu		
	Lower Lateral Bracing :Ll		
Main Truss	* Upper/Lower Member :Bt		
	* Diagonal/Vertical Member:Dt		
	* Portal Bracing Pt		
	* Panel Point :Pp		
	* Embedded Diagonal/vertical Members into Concrete :Em		
Arch	* Arch Rib :Ar	6) Crack 7) Spalling /Exposed rebar 8) Water leakage/Efflorescence 9) Fallen out of deck slab 10) Crack of deck slab 11) Delamination 12) Abnormal spacing 17) Defects of reinforced materials for rehabilitation/strengthening 18) Abnormal anchorage 19) Discoloration/Deterioration 20) Water Leakage/Puddle 21) Abnormal Noise/Vibration 22) Abnormal Deflection 23) Deformation/Break	
	* Stiffening Girder :Sg		
	* Suspended Member :Ha		
	* Column :Ca		
	* Portal Bracing :Pa		
	* Panel Point *Pp		
	* Embedded Diagonal/vertical Members into Concrete :Em		
Rigid Frame	* Rigid Frame (Girder) :Rg		
	* Rigid Frame (Pier) :Rp		
Cable-stayed Bridge	* Stay Cable :St		
	* Tower Shaft		
	Tower hirizontal Member :Th		
	Tower diagonal Member :Td		
* Outer Cable :Co		—	
PC Anchorage :Cn		6) Crack 7) Spalling/Exposed rebar 8) Water leakage/Efflorescence 12) Delamination 18) Abnormal Anchorage 19) Discoloration/Deterioration 23) Deformation/Break	1) Corrosion 5) Deterioration of protective function 23) Deformation/Break
Other Elements :Sx			

Table 5.5 Possible defects for Substructure

<table>
<tr><th colspan="3" rowspan="2">Component/Element</th><th colspan="2">Types of Defects</th></tr>
<tr><th>Concrete Material</th><th>Steel Material</th></tr>
<tr><td colspan="3">Substructure:Sb</td><td></td><td></td></tr>
<tr><td rowspan="7"></td><td rowspan="3">* Piers : P</td><td>Column/Wall :Pw</td><td rowspan="4">6) Crack
7) Spalling /Exposed rebar
8) Water leakage/Efflorescence
12) Delamination
17) Defects of reinforced materials for rehabilitation/strengthening
18) Abnormal Anchorage
19) Discoloration/Deterioration
20) Water Leakage/Puddle
21) Abnormal Noise/Vibration
22) Abnormal Deflection
23) Deformation/Break</td><td rowspan="3">1) Corrosion
2) Crack in steel
3) Loose connection/Missing bolts
4) Fracture
5) Deterioration of protective function
17) Defects of reinforced materials for rehabilitation/strengthening
20) Water Leakage/Puddle
21) Abnormal Noise/Vibration
22) Abnormal Deflection
23) Deformation/Break</td></tr>
<tr><td>Beam :Pb</td></tr>
<tr><td>Corner/Connection :Pc</td></tr>
<tr><td>*Abutment :A</td><td>Parapet :Ap
Vertical Wall :Ac
Wing Wall :Aw</td><td></td></tr>
<tr><td colspan="2">* Foundation :F</td><td>6) Crack
7) Spalling /Exposed rebar
25) Settlement/Tilt/Movement
26) Scouring</td><td>1) Corrosion
2) Crack in steel
5) Deterioration of protective function
25) Settlement/Tilt/Movement
26) Scouring</td></tr>
<tr><td colspan="2">Other Elements :Sbx</td><td></td><td></td></tr>
</table>

Table 5.6 Possible Defects for Bearings

Component/Element	Types of Defects		
	Concrete Material	Steel Material	Others
* Bearings :B			
Bearings (Main Body) :Bh		1) Corrosion 2) Crack in steel 3) Loose connection/Missing bolts 4) Fracture 5) Deterioration of protective function 12) Abnormal spacing 15) Functional Disorder of bearings 20) Water leakage/Puddle 21) Abnormal noise/Vibration 23) Deformation/Break 24) Accumulation of debris 25) Settlement/Tilt/Movement	4) Fracture 12) Abnormal spacing 15) Functional disorder of bearings 19) Discoloration/Deterioration 20) Water leakage/Puddle 21) Abnormal noise/Vibration 23) Deformation/Break 24) Accumulation of debris
Anchor Bolts :Ba		1) Corrosion 2) Crack in steel 3) Loose connection/Missing bolts 4) Fracture 5) Deterioration of protective function 23) Deformation/Break	
Bearing Seat Mortar :Bm Bearing Bed Concrete :Bc	6) Crack 7) Spalling /Exposed rebar 12) Delamination 20) Water leakage/Puddle 23) Deformation/Break		
Other Element :Bx			

Table 5.7 Possible Defects for Deck Surface

Component/Element		Types of Defects		
		Concrete Material	Steel Material	Others
Deck Surface :Ds				
	Railing :Ra Wheel Guard :Wg Median :Me	6) Crack 7) Spalling /Exposed rebar 8) Water leakage/ Efflorescence 17) Defects of reinforced materials for rehabilitation/strengthening 11) Delamination 19) Discoloration/Deterioration 23) Deformation/Break	1) Corrosion 2) Crack in steel 3) Loose connection/Missing bolts 4) Fracture 5) Deterioration of protective function 17) Defects of reinforced materials for rehabilitation/strengthening 23) Deformation/Break	
	Expansion Joint :Ej (Including the elements of post-cast concrete)	6) Crack 11) Delamination 21) Abnormal noise/Vibration 23) Deformation/Break	1) Corrosion 2) Crack 3) Loose connection/Missing bolts 4) Fracture 5) Deterioration of protective function 12) Abnormal spacing 13) Difference in level of road surface 20) Water leakage/Puddle 21) Abnormal noise/Vibration 23) Deformation/Break 24) Accumulation of debris	12) Abnormal Spacing 13) Difference in Level of road surface 19) Discoloration/Deterioration 20) Water leakage/Puddle 21) Abnormal noise/Vibration 23) Deformation/Break 24) Accumulation of debris
	Lighting Facility :Lt Signs :Si		1) Corrosion 2) Crack in steel 3) Loose connection/Missing bolts 4) Fracture 5) Deterioration of protective function 19) Discoloration/Deterioration 23) Deformation/Break	3) Loose connection/Missing bolts 19) Discoloration/Deterioration 23) Deformation/Break
	Curb :Cu	6) Crack 7) Spalling /Exposed rebar 8) Water leakage/ Efflorescence 11) Delamination 19) Discoloration/Deterioration 23) Deformation/Break		
	Pavement :Pm Backside Approaches	13)Difference in level of road surface 14) Bituminous pavement crack 24) Accumulation of debris		13) Difference in level 14) Bituminous pavement crack 24) Accumulation of debris

Table 5.8 Possible Defects for Other Elements

Component/Element	Types of Defects		
	Concrete Material	Steel Material	Others
Drainage System :D			
Drain Opening :Dr Drain Pipe :Dp		1) Corrosion 4) Fracture 5) Deterioration of protective function 19) Discoloration/Deterioration 20) Water leakage/Puddle 23) Deformation/Break 24) Accumulation of debris	4) Fracture 19) Discoloration/Deterioration 20) Water leakage/Puddle 23) Deformation/Break 24) Accumulation of debris
Other Element :Dx			
Inspection Path :Ip ・Utilities :Ut			
		1) Corrosion 2) Crack in steel 3) Loose Connection/Missing bolts 4) Fracture 5) Deterioration of protective function 21) Abnormal noise/Vibration 22) Abnormal deflection 23) Deformation/Break	1) Corrosion 2) Crack in steel 3) Loose Connection/Missing bolts 4) Fracture 5) Deterioration of protective function 21) Abnormal noise/Vibration 22) Abnormal deflection 23) Deformation/Break
Retaining Wall adjacent to Abutment :Rw			
	6) Crack 7) Spalling /Exposed rebar 8) Water leakage/ Efflorescence 19) Discoloration/Deterioration 23) Deformation/Break 25) Settlement/Tilt/Movement		

Element Numbering System

An important activity in preparing for the inspection is to establish a system for identifying the various components and elements of the bridge.

If drawings or previous inspection reports are available, the identification system to be used during the inspection should be the same as that used in these sources. If no previous record is available, then the inspector should establish an identification system.

The route direction chainage should be used to identify the beginning and the end of the bridge.

Detailed Element Numbering System for superstructure, substructure, and deck slab is shown in the **Appendix-4**.

Typical Inspection Methods

Periodic inspection with visual observation shall be implemented by appropriate method with necessary inspection tools and instruments according to inspection items. Table-5.9 shows typical defects and the rerating typical inspection methods to identify defects.

If necessary, other appropriate methods can be chosen depending on the conditions, such as structural characteristics of the bridge, site conditions, or environmental conditions.

Table 5.9 Typical Defects and Typical Inspection Methods of Periodic Inspection

Types of Defects	Typical Inspection Method	Tool/Instrument
Concrete Materials		
6) Crack	Visual check, Measurement of Crack Width	Crack gauge
7) Spalling/Exposed Rebar	Visual check, Hammer Tapping	Tapping Test
8) Water Leakage/Efflorescence	Visual check	
9) Fallen out of Deck Slab	Visual check	
10) Crack of Deck	Visual check, Measurement of Crack Width	Crack gauge
11) Delamination	Visual check, Hammering	Tapping Test
Other Materials		
12) Abnormal Spacing	Visual check, Measurement of Spacing	
13) Difference in Level	Visual check, Measurement of Difference	
14) Bituminous Pavement Crack	Visual check, Measurement of Crack Width	
15) Functional Disorder of Bearings	Visual check	
16) Other Types of Defects		
Common		
17) Defects of Reinforcing Materials for Rehabilitation/Strengthening	Visual check, Hammer Tapping	Tapping Test
18) Abnormal Anchorage	Visual check, Hammer Tapping Measurement	Tapping Test
19) Discoloration/Deterioration of Materials	Visual check	
20) Water Leakage/Puddle	Visual check	
21) Abnormal Noise/Vibration	Hearing, Visual check	
22) Abnormal Deflection	Visual check	Leveling
23) Deformation/Break	Visual check, Leveling string	
24) Accumulation of Debris	Visual check	
25) Settlement/Tilt/Movement	Visual check, Leveling string	
26) Scouring	Visual check	Water depth Sounder
Steel Materials		
1) Corrosion	Visual check, Measurement of thickness by Vernier Caliper	
2) Crack in Steel	Visual check	
3) Loose or Missing Bolts	Visual check, Hammer Tapping	Tapping Test
4) Fracture	Visual check, Hammer Tapping	
5) Deterioration of Paint System	Visual check	

The details and processes described in the manual provide a standardized system for the component breakdown of various types of bridges and culverts commonly found in Bangladesh. However, in some instances, inspectors may encounter a structure with a configuration that does not fit within the terminology described above. For guidance on the designation of bridge components for complex or non-standard structures, it is recommended that Bridge Management Wing be contacted to provide advice on component breakdown of the structure and other related issues.

5.3 Types of Defects and Rating

The types and extent of defects are rated based on the material condition of all components and elements of a bridge structure. Inspectors must grasp information of defects/deterioration accurately during inspections. Specific conditions or degree of defects shall be rated at an element basis and addressed in line with types of defects and rating.
Inspectors are required to collect information on the conditions or degree of defects as objectively and accurately as possible so that proper condition assessment of the bridge can be made.

Essential viewpoints during inspection are summarized as a detailed, systematic guide for inspection on how to find defects in **Appendix-5**

Standard types of defects and ratings are defined in **Appendix-6**.

6. EVALUATION AND COUNTERMEASURES

6.1Evaluation by Bridge Element

(1) Condition classification of bridge element types

Soundness evaluation of the bridge members determine the necessity for rehabilitation, strengthening and emergency response to any member by evaluating each damage type found on the member during the inspection. The classification of the necessity for rehabilitation, strengthening and emergency response is carried out by the 4 Evaluation Category (At-Dt) shown in **Table 6.1**. Specific determination method is divided into 4 categories after comprehensive evaluation of structural importance or damage progress level of the damaged member, refer to [**Appendix-7**: Evaluation Criteria].

Table 6.1 Measures classification of bridge element types

Evaluation Category		Description
At	No Repair	Countermeasures are not required
Bt	Minor Repair	Countermeasures are required within 5 years
Ct	Major Repair	Countermeasures are required within 2 years
Dt	Emergency	Emergency countermeasures are required

The basic idea of classifying each condition category is as follows.

a) Evaluation Category **At: No Repair**

The damages were not recognized during the visual inspection, or do not require the repair work, because it is minor.

b) Evaluation Category **Bt: Minor Repair**

The damages require repair work though it is not emergency like immediate repair, even if left as it is, the safety of structure will not significantly impaired until the next periodic inspection (= within 5 years). However, from the point of view of preventive maintenance, it is desirable to do "Minor Repair" in that part of the bridge.

c) Evaluation Category **Ct: Major Repair**

It can be determined that it is necessary to do early repair (= approximately within 2 years), due to the significant progress of the damage, function and safety factor of the part and the member decreases remarkably.

d) Evaluation Category **Dt: Emergency**

Structural safety of the bridge has been significantly impaired, and it is necessary to take urgent preventive measures, to avoid severe damages such as bridge collapse or high risk of user safety.

(2) Judgment of the need for emergency response for public safety

When the safety of road users like pedestrians, vehicles, or pedestrians and passing vehicles under the bridge is concerned from the damage situation of the inspection result, urgent measures for the public safety is necessary.

For example, when the railing is broken, risk of falling off of vehicles and pedestrians from the bridge, and damage to pedestrians and passing vehicles under the road bridge by falling of concrete mass is very high.

Specific determination methods refer to [**Appendix-7**: Evaluation Criteria].

This determination is carried out independently after conducting an assessment of evaluation (At-Dt) of a bridge member.

(3) Judgment of the need for detailed investigation

There is a limit to understand the damage cause by visual inspection. Because by visual inspection, causes of the damage and future probable progress cannot be predicted all the time. In that case, the detailed investigation is carried out in order to determine the necessity of rehabilitation and strengthening of the particular bridge.

For example, in areas of airborne salt from the sea, or by long longitudinal crack along the reinforcement bar and PC steel, suspicions of chloride attack are considered.

Specific determination methods refer to "**6.3** Detailed Investigation".

This determination is carried out independently after conducting an assessment of evaluation (At-Dt) of a bridge member.

(4) Evaluation method of bridge element types

In the soundness evaluation of the bridge element, judgment of condition category is carried out by span unit to each defect type (**Table 6.3**) in the structural element types (**Table 6.2**) (**Figure 6.1**). If there are more than one kind of damage types on the structural element types, the determination is carried out considering the most severe damage (**Figure 6.2**).

Furthermore, when it is determined that Public Safety is in danger or Detailed Investigation is necessary, to fill the check box in the respective column of **figure 6.2** for the target element.

Table 6.2 Element Types for Evaluation

Component	Super Structure	Sub Structure	Bearings	Others
Element Types	Deck Slab Main Girder Main Truss Main Arch Outer Cable Main Tower Arch Rib Top Slab Cross Beam Stringer Lateral Bracing	Abutment Pier Side Wall Parapet Wall Foundation Footing	Bearings -Bearing Main Body -Anchor Bolts -Bearing Seat -Bearing Bed	Pavement Bridge Approaches Expansion Joints Railing/Wheel Guard Drainage System Lighting Facility Road Sign Facility Inspection Facility Utility Pipe Retaining Wall

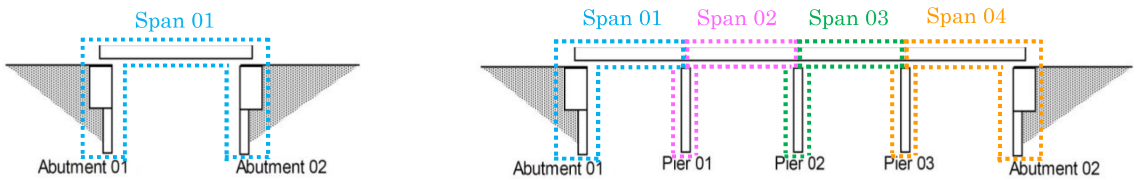


Figure 6.1 Evaluation by span unit

Inspection record

Element Type	Span No.	Element No.	Cracks	Spalling/Exposed Rebar	Water leakage /Efflorescence	…
Girder	1	1	b	a	a	
Girder	1	2	c	b	b	
Girder	1	3	b	a	a	
Girder	2	1	a	a	a	
Girder	2	2	d	c	d	
Girder	2	3	b	a	c	
Deck	1	1	c	b	c	
Deck	1	2	b	a	a	
Deck	2	1	a	a	a	
Deck	2	2	a	a	a	
⋮						

Evaluation result of bridge element types

Element Type	Span No.	Defects	At No Repair	Bt Minor Repair	Ct Major Repair	Dt Emer-gency	Pubric Safty	Detaled Investi
Girder	1	Cracks			✔			
Girder	1	Spalling/ Exposed Rebar		✔				
Girder	1	Water Leakage/ Efflorescence	✔					
Girder	2	Cracks			✔			✔
Girder	2	Spalling/ Exposed Rebar		✔				
Girder	2	Water Leakage/ Efflorescence			✔		✔	
Deck	1	Cracks		✔				
Deck	1	Spalling/ Exposed Rebar	✔					
⋮								

Evaluation is carried out by selecting the most severe damage of each damage type in the element types at span unit.

