



**MINISTRY OF PUBLIC  
WORKS AND TRANSPORT**

General Directorate of Techniques  
Road Infrastructure Department

# **Bridge Inspection Manual**



**February 2018**



# Contents

## **CHAPTER 1. INTRODUCTION**

<b>1.1 Purpose of Maintenance .....</b>	<b>1-1</b>
<b>1.2 Process of Maintenance .....</b>	<b>1-3</b>
<b>1.3 Diagnosis of Inspection Results.....</b>	<b>1-5</b>
<b>1.4 Glossary.....</b>	<b>1-6</b>

## **CHAPTER 2. ORGANIZATION FOR BRIDGE MAINTENANCE**

<b>2.1 Outline.....</b>	<b>2-1</b>
<b>2.2 Schedule .....</b>	<b>2-3</b>
<b>2.3 Jurisdiction .....</b>	<b>2-4</b>
<b>2.3.1 Bridge Inspection .....</b>	<b>2-4</b>
<b>2.3.2 Bridge Inspection Record.....</b>	<b>2-9</b>
<b>2.3.3 Bridge Inspection Seminar and Workshop.....</b>	<b>2-11</b>

## **CHAPTER 3. GENERAL REQUIREMENTS FOR BRIDGE INSPECTIONS**

<b>3.1 Outline.....</b>	<b>3-1</b>
<b>3.2 Scope of bridge inspection.....</b>	<b>3-2</b>
<b>3.3 Preparations before Inspection .....</b>	<b>3-3</b>
<b>3.4 Consideration for Safety Works .....</b>	<b>3-4</b>
<b>3.4.1 General.....</b>	<b>3-4</b>
<b>3.4.2. On the road safety .....</b>	<b>3-4</b>
<b>3.4.3. Work Safety .....</b>	<b>3-4</b>
<b>3.5 Classification of inspection.....</b>	<b>3-6</b>
<b>3.5.1 Definition of inspection.....</b>	<b>3-6</b>
<b>3.5.2 Frequency of inspection.....</b>	<b>3-8</b>
<b>3.6 Inspection Record .....</b>	<b>3-9</b>
<b>3.7 Inspection methods .....</b>	<b>3-10</b>
<b>3.8 General view points for Bridge Inspection .....</b>	<b>3-13</b>
<b>3.8.1 General.....</b>	<b>3-13</b>
<b>3.8.2 Substructure .....</b>	<b>3-15</b>
<b>3.8.3 Superstructure.....</b>	<b>3-18</b>
<b>3.8.4 Drainage facility .....</b>	<b>3-22</b>
<b>3.8.5 Bailey Bridge .....</b>	<b>3-24</b>
<b>3.9 Inspection evaluation .....</b>	<b>2-28</b>

## **CHAPTER4 BRIDGE INSPECTION RECORDING**

<b>4.1 Outline.....</b>	<b>4-1</b>
<b>4.2 How to use ‘Bridge Inspection Database System’ .....</b>	<b>4-2</b>
<b>References .....</b>	<b>4-11</b>

## **CHAPTER 5 - NON-DESTRUCTIVE TESTING**

<b>5-1 Outline .....</b>	<b>5-1</b>
<b>5.2 Non-Destructive Tests .....</b>	<b>5-2</b>
<b>5.2.1 Types of Non-Destructive Tests .....</b>	<b>5-2</b>
<b>5.2.2 Reliability of NDT .....</b>	<b>5-3</b>
<b>5.3 NDT for Concrete Attributes .....</b>	<b>5-4</b>
<b>5.3.1 Rebound Hammer Test .....</b>	<b>5-4</b>
<b>5.3.1.1 Fundamental Principle .....</b>	<b>5-4</b>
<b>5.3.1.2 Description of Apparatus .....</b>	<b>5-4</b>
<b>5.3.1.3 Procedure .....</b>	<b>5-5</b>
<b>5.3.1.4 Operation and Analysis of Measurements</b>	
<b>– Manual Type Concrete Test Hammer .....</b>	<b>5-7</b>
<b>5.3.1.5 Operation and Analysis of Measurements</b>	
<b>– Digital Type Concrete Test Hammer .....</b>	<b>5-9</b>
<b>5.3.1.6 Evaluation and Recommendations .....</b>	<b>5-17</b>
<b>5.3.2 Carbonation Depth Measurement Test .....</b>	<b>5-19</b>
<b>5.3.2.1 Fundamental Principles.....</b>	<b>5-19</b>
<b>5.3.2.2 Description of Apparatus .....</b>	<b>5-19</b>
<b>5.3.2.3 Procedures .....</b>	<b>5-19</b>
<b>5.3.2.4 Analysis .....</b>	<b>5-20</b>
<b>5.3.2.5 Evaluation and Recommendations .....</b>	<b>5-21</b>
<b>5.3.3 Ultrasonic Pulse Velocity Test .....</b>	<b>5-22</b>
<b>5.3.3.1 Fundamental Principles.....</b>	<b>5-22</b>
<b>5.3.3.2 Description of Apparatus .....</b>	<b>5-23</b>
<b>5.3.3.3 Procedures .....</b>	<b>5-23</b>
<b>5.3.3.4 Analysis .....</b>	<b>5-27</b>
<b>5.3.3.5 Evaluation and Recommendations .....</b>	<b>5-28</b>
<b>5.3.4 Half-Cell Electrical Potential Test .....</b>	<b>5-30</b>
<b>5.3.4.1 Fundamental Principles.....</b>	<b>5-30</b>
<b>5.3.4.2 Description of Apparatus .....</b>	<b>5-30</b>
<b>5.3.4.3 Procedures .....</b>	<b>5-31</b>
<b>5.3.4.4 Analysis .....</b>	<b>5-32</b>
<b>5.3.4.5 Evaluation and Recommendations .....</b>	<b>5-33</b>
<b>5.3.5 Rebar Detection Test .....</b>	<b>5-35</b>
<b>5.3.5.1 Magnetic Type .....</b>	<b>5-35</b>



5.3.5.2	Radar Type .....	5-41
5.3.6	Infrared Thermal Image Test.....	5-48
5.3.6.1	Fundamental Principles.....	5-48
5.3.6.2	Description of Apparatus .....	5-50
5.3.6.3	Procedures .....	5-51
5.3.6.4	Analysis .....	5-51
5.3.6.5	Evaluation and Recommendations .....	5-52
5.3.7	Compressive Strength Test.....	5-54
5.3.7.1	Fundamental Principles.....	5-54
5.3.7.2	Description of Apparatus .....	5-54
5.3.7.3	Procedures .....	5-55
5.3.7.4	Analysis .....	5-58
5.3.7.5	Evaluation and Recommendations .....	5-59
5.4	NDT for Steel Attributes.....	5-60
5.4.1	Paint Thickness Test.....	5-60
5.4.1.1	Fundamental Principle .....	5-60
5.4.1.2	Description of Apparatus .....	5-61
5.4.1.3	Procedure .....	5-62
5.4.1.4	Analysis .....	5-63
5.4.1.5	Evaluation and Recommendations .....	5-63
5.4.2	Metal Thickness Test.....	5-65
5.4.2.1	Fundamental Principles.....	5-65
5.4.2.2	Description of Apparatus .....	5-66
5.4.2.3	Procedures .....	5-66
5.4.2.4	Analysis .....	5-68
5.4.2.5	Evaluation and Recommendations .....	5-68
5.4.3	Magnetic Particle Testing (MT) .....	5-69
5.4.3.1	Fundamental Principles.....	5-69
5.4.3.2	Procedures .....	5-70
5.4.3.3	Advantages and disadvantages .....	5-71
5.4.4	Eddy Current Testing (ET) .....	5-72
5.4.4.1	Fundamental Principles.....	5-72
5.4.3.2	Advantages and disadvantages .....	5-73
5.5	Special Non-Destructive Tests .....	5-74
5.5.1	Ultrasonic Flow Detection Test .....	5-74
5.5.1.1	Purpose.....	5-74
5.5.1.2	Description of Apparatus .....	5-74
5.5.1.3	Test Procedures .....	5-75
5.5.1.4	Evaluation and Recommendations .....	5-76
5.5.2	Static Load Carrying Test .....	5-77

5.5.2.1	Purpose.....	5-77
5.5.2.2	Test Procedures .....	5-77
5.5.2.3	Measurement of Deflections .....	5-78
5.5.2.4	Percentage Recovery of Deflections.....	5-79
5.5.2.5	Evaluation and Recommendations .....	5-79
5.5.3	Dynamic Load Carrying Test.....	5-80
5.5.3.1	Purpose.....	5-80
5.5.3.2	Test Procedures .....	5-80
5.5.3.3	Recommendations .....	5-82
5.5.4	Ambient Vibration Test .....	5-83
5.5.4.1	Purpose.....	5-83
5.5.4.2	Test Procedures .....	5-83
5.5.4.3	Evaluation and Recommendations .....	5-84
5.5.5	Impact Vibration Test .....	5-85
5.5.5.1	Purpose.....	5-85
5.5.5.2	Application.....	5-85
5.5.5.3	Test Procedures .....	5-85
5.5.5.4	Soundness.....	5-87
5.5.5.5	Evaluation and Recommendations .....	5-88
5.5.6	SONAR Test (For Scouring).....	5-89
5.5.6.1	Purpose.....	5-89
5.5.6.2	Outline of Testing .....	5-89
5.5.6.3	Evaluation and Recommendations .....	5-90
5.5.7	Impact Echo Test.....	5-91
5.5.7.1	Purpose.....	5-91
5.5.7.2	Outline of Testing .....	5-92
5.5.7.3	Evaluation and Recommendations .....	5-92
5.5.8	X-Ray Test.....	5-93
5.5.8.1	Purpose.....	5-93
5.5.8.2	Description of Apparatus .....	5-93
5.5.8.3	Test Procedures .....	5-93
5.5.8.4	Recommendations .....	5-94
5.5.9	In-Situ Stress Measurement Test .....	5-95
5.5.9.1	Purpose.....	5-95
5.5.9.2	Description of Techniques and Procedures.....	5-95
5.5.9.3	Recommendations .....	5-97

## APPENDIX

AP-1 ..... Sample of SD (Serious Damaged) Bridge

AP-2 ..... Scoring Inspection Results

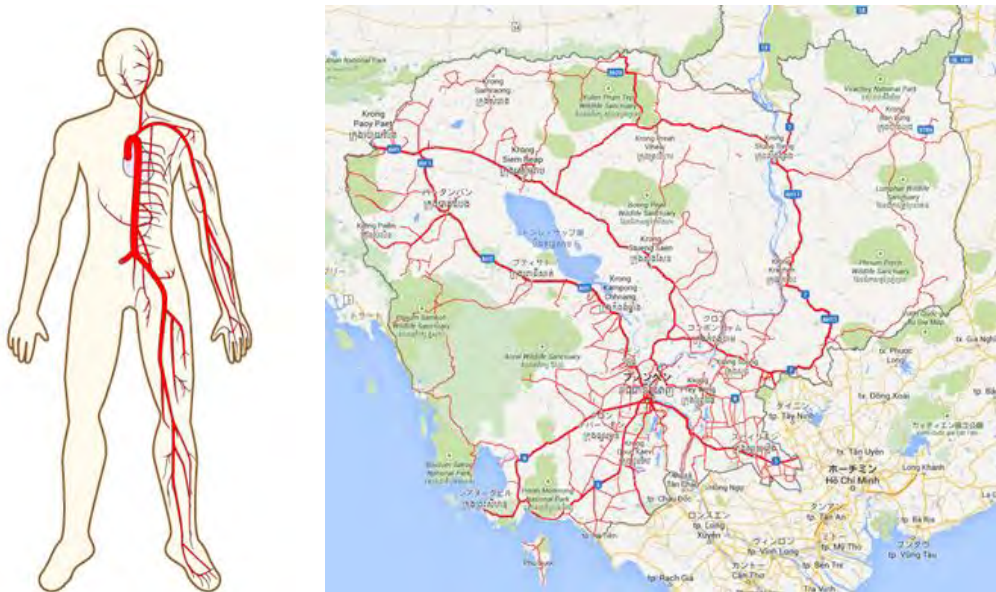
## CHAPTER 1. INTRODUCTION

### 1.1 Purpose of Bridge Inspection

Using a metaphor, the road network which serves for the national socio-economic activities such as logistics, travels and communications, is compared to the vascular network in a human-body (**Fig. 1.1.1**). To maintain a healthy human body, people may check their physical condition daily, and may have some advices from their doctors periodically and then keep their body condition in well, and sometimes people may receive medical treatment or surgery.

It is same manner for road infrastructure for logistics. Therefore, the road infrastructure is very important for Cambodia economy (**Fig. 1.1.2**).

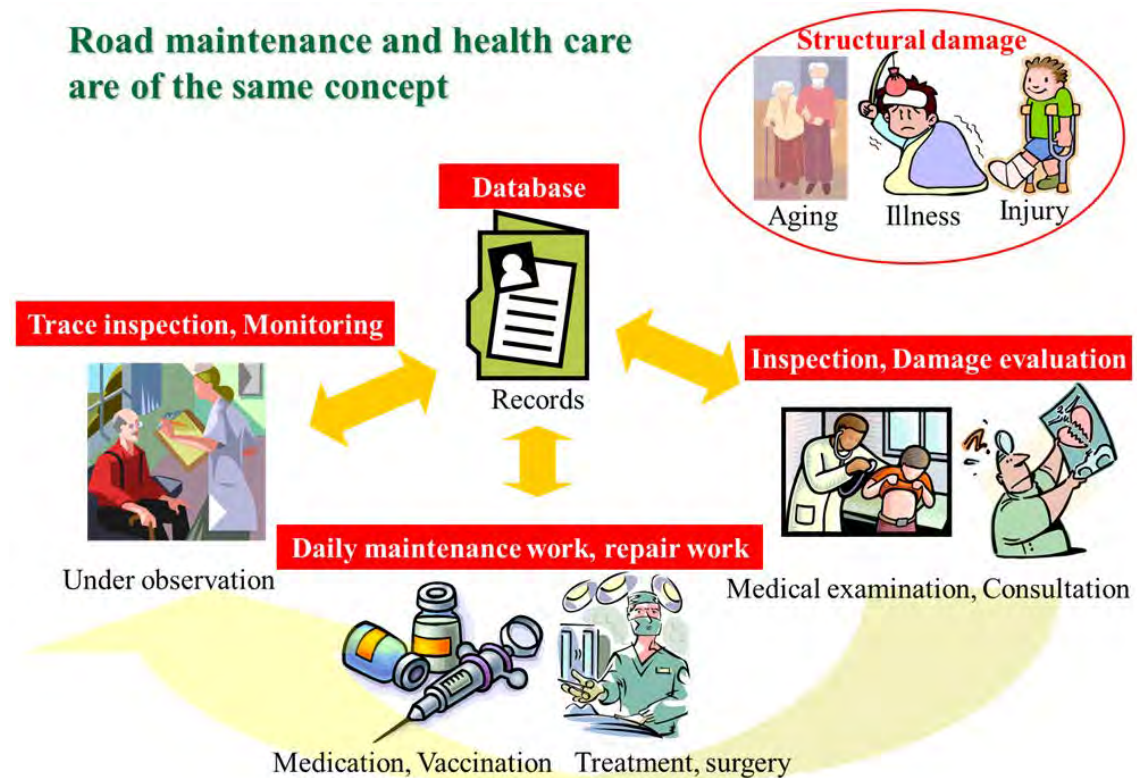
The Bridges are part of the road infrastructure and are important link in a road network. And they must be very well maintained for Cambodia economy.



**Fig. 1.1.1 Road Infrastructure and blood vessel**

The purposes of Bridge Inspection are as follows:

- 1) To confirm the results of bridge condition inspection;
- 2) To confirm as built drawings and design documents
- 3) To undertake additional investigations necessary for evaluation of defects including physical testing and/or structural analysis, and documentation of the observed defects with sufficient information for future design of required major maintenance works;
- 4) To determine the cause/mechanisms of damage;



**Fig. 1.1.2 Road Maintenance and human health care**

- 5) To assess the current bridge structural condition, behavior and load capacity;
- 6) To assess the rate of deterioration and residual life expectancy; and
- 7) To evaluate the need for repair and rehabilitation.
- 8) To investigate the damage for estimating repair cost.

The purpose of this manual is to describe and introduce standard maintenance against defects commonly found in bridges owned and maintained by MPWT (Ministry of Public Work and Transport) and DPWT (Department of Public Work and Transport).

## 1.2 Process of Maintenance

Structural maintenance is a series of actions which consists of inspection, identification of defect cause, deterioration prediction, performance evaluation, determination of necessity of repair, work implementation and record of maintenance. It should be carried out appropriately based on maintenance plan to ensure structural performance throughout the required service.

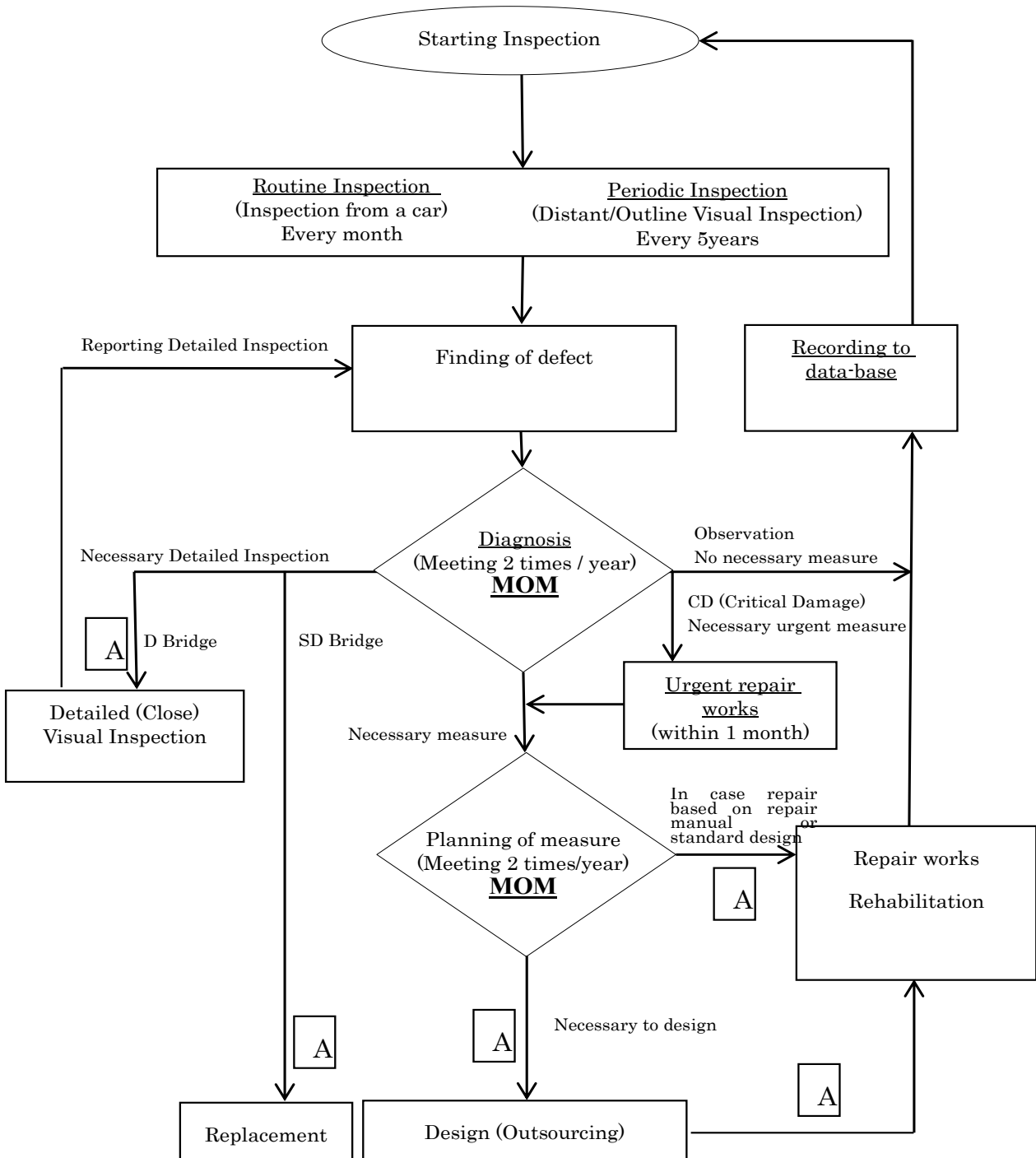


Fig. 1.2.1(a) Process of Bridge Inspection and Planning for Maintenance

Periodic Inspection  
Distant/Outline Visual Inspection)  
Every 5 years

Recording to  
data-base

CD (Critical Damage)  
Necessary urgent measure  
Urgent repair  
works  
(within 1 month)

Necessary to design

ing)

A

A

Method of Follow-up Inspection	
Situation of Defect	Method of Inspection
In case possible to see progression of defect by distant/outline visual inspection	Distant/Outline Visual Inspection
In case impossible to see progression of defect by distant/outline inspection	Close/Detailed Visual Inspection
Situation of Defect	Frequency of Inspection
Damage influence to safety for third party	1 time / month
Damage influence to soundness of structure	1 time / 3 months
Others	1 time / year

**Fig. 1.2.1(b) Process of Bridge Inspection and Planning for Maintenance  
(Follow-up Inspection)**

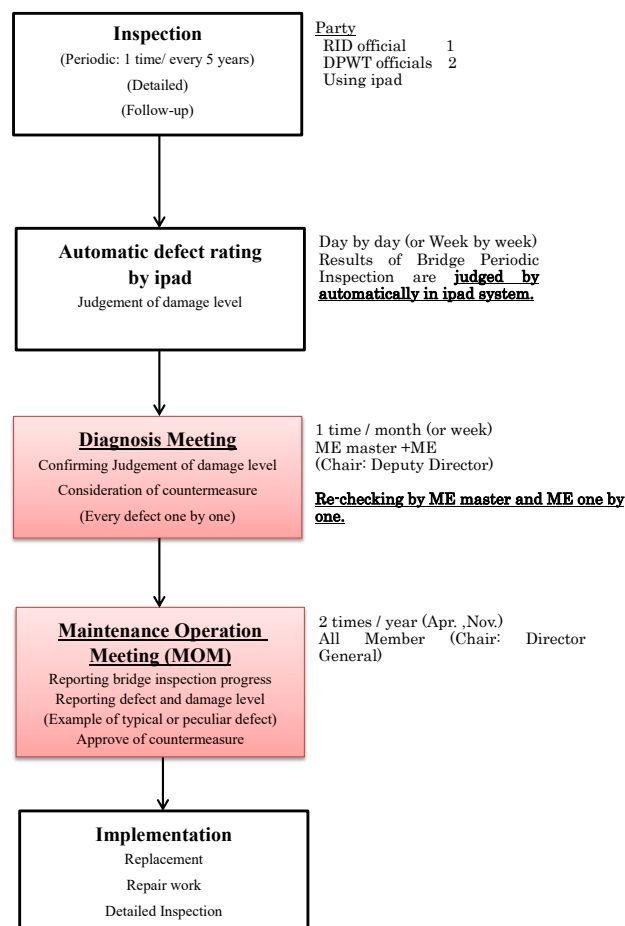
**The Bridge Inspection** is a detailed investigation and evaluation of damage and/or material properties of specified elements. The damage may be due to environmental impact (climate, saline soil, etc.), wear (insufficient maintenance), design and construction errors and overloading or similar conditions.