Figure 6.2 Evaluation method of bridge element types

Table 6.3 Member division and type of defects (1/2)

Element Types		Material		
		Steel	Concrete	Others
Deck Slab Main Girder (Including Gerber Type) Main Truss (Including Portable Steel Bridge) Main Arch Outer Cable Main Tower Arch Rib Top Slab Cross Beam Stringer Lateral Bracing		1.Corrosion 2.Crack in Steel 3.Loose or Missing Bolts 4.Fracture 5.Deteriorasion of Paint 12.Abnormal Spacing 17.Defects of Reinforcing Material for Rehabilitation / Strengthening 18.Abnornal Anchorage 20.Water Leakage / Puddle 21.Abnormal Noise / Vibration 22.Abnormal Deflection 23.Deformation / Break	6.Crack 7.Spalling / Exposed Rebar 8.Water leakage /Efflorescence 9.Fallen out of Deck Slab 10.Crack of Deck Slab 11.Delamination 12.Abnormal Spacing 17.Defects of Reinforcing Material for Rehabilitation / Strengthening 18.Abnornal Anchorage 19.Discolorlation / Deterioration of material 20.Water Leakage / Puddle 21.Abnormal Noise / Vibration 22.Abnormal Deflection 23.Deformation / Break	----------
Abutment Pier Side Wall Parapet Wall		1.Corrosion 2.Crack in Steel 3.Loose or Missing Bolts 4.Fracture 5.Deteriorasion of Paint 17.Defects of Reinforcing Material for Rehabilitation / Strengthening 20.Water Leakage / Puddle 21.Abnormal Noise / Vibration 23.Deformation / Break	6.Crack 7.Spalling / Exposed Rebar 8.Water leakage /Efflorescence 11.Delamination 17.Defects of Reinforcing Material for Rehabilitation / Strengthening 19.Discolorlation / Deterioration of Material 20.Water Leakage / Puddle 21.Abnormal Noise / Vibration 23.Deformation / Break	----------
Foundation Footing		1.Corrosion 2.Crack in Steel 5.Deteriorasion of Paint 25.Settelment / Tilt / Movement 26.Scouring	6.Crack 7.Spalling / Exposed Rebar 25.Settelment / Tilt / Movement 26.Scouring	----------
Bearings	Bearing Main Body Anchor Bolts	1.Corrosion 2.Crack in Steel 3.Loose or Missing Bolts 4.Fracture 5.Deteriorasion of Paint 12.Abnormal Spacing 15.Functional Disorder of Bearings 20.Water Leakage / Puddle 21.Abnormal Noise / Vibration 23.Deformation / Break 24.Accumulation of Debris 25.Settelment / Tilt / Movement	----------	4.Fracture 12.Abnormal Spacing 15.Functional Disorder of Bearings 19.Discolorlation / Deterioration of Material 20.Water Leakage / Puddle 21.Abnormal Noise / Vibration 23.Deformation / Break 24.Accumulation of Debris
	Bearing Seat Mortal Bearing Bed Concrete	----------	6.Crack 7.Spalling / Exposed Rebar 11.Delamination 20.Water Leakage / Puddle 23.Deformation / Break	----------

Table 6.3 Member division and type of defects (2/2)

Element Types	Material		
	Steel	Concrete	Others
Pavement Bridge Approaches	----------	13.Difference in Level 14.Abnormal Bituminous Pavement 24.Accumulation of Debris	13.Difference in Level 14.Abnormal Bituminous Pavement 24.Accumulation of Debris
Expansion Joints (Including the elements of post-cast concrete)	1.Corrosion 2.Crack in Steel 3.Loose or Missing Bolts 4.Fracture 5.Deteriorasion of Paint 12.Abnormal Spacing 13.Difference in Level 20.Water Leakage / Puddle 21.Abnormal Noise / Vibration 23.Deformation / Break 24.Accumulation of Debris	6.Crack 11.Delamination 21.Abnormal Noise / Vibration 23.Deformation / Break	12.Abnormal Spacing 13.Difference in Level 20.Water Leakage / Puddle 21.Abnormal Noise / Vibration 23.Deformation / Break 24.Accumulation of Debris
Railing Wheel Guard (Including Guard Fence, Curb, Median)	1.Corrosion 2.Crack in Steel 3.Loose or Missing Bolts 4.Fracture 5.Deteriorasion of Paint 23.Deformation / Break	6.Crack 7.Spalling / Exposed Rebar 8.Water leakage /Efflorescence 11.Delamination 19.Discolorlation / Deterioration of Material 23.Deformation / Break	----------
Drainage System (Including Catch-Basin, Drainage Pipe)	1.Corrosion 4.Fracture 5.Deteriorasion of Paint 19.Discolorlation / Deterioration of Material 20.Water Leakage / Puddle 23.Deformation / Break 24.Accumulation of Debris	----------	4.Fracture 19.Discolorlation / Deterioration of Material 20.Water Leakage / Puddle 23.Deformation / Break 24.Accumulation of Debris
Lighting Facility Road Sign Facility	1.Corrosion 2.Crack in Steel 3.Loose or Missing Bolts 4.Fracture 5.Deteriorasion of Paint 19.Discolorlation / Deterioration of Material 23.Deformation / Break	----------	3.Loose or Missing Bolts 19.Discolorlation / Deterioration of Material 23.Deformation / Break
Inspection Facility / Utility Pipe	1.Corrosion 2.Crack in Steel 3.Loose or Missing Bolts 4.Fracture 5.Deteriorasion of Paint 21.Abnormal Noise / Vibration 23.Deformation / Break	----------	----------
Retaining Wall	----------	6.Crack 7.Spalling / Exposed Rebar 8.Water leakage /Efflorescence 11.Delamination 17.Defects of Reinforcing Material for Rehabilitation / Strengthening 19.Discolorlation / Deterioration of Material 23.Deformation / Break 25.Settelment / Tilt / Movement 26.Scouring	----------

6.2 Evaluation of Entire Bridges

(1) Category and Criteria of Evaluation

Soundness evaluation of the whole bridge is carried out in order to understand the condition of the whole bridge which is used for ranking priority in asset management.

The entire bridge is evaluated by calculating the Bridge Damage Degree. Bridge Damage Degree (0~100) for the entire bridge is determined by the total damage points obtained from the Evaluation Category (At~Dt) of all the bridge element units. Relation between Bridge Damage Degree (0~100) and Condition Category (A~D) for the entire bridge is shown below.

Table 6.4 Condition category and Criteria of the evaluation of entire bridges

Condition Category	Bridge Damage Degree *)	Expected countermeasure
A	0 ~ 20	Countermeasure not required
B	21 ~ 60	Depending on situation
C	61 ~ 80	Countermeasure required
D	81 ~ 100	Emergency

*) Adopted by the local government of Japan

Bridge Damage Degree is used to formulate the priority order of candidate bridges for rehabilitation and strengthening. And it is calculated automatically by the BMS.

(2) Evaluation method of the entire bridges

a) Element types for evaluation

Bridge is composed of a number of elements which are classified into primary element and another element (Secondary) according to the importance. Evaluation of the entire bridge is carried out focusing the primary elements more as those affect the structural efficiency; secondary elements have small degree of effect to the structural safety of the bridge.

Table 6.5 Element types for evaluation (yellow is primary element, gray is secondary element)

Component	Superstructure	Substructure	Bearings	Others
Element Types	Deck Slab Main Girder Main Truss Main Arch Outer Cable Main Tower Arch Rib Cross Beam Stringer Sway Bracing Lateral Bracing	Abutment Pier Side Wall Parapet Wall Foundation Footing	Bearings -Bearing -Anchor Bolts -Bearing Seat -Bearing Bed	Pavement Bridge Approaches Expansion Joints Railing/Wheel Guard Drainage System Inspection Facility Lighting Facility Road Sign Facility Utility Pipe Retaining Wall

b) Procedure of Calculating Bridge Damage Degree

Bridge Damage Degree is barometer of structural risk of the bridge, calculated as follows (**Figure 6.3**). New bridge has 0 damage degree, and each time, if any defect occurs in any of the element, damage degree will increase

1) Bridge Type with Bearings

Bridge Damage Degree (max: 100pt)

= Damage degree of Superstructure (max: 50pt)

+ Damage degree of Substructure (max: 30pt)

+ Damage degree of Bearings (max: 20pt)

2) Bridge Type without Bearings

Bridge Damage Degree (max: 100pt)

= Damage degree of Superstructure (max: 60pt)

+ Damage degree of Substructure (max: 40pt)

Figure 6.3 Calculation of Bridge Damage Degree

Each Damage degree of component is calculated with " **Impact level** ", "**Evaluated degree** (Numerical value of the Evaluated Condition Category of the Elements.)" , "**Weight coefficient of the element**" and "**Weight coefficient of the defect**" (**Figure 6.4**).

Damage degree of Superstructure
Damage degree of Substructure
Damage degree of Bearings

= Impact level x Evaluated degree (At=0, Bt=33, Ct=67, Dt=100)

x Weight coefficient of the element x Weight coefficient of the defect

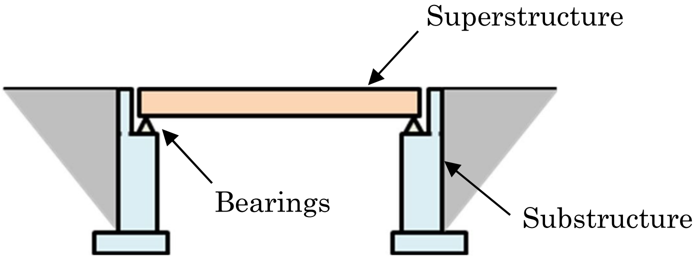
Figure 6.4 Calculation of Damage Degree

"**Impact level**" of the each component is set to be 1.0 in total considering the importance of component (**Table 6.6, Table 6.7**).

Table 6.6 Impact level of Component (Bridge type with bearings)

Component	Impact level *)	Details
Superstructure	0.5	This damage directly impacts bridge function.
Substructure	0.3	Compared to superstructure, the impact of this damage to bridge function is not great as the size of the structure is large.
Bearings	0.2	The impact of this damage to bridge function is not great.

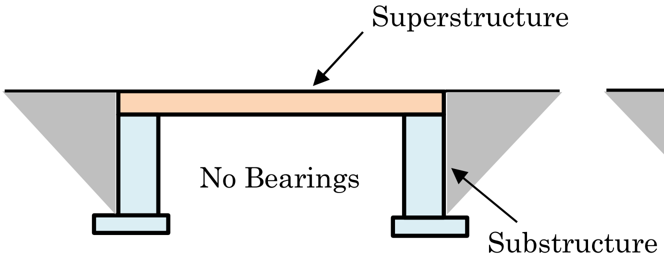
*) Adopted by the local government of Japan



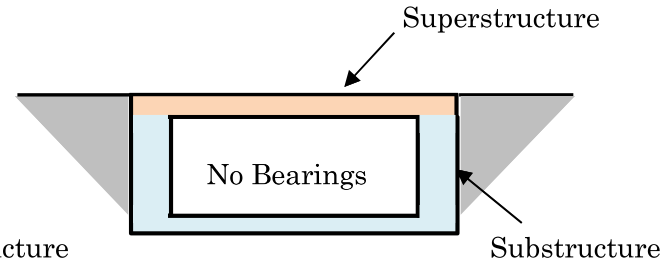
RC/PC Girder Bridge, Steel Girder Bridge

Table 6.7 Impact level of Component (Bridge type without bearings)

Component	Impact level	Details
Superstructure	0.6	This damage directly impacts bridge function.
Substructure	0.4	Compared to superstructure, the impact of this damage to bridge function is not great as the size of the structure is large.



Small Slab Bridge (Former "Slab Culvert")



Box Culvert

“**Evaluated degree**” is based on result of evaluation category (At: No Repair, Bt: Minor Repair, Ct: Major Repair, Dt: Emergency) of the bridge element.
At this point, Evaluated degree are set as "At: No Repair" = 0, "Dt: Emergency" = 100, "Bt: Minor Repair" and "Ct: Major Repair" = equally divided (**Table 6.8**).

Table 6.8 Evaluated degree (Numerical value of the Evaluation Category)

Evaluation Category	Evaluated degree *)	Details
At: No Repair	0	Countermeasures are not required
Bt: Minor Repair	33	Countermeasures are required within 5 years
Ct: Major Repair	67	Countermeasures are required within 2 years
Dt: Emergency	100	Emergency countermeasures are required

*) Adopted by the local government of Japan

“**Weight coefficient of the element**” is set considering the importance of the elements (**Table 6.9**).

Table 6.9 Weight coefficient of the element

Component	Element Types	Weight coefficient *)
Superstructure	Main Girder Main Truss Main Arch Outer Cable Main tower Arch Rib	1.00
	Cross Beam Stringer	0.25
	Deck Slab	0.80
Substructure	Abutment Pier Side Wall Parapet Wall	0.67
	Foundation footing	1.00
Bearings	Bearing Main Body Anchor Bolts	1.00
	Bearing Seat Bearing Bed	0.25

*) Adopted by the local government of Japan

“**Weight coefficient of defect**” is set according to the seriousness of the damage type (**Table 6.10**).

The coefficients shown in Table 6.10 adopt the coefficient of the local government of Japan at the present time. After inspection and evaluation data in Bangladesh has been sufficiently accumulated, it is necessary to reconsider the coefficients by the RHD staff based on the results of the Bridge Damage Degree.

BMS does not calculate the Bridge Damage Degree of the Cable Stayed Bridge. Because the coefficients related to the damage of the Cable Stayed Bridge are not included in that of local government of Japan. Therefore, it is necessary to consider the Bridge Damage Degree of the Cable Stayed Bridge separately.

For example, in the case of “superstructure” has “missing bolts on main girder evaluated as Bt” and “crack on RC deck slab evaluated as Ct”, Damage degree of superstructure is calculated as follows (**Figure 6.5**),

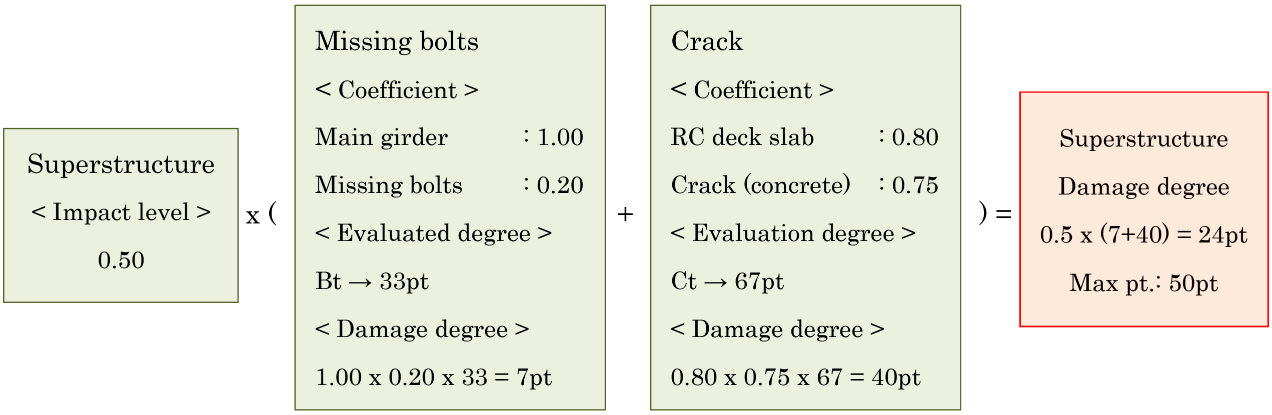


Figure 6.5 Calculation of superstructure damage degree

If total of damage degree is larger than Max pt., damage degree of the component is considered as max point.

c) Calculation of Bridge Damage Degree

The procedure to calculate Bridge Damage Degree is as follows,

1) " Damage degree " = " Impact level of Component " x " Weight of Element Types " x "Weight of Defect" x "Evaluated degree"

2) " Total 1 " = Σ (" Damage degree " focused on each Element Types and each Span No.)

3) " Total 2 " = largest " Total 1 " among spans in the Element Types

4) " Total 3 " = Σ (" Damage degree " focused on each component)

(If point of Total 3 is larger than "Max pt." of each component, it is revised to the Max pt.)

5) " Bridge Damage Degree " = Σ (" Total 3 " of each component)

Table 6.11 Calculation of Bridge Damage Degree

1) 0.50 x 1.00 x 0.60 x 67=21

Component	Max pt	Impact	Element Types	weight	Span No.	Defect	weight	Evaluated degree	Damage degree	Total 1	Total 2	Total 3
Super-structure	50	0.50	Main girder	1.00	1	Corrosion	0.60	C → 67	21 1)	25	Sp1>Sp2 25>10 25 3)	25+3 +12 =40 40 4)
						Missing bolt	0.20	B → 33	4			
					2	Corrosion	0.60	B → 33	10	10		
			Cross beam	0.25	1	Corrosion	0.60	B → 33	3	3	3	
					2	none	0.00	A → 0	0	0		
			Deck slab	0.80	1	Cracks	0.75	B → 33	10	10+2=12 12 2)	12	
						Efflorescence	0.13	B → 33	2			
					2	Cracks	0.75	B → 33	10	10		
Sub-structure	30	0.30	Abutmenet	0.67	1	Cracks	0.43	B → 33	3	3	8	8+8 +21 =37 30
					2	Cracks	0.43	C → 67	6	8		
						Efflorescence	0.29	B → 33	2			
			Pier	0.67	1	Cracks	0.43	C → 67	6	8	8	
						Efflorescence	0.29	B → 33	2			
			Foundation	1.00	1	Scouring	1.00	C → 67	21	21	21	
					2	none	0.00	A → 0	0	0		
Bearings	20	0.20	Bearing	1.00	1	none	0.00	A → 0	0	0	5	5
					2	Function Disorder	0.75	B → 33	5	5		
									Bridge Damage Degree			75 5)

As total point of substructure (37pt) is larger than max point of substructure (30pt), TOTAL POINT is revised to 30pt.

If any element of the Bridge is evaluated as Dt (Emergency), "Bridge Damage Degree" for the entire bridge will be 100 regardless of the condition of other elements

Table 6.10 Weight coefficient of defect *)

*) Adopted by the local government of Japan

----- Superstructure -----

【Deck - Steel】

Type of defects	Weight coefficient
1.Corrosion	0.50
2.Crack in Steel	1.00
3.Loose or Missing Bolts	0.17
4.Fracture	1.00
5.Deteriorasion of Paint	0.17
21.Abnormal Noise / Vibration	0.17
23.Deformation / Break	0.17

【Deck - Concrete】

Type of defects	Weight coefficient
7.Spalling / Exposed Rebar	0.10
8.Water leakage /Efflorescence	0.10
9.Fallen out of Deck Slab	1.00
17.Defects of Reinforcing Material for Rehabilitation / Strengthening	0.25
10.Crack of Deck Slab	0.75
11.Delamination	0.03
18.Abnornal Anchorage	0.25
19.Discolorlation / Deterioration of Material	0.03

【Main Girder - Steel】

Type of defects	Weight coefficient
1.Corrosion	0.60
2.Crack in Steel	1.00
3.Loose or Missing Bolts	0.20
4.Fracture	1.00
5.Deteriorasion of Paint	0.20
12.Abnormal Spacing	0.20
21.Abnormal Noise / Vibration	0.20
22.Abnormal Deflection	0.20
23.Deformation / Break	0.20

【Main Girder - Concrete】

Type of defects	Weight coefficient
6.Crack	0.33
7.Spalling / Exposed Rebar	0.67
8.Water leakage /Efflorescence	0.17
17.Defects of Reinforcing Material for Rehabilitation / Strengthening	0.30
11.Delamination	0.17
12.Abnormal Spacing	0.17
18.Abnornal Anchorage	0.67
19.Discolorlation / Deterioration of Material	0.03
21.Abnormal Noise / Vibration	0.50
22.Abnormal Deflection	0.30
23.Deformation / Break	0.03

【Cross Beam - Steel】

Type of defects	Weight coefficient
1.Corrosion	0.33
2.Crack in Steel	1.00
3.Loose or Missing Bolts	0.17
4.Fracture	1.00
5.Deteriorasion of Paint	0.17
21.Abnormal Noise / Vibration	0.33
23.Deformation / Break	0.17

【Cross Beam - Concrete】

Type of defects	Weight coefficient
6.Crack	0.40
7.Spalling / Exposed Rebar	0.60
8.Water leakage /Efflorescence	0.40
17.Defects of Reinforcing Material for Rehabilitation / Strengthening	0.40
11.Delamination	0.20
18.Abnornal Anchorage	0.80
19.Discolorlation / Deterioration of Material	0.05
21.Abnormal Noise / Vibration	1.00
23.Deformation / Break	0.05

----- **Substructure** -----

【Abutment / Pier - Steel】

Type of defects	Weight coefficient
1.Corrosion	0.60
2.Crack in Steel	1.00
3.Loose or Missing Bolts	0.20
4.Fracture	1.00
5.Deteriorasion of Paint	0.20
20.Water Leakage / Puddle	0.20
21.Abnormal Noise / Vibration	0.20
23.Deformation / Break	0.20

【Abutment / Pier - Concrete】

Type of defects	Weight coefficient
6.Crack	0.43
7.Spalling / Exposed Rebar	0.57
8.Water leakage /Efflorescence	0.29
17.Defects of Reinforcing Material for Rehabilitation / Strengthening	0.57
11.Delamination	0.14
19.Discolorlation / Deterioration of Material	0.14
20.Water Leakage / Puddle	0.14
23.Deformation / Break of Structure Element	0.14

【Foundation】

Type of defects	Weight coefficient
25.Settelment / Tilt / Movement	0.25
26.Scouring	1.00

----- **Bearings** -----

【Bearing - Steel】

Type of defects	Weight coefficient
1.Corrosion	0.25
2.Crack in Steel	1.00
3.Loose or Missing Bolts	0.50
4.Fracture	1.00
5.Deteriorasion of Paint	0.25
15.Functional Disorder of Bearings	0.75
20.Water Leakage / Puddle	0.25
23.Deformation / Break of Structure	0.25
24.Accumulation of Debris	0.25
25.Settelment / Tilt / Movement	0.50

【Bearing - Rubber】

Type of defects	Weight coefficient
15.Functional Disorder of Bearings	1.00
20.Water Leakage / Puddle	0.25
23.Deformation / Break	0.13
24.Accumulation of Debris	0.13
25.Settelment / Tilt / Movement	0.88

【Bearing Seat/Bed - Concrete】

Type of defects	Weight coefficient
6.Crack	0.14
11.Delamination	0.29
23.Deformation / Break	1.00

6.3 Detailed Investigation

6.3.1 The purpose of detailed investigation

The objective of detail investigation is to acquire specific information about degradation of a structure.

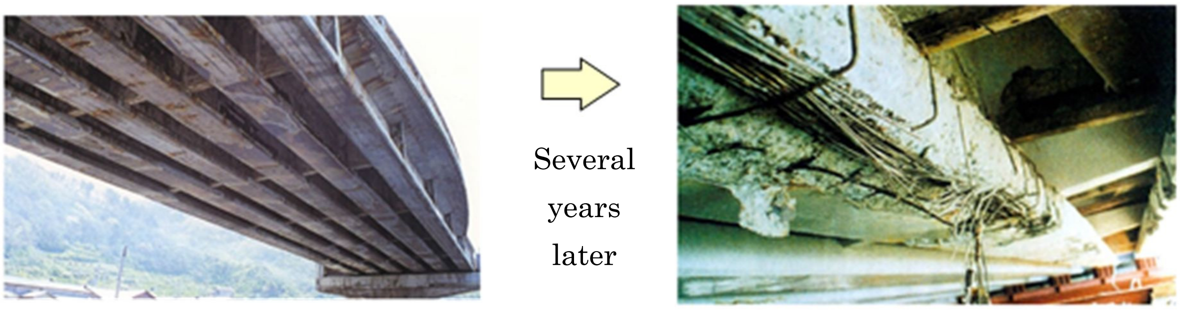
The following are the causes of detail investigation of a structure.

a) Some signs of deterioration or a change in the performance level are observed during last inspection.

b) When the cause of damage is unclear, detailed investigation is required to specify the cause of the damage.

c) To decide the scope and the degree of repair and strengthening.

Some examples of damages require detailed investigation are shown in Photo-6.3.1.



Dangerous conditions by chloride attack

Spalling, Exposed rebar by chloride attack

Photo-6.3.1 Examples of damages require detailed investigation

6.3.2 Selection of the method of detail investigation

Investigation method is selected considering the kind of damage and presumed cause of damage. Many types of Detailed Investigation Method are listed in Table-6.3.1. The responsible persons for the investigation will decide the appropriate method by applying their experiences, engineering judgment and considering other issues related to the investigation process.

Table-6.3.1 Example of investigation method

Factor of damage		Fire	Collision	Settlement	Temperature	Lack of section	Over loading	Carbonation	Chloride attack	Chemical corosion	Note
Confirmation of damage	Visual investigation	◎	◎	◎	◎	◎	◎	◎	◎	◎	
Interior hollow and Internal flaw	Tapping inspection	◎						◎	◎	◎	Non-destructive test
Shape and size	Shape size investigation		◎	◎		◎					
Compressive strength	Strength test by core extraction	◎	◎	◎	◎	◎	◎	◎	◎	◎	Minute destructive test
	Rebound hammer (Ex. Schmidt rebound hammer)	◎	◎	◎	◎	◎	◎	◎	◎	◎	Non-destructive test
Modulus of Elasticity	Strength test by core extraction	◎	◎	◎	◎	◎	◎	◎	◎	◎	Minute destructive test
Rebar corrosion	Taken out rebar and visual observation							◎	◎	◎	Minute destructive test
Rebar investigation	Electromagnetic wave (Ex. RC radar)	◎	◎	◎	◎	◎	◎	◎	◎	◎	Non-destructive test
	Electromagnetic induction (Ex. Prophometer)	◎	◎	◎	◎	◎	◎	◎	◎	◎	Non-destructive test
Carbonation depth	Phenolphthalein method by core extraction							◎			Minute destructive test
	Phenolphthalein method by drilling							◎			Minute destructive test
	Phenolphthalein method by taken out rebar							◎			Minute destructive test
Chloride ion concentration	Core extraction Potentiometric Titration Device							○	◎		Minute destructive test
	Concrete powder by drilling Potentiometric Titration Device							○	◎		Minute destructive test
Physical character (Physical investigation)	Dead-load stress			◎	◎	◎	◎		◎	◎	
	Stress when loading	◎	◎			◎	◎		◎	◎	
	Stress frequency					◎	◎				
	Displacement due to loading	◎	◎			◎	◎		◎	◎	
	Displacment frequency					◎	◎				
	Vibration measurement					◎	◎		◎		

6.3.3 Core extraction

A core is extracted by an electric core drill.
Required core diameter for testing Chloride density and Carbonation depth: More than 50 mm and for Compressive strength: More than 75 mm
Work procedure is described below.

a) Rebar location is confirmed by a rebar detector.
b) The location of core extraction is selected.
c) A core-drill is installed and fixed in position; then core drilling is started.
d) If core drill encounters rebar, PC tendon etc., boring is canceled and the boring location is changed.
e) A core is extracted after the completion of boring.
f) The core is kept sealed until tested.

6.3.4 Compressive strength of concrete structure

(1) Compressive Strength test by core extraction
Compressive strength of concrete is measured by a compressive strength testing machine using an extracted core.
The modulus of elasticity of concrete can be calculated from stress-strain diagram of compressive strength test.
Core extraction for compression test avoids the spalling part and the crack part. Rather a core is extracted from a sound part.
Core diameter must be more than 3 times of the maximum size of coarse aggregate and core length must be more than 2 times of core diameter.

(2) Compressive Strength test by Rebound hammer (Ex. Schmidt rebound hammer)
Compressive strength of concrete is measured by the repulsion hardness method when striking a blow at concrete surface.
Compressive strength is obtained from the arithmetic expression from the repulsion hardness method.
The repulsion hardness method is an effective way to know the relative strength, not the way to investigate the absolute strength of concrete.
Schmidt rebound hammer is being used as a measuring instrument of repulsion hardness method.

Photo-6.3.2 Schmidt rebound hammer

6.3.5 Chloride ion concentration

(1) Core extraction method

Chloride density test analyzes chloride ion concentration by potentiometric titration method. In this method total amount of chloride ion present in the concrete is determined.

Chloride density test is done in the depth direction. Salinity is measured at 4(four) points of different depths. Figure-6.3.3 illustrates the basic idea of the test method.

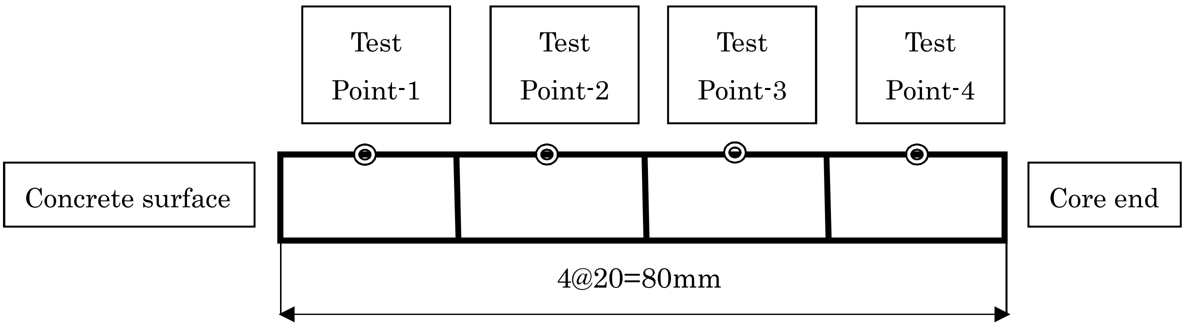


Figure-6.3.3 Example of core division for chloride density test

Photo-6.3.4 A potentiometric titration device

(2) Concrete powder by drilling

As sample for chloride density tests, some concrete powder is extracted by drilling.

Sample from 4(four) different depths in depth direction are extracted for the test.

This test method also analyzes chloride ion concentration by potentiometric titration method and total amount of chloride ion present in the concrete is determined.

6.3.6 Carbonation depth

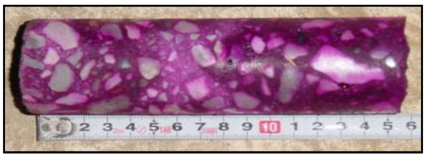
(1) Phenolphthalein method by core extraction

An extracted core is washed with water.

1% Phenolphthalein solution is sprayed on the core surface.

Then the depth of the purple red colored part of the core is measure from concrete surface at 8 points around the circumference of the circular core.

Carbonation depth of the concrete is the mean of these depths measured at 8 points.



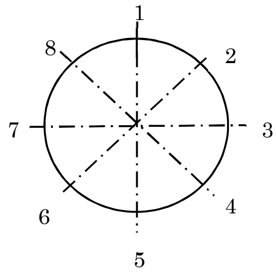


Figure-6.3.5 Estimation of carbonation depth by core extraction

(2) Phenolphthalein method by drilling

Location of rebar and PC tendon is confirmed by a rebar detector and the test is conducted at a location where rebar or PC tendon is not underneath.

1% Phenolphthalein solution is sprayed on a filter paper and it is kept holding just below the drilling location so that concrete powder extracted from the hole can drop onto it. As soon as the filter paper starts to turn red, drilling is stopped. Then the depth of the hole is measured with a slide caliper which is the carbonation depth.

Drilling

If the color of filter paper changes to red purple, drilling is stopped.

Measurement of carbonation depth

Photo-6.3.6 Phenolphthalein method by drilling

(3) Phenolphthalein method by exposed rebar

The location of rebar and PC tendon is confirmed by a rebar detector and concrete is cut in such a way that a significant portion of rebar is exposed.

The point/area is cleaned thoroughly by brushes and syringes, etc.

1% Phenolphthalein is sprayed into the point/area of exposed rebar.

The depth of red purple colored part from concrete surface is measured, which is carbonation depth.

6.3.7 Rebar corrosion (Exposed rebar)

The location of rebar and PC tendon is confirmed by a rebar detector and concrete is cut in such a way that a significant portion of rebar is exposed.

The state of corrosion of rebar is observed visually.

Generally the part of element in which stain of rusty water flow, partial spalling, exposed rebar or big corrosion crack etc. are visible indicates high possibility of rebar corrosion; and that part of the element must be investigated.

In some cases, partial loss of area of a rebar occurs. The loss is determined by measuring rebar diameter by calipers after removing patina by steel brush and comparing new area with original one.

Photo-6.3.7 Phenolphthalein method by exposed rebar and Rebar corrosion

6.3.8 Degradation prediction

(1) Carbonation

Carbonation is a degrading phenomenon caused by CO_2 infiltration into concrete.

To estimate carbonation depth in concrete, formula (1) is presented here as follows.

$y=b\sqrt{t}$ ---------------------------formula (1)

y : estimated carbonation depth (mm)

b : coefficient of carbonation speed (mm/√year)

t : time (year)

(2) Chloride attack

The spread of chloride ion stuck in concrete surface is predicted from diffusion equation derived from Fick's Law.

Fick's Law is shown in formula (2).

$$J_A = -D\frac{dCi}{dx}$$ ----------------------formula (2)

J_A: Mass flux which is a material flow through a unit cross-sectional area in unit time

D: Diffusivity constant

Ci: Concentration of the substance

x: Distance coordinate

The diffusion equation indicated in formula (3) is obtained from continuity of a material flow.

$$\frac{\partial Ci}{\partial t} = D\frac{\partial^2 Ci}{\partial t^2}$$ ----------------------formula (3)

t: Time

When the boundary condition is given and the differential equation is solved, chloride ion concentration diffusion formula is obtained, and presented here as formula (4).

$$Ci(x,t) = C_0\left(1 - erf\left(\frac{x}{\sqrt{4Dt}}\right)\right)$$ ----------------------formula (4)

D: Diffusivity constant

Ci(x,t):Chloride ion concentration at 'x' location(kg/m^3)

C_0: Chloride ion concentration at x=0 (concrete surface)(kg/m^3)

x: Distance coordinate(cm)

t: Time(Year)

erf(x): Error function

$$erf(x) = \frac{2}{\sqrt{\pi}}\int_0^x e^{-t^2}dt$$

6.4 Appraisal Committee

The purpose of the Appraisal Committee is to ensure objectivity and transparency of bridge evaluation results, and to facilitate smooth approval procedure in Circle Office and Zone Office by the involvement of Circle Office and Zone Office staff.
The major responsible roles are as follows;

1) To confirm adequateness of evaluation results of Rating level "D" from basic point of view
2) To guide/advice the Evaluator for evaluating difficult condition case, when required by evaluator

The members of Appraisal committee are as follows;

Members	Position	Organization	No. of Personnel
Chairperson	EE	Division Office	1
Committee member	AE	Zone Office	1
	AE	Circle Office	1
	SDE	Sub-Division Office	1
Secretary	AE	Division Office	1

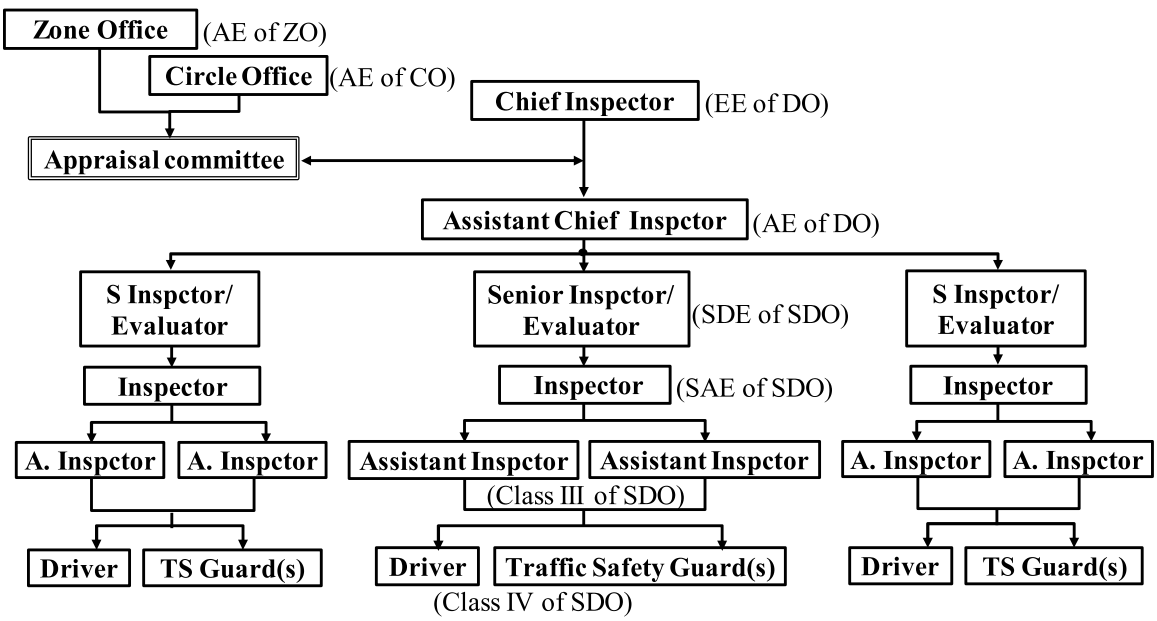


Figure 6.4.1 Organization Chart of Bridge Inspection Team

7. RECORDING OF INVENTORY AND INSPECTION RESULTS

7.1 General

The results from the inspections are used to plan and coordinate preventative maintenance operations on the bridges. Comprehensive bridge inventory and inspection results data will be recorded in the Bridge Management System (BMS).

Chief Inspector (EE) shall ensure that the inventory and periodic inspection data are in the correct format and compatible with existing entries. These data and any recommended actions including inspection inventory amendments and the need for Detailed Investigation or maintenance requirements shall be entered into the BMS. Details of the data recording requirements for the inventory, routine and periodic inspection are described below.

7.2 Bridge Inventory Record

Bridge inventory data is a standardized series of data items that enables the geometry, construction and function of a bridge to be identified and described. All information collected during an initial inspection is recorded or referenced on an inventory form.

General Information

This form presents the basic design data, history of inspection and remedial actions. Visual information including location map and panoramic view of bridge and the specific feature of the bridge are recorded in this form.

Dimensions of structure

Dimensions and structure type of superstructure, substructure, bearing, deck material and expansion joint are recorded in this form.

Bridge's Plans

The plans or as built drawings, if available shall be scanned into this form. If such drawings do not exist, it should be sketched with the dimensions of the bridge including total bridge length, component of the bridge, deck geometry, height of substructure and other special notes shall be scanned into this file.

Photographs of Bridge

Photographs which show the typical feature of the bridge shall be recorded in this form. Photographs on this form do not necessarily need to be updated when the inspection is carried out. However, when the major repair works or rehabilitation works are carried out, the photos on this form shall be renewed.

The following data should be filled:

a) Recording date
b) Identification data (bridge name, jurisdiction, location, etc,)
c) Data regarding service condition (date in service, live load, applied design specification)
d) Basic data of whole bridge (bridge length/number of total spans/structural type)

The measuring point for Bridge ID (GPS coordinates or latitude/ longitude descriptions) identifying the more exact location of the bridge is generally used as shown in Figure 7.1.

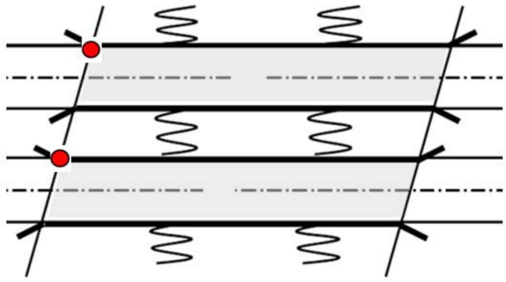


Figure 7.1 Location of Measuring Point of GPS Coordinates

e) Traffic condition (year of traffic survey/heavy vehicle ratio/traffic/load restriction)
f) Width of road

The items shown in the following figure are provided to cover the different road width type. The inapplicable items need not to be filled.

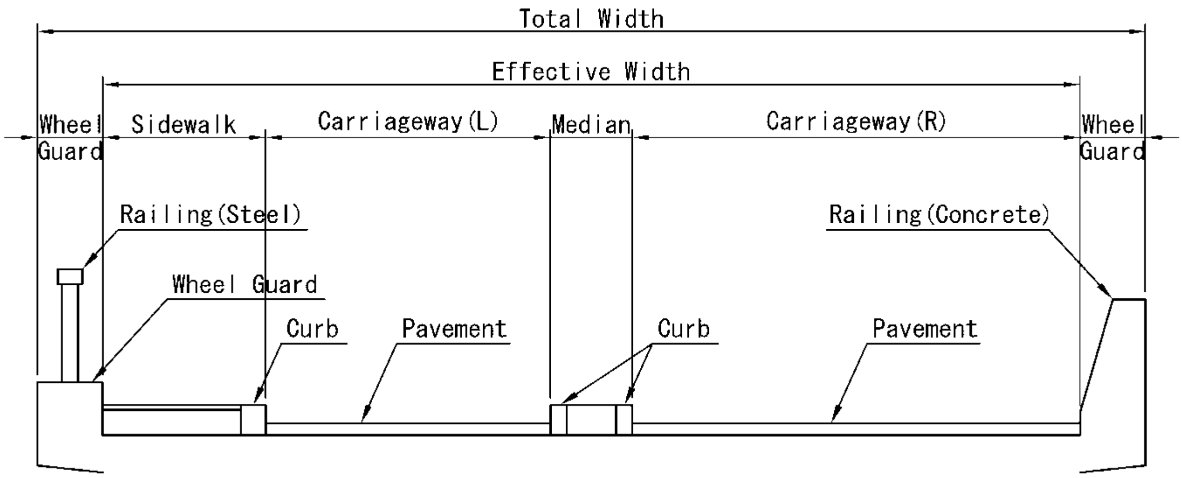


Figure 7.2 Cross Section of Road Structure

g) Site Photograph
- Overall: representative photographs of main superstructure components
- Front view from traffic origin: from top of deck showing alignment, width, curbs
- Side view: showing piers, abutments and waterway or roadways
- Under the bridge: showing superstructure

7. 3 Inspection Results

Inspection data should be recorded in a format that gives a clear and accurate description of the bridge condition. The standardized format used for inspection data should be clear, follow a logical sequence and incorporate all the necessary information of the bridge structure's condition. The inspection reports support maintenance planning and management and should assist this process by adopting a relatively consistent format from one inspection cycle to the next.

The inspection record shall:
- Identify what parts of the bridge were inspected and the location of the defected element.
(To be shown on a defect photographs or sketches of the bridge)
- Provide the following details on any defects identified

    What the defect is.
    Where the defect is located (a sketch may be used to illustrate its location).
    Summarize the inspection findings if necessary
    (addressing how individual defects affect other element's condition).