The scope of ‘The Bridge Inspection’ includes:

- 1) Review of any previous inspection reports;
- 2) Determination and provision of equipment and resources required for the inspection including preparation of a safety plan;
- 3) To supplement the visual inspection, Implementation of bridge inspection including measurements, testing and analysis as necessary;

### 1.3 Diagnosis of Inspection Results

It is very important for bridge maintenance that inspection results are judged appropriately, countermeasure is determined and implemented. Cycle of inspection results judgement is shown in **Fig 1.3.1**. Inspection results which are input into iPad are evaluated by iPad system automatically. In Diagnosis Meeting, evaluated results are confirmed every defect by MPWT/DPWT engineers one by one, and countermeasure is considered. Diagnosis Meeting is held every month (or week). MOM (Maintenance Operation Meeting) is held 2 time in a year. Countermeasure of defect is approved in this meeting. Approved countermeasure is implemented as replacement /repair /detailed inspection.



**Fig 1.3.1 Diagnosis Flow**



## 1.4 Glossary

Bridge component consists of deck slab, superstructure, substructure (pier, abutment and foundation) and approach roads as shown in Fig.1.2.1 and 1.2.2.

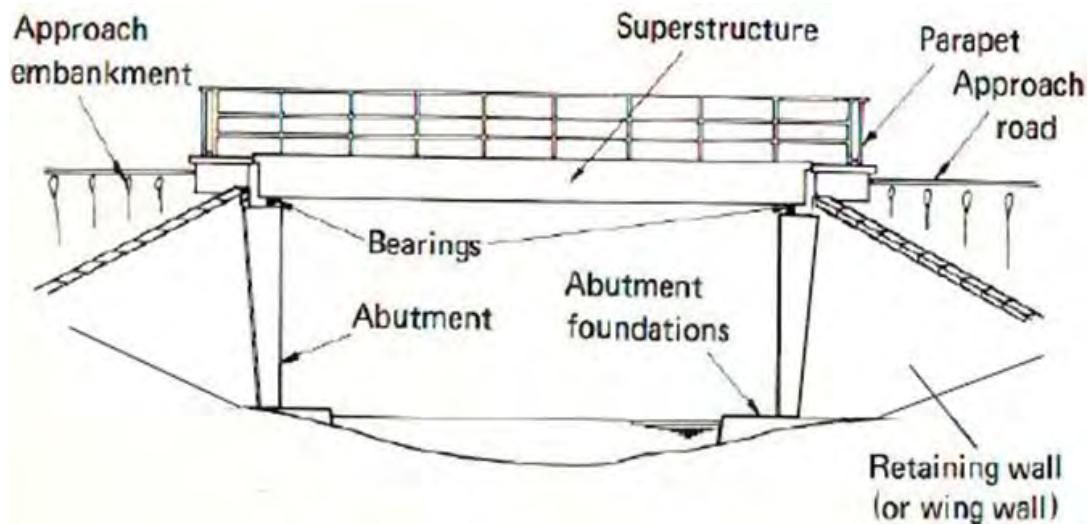


Fig. 1.4.1 Single Span Bridge

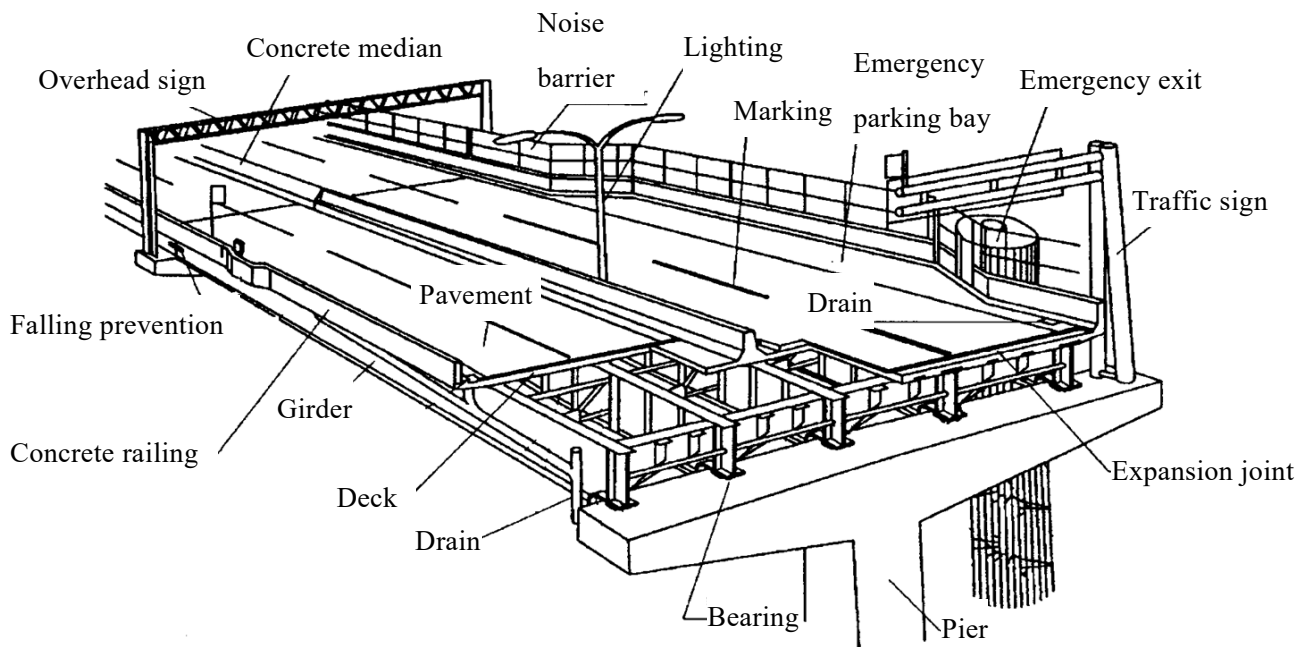
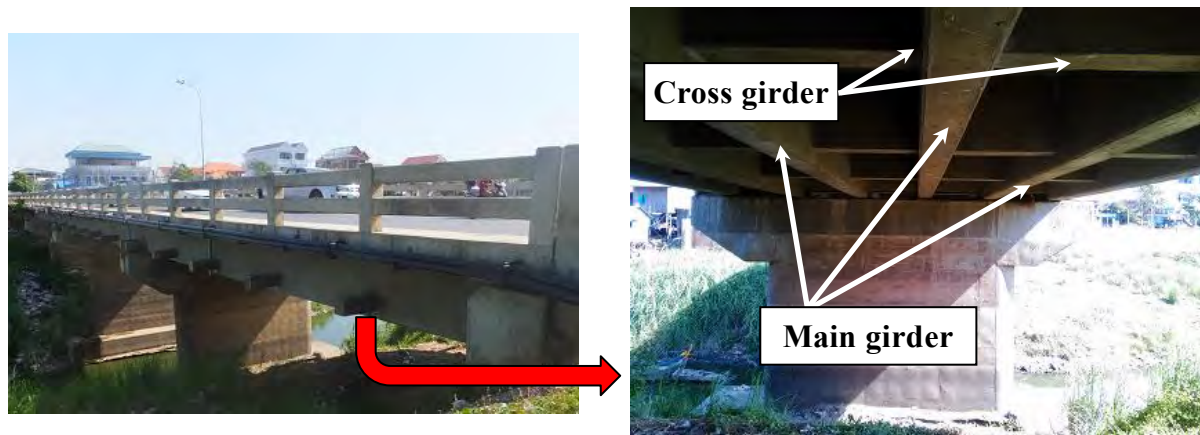
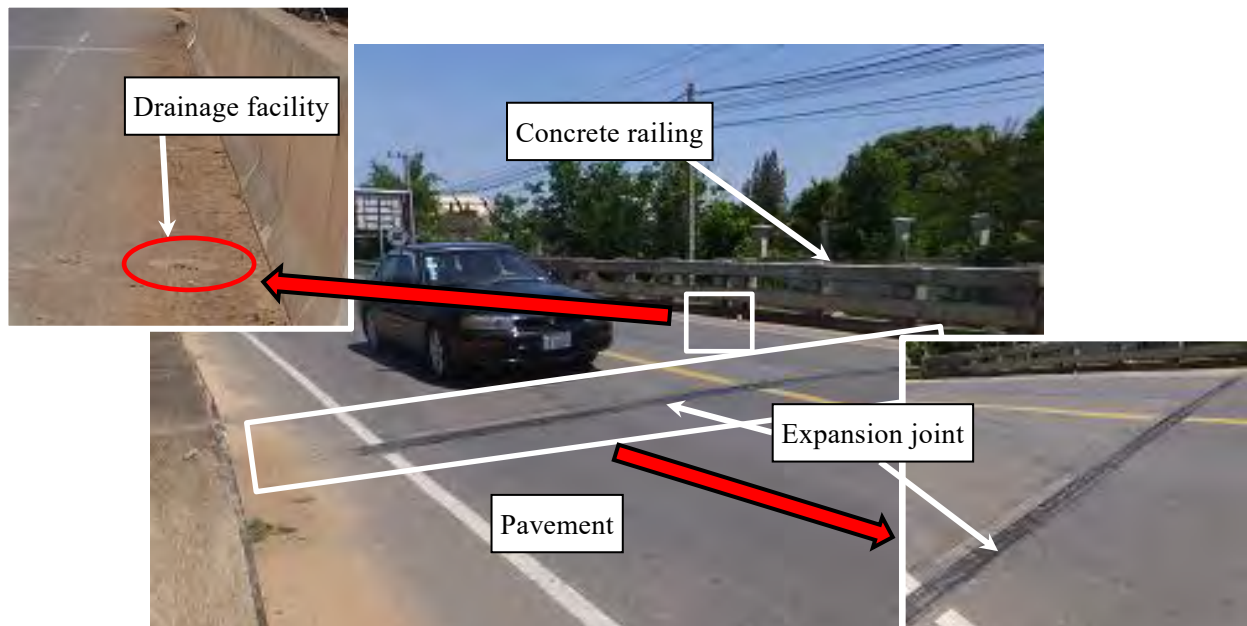


Fig. 1.4.2 Glossary of Bridge Structure



**Photo 1.4.1 Glossary of Girder**



**Photo 1.4.2 Glossary of superstructure (On surface)**

### **1.4.1 Types of bridges**

Bridge configuration consists of two sections: superstructure comprising deck/floor and girder/beam, and substructure supporting superstructure. Type of superstructure is categorized in terms of material, way of supporting and structural feature as follows.

#### **(a) Category by material**

- 1) Steel bridge: Bridge mainly made by steel
- 2) Reinforced concrete (RC) bridge: Bridge mainly made by reinforced concrete
- 3) Pre-stressed concrete (PC) bridge : Bridge mainly made by pre-stressed concrete

## **(b) Category by structural feature**

### **1) Girder bridge**

Mechanical feature of Girder Bridge is that girder utilizes resistibility against bending moment and shear force. I-shaped steel and H-shaped steel are most commonly used for steel bridge and called as “Plate girder bridge” (**Photo 1.4.1**). “Composite girder bridge” is designed as reinforced concrete deck and girder resisting integrally to vehicle load. Bridge which has box shape girder is called as “Box girder bridge” (**Photo 1.4.2**).



**Photo 1.4.3 Box girder bridge**

### **2) Concrete deck bridge**

Concrete deck bridge is applied for relatively short span bridge since dead load becomes heavier due to its span length. Also, it is advantageous to shortening construction period and saving workload at the site because of its simple structure and workability.



**Photo 1.4.4 Concrete deck bridge**

### **3) Bailey Bridge**

The Bailey bridge is a type of portable, pre-fabricated, truss bridge. It was developed by the British during World War II for military use and saw extensive use by both British and the American military engineering units.

A “through” type of steel Deck Girder; the roadway is being carried between the two main girders. The main girders are formed from



**Photo 1.4.5 Bailey Bridge**



modular elements 3m long pinned together end to end for quick assembly

#### 4) Cable stayed bridge

Cable stayed bridge applies pre-stress to continuous girder by cable set up from tower of center pier. Compressive force to the girder and tensile force to the cable are equilibrant on the sides of tower. This type of bridge had been economical for bridge span of up to 400m. These days, available span length has been extended more than 800m. Orthotropic steel plate is usually adopted for decking.



**Photo 1.4.6 Cable stayed bridge  
(Tsubasa bridge)**

#### 5) Truss bridge

Truss is frame structure with setting up members in triangle-geometry and connecting them with pins. Truss bridge employs the truss as main structure. Mechanical feature is that truss member considered exerting only compression or tension of axle force.



**Photo 1.4.7 Truss bridge**

#### 5) Arch bridge

Arch structure supports both sides of girder or truss beam with chamber rigidly. Arch rib is principal structural member resists for compressive axle force and bending moment. Bridge structure which mainly resists force horizontally called as “Arch bridge”.



**Photo 1.4.8 Arch bridge**

## 1.4.2 Configuration of bridges

### (a) Superstructure and substructure

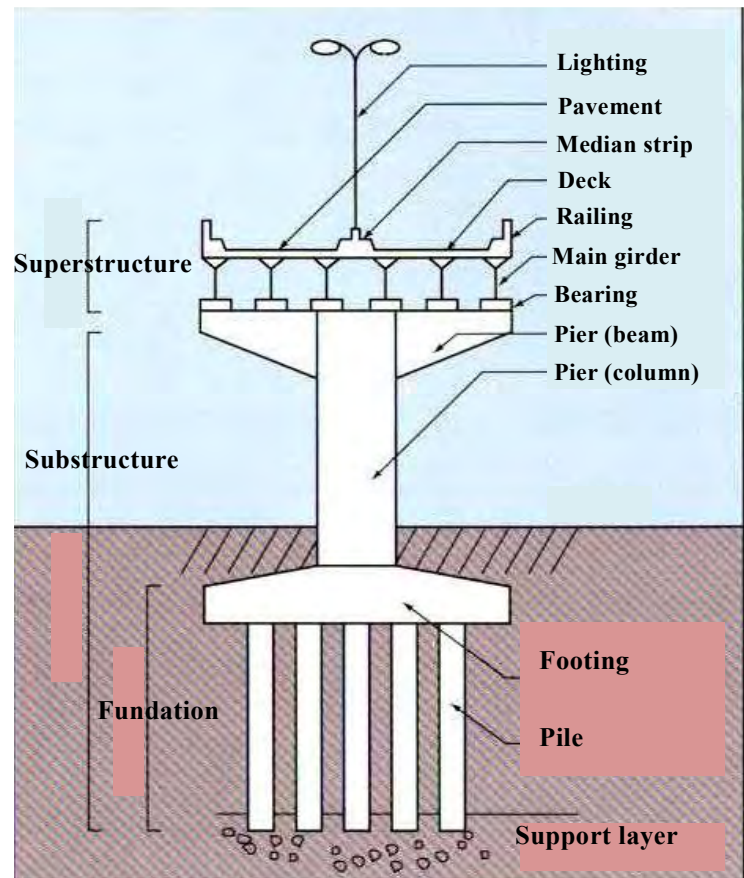
Configuration of bridge is shown in

**Fig-1.3.3** Superstructure is a main part of the bridge comprises deck/floor and girder/beam.

Substructure supports superstructure and transmits its load to the ground. It comprises abutment, pier and foundation.

Layer of asphalt or DBST or concrete provides smooth riding surface.

(Wearing Surface)



**Fig. 1.4.3 Configuration of bridge**

### (b) Bearing

Generally, bearing intermediates connection of bridge girder and pier. Bearings sustain vertical load such as dead load or live load of bridge and lateral load due to wind or earthquake.



**Photo 1.4.8 Bearing**

### (c) Deck plate and floor system

Deck plate is one of the component of superstructure which sustains vehicle load directly and transmit it to girder directly or through floor system. It comprises reinforced concrete deck slab, pre-stressed concrete deck slab and Orthotropic steel deck slab. Pavement is installed on it.

### (d) Lateral bracing and sway bracing

Each girder are connected with truss structure such as lateral bracing in lateral direction and sway bracing in section. Lateral bracing resists force due to wind or earthquake and sway bracing avoids sectional deformation.

## (e) Road furniture

### 1) Drainage facility

In order to lead rainwater on the bridge to ground drainage pipe rapidly, drainage pits are set properly on the surface of bridge. Rainwater is induced from drainage pit to ground along girder and pier with polyvinyl chloride drainage pipe.



Photo 1.4.9 Drainage facility

### 2) Expansion joint

Expansion joint allows displacement of girder due to temperature change and keep flatness of road surface. In addition, it has a function as drainage of rainwater. Generally, type of the joint is selected depending on girder displacement, rubber and steel finger joint account for large part of use.



Photo 1.4.10 Expansion joint

## 1.4.3 Glossary of bridges

There is a list of engineering words that are used in this manual and their meanings.

( \_\_\_\_\_ : Important Word )

**Abutment** – end support of the superstructure of bridges and usually have the additional functions of retaining earth fill for the bridge approaches. (Fig. 1.4.1)

**Approach Embankment** – the earth work or earth fill that forms a transition road up to the bridge abutment. (Fig. 1.4.1)

**Approach Road** – the road near abutting the bridge. (Fig. 1.4.1)

**Bank Seat Abutment** – an abutment set well up the river bank; above the usual river level.

**Barrel** – the main part of an arch which supports fill and roadway.

**Beam** – a narrow structural member such as girders, stringers, floor beams, cross beams (diaphragms), edge beams, etc.

**Bearing** – the part between the superstructure and the coping of pier or abutment. It transmits the load from the superstructure to the substructure and may be movable or fixed depending on the allowed degree of movement. (Photo 1.4.8)



**Bearing Bolt** – type of fixing for joints in steel or timber.

**Bearing Shelf** – part of the abutment, where the superstructure rests.

**Boom** – the upper (top chord) and lower (bottom chord) longitudinal members extending the full length of a truss.

**Box Girder** – a hollow beam with box shape. (Photo 1.4.2)

**Bracing** – parts of a bridge which help to resist lateral forces and keep it stiff so as not to change shape, e.g., lateral braces and sway braces in steel truss and steel Deck Girders.