    Sketches (defect figures) of superstructure or deck slab are described as a general plan of the bridge. The point of view for sketch is shown in Figure 7.3

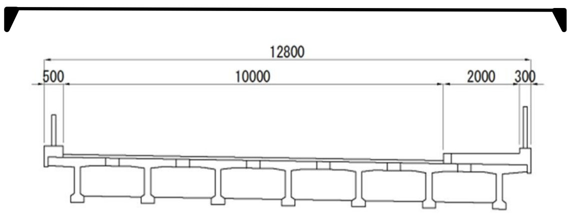


Figure 7.3 Point of View for Sketches of Superstructure or Deck Slab

All the inspection results must be recorded on RHD's Bridge Management System (BMS) within (30) days of the inspection so that concerned engineers/personnel in RHD can browse and find out the exact situation of the bridges and take relevant actions.
However, in the event that a defective structure is identified, all inspection data should be entered as soon as is practicably possible.

a) Routine Inspection Form

Routine Inspection is conducted using the "Routine Inspection Report" form included in **Appendix -9** Recording Forms.
The inspector shall submit a completed Routine Inspection Report to the Chief Inspector and Chef Inspector will take steps to record inspection data and any relevant actions, including the need for a specific inspection, special points to be inspected at the next routine inspection or detailed investigation or maintenance requirements in the Bridge Management System within (30) days of the inspection.
Photographs taken can be attached to the report as required. Advice for further inspection should be clear and these should be included in the next annual inspection plan.

In addition, the inspector shall submit a completed "Inventory Form" so that the current BMS data may be positively verified or amended within (30) working days of the Routine Inspection.

b) Periodic Inspection Form of the Bridge Elements

Inspectors shall carry out the bridge inspection through this condition rating of defects form. Inspector should prepare the records for this form for each bridge element. The record of the condition of defect should be renewed when the inspection is carried out.

An appropriate photographic and sketch record must be compiled for inspection record to illustrate and clarify conditions of structural elements.

✓ Photographic record	-Entire condition and defects condition on the bridges exactly
	-Defects for the worst condition
	-Any information in terms of defects
✓ Sketch record	-Defects with necessary plan and elevation views of the feature
	-Dimensions showing its length, width, and depth if applicable

In the column of "Remarks and Recommendation", a brief summary of the inspection findings should be made by the inspector. Problem areas, those requiring immediate attention should be pointed out.

Evaluator will provide evaluation result sheet according to Evaluation Criteria of the defects for bridge elements that includes any recommendations for maintenance or remedial actions and for scheduling of follow-up Detailed Investigations in the comment section of the visual inspection form, if necessary. The form should be completed according to each span unit.

For Emergency Inspection, no special reporting forms are used as the form developed for routine and periodic inspection can be utilized. The ratings are transferred to the relevant item of the inspection form using Appendix-6: Types of Defects and Rating.

For Special Inspection, the results of a special inspection will generally not be in a format that can be input into the inspection database using the visual inspection report form. The special inspection report will supplement either routine or emergency inspection and will normally be carried out on one or two major primary structural components of the bridge.

Recording Forms

A set of inventory and inspection forms to be stored on BMS is listed below.

- Form-1 Bridge Inventory Record Form
- Form-2 Routine Inspection Report Form
- Form-3 Periodic Inspection Report Form
- Form-4 Bridge Evaluation Report Form
- Sample Inspection / Evaluation Report Form

Appendix-1:

Essential Points to Find Possible Defects in Surveillance Patrol

Reference:

Identifying Abnormality/Defects during routine patrol Tohoku Regional Bureau MLIT, JAPAN

1. Abnormality at Bridge Surface

◆ Possible Defects

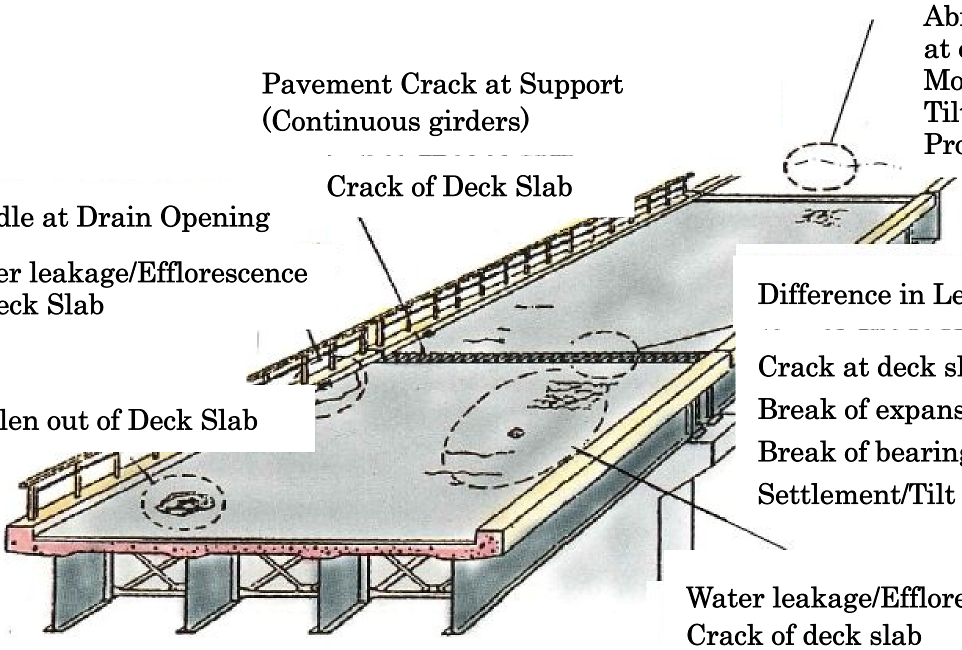
a) Pothole at pavement surface
b) Crack at pavement surface
c) Difference in level or Crack at backside of abutment

◆ Suspected Defects

- ✓ Insufficient water proofing, Crack of deck slab or rebar corrosion
- ✓ Cavity in back fill at backside abutment

◆ Concerned Serious Defects when they are left

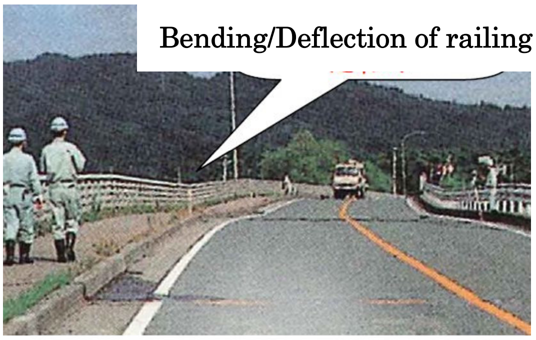
- ✓ Fallen out of deck slab
- ✓ Movement/Tilt of abutment
- ✓ Cave-in in backside of abutment



2. Abnormality of Curb and Railings

◆ Possible Defects

a) Abnormality of Straightness of Alignment
b) Difference in level or
Positional Displacement at Expansion Joint
c) Break or Distortion of Railing
d) Corrosion of Steel Railing

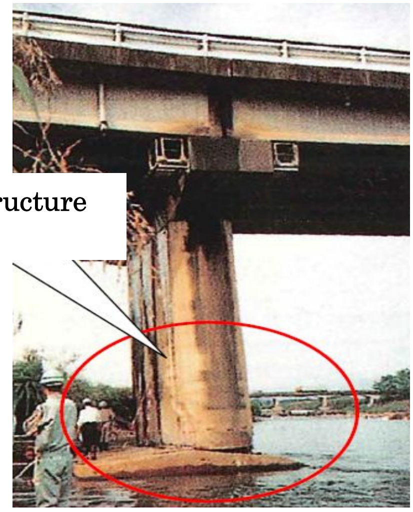


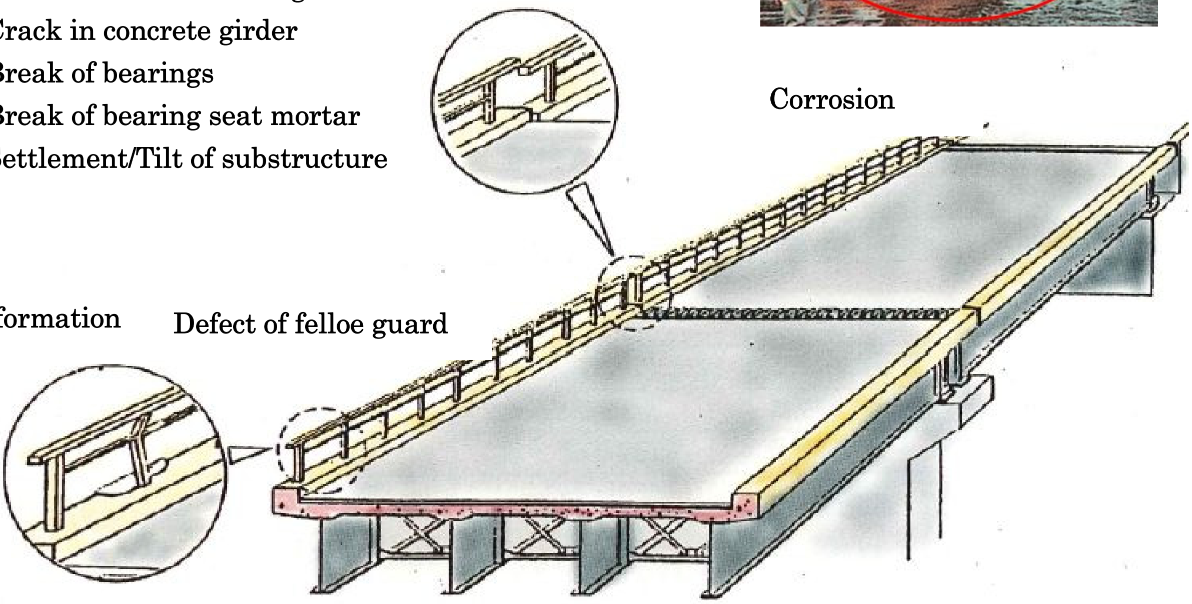
◆ Suspected Defects

✓ Progress of scouring of foundation or
Erosion of embankment
✓ Progress of deformation of main girders

◆ Concerned Serious Defects when they are left

✓ Deformation of substructure
(Bridge collapse in worst case)
✓ Deformation or fracture of main girders
(Bridge collapse in worst case)
✓ Defects of bearings





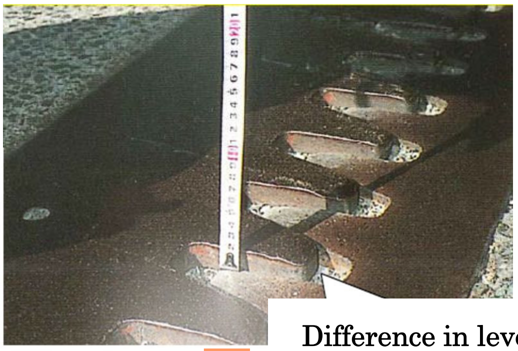
3. Abnormality of Expansion Joint

◆ Possible Defects

a) Abnormal Spacing
b) Difference in Level
c) Position Deviation
d) Damage
e) Accumulated Debris

◆ Suspected Defects

- ✓ Corrosion of girder end or bearings due to defects of expansion joint such as insufficient drainage
- ✓ Telltale signs of lateral flow or land slide

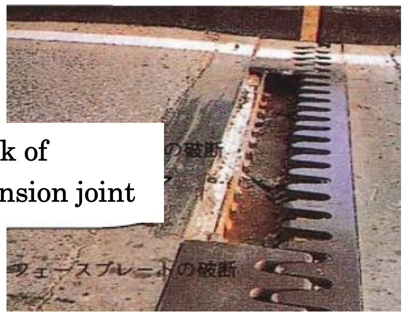


Difference in level

Break of bearing seat mortar

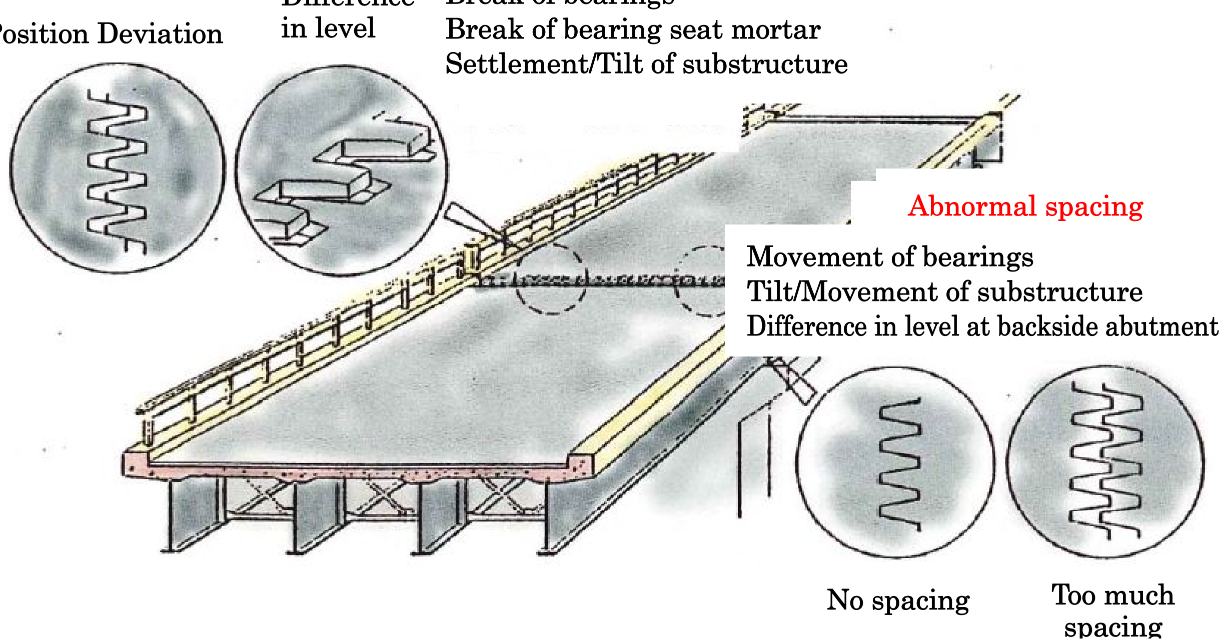
◆ Concerned Serious Defects when they are left

- ✓ Defects of substructure
- ✓ Defects of Bearings



Break of expansion joint

Difference in Level/Position Deviation



4. Abnormality of Drainage System

◆ Possible Defects

a) Insufficient drainage such as a puddle

b) Accumulated Debris such as overgrown weeds

◆ Suspected Defects

- ✓ Corrosion of main girder end and bearings due to accumulated debris
- ✓ Deformation of main girders due to functional failure of bearings

Accumulated debris
such as overgrown weeds

Accumulated debris
due to insufficient drainage

Corrosion of
Expansion joint

Basic Points to Consider

- ➢ Even defects seem to be minor they sometimes will be presaging serious defects, and also they may accompany with rapid progress to serious defects.
- ➢ Emergency report to SDE (bridge manager) may be required according to the organizational rules.

When you pass a bridge, special attention should be required with the window opening, for detecting abnormal noise or vibration.

When insufficient drainage is identified, special observation on water gradient on a bridge and water flow inlet port is required.

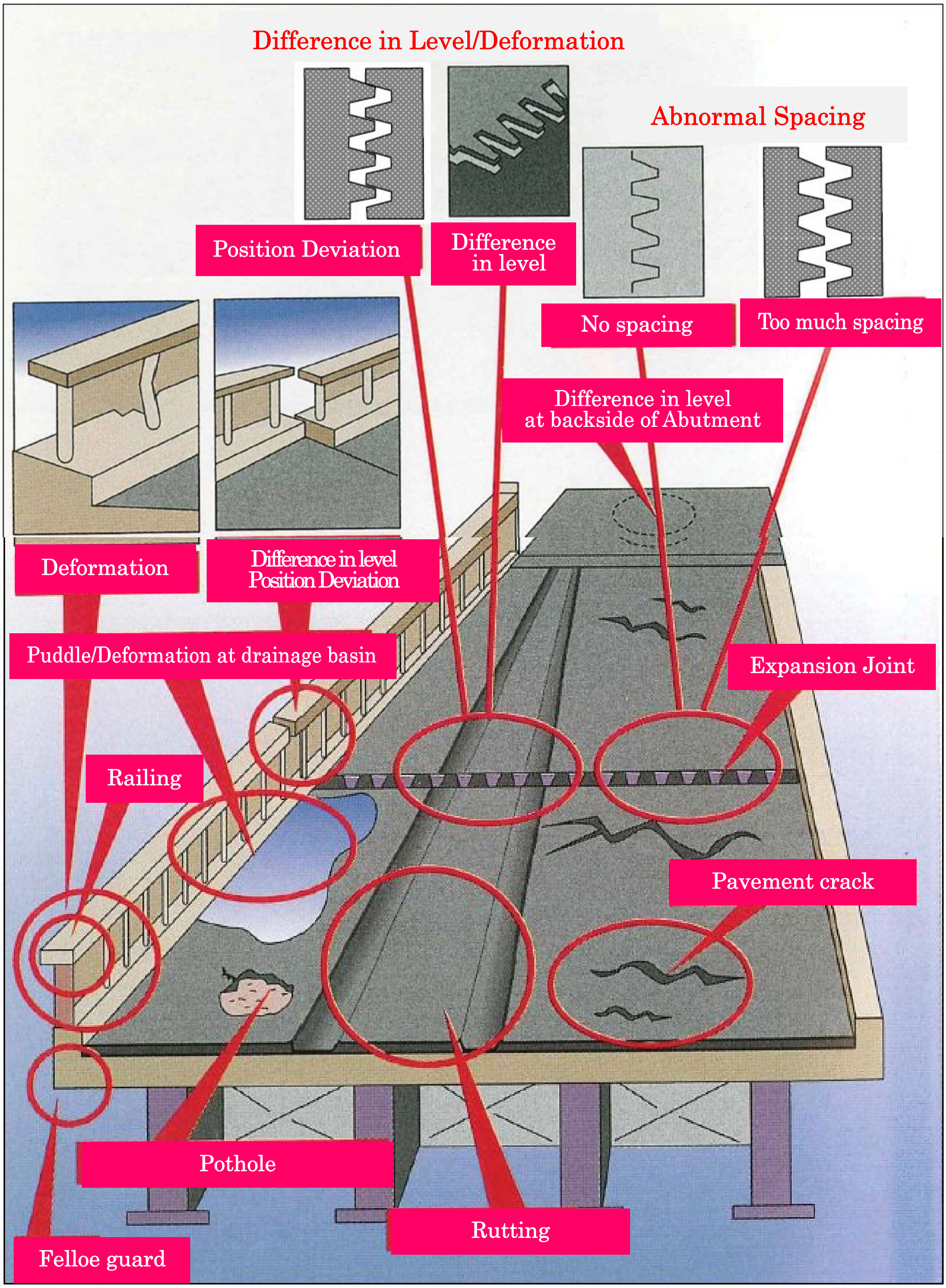


Figure Summary of Possible Defects and Locations

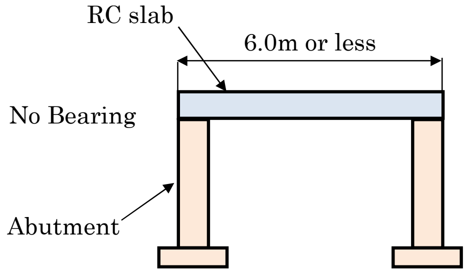
Appendix-2: Guideline for Bridge Types and Configurations

Bridge and Culvert Type

<Concrete Bridge >

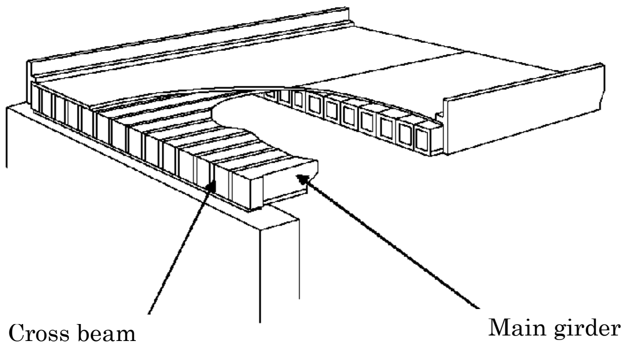
1. Small Slab Bridge (Former "Slab Culvert")

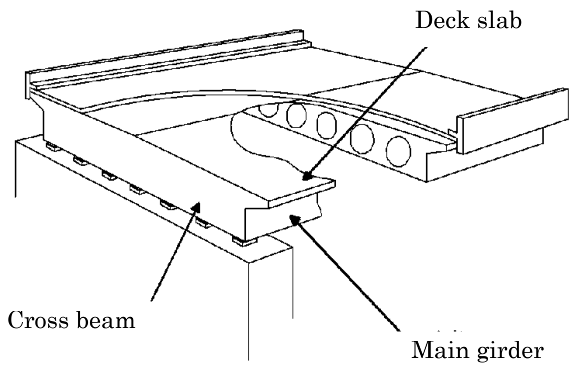
A structure comprising a slab(s) without girders supported on abutments/piers and having a length of 6.0m or less measured at right angles between the extreme vent way boundaries.



2. RC Slab Bridge

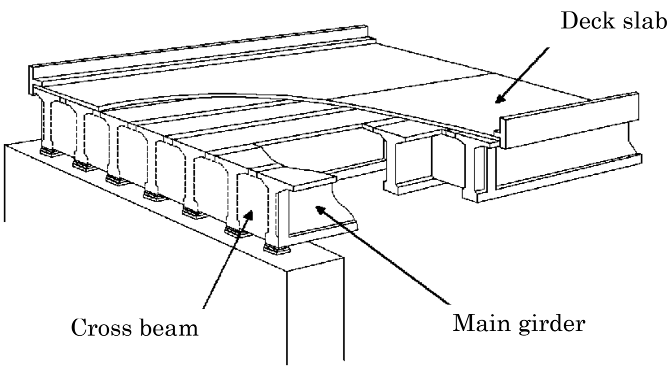
In general, the span is less than 16m





3. RC Girder Bridge

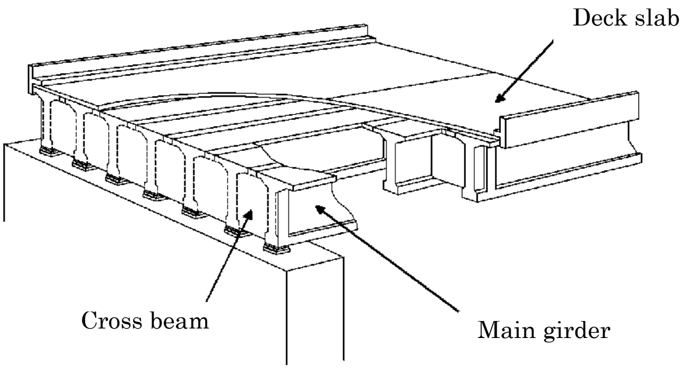
In general, the span is less than 20m. In special case It can be less than 30m



Bhuvagati Bridge in SirajGanj

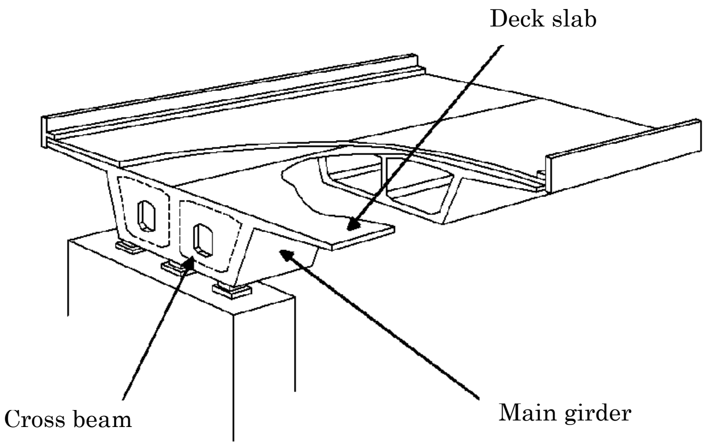
4. PC Girder Bridge

In general, the span is more than 20m



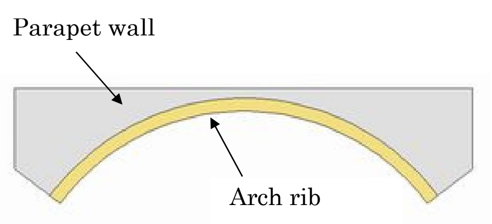
Kanchpur Bridge in Narayanganj

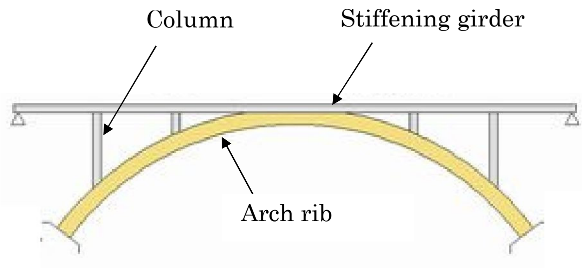
5. PC Box Girder Bridge

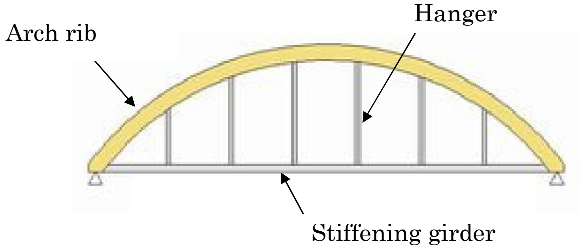


Rupsha Bridge

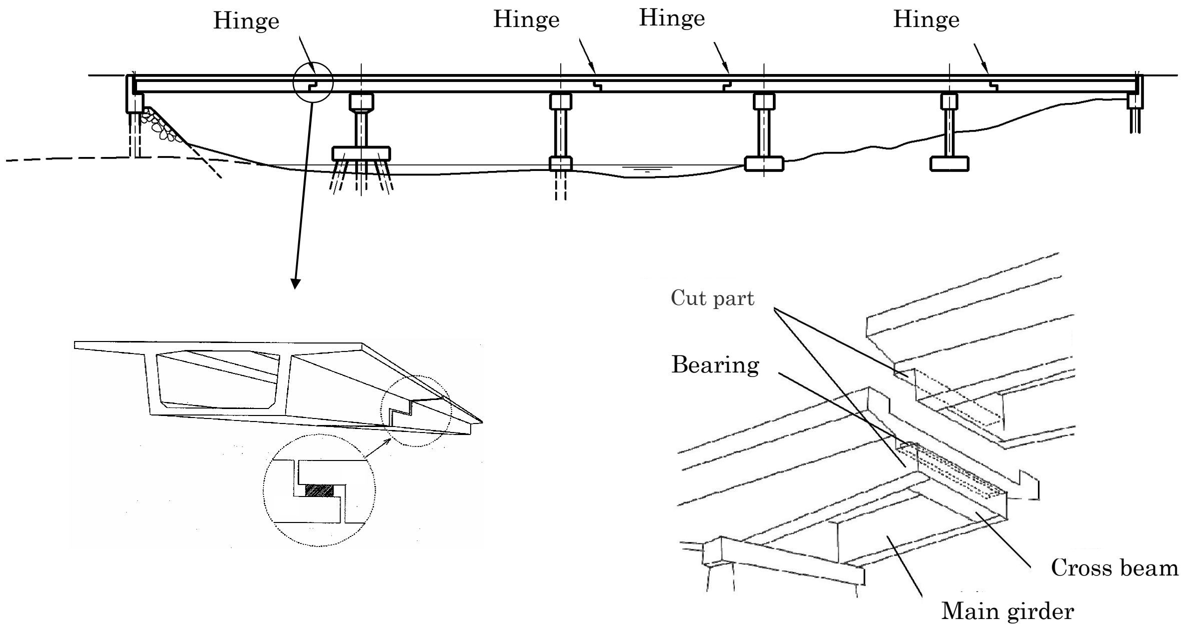
6. Concrete Arch Bridge



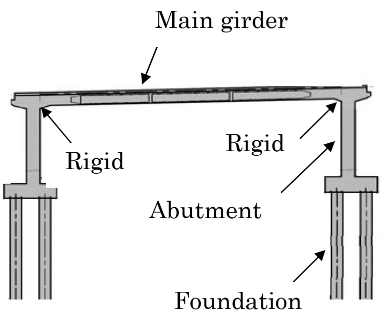


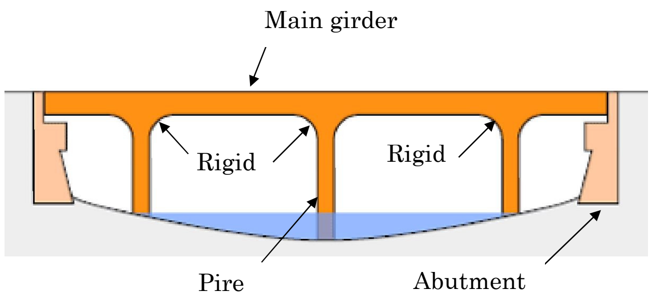


7. Cantilever Bridge with Hinge

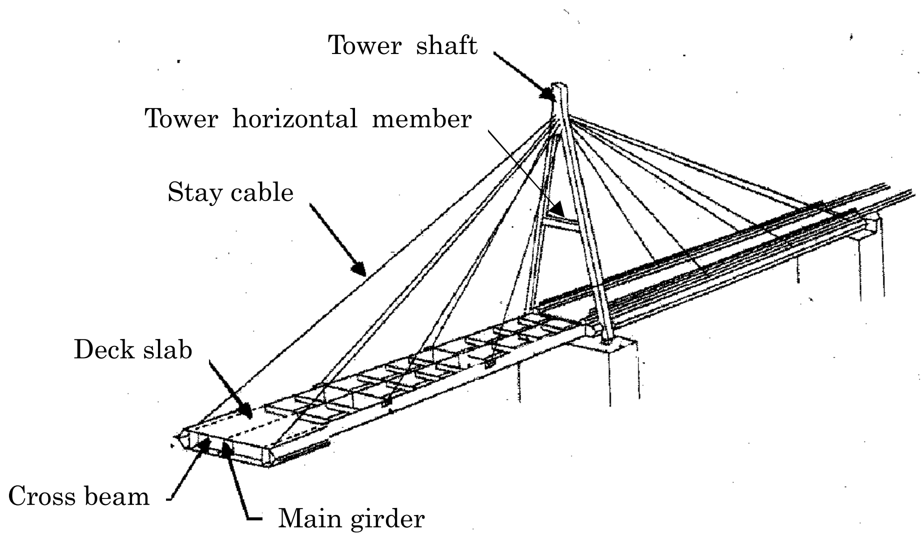


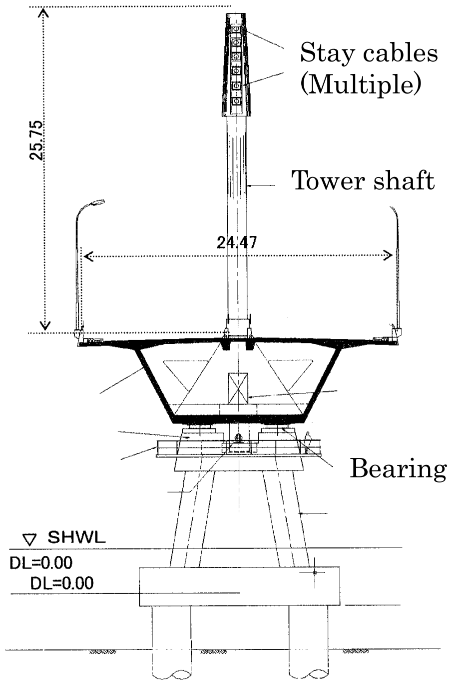
8. Rigid Frame Bridge

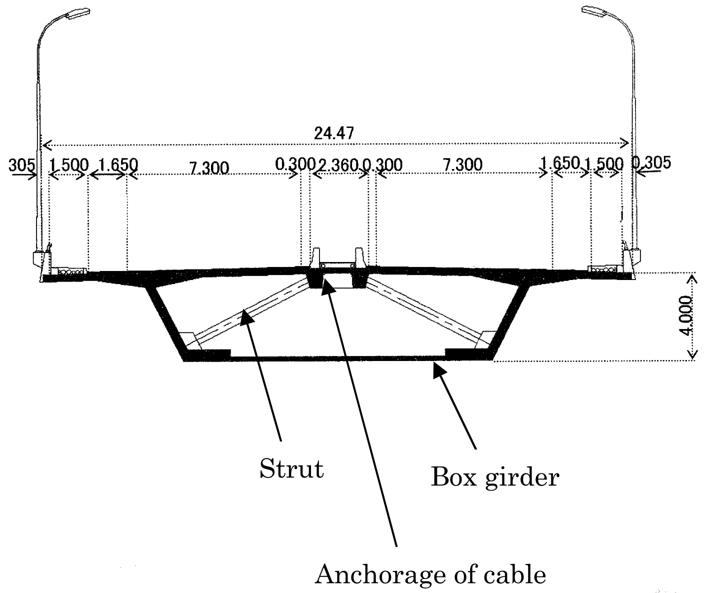




9.Cable- Stayed Bridge



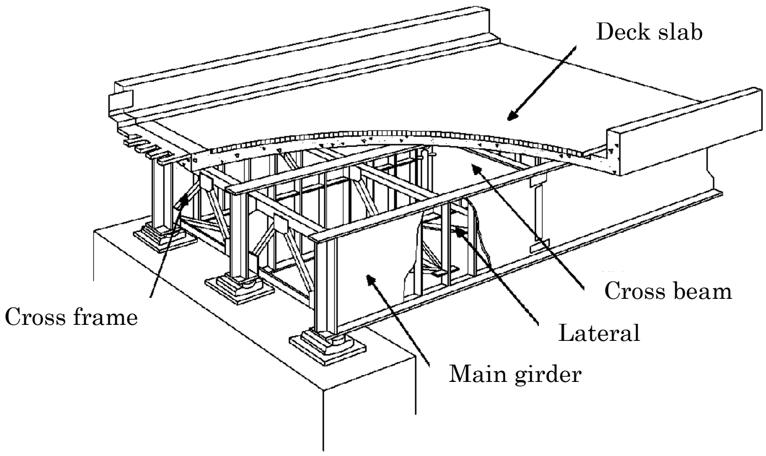




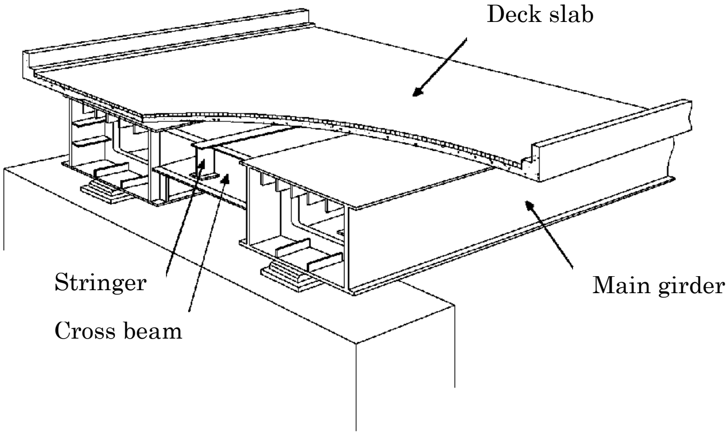
Section and elements of the 3rd Karnaphuli Bridge (Extradosed bridge)

< Steel Bridge >

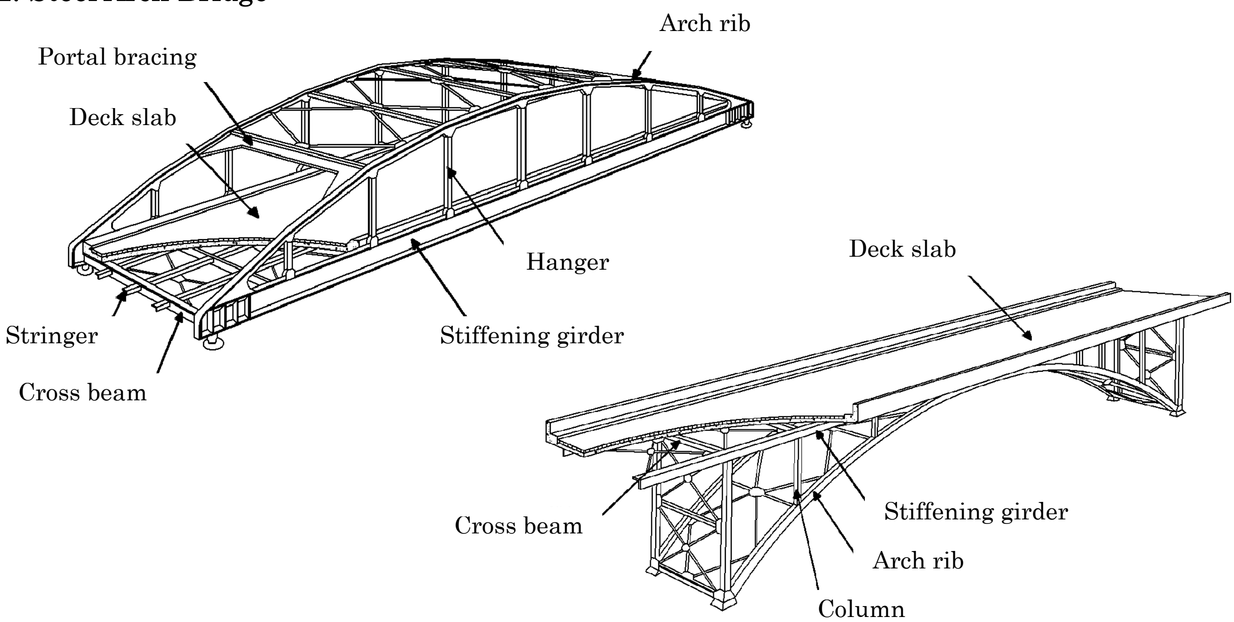
10. Steel Girder Bridge



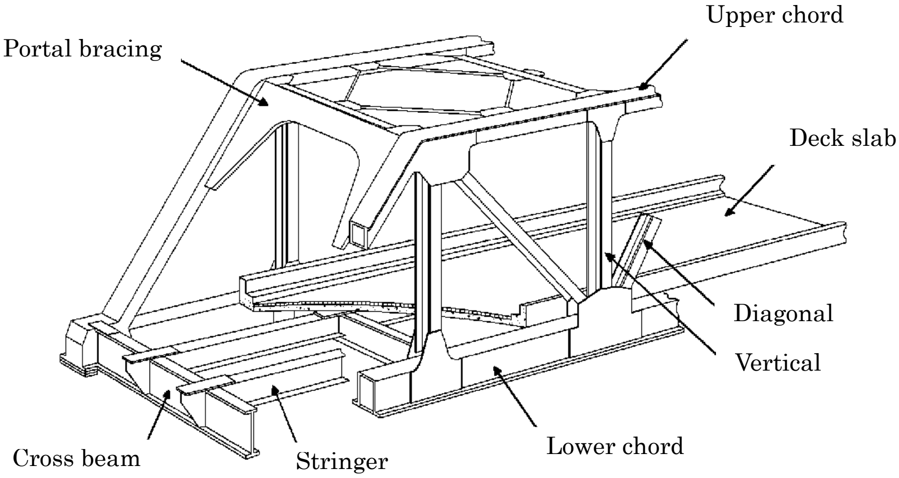
11. Steel Box Girder Bridge



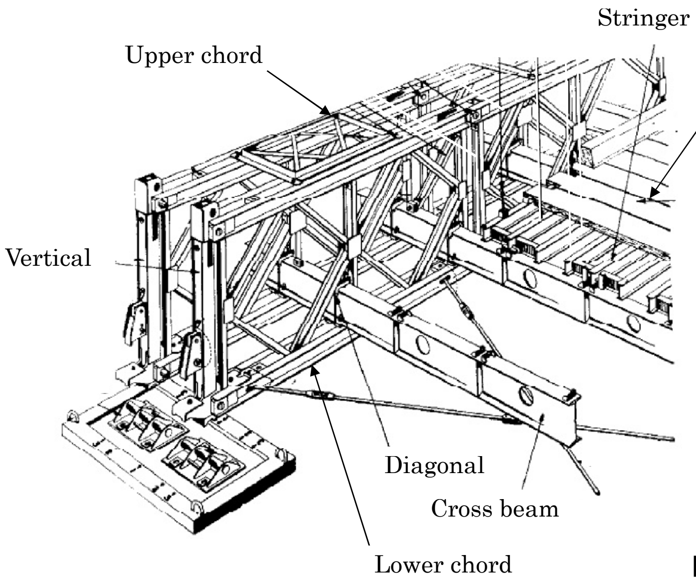
12. Steel Arch Bridge



13. Truss Bridge with Steel Deck
14. Truss Bridge with RC slab
15. Truss Bridge with Timber Deck



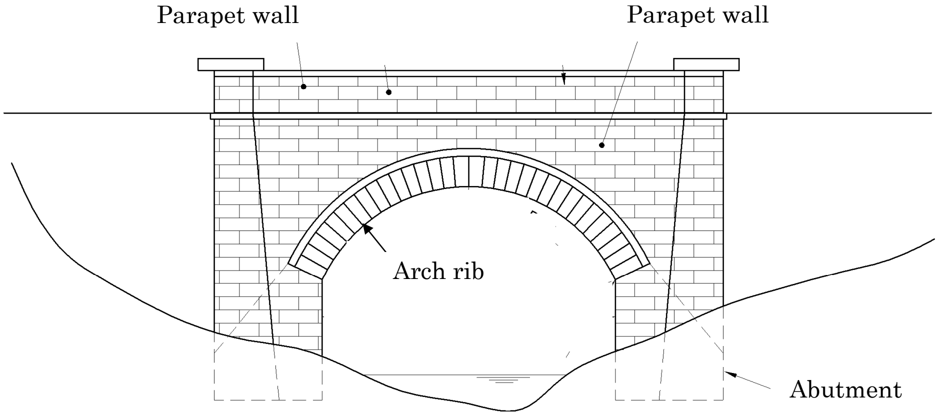
16. Portable Steel Bridge with Steel Deck
17. Portable Steel Bridge with Timber Deck