**Bulging** – where a flat place changes shape and is bent.

**Camber** – the slight convexity (curve) required for construction of bridges, provided to compensate for the dead load deflection.

**Caissons** – type of masonry or concrete foundations, built like a tube.

**Cantilever** – a beam, fixed at one end and free to move at the other.

**Compression** – being pushed together.

**Corrosion** - It is the gradual destruction of materials (usually metals) by chemical reaction (more stable oxide).



**Corrosion**

**Corrugated Steel** – thin sheet of steel which have been shaped to make strong.

**Cross Beam** – commonly called FLOOR BEAMS, the beams that connect two trusses wherein the stringers are connected.

**Debris** – rubbish and other unwanted things.

**Decay** – rotting of wood, making it soft and weak; caused by dampness and fungus.

**Deck Slab** – top of bridge superstructure. This allows bear vehicular loads directly. (Fig. 1.4.3)

**Deformation** - Permanent deformation of steel members can take the form of bending, buckling, twisting or elongation, or any combination of these.

**Delamination** - defined as a discontinuity in the surface concrete which is substantially separated but not completely detached from concrete below or above it.

**Diaphragm** – a beam connecting the girders of concrete and steel deck girder bridge

**Disconnection** - Loose or defected joints can seriously affect the strength of the timber bridge.

**Disintegration** - the physical deterioration or breaking down of the concrete into small fragments or particles.

**Downstream** – where the river flows away from a bridge.

**Drainage** – system for taking away water (usually rainwater) (Photo 1.4.9)

**Embankment** – soil bank which supports the roadway pavement.



**Fill** – soil placed in front of the abutment.

**Fixed (Fixed Bearing)** – not able to move.

**Flange** – the top and bottom plates of a girder; the enlarged top/bottom portion of a concrete Deck Girder e.g., an AASHTO Standard I-section and steel I-Beam for steel girder bridge.

**Foundations** – the lowest part of the bridge which sits or in the ground. (Fig. 1.4.3)

**Fretting** -This defect is caused by the loss of cementing or binding agents by leaching due to the percolation of water through the structures.

**Gabion** – wire basket filled with stones.

**Galvanizing** – a thin layer of zinc on steel to protect it against corrosion.

**Girder** – a beam usually made of steel and reinforced concrete. (Fig. 1.4.2)

**Groyne (or Spurdike)** – a wall built to change the flow of a river and protect the river bank from scour.

**Headwall** – a wall at the end of a culvert to hold the soil fill above the culvert pipe.

**Honeycombing** – badly made concrete with lots of holes.

**Impact** – to hit hard, as when a vehicle hits a bridge parapet.

**Curb** – the step between the road and Sidewalk.

**Landslide** – soil and rocks slipping down a mountain or hill.

**Loose connections** - Loose tightening or missing in bolted or riveted connections

**Lubrication System** – a system to supply oil or grease to a mechanical bridge bearing.

**Maintain (as in Well Maintained)** - to look after carefully and repair when it is necessary

**Masonry** – bricks or stones set together with mortar.

**Mass Concrete** – concrete without any steel in it.

**Moisture** – some water or dampness.

**Overloaded** – carrying too much weight.



**Gabion**



**Honeycombing**



**Curb**



**Overloaded**

**Panel** – a flat frame or plate.

**Parapet** – a wall or rail along the edge of bridge.

**Rebar** – steel bars in reinforced concrete, to make it stronger.

**Pier** – a support between abutments for bridges with more than one span. (**Fig. 1.4.2**)

**Pile** – a long, thin, foundation driven deep into the ground; bored pile - a cast-in-place pile. (**Fig. 1.4.3**)

**Piled Walls** – walls made of long pieces of material driven into the ground.

**Plate** – a flat, stiff piece of steel.

**Pointing** – the mortar between bricks or stones on masonry.

**Pre-stressed** – a way of making concrete stronger with pre-stressing steel bars or cables.

**PTFE** – a slippery white material used in bearings.

**Rendering** – a thin layer of mortar put on masonry or brickwork to protect it.

**Reno Mattress** – a long thin gabion.

**Retaining Wall** – a wall to hold back soil.

**River Bed** – the bottom of the river.

**Riprap** – layer of loose rocks to protect the river bank from scour.

**Rust** - Usually red oxide formed by the redox reaction of iron and oxygen in the presence of water or air moisture.

**Safety Pins** – the small clips on a bailey bridge, that stop the panel pins from falling out.

**Scaling** - the local flaking or loss of the surface portion of concrete or mortar.

**Scouring** – erosion of the river bed or bank caused by the flow of the river.



**Scaling**



**Scouring**

**Seating** – the place where one part rest on another part. For example, the place where a bearing is set on a pier or abutment.

**Services** – cables and pipes for service facilities and utilities such as water, electricity and tele-communication belonging to other authorities.

**Settlement** – small movement downwards of a structure.

**Sheet Piled Wall** - a wall made from steel panels, concrete piles or timber bored hammered into the ground to form a wall.

**Shrinkage (in Timber)** - Shrinkage happens when the timber dries up below its fiber saturation point.

**Slab** – a large piece of concrete (For example a bridge deck).

**Spacer Plates** – plates which are put between two other parts.

**Spall** – to break off in a piece.

**Spalling** – an area where concrete has broken away; e.g. due to corrosion of reinforcing steel bars.

**Span** – the part of a bridge, or the distance, between the supports; span length refers to the length of a bridge.

**Spandrel Walls** – the side walls of a masonry arch bridge.

**Splitting** - Splitting happens when the interior member remains above the fiber saturation point while the outer layers shrink.

**Spread Foundations** – wide base to a pier or abutment, usually made of reinforced concrete.

**Stiffener** – in a steel plate girder, in prevents buckling of the web due to bending; also bearing stiffeners which are provided directly over the bearing in a steel plate Deck Girder to prevent buckling of web as well as to prevent bending failure of the bottom flange.

**Stone Pitching** – stones set in cement mortar to cover a sloping or an invert.

**Stringer** – a horizontal deck member.

**Structural Member** – all members which contribute to the structural integrity of a bridge.

**Substructure** – all parts of a bridge below the bridge seats, or below the springing line of arches, and including abutments, piers, wingwalls and bents below the level of the top of cap.

(Fig. 1.4.3)

**Superstructure** – all of the deck, including parapets, trusses, beams and running surface. (Fig. 1.4.3)

**Suspended Span (or Drop-in Span)** – the middle span of a cantilever bridge.

**Tension** – pulling apart.

**Upstream** – the direction where the water is coming from.

**Vibration** – repeated small movements caused by a heavy vehicle or perhaps an earthquake.

**Web** – the part of a girder that joins the top and bottom flanges.

**Weephole** – a hole to allow water to come through.

**Wingwalls** – walls which are at the side of the abutments and part of it.

### **【Definition of Terms】**

**Maintenance** – All engineering work provided to maintain structures' performance at the required level or higher, sometimes simply called, "maintenance"

**Required Performance** – Performance required for structures based on the purpose and the function

**Scheduled Maintenance** – Necessary measures are selected in accordance with the evaluation and determination that are made based on the inspection and the examination of maintaining the structure's required performance so as to optimize LCC (life cycle cost). Maintenance is scheduled so as to prevent it from being concentrated in a certain period of time. (Preventive maintenance and corrective maintenance are included.)

**Life Cycle Cost (LCC)** – Total costs required for future maintenance and operation (This is abbreviated to LCC.)

**Preventive Maintenance** – Operation and maintenance that are implemented for the purpose of preventing deterioration which results in the degradation of structure performance

**Corrective Maintenance** – Operation and maintenance that are implemented in accordance with the degradation of structure performance

**Scheduled In-service Period** – Planned period that a structure is intended to be in service, which is subject to change in accordance with the reviewed maintenance plan.

**Design Service Period** – Period that a structure or member should fully carry out its function. The period is decided during the design phase.

**Remaining Scheduled In-service Period** – Period from inspection or study to the end of scheduled in-service period

**Remaining Design Service Period** – Period from inspection or study to the end of design service period

**Function of Structure (Member)** – Function that the structure (member) carries out in accordance with the purpose or requirement

**Performance of Structure (Member)** – Performance that the structure (member) exercises in accordance with the purpose or requirement

**Durability** – Resistance held by the structure against degradation over time, caused by deterioration of materials in the structure under normal conditions

**Safety** – Structure performance that prevents lives and property of users and third parties from

being harmed

**Usability** – Structure's Performance that enables users to use the structure problem free or that prevents negative impacts to the surrounding environment, and performance for the purpose of properly maintaining other functions required for the structure

**Impact on Third Parties** – Degree of impact on property or injury of a person caused by falling concrete pieces that separated from the structure

**Inspection** – Collective term for diagnostic examinations to discover any abnormalities on the structure or members

**Monitoring** – To observe conditions of structures and members through sensors mounted on structures and members

**Repair** – Measures intended to remove impact to a third party or, restore/enhance structure's aesthetic appearance or durability, including measures to restore safety or usability (mechanical performance) to a degree that the structure had when constructed

**Reinforcement** – Measures to restore safety or usability (mechanical performance) to a higher degree than when originally constructed

**Defect** – Collective term for initial flaw, damage, and deterioration

**Initial Flaw** – Cracks, honey comb, and cold joint which occur during construction

**Damage** – Damage that occurs in a short period time by an earthquake or a collision and does not progress as time passes

**Deterioration** – Deterioration that progress as time passes.

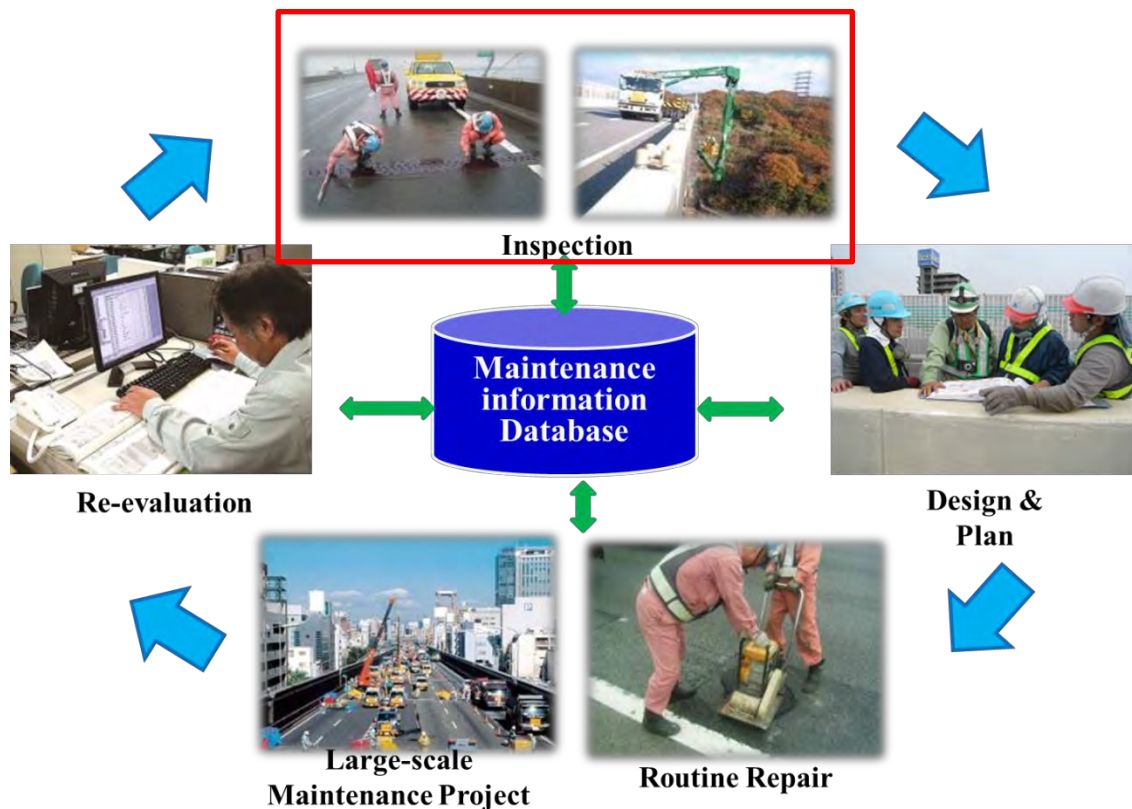
**Soundness** – Level of current performance against required performance for the structure



## CHAPTER 2. ORGANIZATION FOR BRIDGE MAINTENANCE

### 2.1 Outline

As described in CHAPTER1, it is important to conduct a routine maintenance of bridge structures for their sustainability, and it is necessary to establish a basic and feasible management cycle as shown in **Fig. 2.1.1** in the authority.



**Fig. 2.1.1 Routine Bridge Maintenance Cycle**

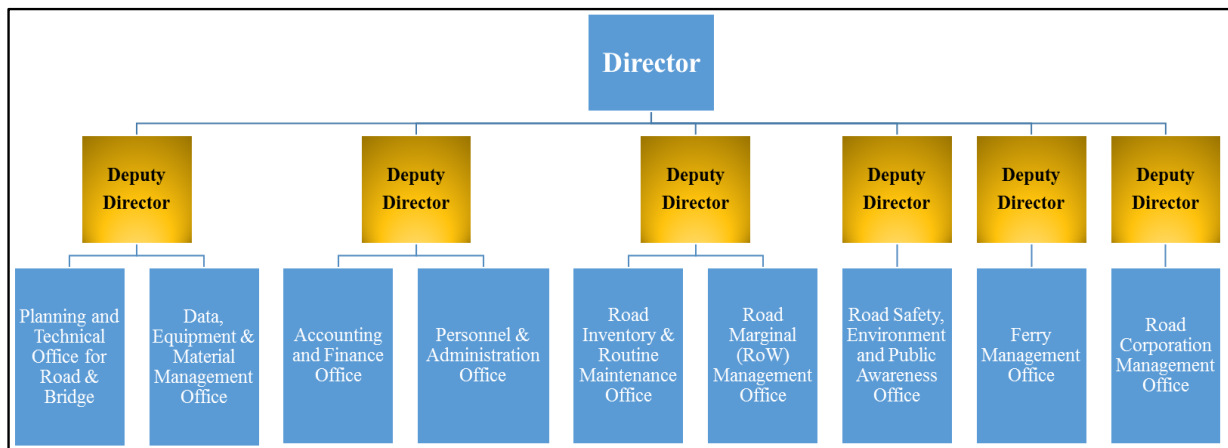
In order to implement this routine bridge maintenance cycle in a sustainable manner, it is essential to determine in advance the responsible entity in the relevant departments for each segment of the cycle. Furthermore, the range of responsibility and the relevant annual schedule should be prescribed in an official document is useful for sharing the understandings among entities in charge.

The following chapters prescribe the field of inspection as a core portion of bridge maintenance and clarify the entities in charge of each inspection work and its standard procedures.

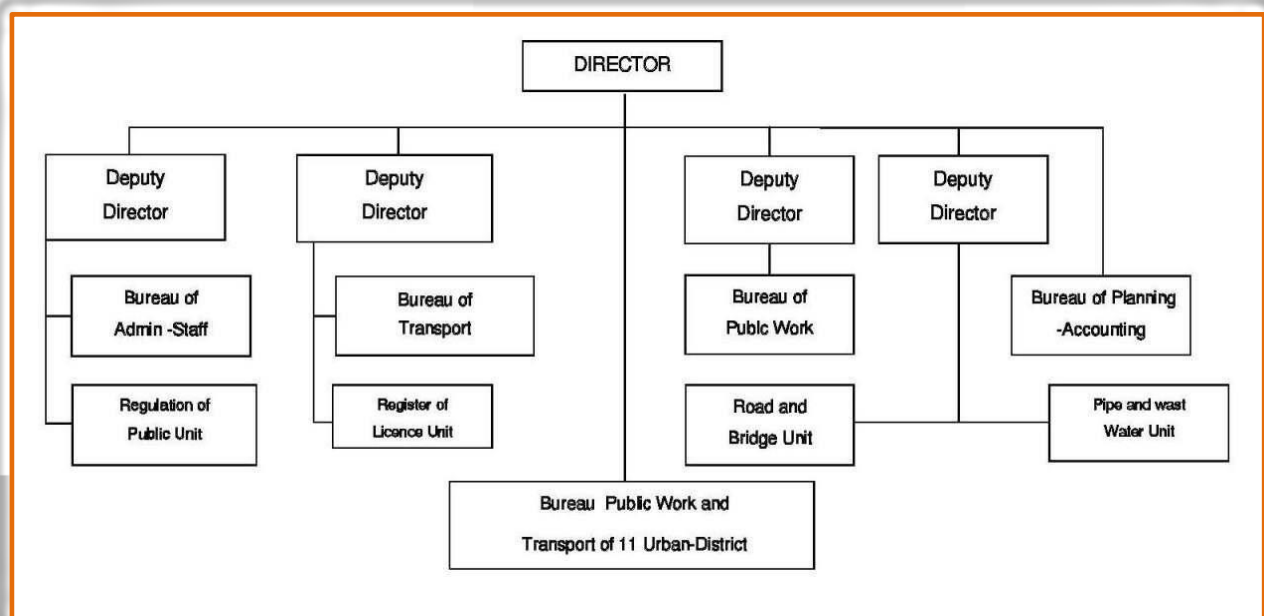
It should be noted that each entity is not independent from others and the mutual cooperation is the key for smooth flow of this inspection cycle. Each entity should respond any request from the correspondent entities accordingly and sincerely. Also, the request should be shown with the deadline and be as concrete as possible.

In addition, in order to exchange information, challenging issues, and necessary actions taken in the next step among the relevant entities, it is highly recommended to organize the regular joint meeting. Here, information on inspection technology is shared, identified damages are briefed and necessary type of repairing intervention is planned.

The organization charts of RID and DPWT are shown in **Fig. 2.1.2**, and **Fig. 2.1.3** respectively.



**Fig. 2.1.2 Organization Chart of RID**



**Fig. 2.1.3 Organization Chart of DPWT Kandal Provice**



## 2.2 Schedule

Annual action plan for inspection is shown in Fig. 2.2.1. It is preferable to conduct each action by reflecting this schedule.

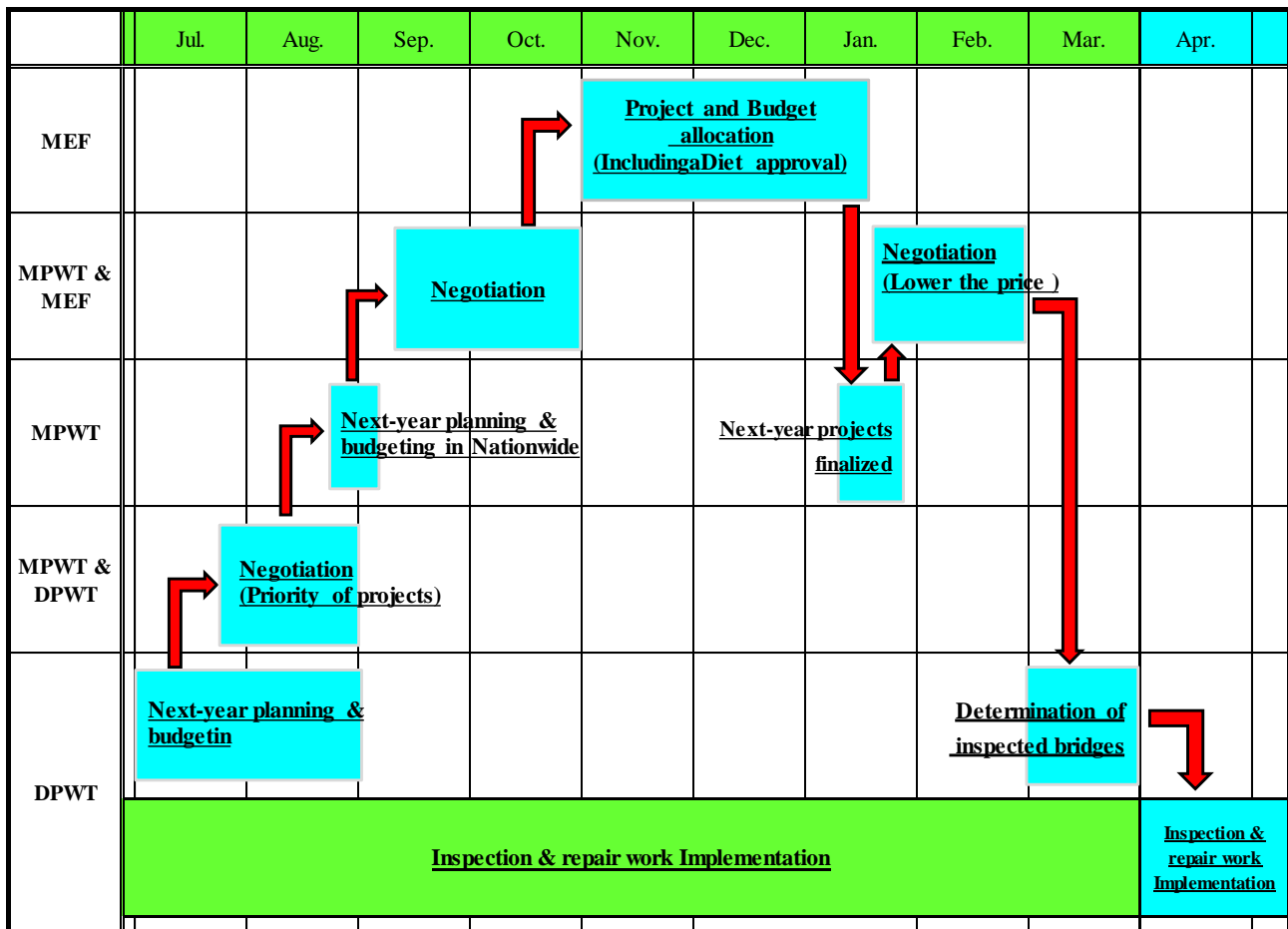


Fig. 2.2.1 Inspection and Maintenance Budgeting Schedule

MPWT: Ministry of Public Work and Transport

DPWT: Department of Public Works and Transportation

MEF: Ministry of Economy and Finance

## 2.3 Jurisdiction

### 2.3.1 Bridge Inspection

When bridge inspection is carried out, the following responsibilities of bridge inspection are necessary to be assigned to a certain entity.

- (a) **Annual Implementation Plan**
- (b) **Cost Estimation**
- (c) **Budget Management**
- (d) **Implementation**
- (e) **Technical advisory**

#### (a) Annual Implementation Plan

Annual implementation plan includes 'Bridge inspection location, volume, method and schedule' and along with inspection budget estimates prepared in (b), it is used for budget request and negotiation with MEF. The plan should consider metrological condition like squall and flood and be prepared to secure the efficient implementation.

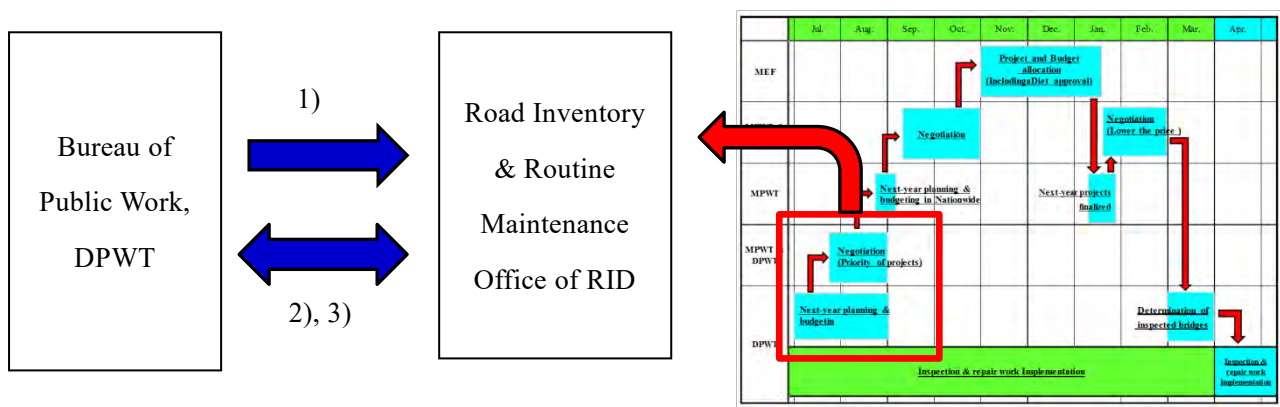
The entity in charge and the formulation process are as follows:

- 1) The annual implementation plan is prepared by each **Bureau of Public Work, DPWT** by referring to the inspection database and previous inspection record. The plan shall be sent to **Road Inventory & Routine Maintenance Office of RID, MPWT**.
- 2) In order to collect necessary information for the negotiation with MEF, **Road Inventory & Routine Maintenance Office** questions to and receives answer from each **Bureau of Public Work** on the content if any.
- 3) **Road Inventory & Routine Maintenance Office** summarizes the collected information and edited it as a plan.

The rough timing of the abovementioned actions is shown in **Fig. 2.2.1**. The specific deadline of submission shall be informed by **Road Inventory & Routine Maintenance Office** every year.

**Table 2.3.1 The entity in charge of Annual Implementation Plan**

Content	The entity in charge	Relevant division
1)To Prepare the annual implementation plan	Bureau of Public Work, DPWT	Road Inventory & Routine Maintenance Office of RID
2)To quest and to receives answer about the plan	Road Inventory & Routine Maintenance Office of RID	Bureau of Public Work, DPWT
3)The collected information and edited	Road Inventory & Routine Maintenance Office of RID	Bureau of Public Work, DPWT



**Fig. 2.2.2 Image of Annual Implementation Plan**

### (b) Cost Estimation

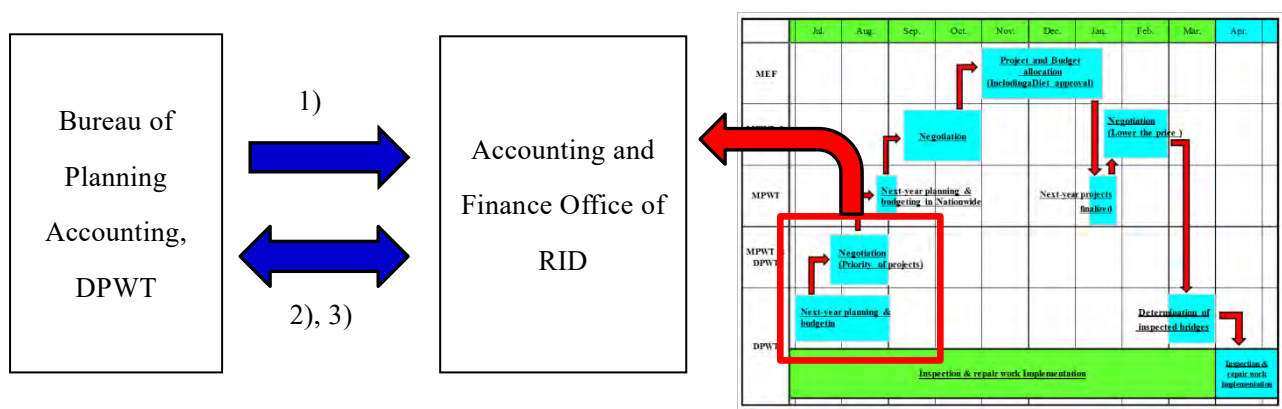
Properly estimated cost is a key reference for the negotiation with MEF. The entity in charge and the formulation process are as follows:

- 1) The cost shall be estimated by each **Bureau of Planning Accounting, DPWT** based on the annual implementation plan. The estimated cost shall be sent to **Accounting and Finance Office of RID**.
- 2) **Accounting and Finance Office** questions to and receives answer from each **Bureau of Planning Accounting** on cost-related matters if any.
- 3) **Accounting and Finance Office** summarizes and edited the bill of quantity document.

The rough timing of the abovementioned actions is shown in **Fig. 2.2.1**. The specific deadline of submission shall be informed by **Accounting and Finance Office** every year.

**Table 2.3.2 The entity in charge of Cost Estimation**

Content	The entity in charge	Relevant division
1) To estimate the cost	Bureau of Planning Accounting, DPWT	Accounting and Finance Office of RID
2) To quest and to receives answer about the Cost Estimation	Accounting and Finance Office of RID	Bureau of Planning Accounting, DPWT
3) To summarize and to edit the estimation	Accounting and Finance Office of RID	Bureau of Planning Accounting, DPWT



**Fig. 2.2.3 Image of Cost Estimation**

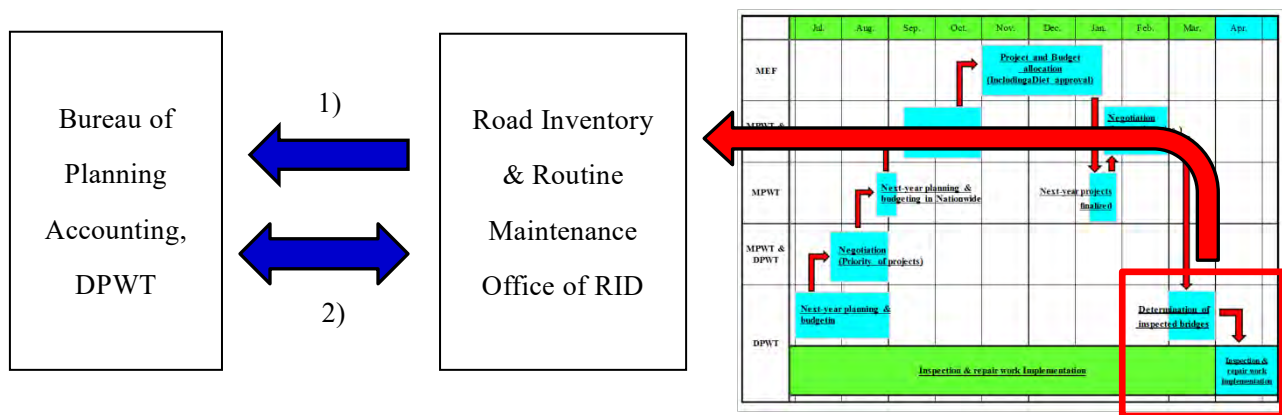
### (c) Budget Management

Proper management of the given budget for inspection prevents from the shortage of inspection payment and the consequent negative reaction from MEF, which may cause problems on the next budget request. Therefore, routine check and assurance of budget implementation should be made if any diversion or misuse of the budget to irrelevant purposes occur. The entity in charge and the formulation process are as follows:

- 1) **Road Inventory & Routine Maintenance Office of RID** is responsible for the management of overall national budget. And each **Bureau of Planning Accounting, DPWT** manages the budget of jurisdiction in charge.
- 2) By the end of September, **Road Inventory & Routine Maintenance Office** checks and confirm the balance between budget and actual spending in each **Bureau of Planning Accounting**. If any shortage is identified, **Road Inventory & Routine Maintenance Office** shall conduct the budget reallocation.

**Table 2.3.3 The entity in charge of Budget Management**

Content	The entity in charge	Relevant division
1) Management of overall national budget	Road Inventory & Routine Maintenance Office of RID	Bureau of Planning Accounting, DPWT
2) To checks and to confirm the balance between budget and actual spending	Road Inventory & Routine Maintenance Office of RID	Bureau of Planning Accounting, DPWT



**Fig. 2.2.4 Image of Budget Management**

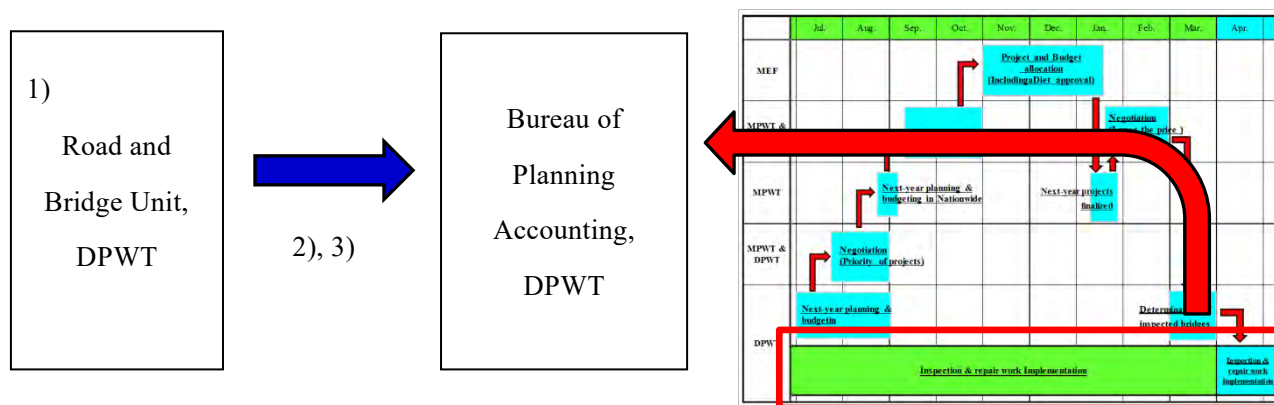
#### (d) Implementation

Inspection methodologies are shown in ‘CHAPTER 3.GENERAL REQUIREMENTS FOR BRIDGE INSPECTIONS’. The entity in charge and the formulation process are as follows:

- 1) Bridge inspection is conducted by designated inspectors belonging to each **Road and Bridge Unit, DPWT** regardless of the presence or absence of damages, **Inspectors** must register and input the inspection results in the Bridge inspection Database System.
- 2) For the inspection budget management, each **Road and Bridge Unit** must report the actual inspection cost to the **Bureau of Planning Accounting, DPWT** within one week after the payment.
- 3) If any excessive spending is assumed, the **Road and Bridge Unit** must report to the **Bureau of Planning Accounting** in advance.

**Table 2.3.4 The entity in charge of Implementation**

Content	The entity in charge	Relevant division
1) To conduct bridge inspection	Road and Bridge Unit, DPWT	—
2) To report the actual inspection cost	Road and Bridge Unit, DPWT	Bureau of Planning Accounting, DPWT
3) The report inspection cost (In case of excessive spending)	Road and Bridge Unit, DPWT	Bureau of Planning Accounting, DPWT



**Fig. 2.2.4 Image of Implementation**

### (e) Technical Advisory

When a new structural material is introduced on a certain bridge and inspectors need some guidance on the inspection methodology, they can contact with the designated department for technical advice. The entity in charge and the formulation process are as follows:

- 1) **Planning and Technical Office for Road & Bridge of RID** and **Road Inventory & Routine Maintenance Office of RID** are responsible for the technical advisory
- 2) **Planning and Technical Office** and **Road Inventory & Routine Maintenance Office** shall record the consultation contents for the future reference to the similar cases and the basic information for the revision of Bridge Maintenance Manual.

**Table 2.3.5 The entity in charge of Technical Advisory**

<b>Content</b>	<b>The entity in charge</b>	<b>Relevant division</b>
1) Technical advisory	Planning and Technical Office for Road & Bridge of RID / Road Inventory & Routine Maintenance Office of RID	DPWT, MPWT
2) To record the consultation contents	Planning and Technical Office for Road & Bridge of RID / Road Inventory & Routine Maintenance Office of RID	DPWT, MPWT

### **2.3.2 Bridge Inspection Record**

The recorded inspection results are the essential source of information for keeping all bridges in healthy condition with the sustainable maintenance activities including damage diagnosis, repair work planning, and the budget preparation. The results which are input in the Bridge Inspection Database System include not only the level of damage if any but also the no-damage status. It is because the data of current condition regardless of damage existence is necessary for the rough estimate of occurrence period when the damage is identified. When bridge inspection is carried out, the following responsibilities of bridge inspection are necessary to be assigned to a certain entity.

#### **(a) Data Input of Inspection Results**

#### **(b) Confirmation of the Data Input**

#### **(c) Database Management**

#### **(a) Data Input of Inspection Results**

The entity in charge and the formulation process are as follows:

- 1) Inspectors in each **Road and Bridge Unit, DPWT** shall be responsible for inputting the inspection result data in the Bridge Inspection Database System. It is preferable that the input shall be done on the site right after the inspection unless the site condition is not allowed



**Table 2.3.6 The entity in charge of Data Input**

Content	The entity in charge	Relevant division
1) Inputting the inspection result data in the Bridge Inspection Database System	Inspector (Road and Bridge Unit, DPWT)	—

**(b) Confirmation of the Data Input**

The confirmation is to make sure that the given budget is properly implemented without diversions to any misappropriate cause. This process is helpful for gaining trust relationship with MEF and facilitating the future budget negotiations. The entity in charge and the formulation process are as follows:

- 1) **The chief of inspector team** is responsible for input confirmation. Intermediate check for the balance between the initial schedule in the inspection implementation plan and the actual progress shall be conducted in December.

**Table 2.3.7 The entity in charge of Confirmation**

Content	The entity in charge	Relevant division
1) Input confirmation	The chief of inspector team	Inspector

**(c) Database Management**

The database server of Bridge Inspection Database System shall be in the computer system of the RID. The entity in charge and the formulation process are as follows:

- 1) **Data, Equipment & Material Management Office of RID** is responsible for the database server management. The server shall be kept activated constantly so that anyone can access to the system and input and reference actions can be made at any time.

**Table 2.3.8 The entity in charge of Database Management**

Content	The entity in charge	Relevant division
1) The database server management	Data, Equipment & Material Management Office of RID,	—

### 2.3.3 Bridge Inspection Seminar and Workshop

It is very beneficial to share information on new know-hows and technologies and the tendency of damage patterns through seminars and workshops which are held nationwide. Seminars and workshops shall be held in a regular basis in order to build partnerships and network among DPWT staff.

In addition, it is preferable to establish and promote an information sharing mechanism in each DPWT. The entity in charge and the formulation process are as follows:

- 1) **Planning and Technical Office for Road & Bridge of RID** is responsible for the organization and implementation of national seminars and workshops.
- 2) Local workshop an information sharing are carried out by each **Deputy Director, Bureau of Public Work, DPWT** and **Deputy Director, Bureau of Road and Bridge Unit, DPWT.**

**Table 2.3.9 The entity in charge of Bridge Inspection Seminar and Workshop**

Content	The entity in charge	Relevant division
1) The organization and implementation of national seminars and workshops	Planning and Technical Office for Road & Bridge of RID	MPWT, DPWT
2) To carry out local workshop an information sharing.	Deputy Director, Bureau of Public Work, DPWT  Deputy Director, Bureau of Road and Bridge Unit, DPWT	DPWT

## CHAPTER 3. GENERAL REQUIREMENTS FOR BRIDGE INSPECTIONS

### 3.1 Outline

Key points for bridge inspection are that it shall be conducted with required accuracy and thoroughness. Bridge inspectors should keep sufficient time for undertaking inspection and collection of data which is required by structural type and element.

The purpose of inspection shall be not only identifying clearly visible defects but also anticipating the progress of minor defects and recognizing where they are likely to occur and their probable causes. That is the first step of preventive maintenance where any deterioration shall be detected and treated before it gets worse and costly.

**Close visual check, and palpation (touching and hitting) if possible are the basic methodologies of bridge inspection. In addition, the inspection shall not be limited to bridge's topside but cover also its underside because serious but hidden damages are often concentrated on this part.**



Photo 3.1.1 Bridge inspection



Photo 3.1.2 The necessity of bridges inspection from underside

### **3.2 Scope of bridge inspection**

The bridge inspection is a detailed investigation and evaluation of damage and/or material properties of specified elements. The damage may be due to environmental impact (climate, saline soil, etc.), wear (insufficient maintenance), design and construction errors and overloading or similar conditions.

The scope of the bridge inspection will include:

- 1) Review of any previous inspection reports;
- 2) Determination and provision of equipment and resources required for the inspection including preparation of a safety plan;
- 3) Inspection of all relevant bridge attributes including measurements, testing and analysis as necessary to supplement the visual inspection; and
- 4) Identification of the probable causes and projected rate of deterioration and the effects of continued deterioration on the performance, durability and residual life of the structure.

### 3.3 Preparations before Inspection

Prior to the inspection, available information on the type of bridge, its maintenance history and previous inspection reports shall be reviewed by the officer who will undertake the inspection. It may be necessary to search further for bridge drawings, maintenance histories, consultant's reports, etc.

The points of preparations before Inspection are as follows:

- 1) Inspector shall collect the Inspection Report and all available documents (plans, drawing and reports) of the bridge to be inspected;
- 2) Inspector shall check equipment (including all non-destructive testing apparatus) and/or vehicles required for Engineering Inspection;
- 3) Inspector shall check and confirm that all necessary materials and safety gadgets are prepared and operative;
- 4) Inspector shall prepare 'Inspection Result Form' (**Fig. 3.9.1**); and
- 5) Inspector shall make sure that safety measures are in-place prior to inspection.

### **3.4 Consideration for Safety Works**

#### **3.4.1 General**

For the protection and safety of inspectors, general public and the surrounding environment, safety practices are essential on every work site. Health and safety have a high priority at all times during field operations.

The following safety shall aspect apply to bridge inspection works and must be considered prior to commencement of any inspection:

- \* On the road safety
- \* Work safety

#### **3.4.2. On the road safety**

Working on near roads is extremely hazardous.