Rodal Tlki Portable Steel Bridge in Manikganj

< Masonry Arch Bridge >

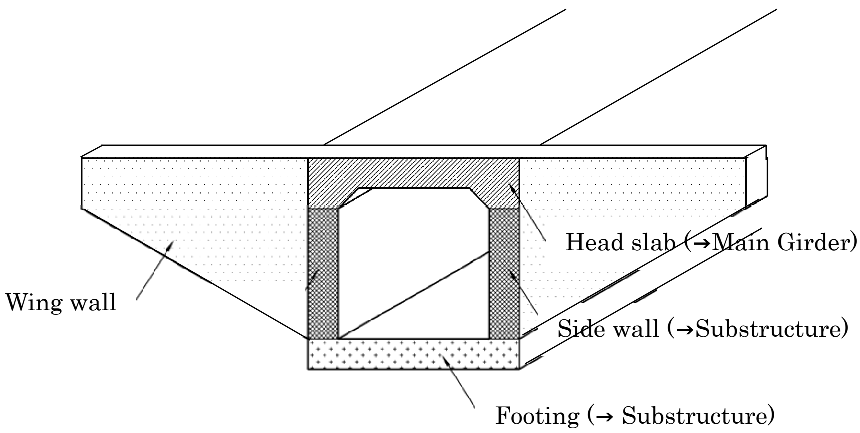
18. Masonry Arch Bridge



< Culvert >

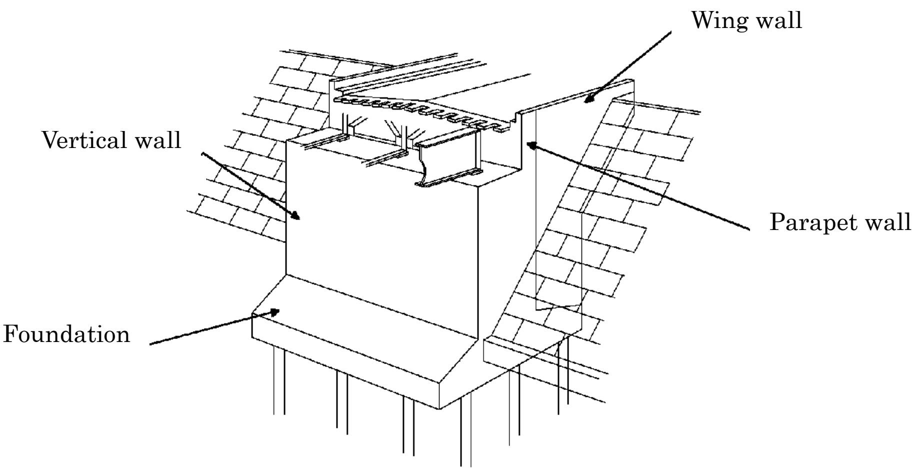
19. Box Culvert

A structure which is in a box form (single or multiple cell) in cross-section which contains a ground slab, and where the floor, walls and deck are of monolithic construction, i.e. there are no joints or bearings within the structural unit.

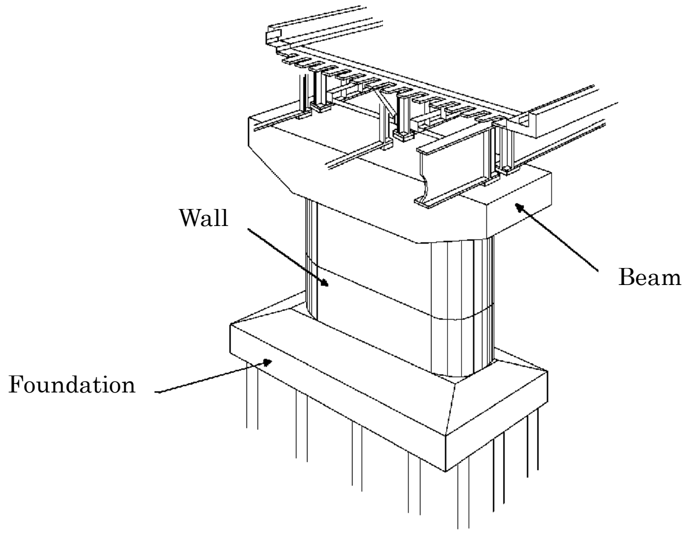


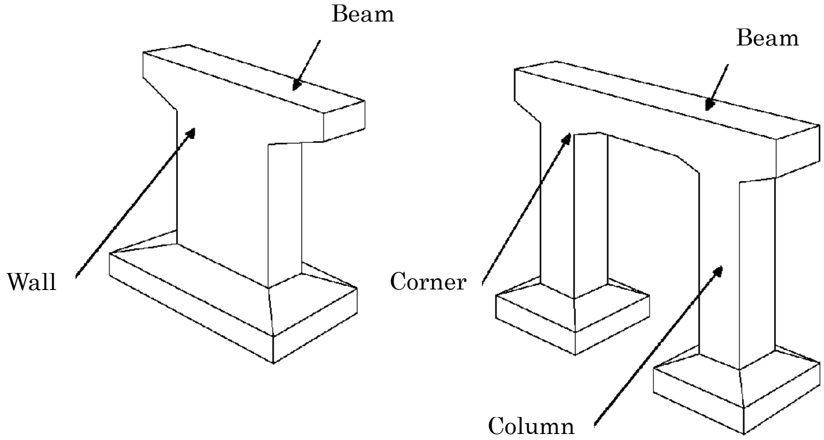
Substructure Type

<Abutment>

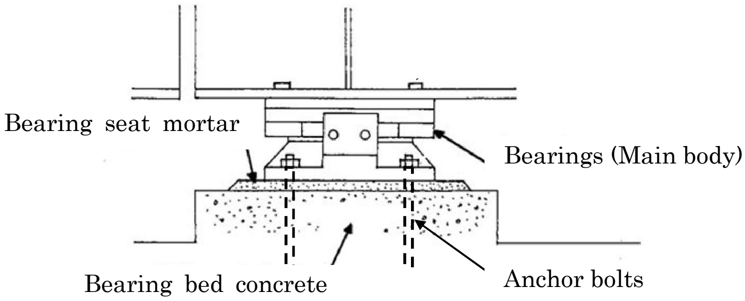


<Pier>



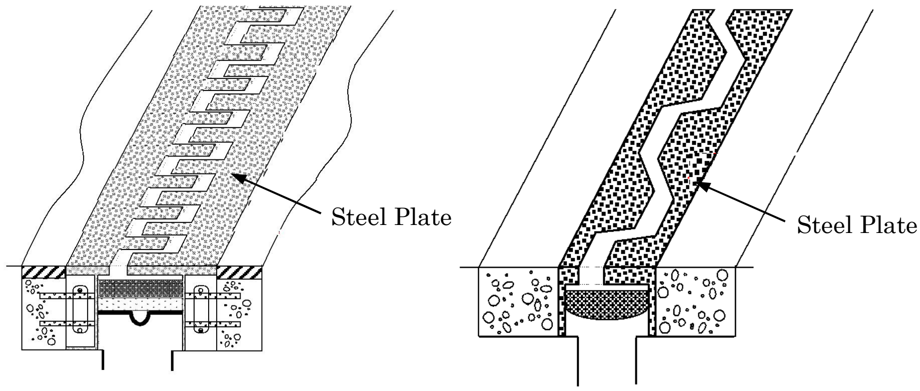


Bearings

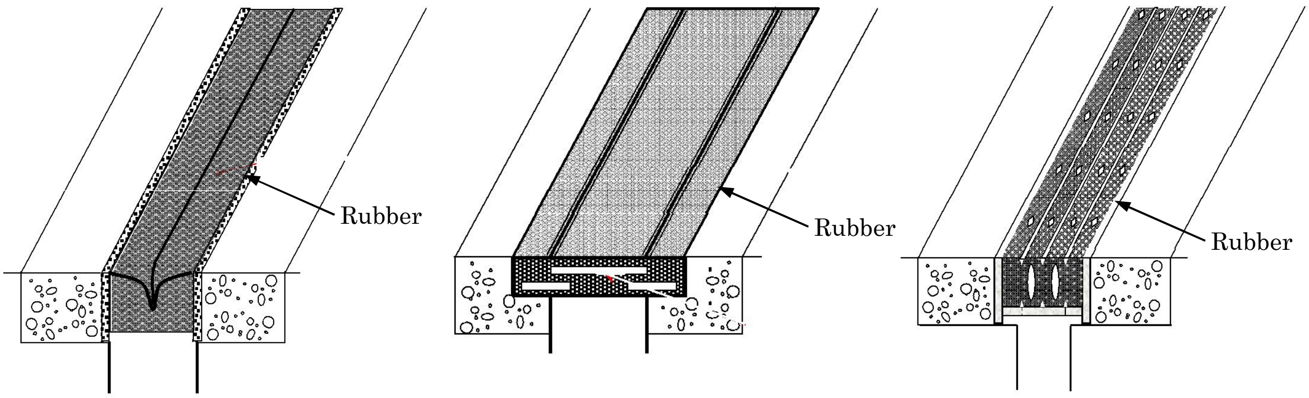


Expansion Joint

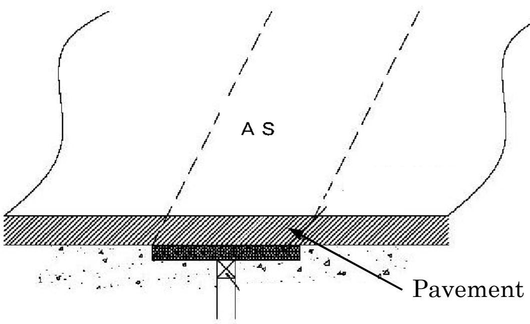
<Steel>



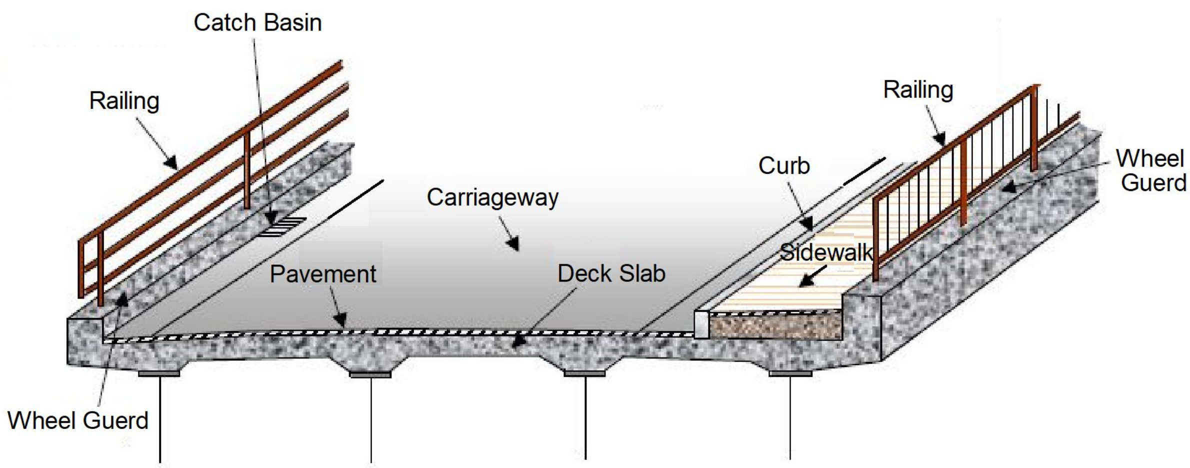
<Rubber>

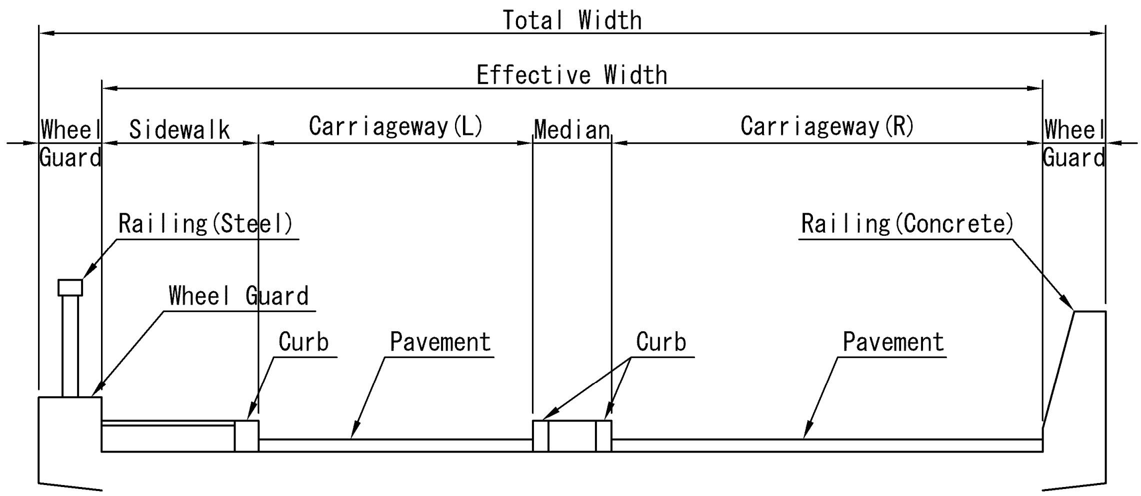


<Others>



Deck Surface



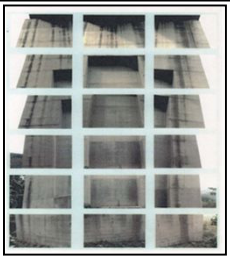
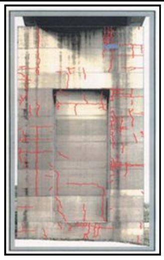
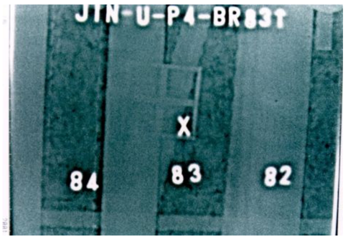
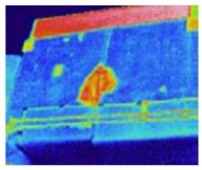
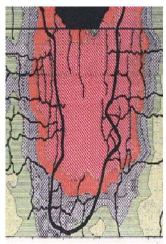


Appendix-3: Inspection Tools and Instruments

Equipment for Detailed Investigation

No.	Name	Specification	Pieces	Purpose of Use	Photos
1	Re-bar detector	Electromagnetic rader method, maximum detective depth ≧ 200mm	2	Covering depth, Re-bar position	
2	Concrete core cutter	core size =100 mm, maximum depth = 100 mm	2	Chloride ion concentration, ASR test	
3	Concrete drill	core diameter = 22 mm	2	Carbonization, Salt content	
4	Salinity measuring instrument	Coulometric titration method	2	Salt content	
5	Reagent etc.	Phenolphthalein solution, Distilled water		Carbonization, Salt content	
6	Miscellaneous goods	Vernier caliper, Straight scale, Sprayer		Carbonization, Salt content	

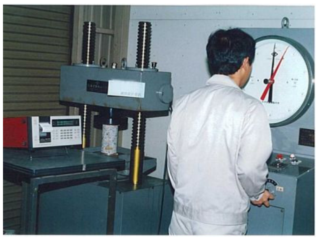
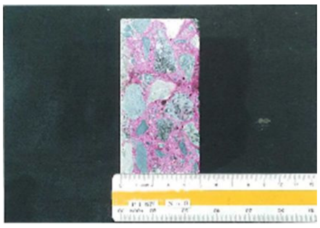
Equipment for Detailed Investigation (Non destructive test) - 1/2

No.	Name	Specification	Pieces	Purpose of Use	Photos
1	Rebound hammer (Ex. Schmidt rebound hammer)	The repulsion hardness method	—	The compressive strength	
2	Digital camera	Digital photographic image	—	Crack width	 
3	Rebar detctor (Ex. Prophometer)	Electromagnetic induction	—	Rebar investigation	
4	X-rays device	X-rays	—	Rebar investigation	
5	Impact elastic wave device (Ex. Impact Acho)	Impact elastic wave method	—	The interior hollow and Internal flaw	
6	Infrared rays camera	Infrared rays	—	The interior hollow and Internal flaw	 
7	Natural electric potential measuring machine	Natural electric potential	—	Rebar corrosion	 

Equipment for Detailed Investigation (Non destructive test) -2/2

No.	Name	Specification	Pieces	Purpose of Use	Photos
8	Ultrasonic measuring machine	Ultrasonic	—	The crack depth	
9	Ultrasonic measuring machine	Ultrasonic	—	The thickness of member	
10	X-rays device	X-rays	—	The thickness of member	
11	Ultrasonic thickness gage	Ultrasonic	—	The plate thickness	
12	Device for measuring film thickness	Electromagnetic induction	—	The coating film thickness	
13	A magnetic particle including the luminous paint and light of ultraviolet rays	Magnetic particle inspection	—	Crak investigation (The surface crack)	
14	Ultrasonic testing device	Ultrasonic	—	Crak investigation (The interrior crack)	

Equipment for Detailed Investigation (Minute destructive test)

No.	Name	Specification	Pieces	Purpose of Use	Photos
15	Compression test machine	Strength test by an extraction of core	—	The compressive strength	
16	Phenolphthalein method	Phenolphthalein method by an extraction of core	—	Carbonation depth	
17	Potentiometric titration device	Core	—	Chloride ion concentration sampling	
18		Boring by drilling	—	The thickness of member or The plate thickness	

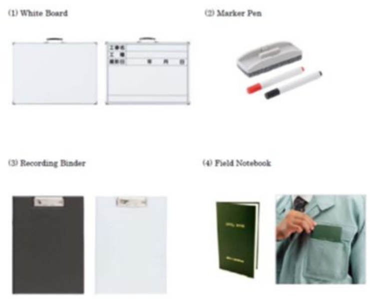
Inspection Tools

No.	Name	Specification	Pieces	Purpose of Use	Photos
1	Binocular	Prism Type : Roof Objective Lens : 25mm Maginification : 10	5	Inspection	
2	Inspection hammer	Appellation : #1/2 Length : 420mm Head Diameter : ϕ17 Head Length : 113mm Head Weight : 200g	5	Inspection	
3	Inspection hammer (Long)	Appellation : #1/2×900 Length : 900mm Head Diameter : ϕ17 Head Length : 113mm Head Weight : 200g	5	Inspection	
4	Measuring tape, Surveying pole, Leveling gage, Vernier caliper, LED light, etc.		5	Inspection	
5	Clack Gauge		5	Inspection	

Inspection Tools

No.	Name	Specification	Pieces	Purpose of Use	Photos
6	GPS		5	Inspection	
7	Inspection Mirror	Length : 4m (1m × 4joint) Mirror Size : 203 × 90mm Weight : 770g Material : Aluminum	5	Inspection	
8	Leser Range Finder	Maximum Measurement Distance : 250m	5	Inspection	

Recording Tools

No.	Name	Specification	Pieces	Purpose of Use	Photos
1	Digital camera		5	Recording	
2	Video camera		5	Recording	
3	White board, Marker pen, Recording binder, Field notebook		5	Recording	
4	Laptop		11	Recording	
5	Server for PC	HDD : 2TB	11	Recording	