The points to keep in mind on the road working are as follows:

1) Before commencing inspection at the site ensure that:

- \* All personnel are wearing high visibility vests;
- \* Inspector must know where to take refuge in case of emergency; and
- \* Locations of unsafe areas and roads must be identified and shared to all personnel;

2) Do not walk on or near the road unless absolutely necessary.

3) Always walk in the direction so that you are facing the oncoming vehicles (The vehicles should not come from behind you).

4) When inspector crosses roads, they make sure that all the lanes are clear; and

5) Inspector must not step backwards without looking. Under the noise of your machine and traffic you may not hear the sound of approaching vehicles.



**Photo 3.4.1 vehicle's passage on bridge**

#### **3.4.3 Work Safety**

Work safety measures must be planned ahead.

The points of work safety are as follows:

- 1) Ensure that all tools, equipment and apparatus are available and in good working order;
- 2) Inspector shall prepare helmets, masks, safety harnesses, footwear, gloves, and any other necessary safety gears.

- 3) Plan and arrange road closures and suitable traffic management procedures if necessary;
- 4) Identify and locate all the utilities existing at site such as electricity, water, sewerage, communications, and gas lines. If any risk is foreseen, inspector shall inform the relevant authorities to stand by for any emergencies;
- 5) All inspections should be carried out in well-ventilated and well-lit areas. If necessary, make prior arrangements for exhaust fans and artificial lighting; and
- 6) Do not allow personnel under the influence of alcohol (or any medication which impairs alertness or causes drowsiness) to work at site or to operate any mechanical equipment.



### 3.5 Classification of inspection

Inspections are classified as follows according to purposes and contents that are requested.

#### 3.5.1 Definition of inspection

##### (1)Initial Inspection

Initial inspection determines the primary condition of bridge structures that are newly constructed.

##### (2)Routine Inspection

Routine inspection confirms the safety condition of the bridge structures. The main methods are the visual check from such as a running vehicle. When an inspector checks clogging of drainage pipes, in a routine inspection, it is necessary to conduct a cleaning as a part of routine repair works (Photo 3.5.1 (1)). Also, an inspector checks whether an abnormal condition is shown on there that was repaired in an emergency repair work. (Photo 3.5.1 (2)).



**Photo 3.5.1 Routine Inspection**

##### (3) Periodic Inspection

‘Periodic Inspection’ is to be carried out on a regular basis by visual inspection or hammering test in order to confirm the total condition of the structure. During the inspection, it is necessary to check visually from close distance or touch the road structure directly as much as possible.



**Photo 3.5.2 Periodic Inspection**

#### **(4) Detailed Inspection**

‘ Detailed Inspection’ is to be carried out by hammering test or non-destructive testing or close visual check in order to confirm whether the damage that were detected by a former inspection has been in progress.

When the level of the damage is determined to be severe, it is necessary to consider appropriate measures such as conducting repair works, road closures and to share the information within an organization.



**Photo 3.5.3 Example of Detailed Inspection (Non-destructive testing)**

#### **(5) Follow-up Inspection**

‘ Follow-up Inspection’ is to be carried out to monitor progress of damage in case of the damages cannot be repaired early. Frequency of follow-up inspection is decided by considering influence on safety for the third party or soundness of structure.

### (6) Emergency Inspection

Emergency inspection is to be implemented on demand to supplement routine inspections or to check road structures when abnormal weather conditions occur such as heavy rainfall. Also, an emergency inspection is to be immediately conducted when the road structures are damaged by any major accidents. It is important to compare with the past data regarding the similarity of road structure category, accident category, level of damage and weather condition.

### 3.5.2 Frequency of inspection

The frequency of inspections by the category of inspection is shown below.

However, the frequency can be modified according to the condition of structures, the past inspection results, and environmental conditions.

**Table 3.5.1 Inspection interval**

Classification of inspection	Standard Frequency	Remarks
Initial Inspection	Conducted before in-service	—
Routine Inspection	Once/month	With road inspection
Periodic Inspection	Once/Every 5 year	Afar inspection by using binocular
Detailed Inspection	Once/5 years	Closed inspection
Follow-up Inspection	Once/1 month or 3month or year (Depending on situation)	Until finishing repair work or placement
Emergency Inspection	Whenever necessary	—

**Table 3.5.2 Follow-up Inspection interval**

Situation of Defect	Frequency of Inspection
Damage influence to safety for third party	1 time / month
Damage influence to soundness of structure	1 time / 3 months
Others	1 time / year

### 3.6 Inspection Record

The recorded inspection results are the essential source of information for keeping all bridges in a healthy condition, leading to the sustainable maintenance activities including damage diagnosis, repair work planning, and budget planning. The data is also used to plan inspection for the next term and research the countermeasures.

The inspection results which are input in the Bridge Inspection Database System are to include not only the level of damages but also the non-damage status. The data of the current condition is inevitable even if the structures have no damage. This is because the data helps managers roughly project when damage is likely to occur.

Operation Method of the ‘the Bridge Inspection Database System’ is shown in **Chapter 4**

As necessary, the initial data shall be checked for correctness, be made corrections, and be added missing information.

The points of accumulating inspection results are as follows:

- 1) The results of the inspection are very important as a basic data that will be reflected in the planning of inspection and research and also measures plan for the future.
- 2) The inspection results which are input in the Bridge Inspection Database System must be to include not only the level of damages but also the non-damage status.
- 3) The status is to be recorded when an emergency first aid is conducted to structures during an inspection.
- 4) The corresponding results must be reported to the department in charge of bridge maintenance when different inspections are conducted together.
- 5) The pictures recording the degradation condition of road structures must be stored as electronic data.

### 3.7 Inspection methods

#### (1) Visual inspection

Visual inspection is classified as-two ways.

The first is a distant inspection from a distance by using binoculars and the other another is close visual inspection by using scaffolding and passage and boat as much as possible.

The consideration to conduct the visual inspections is shown in **Table 3.7.1**.



**Photo 3.7.1 Visual inspection**

**Photo 3.7.1 The consideration to conduct the visual inspections**

Distant visual inspection	<ul style="list-style-type: none"><li>• Inspectors shall use their own eyes and/or equipments such as binoculars to look for defects and/or damages on bridge structures.</li><li>• Inspectors shall check following events;<ul style="list-style-type: none"><li>*Abnormal sound from a bridge and its members</li><li>*Abnormal vibration of a bridge and accesaries of a bridge</li><li>*Any deformation and condition change of a bridge and/or structure members</li><li>*Other signs and/or indicators of defects and deteriorations of a bridge and its structure members</li></ul></li></ul>
Close visual inspection	<ul style="list-style-type: none"><li>• To close distance as touch the road structure directly.</li><li>• It is highly recommended to check thier own eyes and conduct simple in-site tests, including hammering test.</li></ul>

#### (2) Hammering test

Hammering test is method that estimates existence or non-existence of damage method from the tapping sound of the concrete surface.

In the case of having clear sound, the concrete is considered as healthy. And in the case of

having dull sound, the concrete is considered as having peeling or lifting or cavity. The concrete peeling can be captured and flicked off in advance of falling.

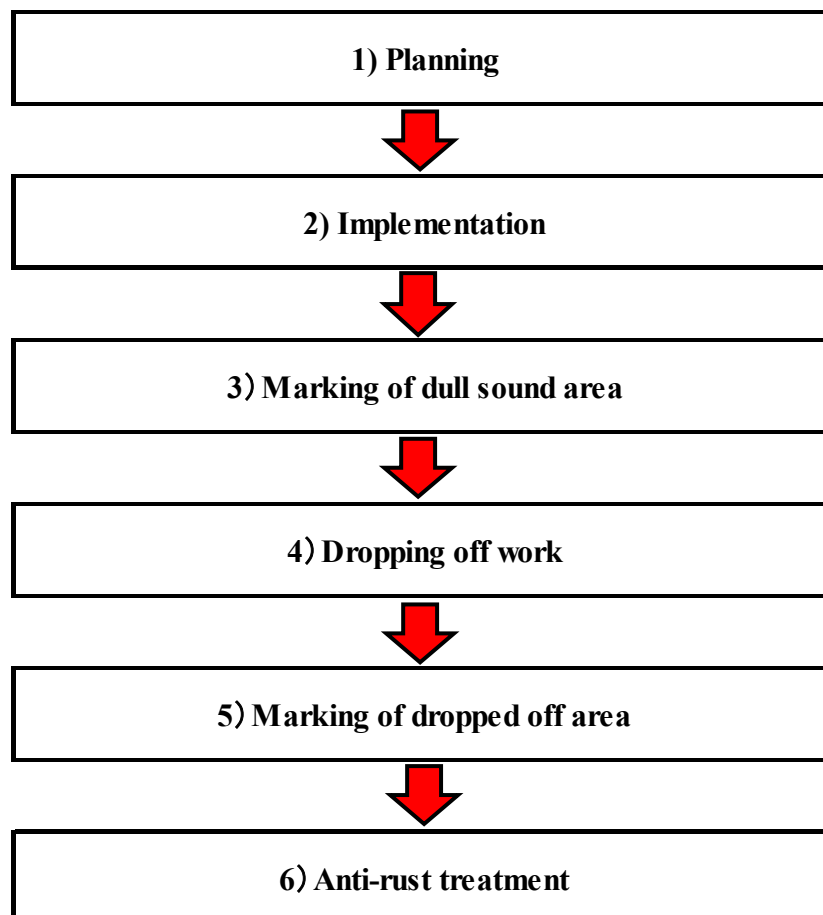
This testing is advantageous since its measurement is very simple and can be executed by inexpensive tool.

Hammer with weight of about 1/2 pound (230g) is used for this testing.



**Photo 3.7.2 Hammering test**

The flow of the hammering test is shown in **Fig. 3.7.1**.



**Fig. 3.7.1 The flow of the hammering test**



### 1) Planning

Plan test area focusing on structural important member such as bridge pier or deck. Especially, around the place seemed to have damage by visual inspection shall be tested elaborately.

### 2) Implementation

In the case of clear sound, this concrete doesn't have damage and no peeling. And in the case of dull sound, this concrete has peeling or cavity.

### 3) Marking of dull sound area

After marking by using spray type paint of dull sound area, take photo before dropping off.

### 4) Dropping off work

Drop off by hitting the marked area which is detached or peeled.

Healthy concrete should not be damaged by this action. Alternative measure should be taken if there is a possibility of collapse by dropping off.



Photo 3.7.3 Dropping off work

### 5) Marking of dropped off area

Measure size of dropped off area and mark with choke. Take photography for record.



Photo 3.7.4 Marking of dropped off area

### (3) Non-destructive testing equipment

#### (Reference: CHAPTER 5)

Non-destructive testing equipment such as infrared camera, electromagnetic or supersonic rebar sensor is needed to detect structural deformation or inside damage.

### 3.8 General view points for Bridge Inspection

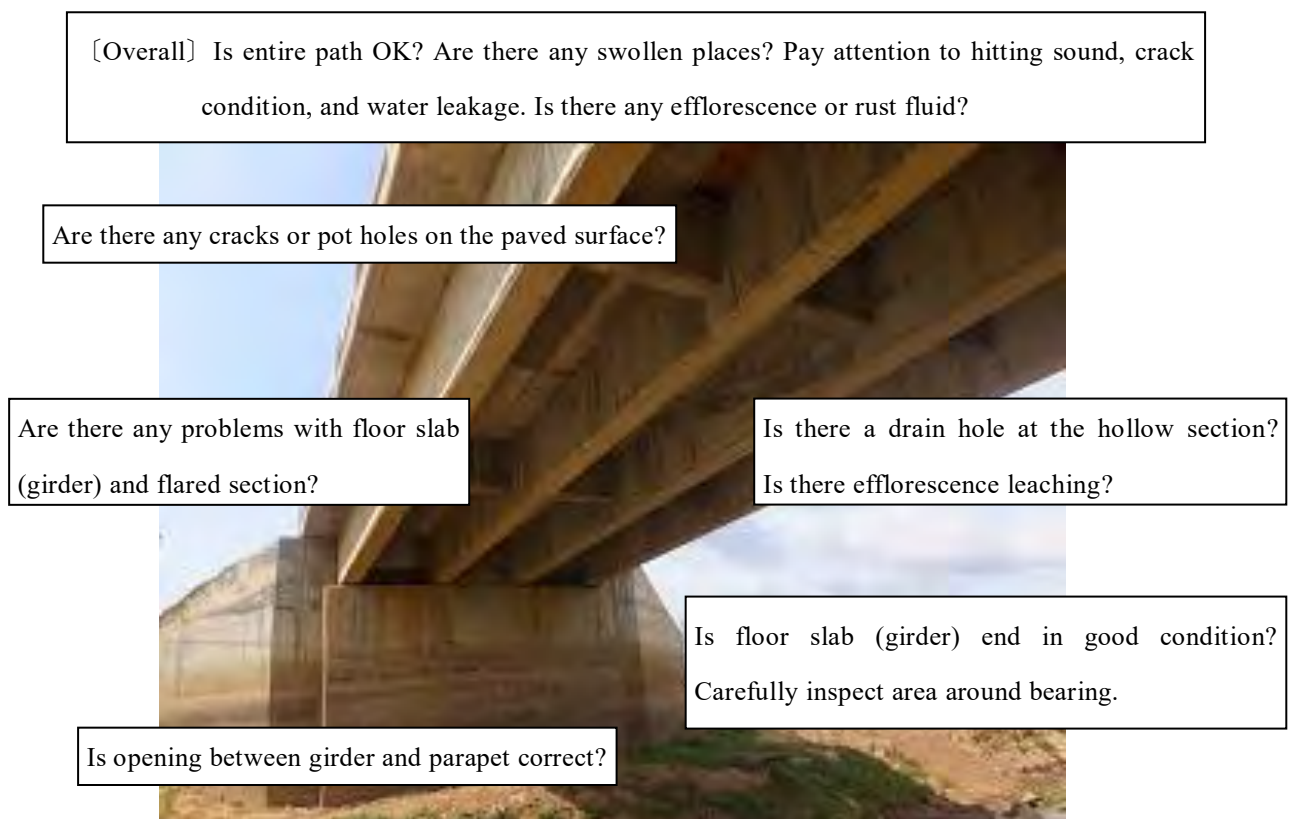
In this section, inspection point of each structure is mentioned.

#### 3.8.1 General

##### (1) General Inspection Places

##### 1) Concrete structure

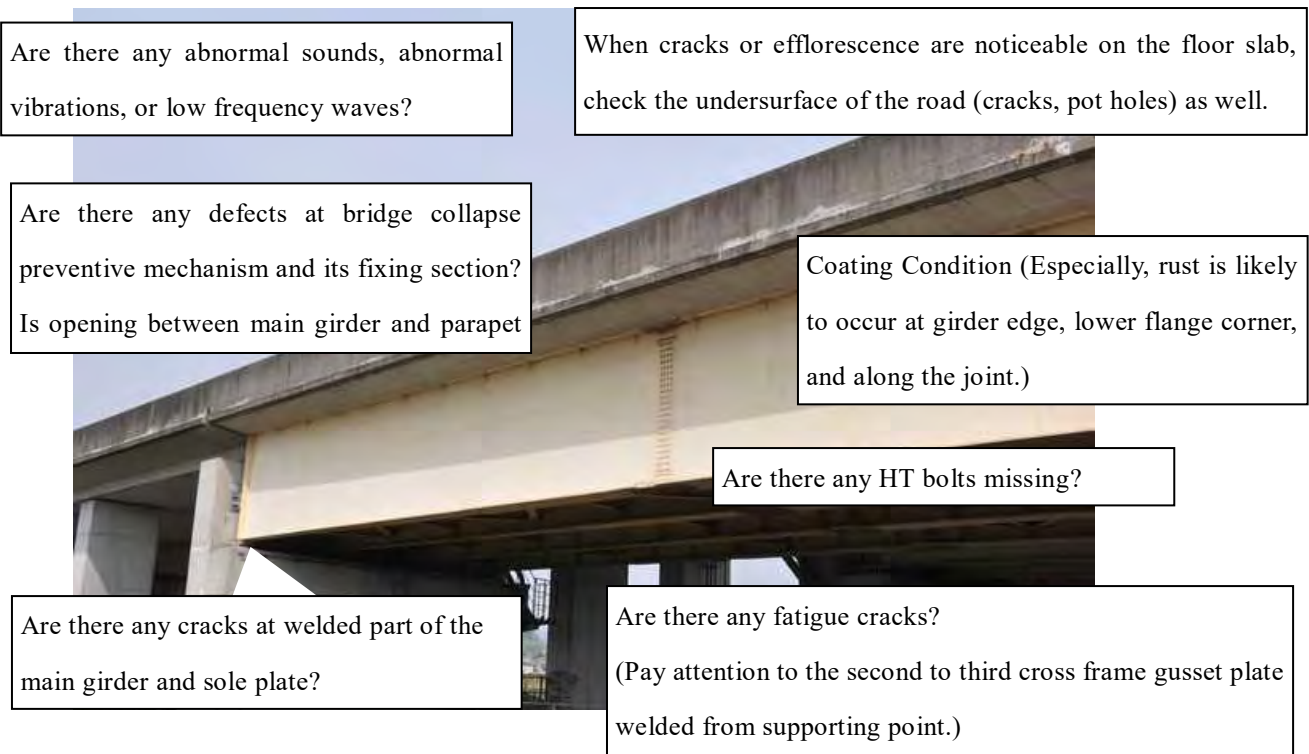
**Photo 3.8.1** shows locations where defects may occur in general concrete bridge.



**Photo 3.8.1 General Inspection Sections of Concrete bridge**

## 2) Steel structure

**Photo 3.8.2** shows locations where defects may occur in general steel bridge.



**Photo 3.8.2 General Inspection Sections of Steel bridge**

## (2) Construction joint (Concrete Structure)

Although fresh concrete is advisable to be placed continuously during construction, it is often conducted intermediately in the process. This work interruption makes joint section so called 'construction joint'.

Disconnection of old and new concrete at 'construction joint' is called as 'cold joint (**Photo 3.8.3**)' and it is difficult to detect visually. Hammering test is recommendable to conduct.

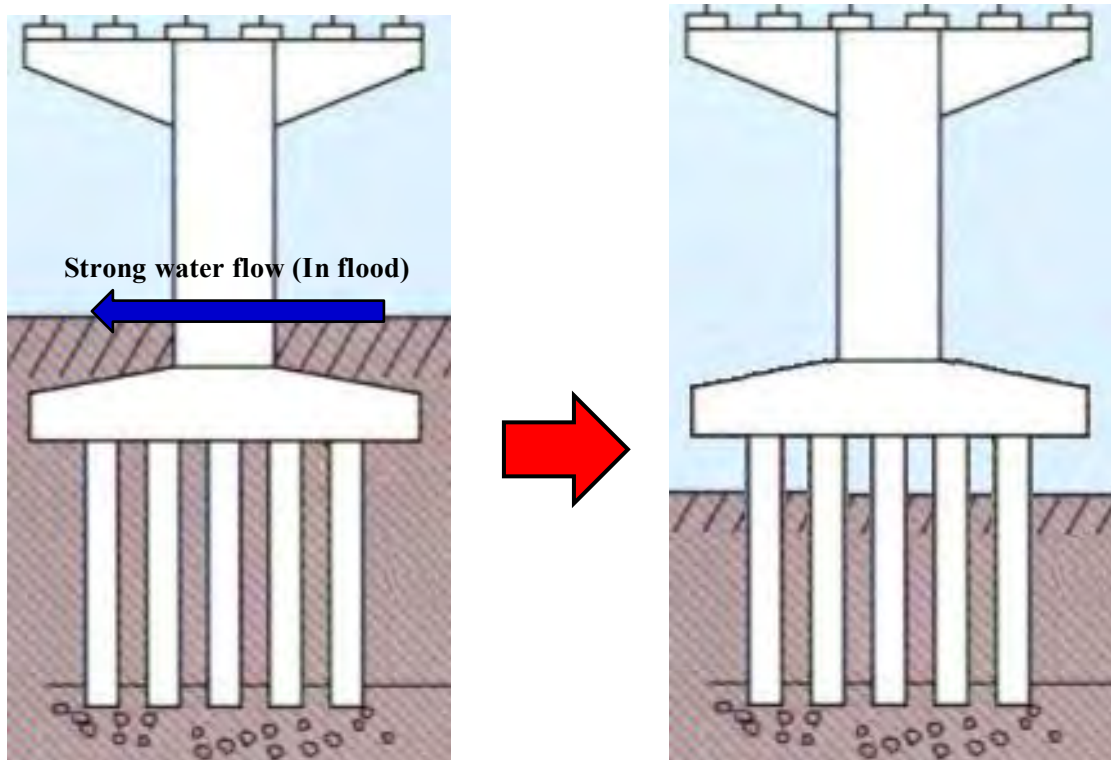


**Photo 3.8.3 Cold Joint**

### 3.8.2 Substructure

#### (1) Scouring (Abutment, Pier)

The scouring mechanism is shown **Fig. 3.8.1**. Rising of water level in rainy season leads scouring at bridge abutment or pier. However, around the abutment or pier is strengthened against scouring, this part is damaged in some case resulting from poor construction quality.