Auxiliary Tools

No.	Name	Specification	Pieces	Purpose of Use	Photos
1	Safety belt		9	Safety	
2	Helmet, Safety best, Protective glasses, Protective mask etc.		1	Safety	
3	Work clothes, Work boots, Gloves, etc.		1	Safety	

Appendix-4: Numbering System of Bridge Elements

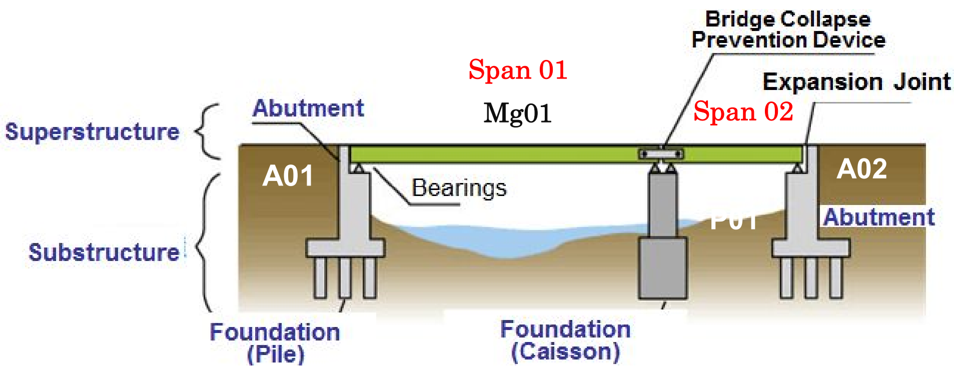
Bridge Element Numbering System

In order to standardize the reporting system and to easily interpret the inspection report, a reference system in identifying the bridge components and elements are devised. The reference systems are described below:

1) Superstructure

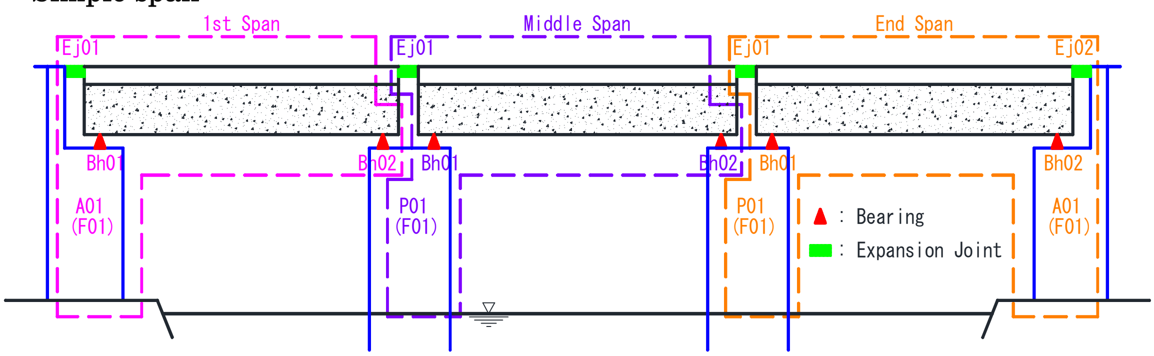
The superstructure element numbering system should include the spans, the girders, and in case of truss the panel point

The spans should be numbered consecutively, with Span 1 located at the beginning of the bridge. Multiple girders should be numbered consecutively from left to right facing in the route directions.

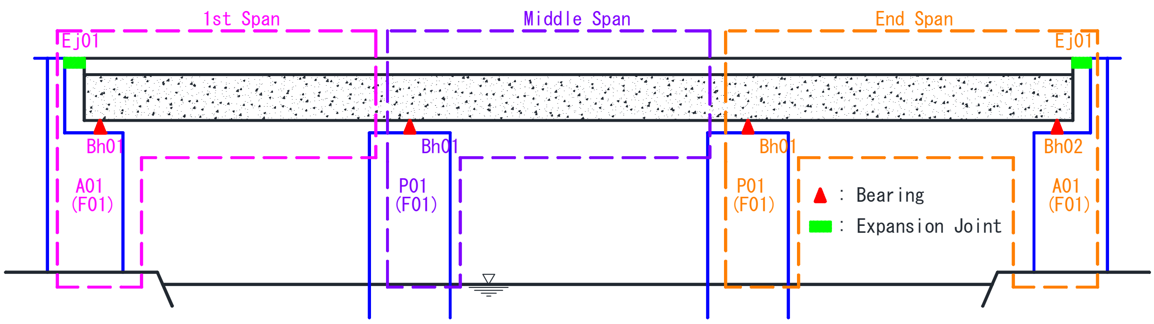


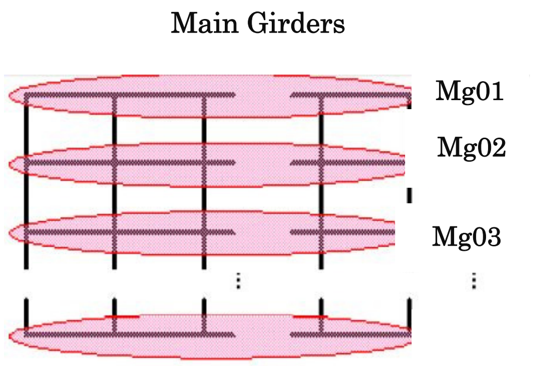
Each element of main girders and deck slab, abutment and piers, and bearings is numbered according to the following span configuration..

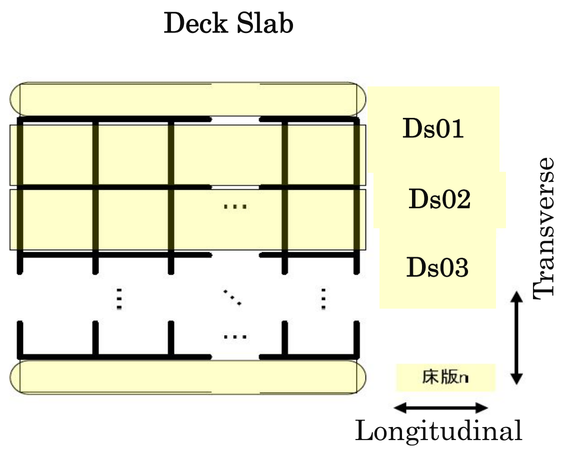
a. Simple span



b. Continuous Span



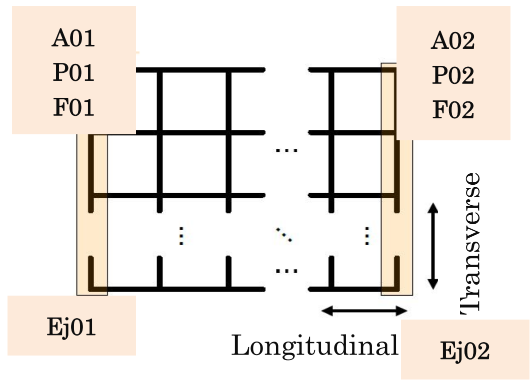




2) Substructure and Expansion joint

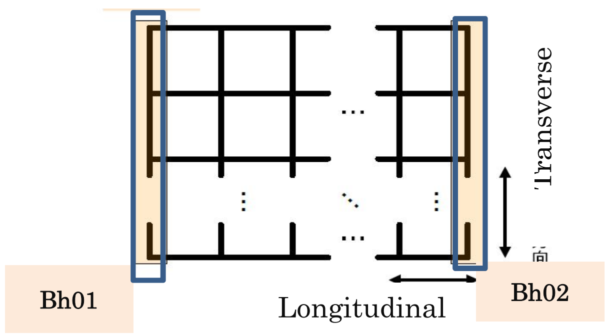
Substructure element numbering system should include the abutments and piers. A01 is located at the beginning of the bridge, and A02 is located at the end.

The piers should be numbered consecutively, with P01 located closest to the beginning of the bridge.



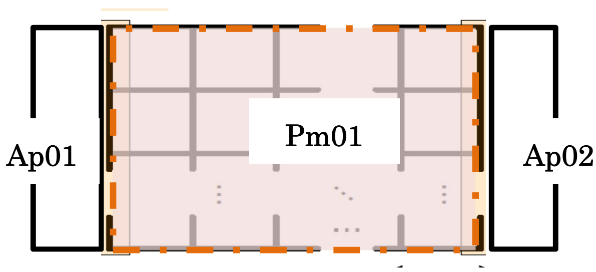
3) Bearings (Bh)

Bearings are numbered consecutively as a lined group on an abutment or a pier regardless of the number and types of bearings.



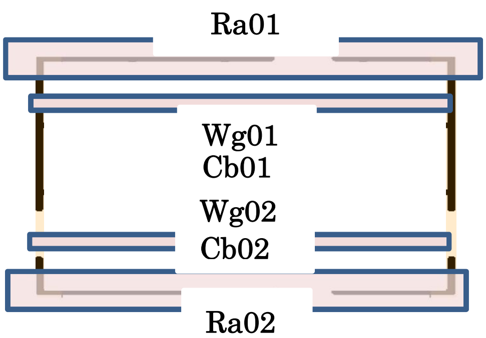
4) Pavement (Pm), Approaches (Ap)

Pavement is defined as one section in a span. Approaches are classified as that of closer to the origin and that of closer to the terminus.



5) Railing (Ra), Wheel Guard(Wg), Curb (Cb)

Railing, wheel guard, curb are numbered along either left or right side line in the same way.



Appendix-5: Essential Viewpoints during Inspection

- Tips on How to Find Defects -

Essential Points to Find Possible Defects during Inspection

The essential points present as a detailed, systematic guide to the inspection of each bridge component. The inspector must be careful and attentive to the work at hand, and no portion of the bridge should be overlooked. Those portions that are most critical to the structural integrity of the bridge should be given special attention.

For bridges of average length and complexity, it is convenient to conduct the inspection in the following sequence.

1) Side View	Whole bridge structure
2) Bridge surface	Railing, Curbs, Wheel guard, Signs, Lighting facilities
	Pavement, Expansion joint, Drainage
	Approaches behind abutment
3)Under-bridge girder	Substructure (Abutment, Piers)
	Superstructure, Deck slab
	Bearings
	Utilities

At the site, Inspector shall proceed in a systematic manner to check the following inspection items:-

(1) General View of the Bridge

It is important that general view of a bridge should be observed to detect any misalignment or settlement.

⬅Low chainage High chainage ➡

(2) Bridge/Road Surface

The inspector should note the general approach roadway alignment, and sight along the railing and edge of the deck or girder to detect any misalignment or settlement.

Generally, inspection points for bridge surface are as follows.

▪ **Railing, Curb and Wheel Guard**

- **Correct alignment** and damaged posts and rails,
- **Loose and missing bolts** and clamps, missing and damaged spacer blocks, **corrosion**,
- **Settlement or movement of substructures, abnormality of bridge girder or bearing deficiencies,**
- **Damage caused by collision** and **weakening caused by some form of deterioration,**
- **Damage of the connections of the posts to the decks** due to abnormal vibration,
- Adequate height, secure, and relatively free of slivers or any projections which would be hazardous to pedestrians.
- Any hazards on the railing

Pavement surface

- **Cracks** and **fallen out of bridge deck**

Bridge drainage system

- Accumulations of debris on the deck, in gutters, scuppers and drains which may obstruct free drainage and cause ponding,
- Damage of drain pipe due to corrosion, or collision

Poor deck drainage usually leads to deck disintegration.


Puddle

Approaches behind abutment

- Difference in level, settlement, or roughness of approach pavement
- The condition of the shoulders, slopes, drainage

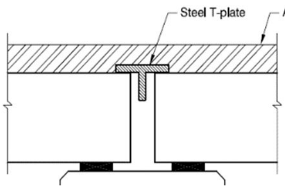
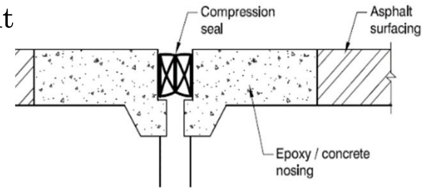
Difference in level


Landslide backside abutment

Expansion Joints

- Abnormal spacing, and dirt or objects which may impede free movement and proper functioning
- Difference in level, water leakage, loose or missing bolts and components




Type of Expansion Joints	Inspection Points
Buried Joint 	Fallen out of sealing compound Cracks or separation of pavement material Water Leakage
Butt Joint 	Fallen out of sealing compound, break of rubber Deformation Cracks or subsidence of nearby pavement Difference in level
Elastomeric Joint 	Abrasion or deterioration of rubber Loose or missing bolts Broken out of anchor Deformation Cracks or subsidence of nearby pavement Abnormal sound during vehicular traffic Difference in Level
Finger Joint (Steel) 	Break or corrosion of steel element Loosening of bolts Cracks or separation of pavement material Cracks on concrete of anchor Difference in Level Abnormal sound during vehicular traffic Abnormal spacing Water Leakage

✓ In case of steel joint, when abnormal sound occurs during vehicular traffic, the location of the source should be clarified.

(3) Under the Bridge

If the damages on the bridge surface described above are identified, then its lower side of the bridge girders should also be inspected. If any abnormality is observed, the severity and extent where the abnormality may affect similar structural bridge elements should be inspected.

- Settlement, movement of the substructures
- The source of abnormal sound, vibration, deflection on road surface
- Damage conditions of the lower surface of bridge deck
- Deterioration of bearing

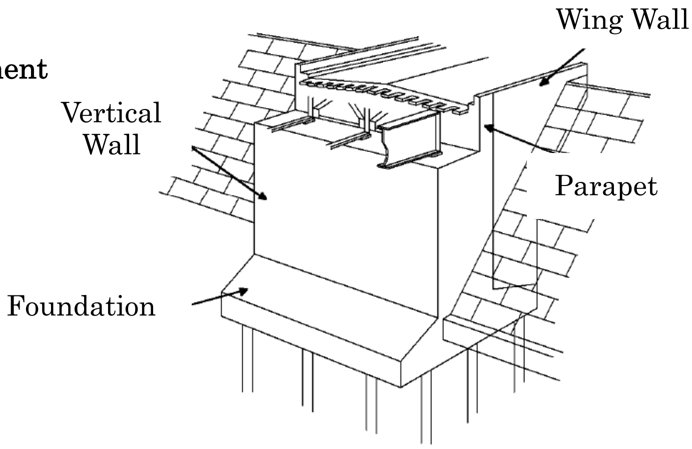
A. Substructures

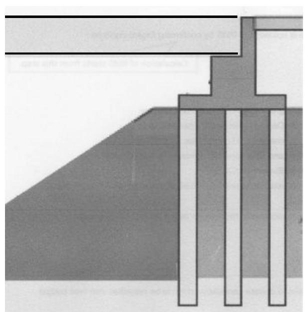
Substructure elements comprise abutments and piers.

- **Abutments** are the end supports of a bridge, where it connects with approach roadway. Their function is twofold: to transmit the reactions from the superstructure to the foundation, and to retain the earth embankment of the approach roadway.

- **Piers** are intermediate vertical supports that perform two main functions: transfer the vertical loads to the foundation, and resist all horizontal and transverse forces acting on the bridge.

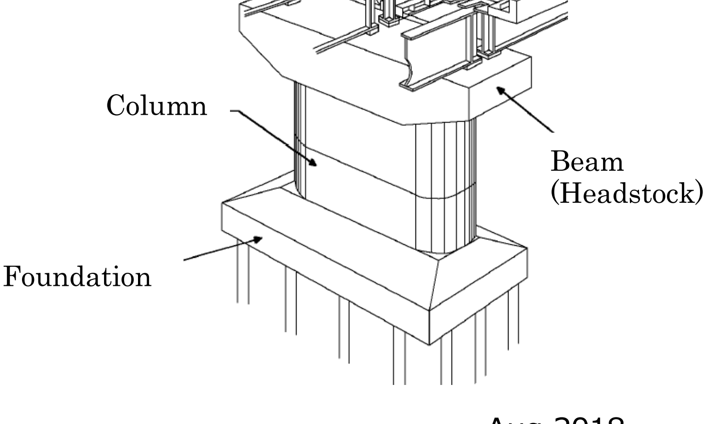
Abutment



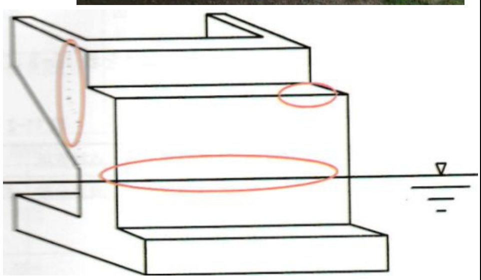


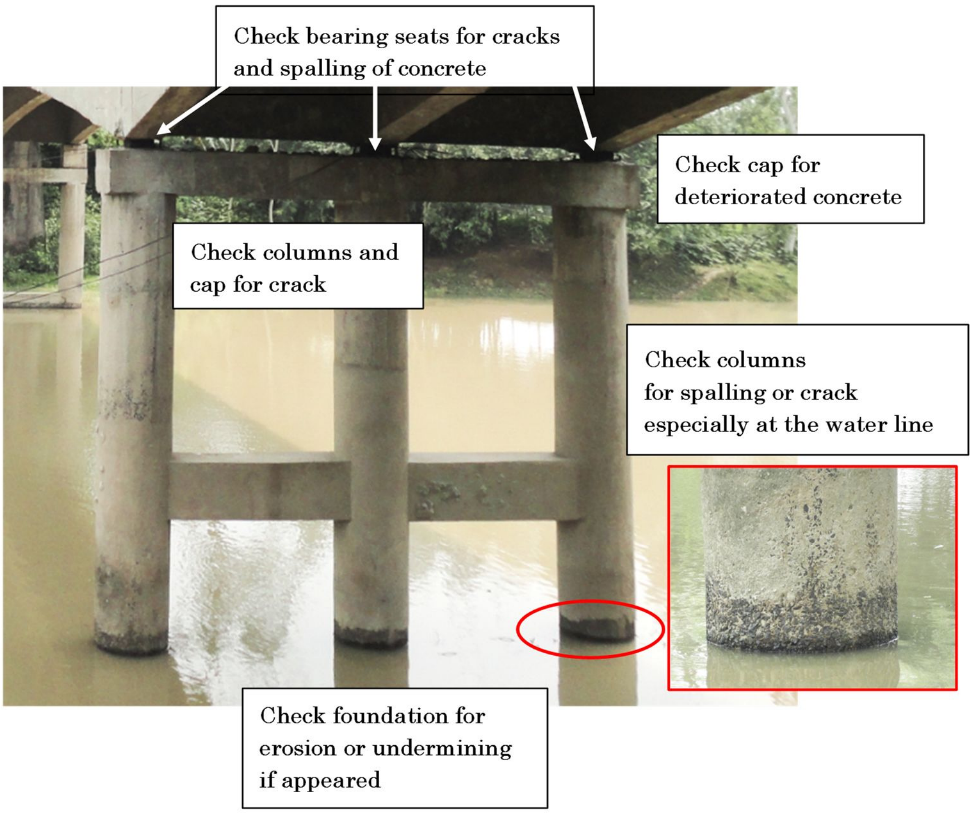
Spill-Through Abutment

Piers



The elements which suffer defects and should be considered during inspection are shown below:

Element	Possible Defects
Abutment	▪ **Scour or erosion** around the abutment and for **evidence of any movement (sliding, rotation, etc.) or settlement.**  ▪ **Inadequate or abnormal clearances** between the parapet wall and the girder end are indications of probable **movement.** ▪ **Cracks** with water leakage/efflorescence through joints and which may indicate accumulation of water behind the abutment.  ▪ **Crack and spalling** of bearing seats especially near the edges, and presence of debris and standing water.  ▪ Abutments with wide vertical wall, **vertical cracks** due to **differential settlement** of foundations. ▪ Open **cracks** between adjoining wing walls  ▪ **Tilting or movement** due to the damage of revetments around abutments by instability of river channel  

Piers and Foundations	▪ **Tilting or settlement** If defects of this type are identified, thorough subaqueous investigations should be ordered to determine the cause of the problem.  ▪ **Erosion** or undermining of the foundation by **scour** ▪ **Spalling** especially in the splash zone, at the water line, at the ground line ▪ **Cracks** at pier columns and the pier caps  ▪ **Crack and spalling** of bearing seats especially near the edges, and presence of debris and standing water ▪ **Structural damage** caused by collision or overstress for all piers and bent members ▪ **Unusual movement** in any of the bent members during passage of heavy loads 