**Fig. 3.8.1** Image of Scouring





**(a) Foundation of pier**



**(b) Foundation of abutment**

**Photo 3.8.4 Scouring**

## **(2) Abutment**

Stress concentration tends to be occurred around bearing on the abutment. Crack at this point shall be checked especially for bridge which has heavy traffic volume. Moreover, dust or trash is easy to be accumulated at abutment. It may cause damage or miss detecting damage, so that it shall be cleaned periodicity as routine maintenance (periodic cleaning).



**Photo 3.8.5 Inspection point of abutment**

### **(3) Pier**

#### **1) Concrete pier**

Stress concentration tends to be occurred around bearing on the pier. Crack at this point shall be checked especially for bridge which has heavy traffic volume.

And around foundation, honeycomb and lifting often is noticeable.

Moreover, dust or trash is easy to be accumulated at pier. It may cause damage or miss detecting damage, so that it shall be cleaned periodicity as routine maintenance (periodic cleaning).

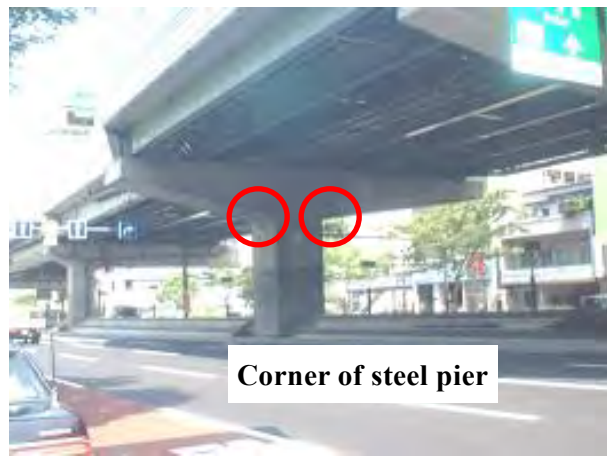


**Photo 3.8.6 Inspection point of Pier**



## 2) Steel Pier

In Cambodia, steel pier is used very few. There is a case that adopt steel pier to shortening construction period. Fatigue damage is occurred on welds in steel pier. Especially the crack occurred on weld in corner of steel pier may lead collapse of bridge without repair.



**Photo 3.8.7 Steel Pier (Osaka/Japan)**

## 3.8.3 Superstructure

### (1) Slab

#### 1) Concrete Slab

Concrete structure has relatively low tensile strength. Therefore, cracks of concrete slab are often occurred in under side instead of over side initially. For this reason, the slab inspection had better to implement from underside as possible.

**Photo 3.8.8** shows sever damage degraded by negligence of inspection. To avoid such kind of situation, the crack shall be detected in early stage like shown in **Photo 3.8.8 (a)** and repaired.



(a) Occurrence of cracking  
(Occurred from underside the slab)



(b) Spreading crack



**Danger!!**

(c) Through the floor slab

**Photo 3.8.8 Damage of concrete slab**

## 2) Orthotropic deck plate (Steel Slab)

In Cambodia, orthotropic steel deck plate is used very few.

Fatigue damage is often occurred on welds in the orthotropic steel deck plate under heavy traffic loading.

The fatigue crack on the orthotropic deck plate doesn't lead to collapse the bridge immediately. However, especially the damage which is occurred to the welding on orthotropic steel deck, may become cause of pothole on pavement.



**Photo 3.8.9 Orthotropic deck plate  
(Chroy Changva bridge)**



**Photo 3.8.10 Fatigue crack on the orthotropic**

## **(2) Bearing**

Because of its structural feature, stress is often concentrated at bearing. Therefore, crack is easy to be occurred in this area. In addition, accumulation of sediment leads function degradation of bearing, so that the sediment shall be removed using jet water at routine maintenance.



**Photo 3.8.11 Damage of bearing**

## **(3) Girder**

### **1) Concrete girder**

Crack penetration which starts around bearing to girder may leads collapse in worst case as shown in **Photo 3.8.12**. Therefore, this crack shall be detected in the early stage by inspection. Also center of girder span is often cracked by heavy traffic load.





**Photo 3.8.12 Damage of concrete girder**

## 2) Steel girder

For steel girder, it is necessary to pay attention to rust and fatigue cracking.

In particular, rust is often occurred in place where water easily stagnates such as joint, drainage pipe and bearing.

Especially the steel girder directly put on pier and abutment without bearing causes rust in high probability (**Photo 3.8.14**). Progress of rust may lead bridge collapse so that it shall be checked carefully.



**Photo 3.8.13 Corrosion of the steel girder**



**Photo 3.8.14 Put on abutment directly**

#### **(4) Others**

The other damage to the superstructure is shown in **Photo 3.8.15**



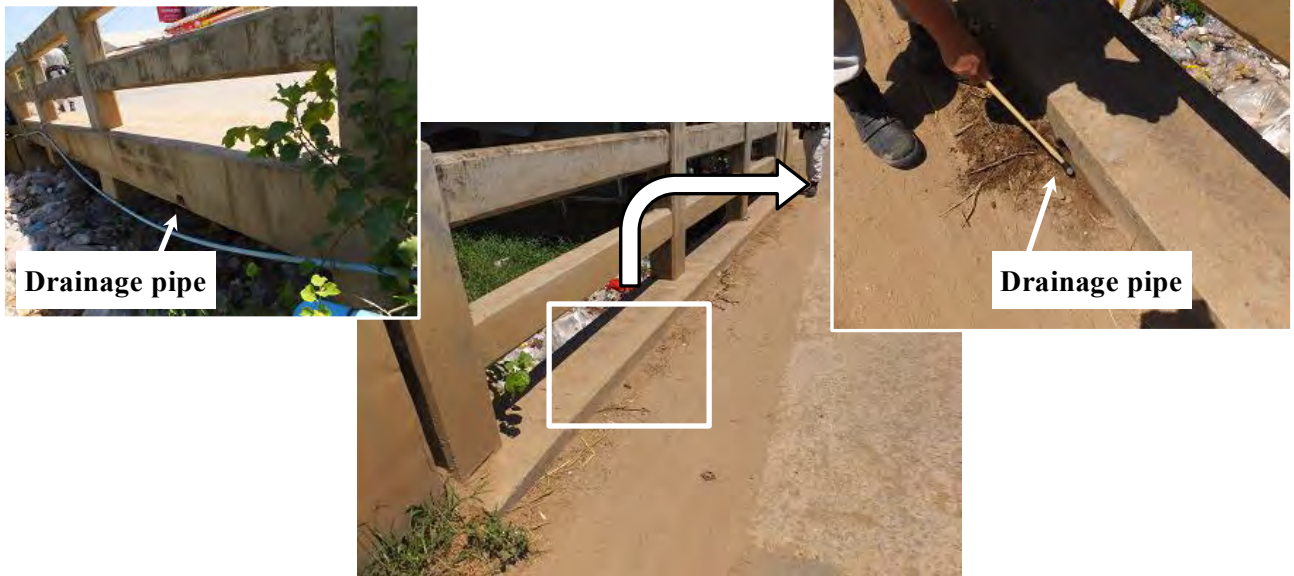
**Photo 3.8.15 Handrail Accident**

#### **3.8.4 Drainage facility**

Clogging of drainage facility causes water flow on the bridge surface and it is drained from unintended locations. (It is usually drainage via a joint section or the bearing.)

This situation triggers damage of the bridge.

Therefore, drainage clogging is desired to be removed by the water jet (**Photo 3.8.17**).



**Photo 3.8.16 Clogged drainage facility**



**Photo 3.8.17 Water jet**



**Photo 3.8.18 Drainage Cover Broken**



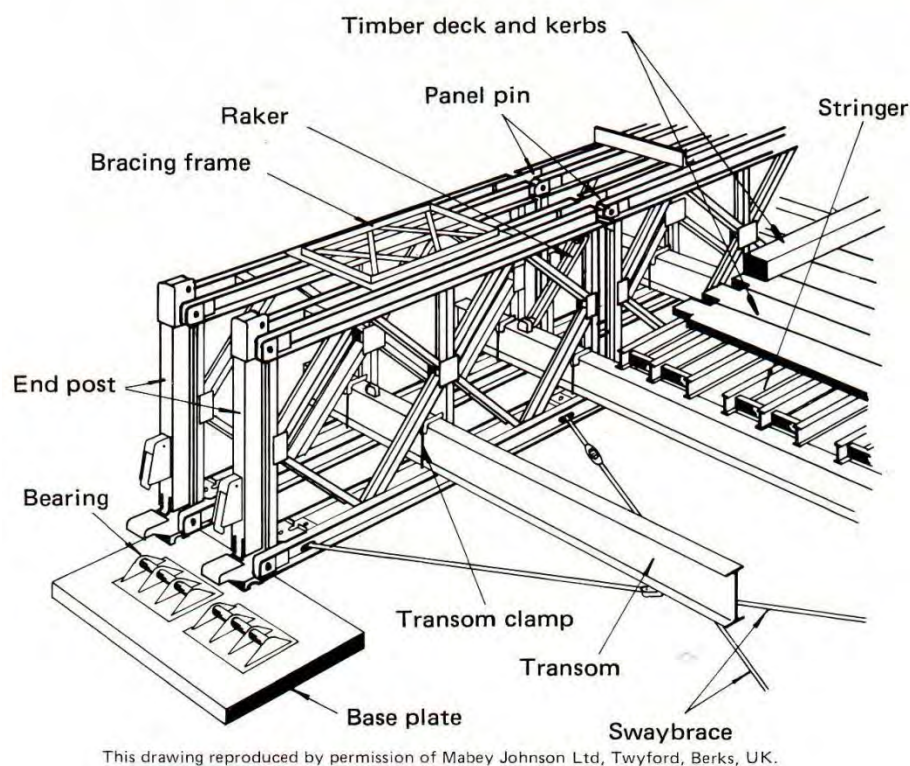
### 3.8.5 Bailey Bridge

The Bailey bridge is a truss bridge which is portable and pre-fabricated. It was originally developed for military use. It is advantageous that the bridge elements are small and light enough to carry them by trucks and erect without using crane.

Many different kinds of bridge have been made using the basic Bailey panels. Design details have changed over the years, and different strengths of steel have been used.

All the parts of a Bailey bridge shall be furnished since there is no structural redundancy for this bridge type. Loss of the parts can trigger bridge collapse by heavy traffic loading, so that thorough inspection is important.

The drawing below shows the most of the parts of a typical Bailey bridge. Not all the Bailey bridges are exactly like this.



**Fig. 3.8.2 The parts of Bailey bridge**

For single span baily bridge, panel pins is usually stable because of its structural feature. For continuous bridge which has two or more spans, panel pine is easy to be moved by traffic passage on the bridge.

**1) CHECK for missing or loosening of panel pin (Photo 3.8.19)**

Panel pin can be loosen or missed by traffic passage vibration for many years use. This situation is unacceptable since panel pin is a critical member in the bridge.

Loose panel pin shall be hammered in by large hammer and missing one shall be replaced.



**Photo 3.8.19 Missing or loosening panel pins**

**2) CHECK for missing or loose bolts.**

The bolts that connect the chord rebar and hold together double storey bridges are very important.

**3) CHECK for missing rakers and tie plates.**

Some bridges use vertical bracing frames in place of rakers.

**4) CHECK for missing or loose sway braces.**

Check that the pins are in place and that the lock nuts are screwed up. Some Bailey bridges have horizontal bracing frames on the top chords of the panels.

**5) CHECK for missing, loosening or defected horizontal bracing frames.**

**6) CHECK for missing or loose transom clamps.**

Some modern Bailey bridges do not use transom clamps. In this case, note - 'no transom clamps' to the inspection form.

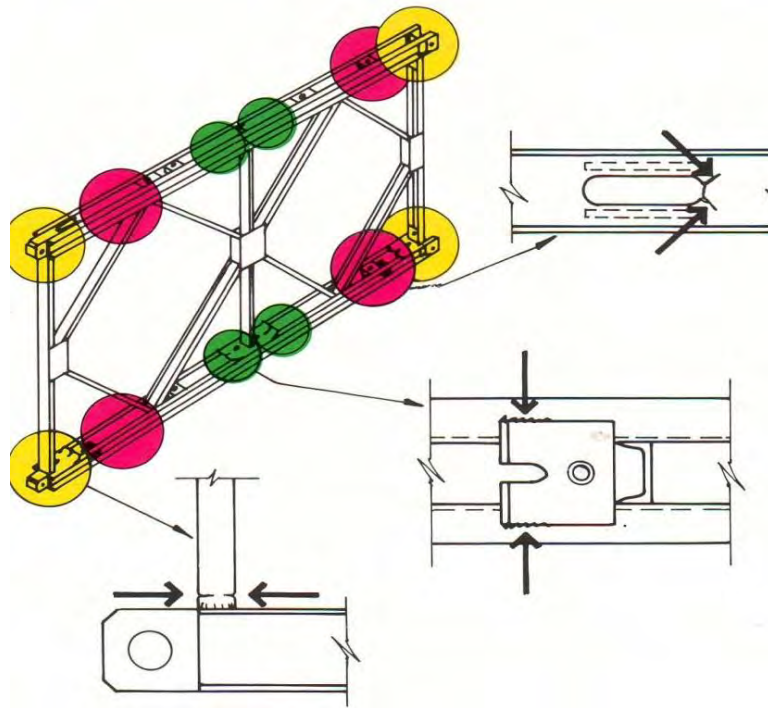
**7) CHECK for wear at the stringer to transom SEATING.**

Bailey bridges move a lot when vehicles cross them. This causes wear, where the stringers sit on the transoms.

**8) CHECK ALL Bailey bridges for cracking.**

**Fig. 3.8.3** shows where you should look for cracks:

*All these places must be checked on each panel at each inspection*



**Fig. 3.8.3 Check points cracks of Bailey bridge**

**9) CHECK for bends in bridge members.**

Note where the defect is and sketch the defect.

**10) CHECK for corrosion.**

There are some areas in a Bailey bridge where dirt and moisture are accumulated. Check especially at:

1. Bearings.
2. Base of the rakers.
3. Bottom chord near the spacer plates and where the diagonal members (diamonds) join.
4. Panels around transoms sit on the bottom chord.

Bailey bridges consist of lots of panels, so it is not easy to make a sketch showing where you have found a problem. If you find a panel that is defected, or has any problem, mark it with paint and give it a number. When you fill in the report form you can write the number in the column for notes.

**11) CHECK for settlement of the bearings.**

**12) CHECK for defect of the bearings and base plates.**

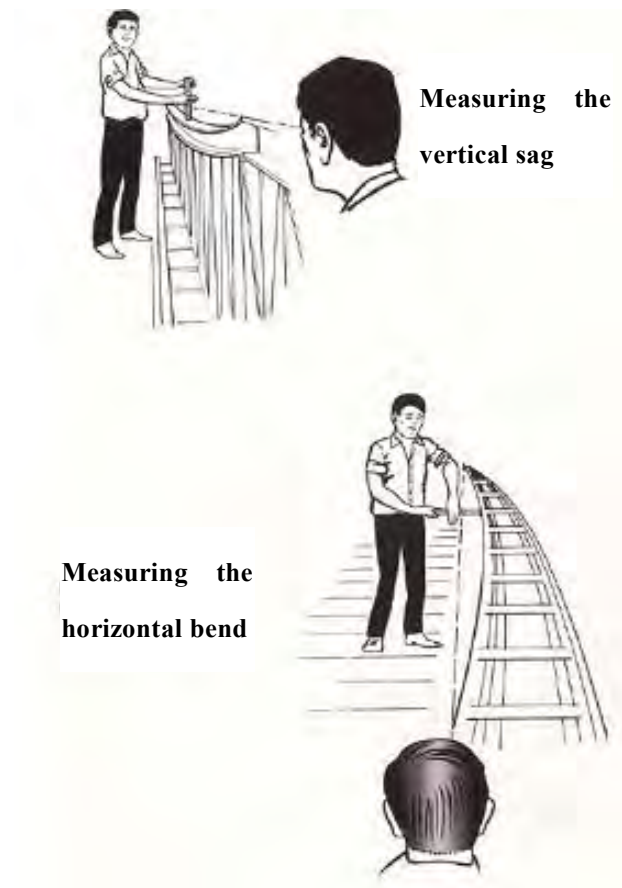
All Bailey bridges sag a little at the middle of the span, and some are bent sideways. Look at the photograph and the two drawings. They show you how to measure the vertical sag and the horizontal bend.

Look along the top of the panels on one side of the bridge. You will need an assistant to help me measure the sag and the bend with a rule of measuring tape, taking instructions from you.

Write on the report form the biggest measurement of vertical sag and the biggest measurement of horizontal bend on the upstream side of the bridge. Then measure the sag and bend on the downstream side of the bridge and write these measurements on the report form.



**Photo 3.8.20 Check the sag of Baile**



**Fig. 3.8.4 How to measure sag and horizontal bend**

### **3.9 Evaluation of inspection**

As mentioned in '**3.6 Inspection Record**', the evaluation by means of inspection result record is important to maintain the bridge continuously.

Inspection Result Form (inspection result evaluation sheets) is shown in **Figure -3.9.1**.

These sheets are stored in the computer server of RID and it can be use with smart phone via internet.

It is necessary to keep in mind that scores of this form is the basis of determining the priority of repair. If the evaluation is difficult, consult to '**Planning and Technical Office for Road & Bridge of RID**'. The evaluation result shall not be remained unscored.

The Bridge which is judged as SD (Serious Damaged) should be replaced early. Sample of SD is shown in **AP-1**. And Scoring Inspection Results is shown in **AP-2**.



Bridge Name	Perk tateun	III - Urgent	II - Observation	I - Unnecessary
-------------	-------------	--------------	------------------	-----------------





Road Surface	Pavement	Unevenness / Pot hole / Rutting / Crack	<input checked="" type="radio"/> No Damage <input type="radio"/> Damaged Unevenness / Pot hole Rutting Crack			6	II				
	Bridge Railing / Guardrail / Curb	Damage	<input checked="" type="radio"/> No Damage <input checked="" type="radio"/> Damaged Small damage (Lacking and/or Deformation) Big damage (Partially collapse)	x							
	Expansion Joint	Step	<input checked="" type="radio"/> No Damage <input type="radio"/> Damaged Step under 20mm Step over 20mm								
		Deformation / Damage	<input checked="" type="radio"/> No Damage <input type="radio"/> Damaged Abnormal expansion gap Deformation / Damage								
			Abnormal Sound	<input checked="" type="radio"/> No Damage <input type="radio"/> Damaged Abnormal sound							
	Drainage system	Clog of drainage pipe	<input type="radio"/> No Damage <input checked="" type="radio"/> Damaged Partly no function Almost no function	x							
	Underside	Superstructure (Steel)	Corrosion / Rust	<input type="radio"/> No Damage <input type="radio"/> Damaged <input type="radio"/> Invisible Corrosion on steel member Steel member thickness is thinning					0		
			Crack, Deformation, Loss, Break	<input type="radio"/> No Damage <input type="radio"/> Damaged <input type="radio"/> Invisible Crack on steel member Steel member deformation Steel member loss/broken							
				Missing bolt	<input type="radio"/> No Damage <input type="radio"/> Damaged <input type="radio"/> Invisible Bolt is missing less than 10% Bolt is missing more than 10%						
					Superstructure (Concrete)			Crack			<input type="radio"/> No Damage <input checked="" type="radio"/> Damaged <input type="radio"/> Invisible Crack on undersurface Crack on side Rust fluid from crack
Honeycomb / Flaking / Exposure of rebar			<input checked="" type="radio"/> No Damage <input type="radio"/> Damaged <input type="radio"/> Invisible Honeycomb Lacking and/or Flaking concrete Exposure of rebar Rebar thinning								
			Superstructure (Wooden)	Rotting		<input type="radio"/> No Damage <input type="radio"/> Damaged <input type="radio"/> Invisible Rot of wood Reduction of cross section					0
		Crack / Damage		<input type="radio"/> No Damage <input type="radio"/> Damaged <input type="radio"/> Invisible Big damage / Impassable							
		Slab (Steel)	Corrosion / Crack	<input type="radio"/> No Damage <input type="radio"/> Damaged <input type="radio"/> Invisible Corrosion and/or Rust on steel member Crack Hole			0				

Fig. 3.9.1 (a) Inspection Result Form (Sample)



Bridge Name	Perk tateun	III : Urgent	II : Observation	I : Unnecessary
-------------	-------------	--------------	------------------	-----------------

Underide	Slab (Concrete)	Crack / Hole	<input checked="" type="radio"/> No Damage <input type="radio"/> Damaged <input type="radio"/> Invisible			0	
			Crack on undersurface				
			Free lime				
			Rust fluid from crack				
			Hole				
	Honeycomb / Flaking / Exposure of rebar		<input checked="" type="radio"/> No Damage <input type="radio"/> Damaged <input type="radio"/> Invisible			0	
			Honeycomb				
			Flaking and/or Lacking concrete				
			Exposure of rebar				
			Rebar thinning				
	Slab (Wooden)	Rotting	<input type="radio"/> No Damage <input type="radio"/> Damaged <input type="radio"/> Invisible			0	
			Rot of wood				
			Reduction of cross section				
		Crack/Damage	<input type="radio"/> No Damage <input type="radio"/> Damaged <input type="radio"/> Invisible				
			Big damage / Impassable				
	Bearing	Sedimentation / Damage	<input type="radio"/> No Damage <input type="radio"/> Damaged <input type="radio"/> Invisible			0	
			Sedimentation				
			Corrosion and/or damage				
			No function				
	Substructure (Pier/Abutment)	Scouring / Settlement	<input checked="" type="radio"/> No Damage <input type="radio"/> Damaged <input type="radio"/> Invisible			2	I
			Scouring around substructure				
			Settlement of substructure				
		Crack	<input checked="" type="radio"/> No Damage <input type="radio"/> Damaged <input type="radio"/> Invisible				
			Crack				
			Free lime				
			Rust fluid from crack				
		Peeling / Flaking / Honeycomb	<input type="radio"/> No Damage <input checked="" type="radio"/> Damaged <input type="radio"/> Invisible				
			Honeycomb				
			Flaking and/or Lacking concrete	x			
			Exposure of rebar				
			Rebar thinning				

Comment

Fig. 3.9.1 (b) Inspection Result Form (Sample)

The inspection items are shown as following.

Check points filled red color is damage which is influence to the third party, it shall be repaired urgently as soon as possible after finding damages.

(a) Road Surface

(1) Bridge Railing/ Guardrail/ Curb

Inspection item	Check point
Damage	No Damage
	Damage
	Damage (Possibility of harm third party)

(2) Expansion Joint

Inspection item	Check point
Step	No damage
	Step under 20mm
	Step over 20mm
Deformation / Loss	No damage
	Abnormal expansion gap (More than 2cm)
	Deformation / Damage
	Abnormal sound

(3) Drainage System

Inspection item	Check point
Clog of drainage pipe	No Damage
	Partial no function (Impossibility flood )
	Almost no function(stuffed, broken, etc)

(b) Underside

(1) Superstructure (Steel)

Inspection item	Check point
Corrosion / Rust	No Damage
	Corrosion on steel members

	Hole by corrosion
	Invisible
Crack / Deformation / Loss / Break	No Damage
	Steel members deformation
	Crack on steel member
	Steel member loss/broken (Secondary member)
	Steel member loss/broken (Primary member)
	Invisible
Missing bolt	No Damage
	Missing less than 10%.
	Missing more than 10%.
	Invisible

(2) Superstructure (Concrete)

Inspection item	Check point
Honeycomb / Flaking / Exposure of rebar /Crack (Crack width) RC: >about 0.3mm PC: >about 0.2mm	No Damage
	Free lime/ Honeycomb/ Flaking and/or Lacking concrete
	Exposure of rebar
	Rebar rusting
	Rust fluid from crack
	Crack on girder
	Crack on girder (above Bearing)
	Invisible

(3) Superstructure (Bailey Bridge)

Inspection item	Check point
Missing pin	No Damage
	Loosing pin on bailey bridge
	Missing pin on bailey bridge (Connecting part)
Truss Girder Corrosion / Rust / Crack /	No Damage
	Corrosion on steel member

Deformation /Loss /Break	Steel member deformation
	Hole by corrosion
	Crack on steel member
	Steel member loss/broken
	Invisible
Slab Corrosion / Crack	No Damage
	Corrosion and/or Rust on steel member
	Crack
	Hole
	Invisible

(4) Superstructure (Wooden)

Inspection item	Check point
Rotting	No Damage
	Rot of wood
	Reduction of cross section
	Invisible
Crack / Damage	No Damage
	Big damage (collapse risk) / Impassable
	Hole / Missing slab plate
	Invisible
Vibration, Abnormal Sound	No Damage
	Vibration and/or Abnormal sound at travelling

(5) Slab (Concrete)

Inspection item	Check point
Honeycomb / Flaking / Exposure of rebar /Crack (Crack width) RC: >about 0.3mm PC: >about 0.2mm	No Damage
	Free lime/ Honeycomb/ Flaking and/or Lacking concrete
	Exposure of rebar
	Rebar rusting
	Rust fluid from crack
	Crack on undersurface (Transversal)

	Crack on undersurface (Longitudinal)
	Hole
	Invisible

(6) Slab (Wooden)

Inspection item	Check point
Corrosion	No Damage
	Rot of wood
	Reduction of cross section
	Invisible
Crack / Damage	No Damage
	Big damage (collapse risk) / Impassable
	Hole / Missing slab plate
	Invisible
Vibration / Abnormal sound	No Damage
	Vibration and/or Abnormal sound at travelling

(7) Bearing

Inspection item	Check point
Corrosion / Crack	No Damage
	Partial sedimentation
	Corrosion and/or damage
	Partial sedimentation (Cannot see bearings)
	No function (Include rusting)
	Invisible

(8) Substructure (Pier / Abutment)

Inspection item	Check point
Scouring / Settlement	No Damage
	Scouring around substructure
	Settlement of substructure
	Invisible
Honeycomb / Flaking / Exposure of rebar /Crack (Crack width) RC: >about 0.3mm PC: >about 0.2mm	No Damage
	Free lime/ Honeycomb/ Flaking and/or Lacking concrete
	Exposure of rebar
	Rebar rusting
	Rust fluid from crack
	Crack on surface (Horizontal Direction)
	Crack on surface (Vertical Direction)
	Invisible



## CHAPTER 4. BRIDGE INSPECTION RECORDING

### 4.1 Outline

It is important to record bridge inspection results in a fixed format for sharing them among the relevant organizations and for using them for the preparation of annual maintenance plan. All bridges under the jurisdiction of MPWT or DPWT, must be recorded in the Bridge Inspection Database System.

Even in case any damage is not found, this fact should be noted in the database because this information is a useful reference for the prediction of damage occurrence period. The Bridge Inspection Database System shall not only record inspection results but also inventory data of individual bridges.

Moreover, the Bridge Database System can be sent the inspection data from the inspection site through the Internet to the server in MPWT directly. (Fig. 4.1.1)

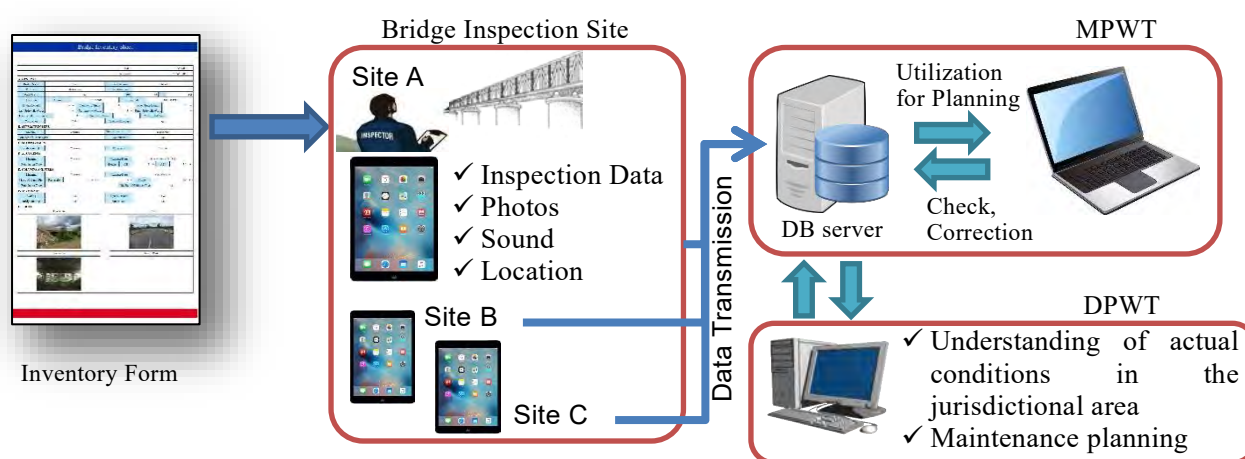


Fig.4.1.1 Outline of Data Transmission of the Database System

The entities in charge of the inspection recording are shown in "CHAPTER2 ORGANINATION FOR BRIDGE MAINTENANCE 2.3.1 Bridge Inspection".

## 4.2 How to use ‘Bridge Inspection Database System’

### (a) Top screen

The top screen of ‘Bridge Inventory Input & Brief Inspection System’ is shown in **Fig.4.2.1**.

At first, bridge inventory data shall be input.



**Fig.4.2.1** Top screen of ‘Bridge Inventory Input & Brief Inspection System’

### (b) Creation of Bridge Inventory Data

Before stating bridge inspection work, bridge inventory information should be prepared. When inputting bridge inventory information, tap the button “Bridge Inventory” (**Fig.4.2.2**). After this, commence data collection work.

At first, 3 photos of the target bridge will be shot (**Fig.4.2.3**). Camera mode automatically will start up by tapping the blank cell of each item (**Fig.4.2.4**). If camera mode will not start up automatically, select “Camera” on “Import” window. After shooting a photo, tap “Use Photo” located bottom, then photo data will be saved in the database.

To shoot three photos indicated below angles one by one.

- 1) Overview (between abutments) (Sample **Photo 4.2.1**)
- 2) Road Surface (Sample **Photo 4.2.2**)
- 3) Bridge Nameplate (If any) (Sample **Photo 4.2.3**)



Fig.4.2.2 Screen for Data Input

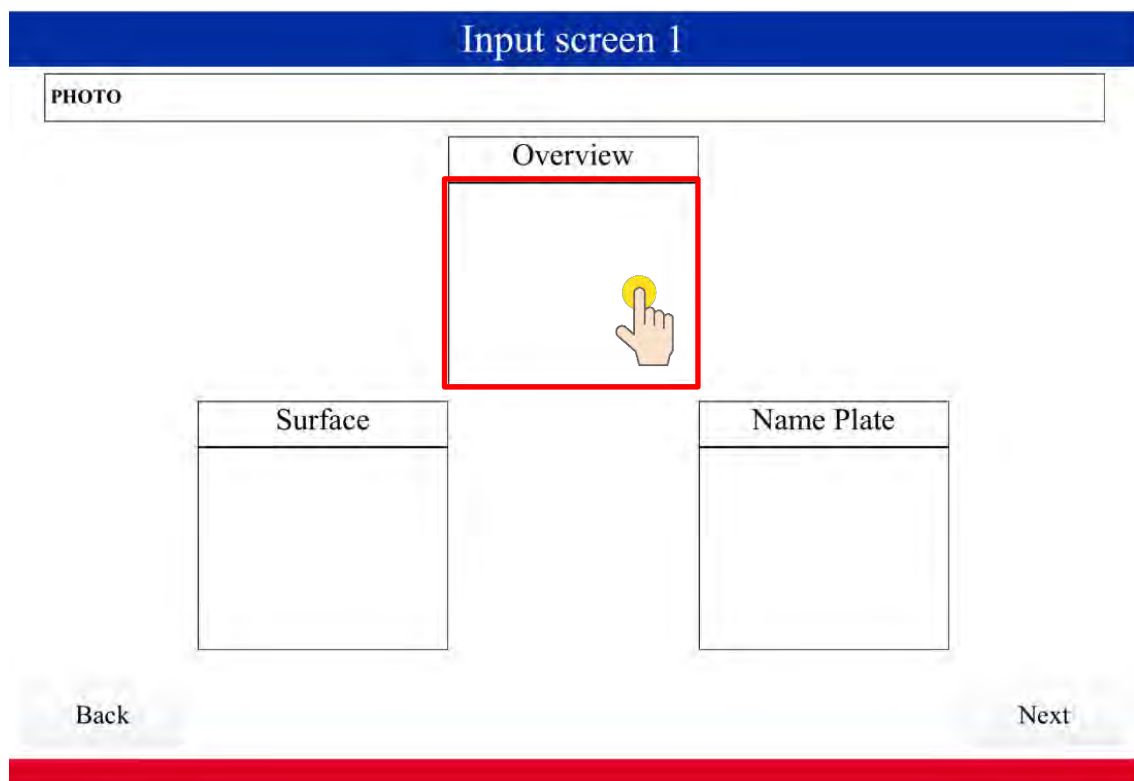
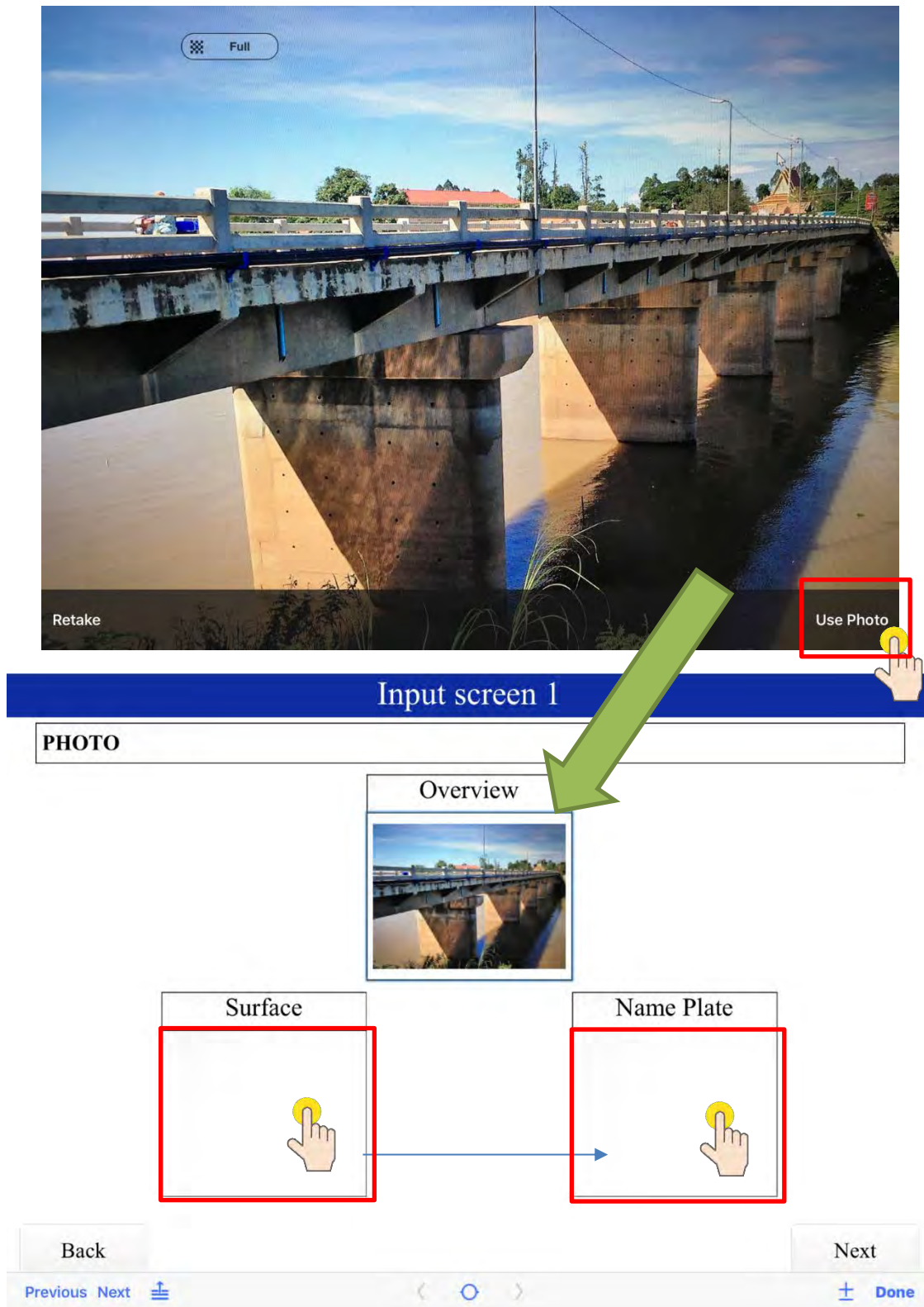


Fig.4.2.3 Screen for Shooting photos



**Fig.4.2.4 Shoot a photo and store in the storage in iPad**

	
<p><b>Photo 4.2.1 Overview</b></p>	<p><b>Photo 4.2.2 Road Surface</b></p>
	
<p><b>Photo 4.2.3 Bridge Nameplate</b></p>	

The input screens of bridge inventory and inspection result data are shown in **Fig.4.2.5 (General)**, **Fig4.2.6 ('Slab/Pavement' and 'Accessory' and 'Superstructure')** and **Fig4.2.7 ('Columns and Piers' and 'Accessory')**. In each screen, filling red box is mandatory. Location is automatically filled up from GPS function of smartphone or the tablet. Any box may remain void until the data is available.

i) Input General Information

Screen image is shown in Fig.4.2.5. Red cell is a cell that needs to input information below.

Contents of 'GENERAL';

- Bridge Name (Manual input)
- Road Category (Selection input)
- Province (Selection input with pull-down menu)
- Village/Commune (Manual input)
- Road Name (Road Number, manual input)
- PK (Post Kilo) (Manual input)
- Location (Latitude and longitude, automatically input)
- Bridge Length (Manual input)
- Number of Spans (Manual input)
- Max. Span Length (Manual input)
- Width (Manual input)
  - Left sidewalk
  - Carriageway
  - Right sidewalk
  - Total width
- Number of Lane (Manual input)
- Constructed Year (Manual input)
- Contractor (Manual input)
- As built drawing (Selection input)

After input all of necessary information below, tap button "Next".



**Input screen 2**

**GENERAL**

Bridge Name		Road Category	<input type="radio"/> National	<input type="radio"/> Provincial
Province		Village/Commune		
Road Name		PK		+
Location	Latitude	42.870571	Longitude	74.590697
Bridge Length	m	Number of Span		Max. Span Length
				m
Left Sidewalk Width	m	Carriageway Width	m	Right Sidewalk Width
				m
Total Width (including Curb)	m	Number of Lane		Constructed Year
Contractor		As built drawings	<input type="radio"/> Yes	<input type="radio"/> No

Back Next

**Fig.4.2.5 Input screen2 (Third screen)**

ii) Input the information regarding Slab/Pavement, Accessary and Superstructure  
Screen image is shown in Fig.4.2.6. Red cell is a cell that needs to input information below.  
Contents of 'SLAB/PAVEMENT';

- Slab Material (Selection input with pull-down menu)
- Pavement (Selection input with pull-down menu)

Contents of 'ACCESSARY';

- Bearing (Yes or No) (Selection input)
- Expansion Joint (Yes or No) (Selection input)
- Bridge Railing (Yes or No) (Selection input)
- Attachment\* (Yes or No) (Selection input)

\*Attachment means lifeline (electric cable, communication cable, water supply, etc.)

Contents of 'SUPERSTRUCTURE';

- Material (Selection input with pull-down menu)
- Superstructure Type (Selection input with pull-down menu)
- Number of Girders per span (Manual input)
- Continuous (Yes or No) (Selection input)

13:57 89%

Riceplant\_Client

### Input screen 3

**SLAB/PAVEMENT**

Slab Material  Pavement

**ACCESSORY**

Bearing ☐ Yes ☐ No Expansion Joint ☐ Yes ☐ No

Bridge Railing ☐ Yes ☐ No Attachment ☐ Yes ☐ No

**SUPERSTRUCTURE**

Material  Superstructure Type

Number of Girders/Span  Continuous ☐ Yes ☐ No

Back Next

**Fig.4.2.6 Input screen3 (Fourth screen)**

iii) Input the information regarding Columns and Pier and Abutment

Screen image is shown in Fig.4.2.7. Firstly, photo must be taken from underside (**Photo 4.2.4**). It should be taken care to take a photo including deck slab and substructure. Then, red cell is a cell that needs to input information below.