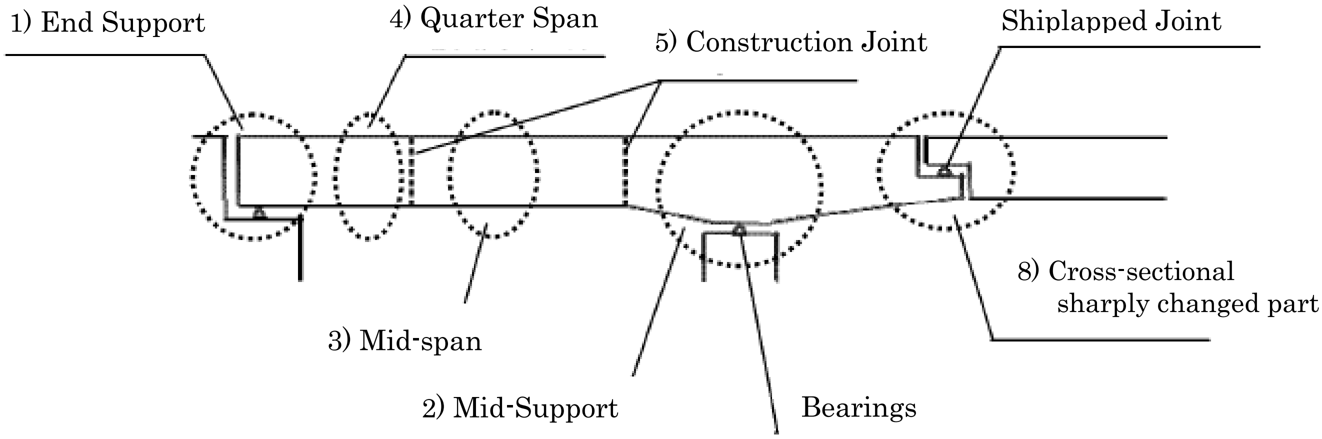
B. Superstructure

Superstructure elements are the main load carrying systems that receive the loads from the deck. In assessing defects, bridge superstructure s may be articulated as concrete or steel.

a. Concrete Bridges (Main Girder)

In general, damages which likely occur in concrete bridges are cracks, and spalling/ efflorescence. The viewpoints on inspection are shown below;

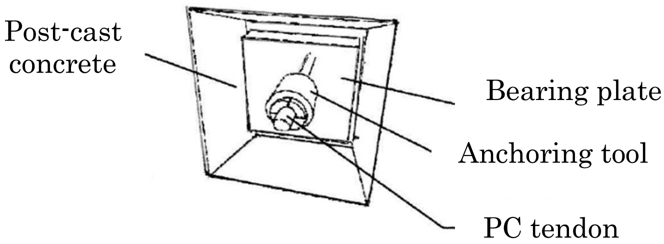
Location	Possible Defects
1) End Support	**Diagonal or vertical cracks** by horizontal force due to bearing reaction, temperature change, **and/or leakage** from expansion joint likely occur.
2) Mid Support (Continuous girders)	Negative bending moment and shear force are maximized, and stress concentration at mid-support points causes complicated reaction force. These situations may cause **cracks** due to bending.
3) Mid-span	Bending moment which gets maximized at mid-span, may cause **cracks** due to bending.
4) Quarter Span	Rebars generally bent-up at quarter span may cause insufficient quantity of steel rebars at this part. This situation may cause unexpected **vertical cracks** due to improper function of bearings.
5) Construction Joint	**Cracks** due to drying shrinkage, improper construction work, **spalling, delamination, or water leakage** may occur.
6) Segment Joint	If segmental construction method was applied for bridge girder, defects similar to construction joint likely occur.
7) Anchorage	**Cracks** due to concentrated tensile stress may occur, if pre-stressing rebars are anchored by installing projections in girder web or flange. And anchorage system likely **corrodes** due to permeated rainwater from construction joint where anchorage is covered by post-cast concrete.
8) Cross-sectional sharply changed part	**Cracks** likely occur due to stress concentration at the cross-sectional sharply changed part (such as Gerber-type hinge part, cross-sectional sharply changed part, etc.).



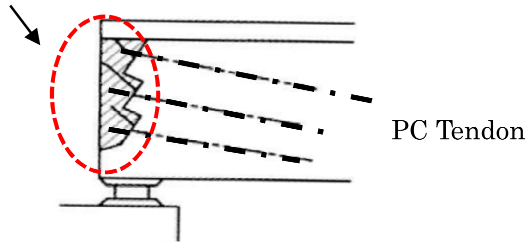
Pre-stressed Concrete Girders

It is usually impossible to make a visual check on the condition of the prestressing tendons because they are embedded either directly in the concrete or in grouted ducts inside a reinforced concrete element.

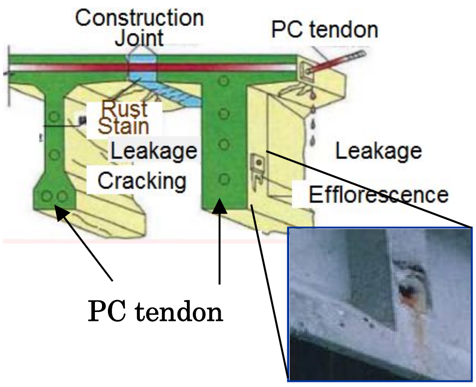
PC Anchorage

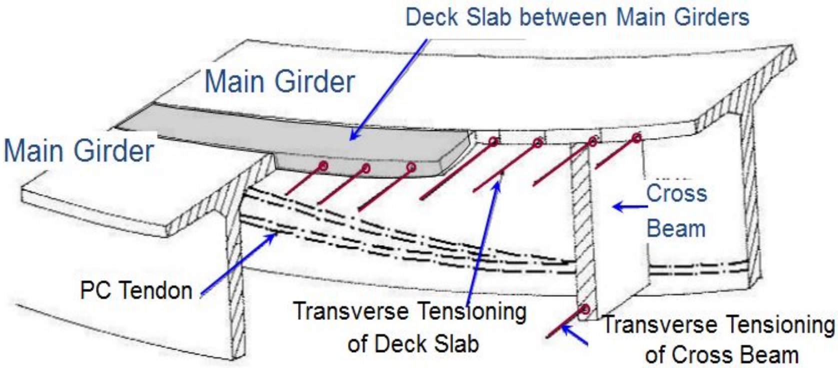


7) Anchorage

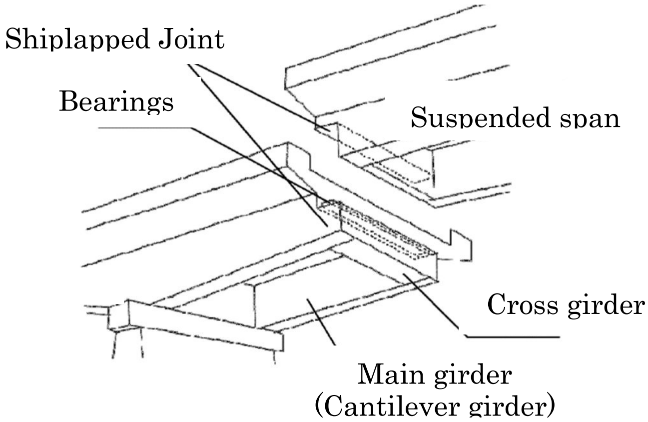


PC T-girders





Shiplapped joint of concrete girders



Particular defects of pre-stressed concrete superstructure are;

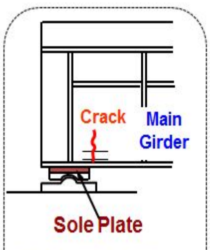
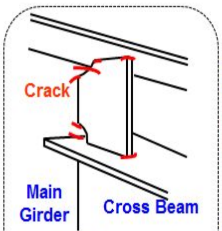
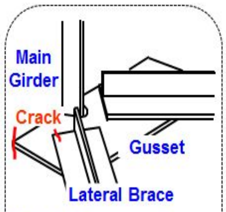
- **Cracks** along pre-stressing tendon due to insufficient grouting.
- **Cracks** at the post-cast concrete of the anchorage
- **Efflorescence and rust stain** at the post-cast concrete of the anchorage.
- **Broken out** of pre-stressing steels.
- **Water leakage and rust stain** at construction joints of cast-in-situ concrete.

Rust stain at construction joint

Check the camber of the box girders. Loss of positive camber indicates loss of prestress in the tendons.

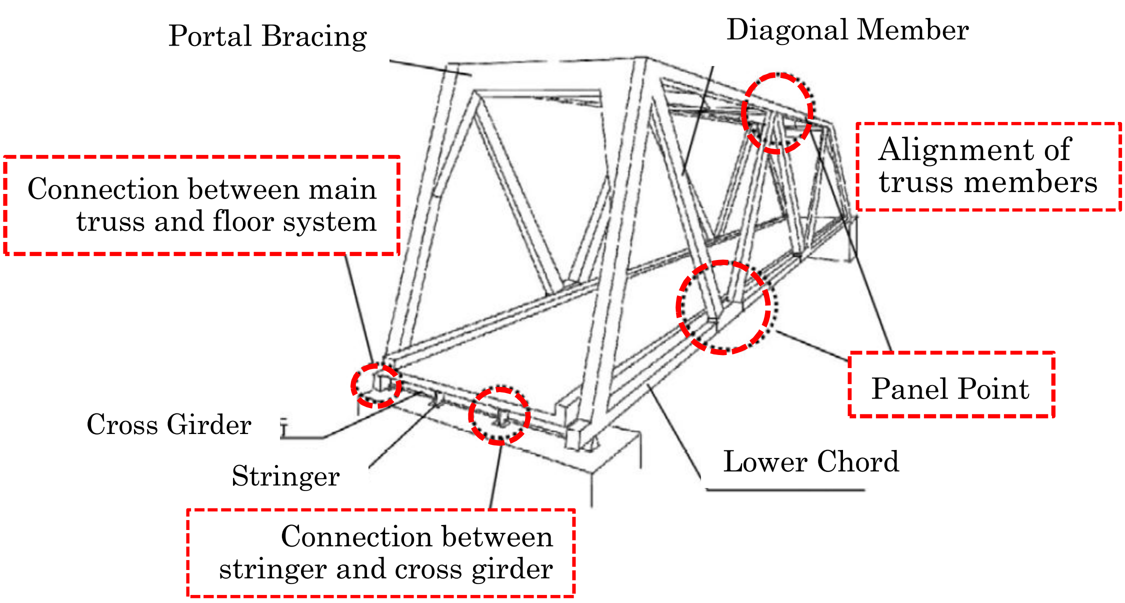
b. Steel Bridges (Main Girder)

Any serious problem found in steel girders should be addressed immediately since its failure could cause total collapse of the bridge. Immediate closure of the bridge may be warranted if the defect is deemed serious. The following items should be inspected:

Location and Possible Defects	Photograph
▪ General alignment by sighting along the members. **Misalignment** or **distortion** may result from **overstress, collision, or fire damage**. If such a condition is present, its effect on structural safety of the bridge should be fully investigated.	
▪ **Corrosion, deterioration of protective function** and **missing bolts,** especially at the following places: - Along the upper flange - Around bolts and rivet heads. - At gusset, diaphragm, and bracing connections. - At cantilever hanger and pin connections. - At any point where two plates are in face-to-face contact and water can enter (such as between a cover plate and a flange). - At the fitted end of stiffeners	
▪ Any **abnormal vibration or abnormal deflections** under the passage of heavy loads.	
▪ Members for **cleanliness and freedom from debris**, especially on the top side of the bottom flange. When section loss occurs, after the flaked steel is removed, measure the remaining section.	
▪ [When section loss identified, after removal of flaked steel] Measurement of the rusting members to determine the extent of **reduced cross-sectional area**, using calipers, rulers, corrosion meters, or section templates.	
▪ **Welds, weld terminations, and adjacent metal for cracks,** particularly at: - Field welds prone to **fatigue cracking** - Connections transmitting heavy torsional or in-plane moments to the members. - Coped sections/reentrant corners. - Sudden changes in cross section or other locations subject to stress concentrations or fatigue loadings - Intersection of horizontal/vertical fillet welds. - Stiffeners for straightness, break, and buckled of connections	 Welded Sole Plate on Bearing Support  Welded Connection between Main Girder and Cross Beam  Welded Connection with Lateral Bracing, Gusset and Main Girder

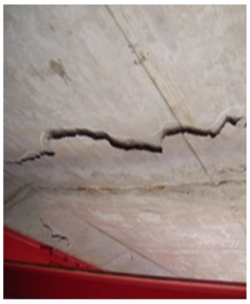
Steel Trusses and Portable Steel Bridge

Location	Possible Defects
Truss members	▪ Corrosion and deterioration of protective function ▪ On through trusses, moisture from the roadway is often splashed on the lower chord members and the member adjacent to the curb. The moisture is retained at the connection and between the adjacent faces of plates leading to rapid deterioration of the member. 
Alignment of truss members	▪ End posts/interior members are vulnerable to collision damage from passing vehicles. ▪ **Buckled, torn, or misaligned** members may severely reduce the load carrying capacity of the truss.  **Misalignment** can be detected by sighting along the roadway rail or curb and along the truss chord members.
Over-stressed members	▪ Local **buckling** indicates overstress of a compression member. Waves in the flanges, webs, or cover plates are common forms of **buckling**.
Loose connections	▪ **Cracks** in the paint or **displaced** paint scabs around the joints and seams of gusset plates and other bolted connections may indicate **looseness or slippage** in the joints.



C. Deck Slab

Main defects which likely occur and the inspection points in deck surface and under-side concrete deck slab are as follows;

Location	Possible Defects
Under-side Deck Slab	▪ Cracks due to repeated wheel load ▪ **Efflorescence or rust stain** due to **water leakage** from upper deck ▪ Susceptible to impact directly by wheel load due to **difference in level** or expansion joint  ▪ Susceptible to **delamination, spalling/exposed rebar** due to **fatigue crack**, or other factors such as carbonation and chloride attack ▪ **Penetrated Cracks** of deck slab with rapid progress of crack with **water leakage/efflorescence**  
Pavement Covering the concrete deck	▪ When reflection cracking (the form of map cracking) in concrete deck slab is found, pavement is susceptible to be defected. (If deterioration is suspected, remove a small section of the wearing surface to check the condition of the concrete deck.) ▪ Connection with expansion joint is susceptible to **difference in level or ponding.**   
Steel (Plate) Decks	▪ **Corrosion** and **cracked welds** (Check to determine if the deck is securely fastened. Note any broken welds or clips.) ▪ Determine if there is any **loss of section** due to rust or wear  

D. Bearings

The function of bearing is to allow the rotation of bridge girder by live load and to transfer the load of bridge superstructure to substructure. Inspection of bearing should be carried out sufficiently approaching it as close as possible.

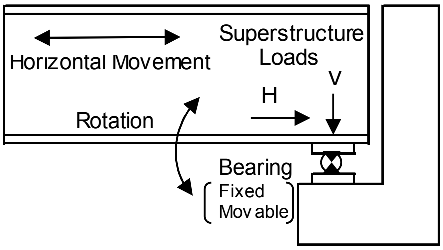


Figure Functions of a Bearing

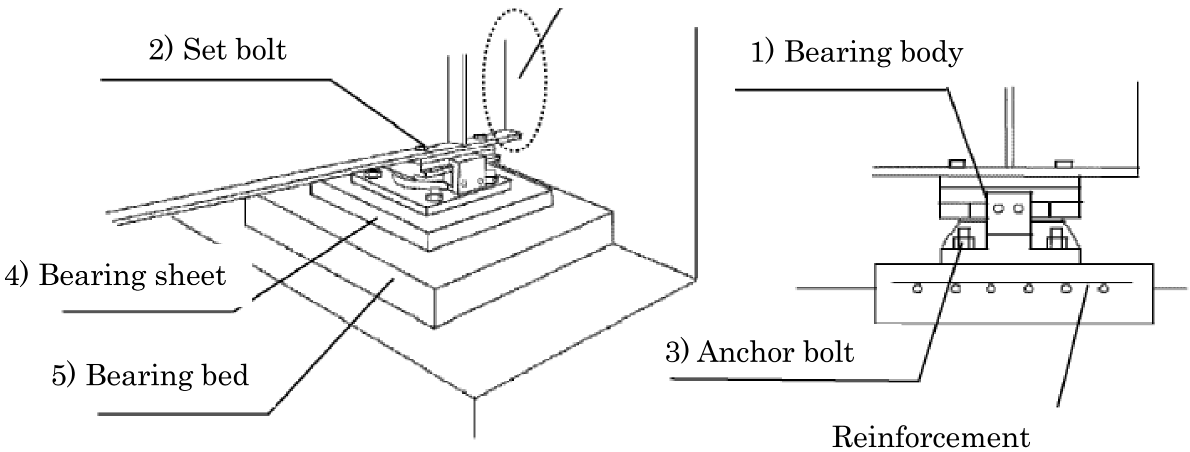
- Observe whether they are actually performing the functions. In case of movable bearing, its function is to smoothly absorb the expansion of bridge girder due to temperature change and loading. If the bearing becomes corroded, these functions cannot be done properly. Consequently, fatigue crack may occur in the welded elements.

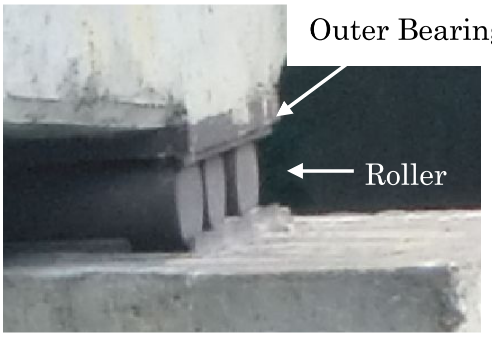
- Bearings should be carefully examined after unusual occurrences such as heavy traffic damage, earthquakes, or damage due to debris in flood periods.

The points in inspection for identifying possible defects of bearings are as follows;

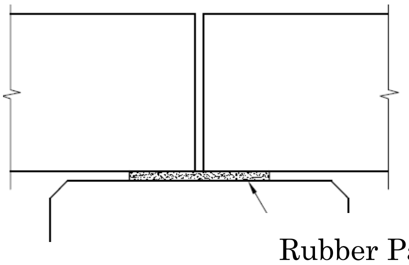
Element	Possible Defects
Bearing Body	▪ Check proper alignment, in complete contact across the bearings surface, and clean surfaces ▪ Check to ensure that rockers, pins, and rollers are free of **corrosion and debris.** ▪ Excessive **corrosion** may cause the bearing to "freeze" or lock and become incapable of movement. 
Set Bolt Anchor Bolt	▪ Susceptible to progressive **corrosion** due to the decrease of protective function of paint system ▪ Check anchor bolts for **loose/missing** nuts. ▪ Susceptible to excessive force and may cause **break** due to earthquake 
Bearing Seat	▪ At welded part of metal bearings, susceptible to support reaction with impact resulting **fatigue crack** ▪ At mortar bearing seat, susceptible to excessive force resulting **crack, delamination or break.** 
Bearing Bed	▪ Susceptible to excessive force resulting **crack, delamination or break.**
Elastomeric Pad	▪ Splitting or tearing either vertically or horizontally often due to **inferior quality** pads ▪ Bulging caused by excessive compression due to poor material composition. 

Bearings

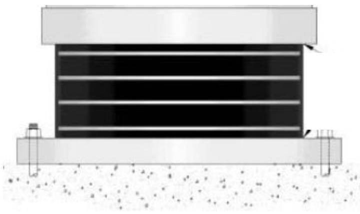




Multiple Roller Bearings



Rubber Pad



Elastomeric Pad
with Steel Plate

E. Utilities

It is strongly recommended to check whether any types and numbers of utility attachments on and under the bridge such as pipe, ducts and/or cables, have adverse effects on bridge structures.

Element	Possible Defects
Pipe, ducts Supports Power cables Conduit	▪ Inadequate roadway clearance and support ▪ Leaks, breaks, cracks, and deteriorating covers. ▪ Corrosion, loose connections, and general lack of rigidity ▪ Presence of a hazard to any traffic which may pass under the bridge ▪ Any adverse effect utilities may have on the bridge  Positioned to hinder drift removal during periods of high water