Contents of ‘COLUMNS AND PIERS;

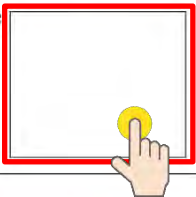
- Material (Selection input with pull-down menu)
- Structure Type (Selection input with pull-down menu)
- Size of Column/Pier (Manual input)
- Foundation Type (Selection input with pull-down menu)
- Number of Columns/Piers (Manual input)

Contents of “ABUTMENT”;

- Material (Selection input with pull-down menu)
- Structure Type (Selection input with pull-down menu)
- Foundation Type (Selection input with pull-down menu)
- Height (Manual input, Abutment 1 and Abutment 2)

13:57 Riceplant\_Client 89%

## Input screen 4

Underside 

**Tap this button**

COLUMNS AND PIERS					
Material			StructureType		
Size of Column/Pier	Rectangle		mm ×		mm
				Circle	φ
Foundation Type			Number of Column / Pier		
ABUTMENTS					
Material			StructureType		
Foundation Type		Height	A1		A2
			m		m

Back
Confirm

**Fig.4.2.7 Input screen4 (Fifth screen)**



**Photo 4.2.4 Underside of bridge**

Bridge inventory sheet with 4 photos is automatically created as shown in Fig.4.2.8.

Smart

10:27





67%

Riceplant\_Client

Bridge Inventory Sheet

Back

Delete this bridge data

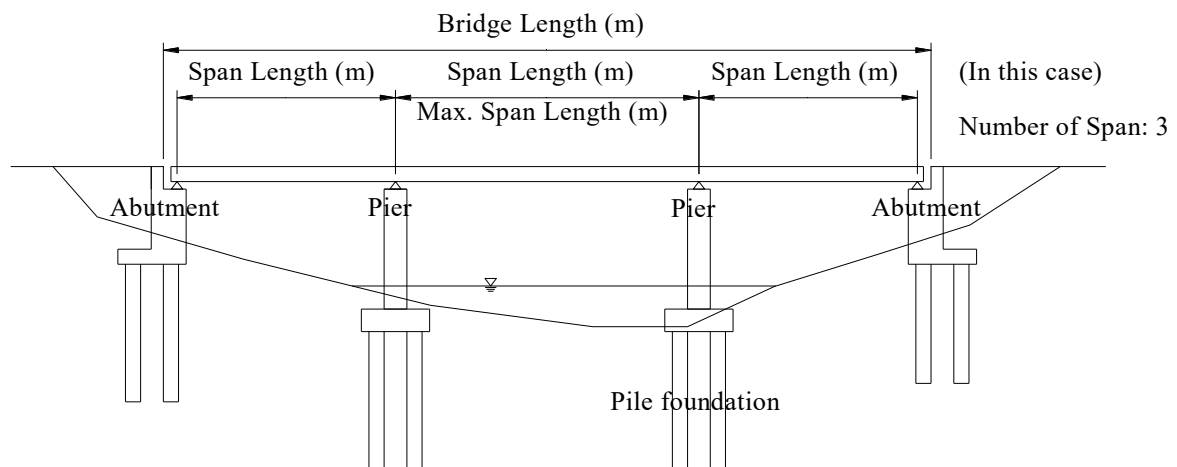
Fill in		2015/05/29	
Revised in		2015/05/29	
<b>A. GENERAL</b>			
Bridge Name		Road Category	
DPWT		Prov./City	
Road Name		Kp	km +
Location	Latitude	11.574191	Longitude
			104.922699
Bridge Length	m	Number of Span	Max. Span Length
			m
Left Sidewalk Width	m	Carriageway Width	Right Sidewalk Width
			m
Total Width (including Kerb)	m	Number of Lane	Constructed Year
Contractor		As_built drawings	Yes No
<b>B. SUPERSTRUCTURE</b>			
Material		Superstructure Type	
Number of Girders/Span		Continuous	Yes No
<b>C. SLAB/PAVEMENT</b>			
Slab Material		Pavement	
<b>D. ABUTMENTS</b>			
Material		StructureType	
Foundation Type		Height	A1 m A2 m
<b>E. COLUMNS AND PIERS</b>			
Material		StructureType	
Size of Column/Pier	Rectangle	mm × mm	Circle φ mm
Foundation Type		Number of Column / Pier	
<b>F. ACCESSARY</b>			
Bearing	Yes No	Expansion Joint	Yes No
Bridge Railing	Yes No	Attachment	Yes No
<b>G. PHOTO</b>			
			
			

Back

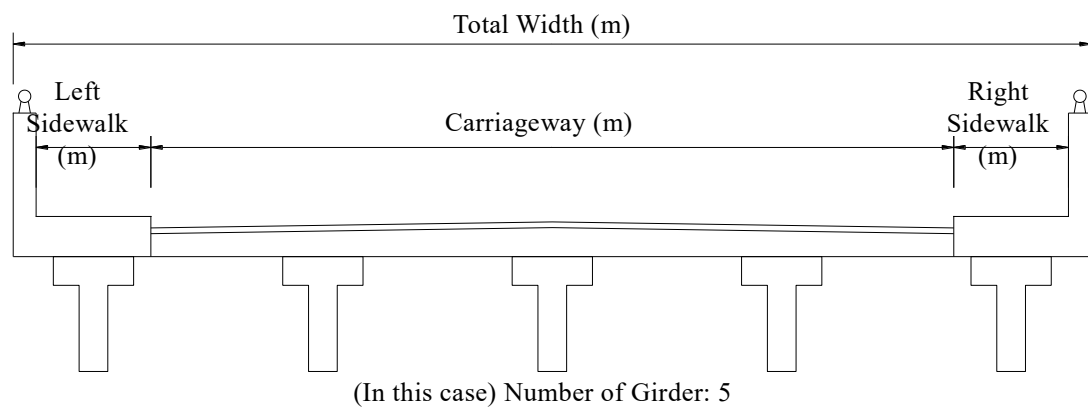
Fig.4.2.8 Bridge inventory data sheet

**\*Reference: Definition of each dimension**

**a) Each Length and Each Width**



**Fig. R4.1 Bridge Length**








**Fig. R4.2 Bridge Width**






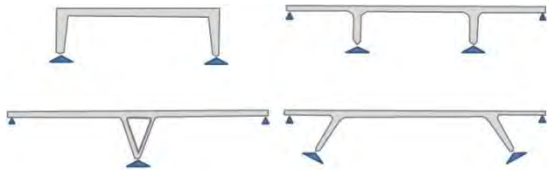




## b) Superstructure

Material for superstructure is selected from 5 items below.





(1) Concrete	(2) Steel
	
(3) Wooden	(4) Masonry
	
(5) Others	
 <p>Above bridge is a bridge for pedestrian which is made from Glass Fiber Reinforced Plastic.</p>	

As superstructure type in pull down menu is prepared 6 items below.





(1) Girder	(2) Slab girder
	
(3) Truss	(4) Arch
	
(5) Frame (Rigid Frame, No bearing on the pier)	
	
 <p>Other types of Rigid Frame</p>	
(6) Cable-stayed	(7) Others
	



As slab material in pull down menu is prepared 4 items below.





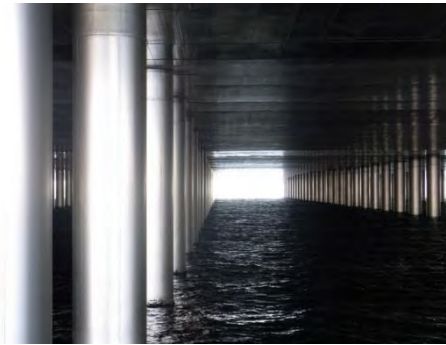
(1) Concrete	(2) Steel
	
(3) Wooden	(4) Others (If present)
	

As pavement type in pull down menu is prepared 4 items below.

(1) Asphalt Concrete	(2) DBST or SBST
	
(3) Concrete	(4) No pavement (Steel plate)
	

**c) Substructure (Abutment, and Column and Pier)**

As abutment material in pull down menu is prepared 5 items below.

(1) Concrete	(2) Steel
	
(3) Wooden	(4) Masonry
	
(5) Others (If present)	
 <p>These piers are made of titanium.</p>	







As structure type of pier in pull down menu is prepared 4 items below.

(1) Wall Type		
		
(2) Single Column		
		
(3) Multi Columns		
		
(4) Others		
		

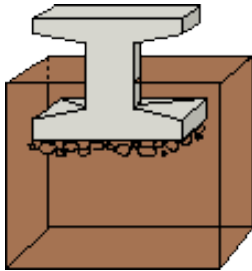
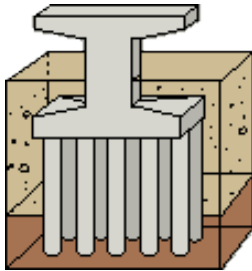
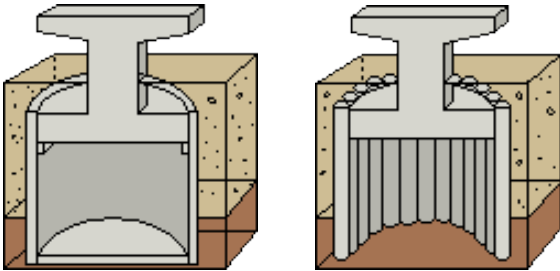


As structure type of abutment in pull down menu is prepared 4 items below.

(1) Full-Retaining ( $h > 5\text{m}$ )	(2) Semi-Retaining ( $h < 5\text{m}$ )
	
(3) Spill Through (Open)	(4) Others
	 <p data-bbox="791 1137 1283 1279">There is a bridge without abutment mainly in case of wooden bridge and masonry bridge.</p>









#### d) Foundation

As structure type of foundation of abutment and pier in pull down menu is prepared 4 items below. But, it is difficult to find bridge foundation after construction. So, when it is difficult to estimate bridge foundation type in consideration around bridge, "(4) unknown" should be selected.

(1) Spread Foundation	(2) Pile Foundation
	
(3) Others	(4) Unknown
	

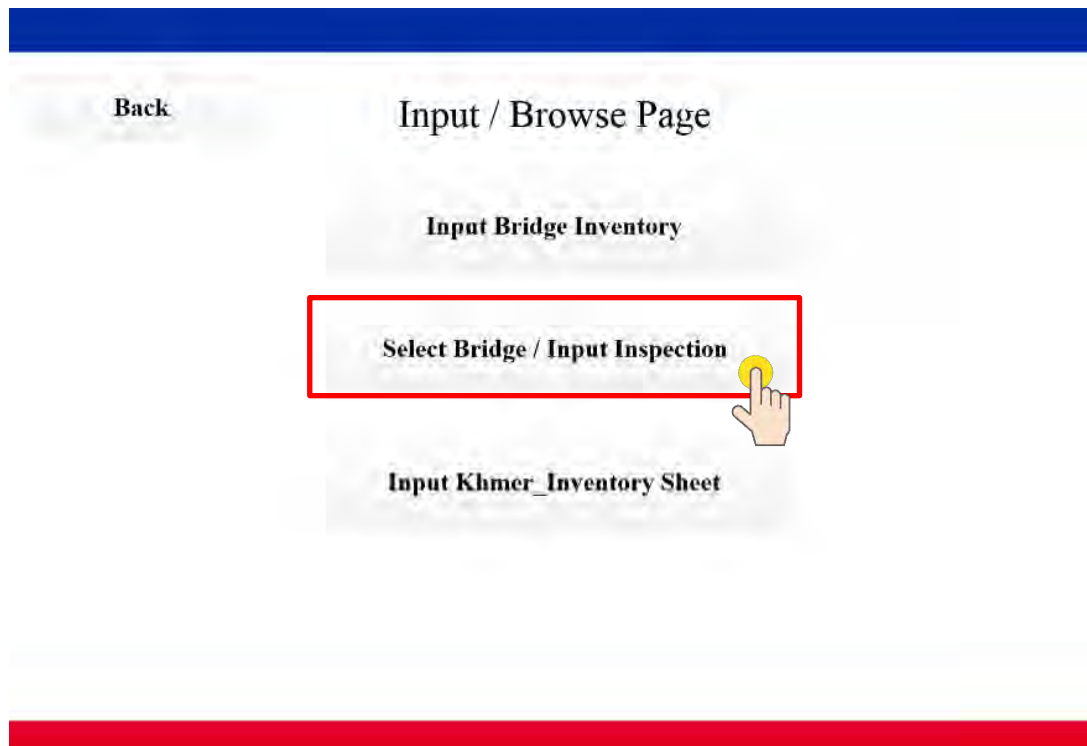
### e) Accessories

As bridge accessories, it should be checked that 4 items below is existed or not.

(1) Bearing	(2) Expansion Joint
 	 
(3) Bridge Railing	(4) Attachment
 	  <p data-bbox="810 1966 1316 2060">Ex) Electric Cable, Water supply line, Communication Cable, etc.</p>

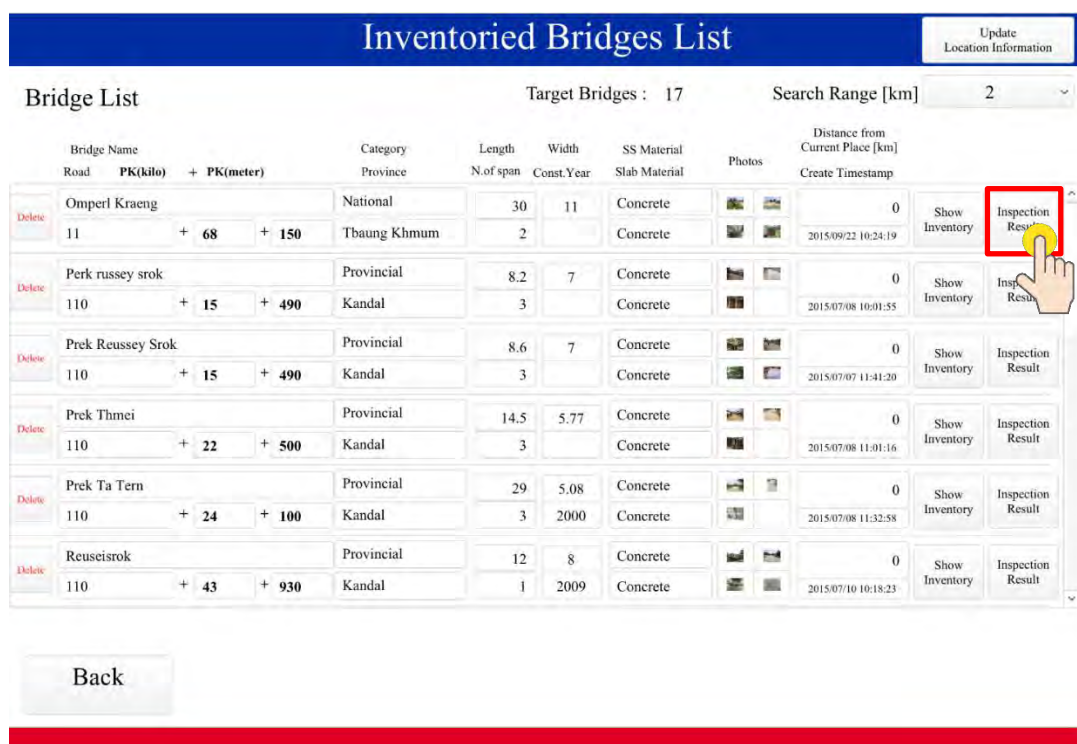
### (c) Record Bridge Inspection

After preparation of bridge inventory data, next step is to start bridge inspection work. Tap the button of “Select Bridge/Input Inspection”.



**Fig.4.2.9 To start bridge inspection work**

After that, Bridge List is displayed (Fig.4.2.10). Find the bridge to be started inspection and tap the button “Inspection Result”.



**Fig.4.2.10 Bridge List**



After selection of bridge, inspection data carried out in the past is displayed. When tap the button of “Show Inspection Sheet”, result in detail can be browsed. There are 3 kinds of inspection sheet in the database system.

Inspection Data List

Inspection List  
Bridge Name : Omperl Kraeng

Bridge Inspection   Detailed Inspection   Bridge Inspection\_2016ver.

New Inspection

	Road Surface	Superstructure steel   concrete   wood	Slab steel   RC   wood	Sub-structure Bearing	Damage Rank	Create Timestamp
Omperl Kraeng					N	2015/09/22 10:32:10
Omperl Kraeng					N	2017/06/07 9:23:03

Back   Go to CoverPage

**Fig.4.2.11 Inspection result carried out in the past**

- “Bridge Inspection” is 1<sup>st</sup> inspection format that was carried out in 2015. The result of 173 bridges survey carried out in beginning of 2017 also is stored in this sheet.
- “Detailed Inspection” is for Maintenance Operating Meeting.
- “Bridge Inspection\_2016ver.” is the latest inspection format for periodic inspection. Periodic bridge inspection work shall be based on this form since 2017.

When start the inspection newly since 2017, tap the button of “Bridge Inspection\_2016ver.”, next tap the button of “New Inspection 2016ver.” (Fig.4.2.12). And, inspection item will be displayed.

Inspection method is selection method (Fig.4.2.13). If no damage, tap the blue button of “No Damage”, and the screen of iPad will be shifted for the next inspection item. If damage is found, tap the red button of “Damaged”, and the screen will change to record photos and/or abnormal sound (Fig.4.2.14). Two photos/sound data can be recorded per one inspection item. After recording photos/sounds, check damage level. And then, tap the button of “Next”. Repeat this work to the end.



## Inspection Data List

Inspection List

Bridge Name : Omperl Kraeng

Bridge Inspection\_2016ver.

New Inspection 2016ver.

Road Surface

Superstructure concrete wood

Bailey Bridge

Slab RC wood

Bearing

Sub-structure

Damage Rank

Create Timestamp

Omperl Kraeng

N

2017/06/24 9:27

Show Inspection Sheet

Back

Go to CoverPage

**Fig.4.2.12 Start inspection work**

Bridge Name Omperl Kraeng

SS\_Material Concrete

SlabMaterial Concrete

SS\_Type Girder

Road Surface

1 Bridge Railing/Guardrail/Curb Damage

橋面  
橋欄/防護欄/地護  
損傷

No Damage

Damaged

Back

Inspection item

**Fig.4.2.13 Inspection item and selection method**

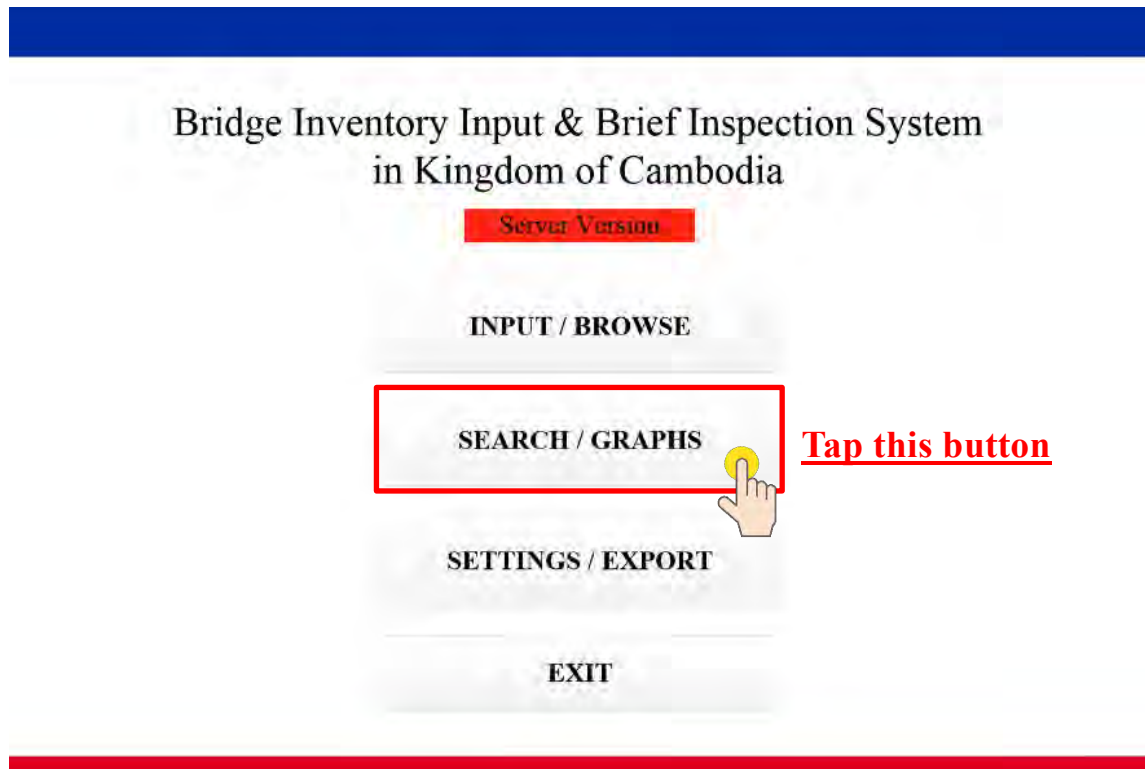


#### (d) Search by Specifying Conditions

In the following cases, search with specified conditions is convenient.

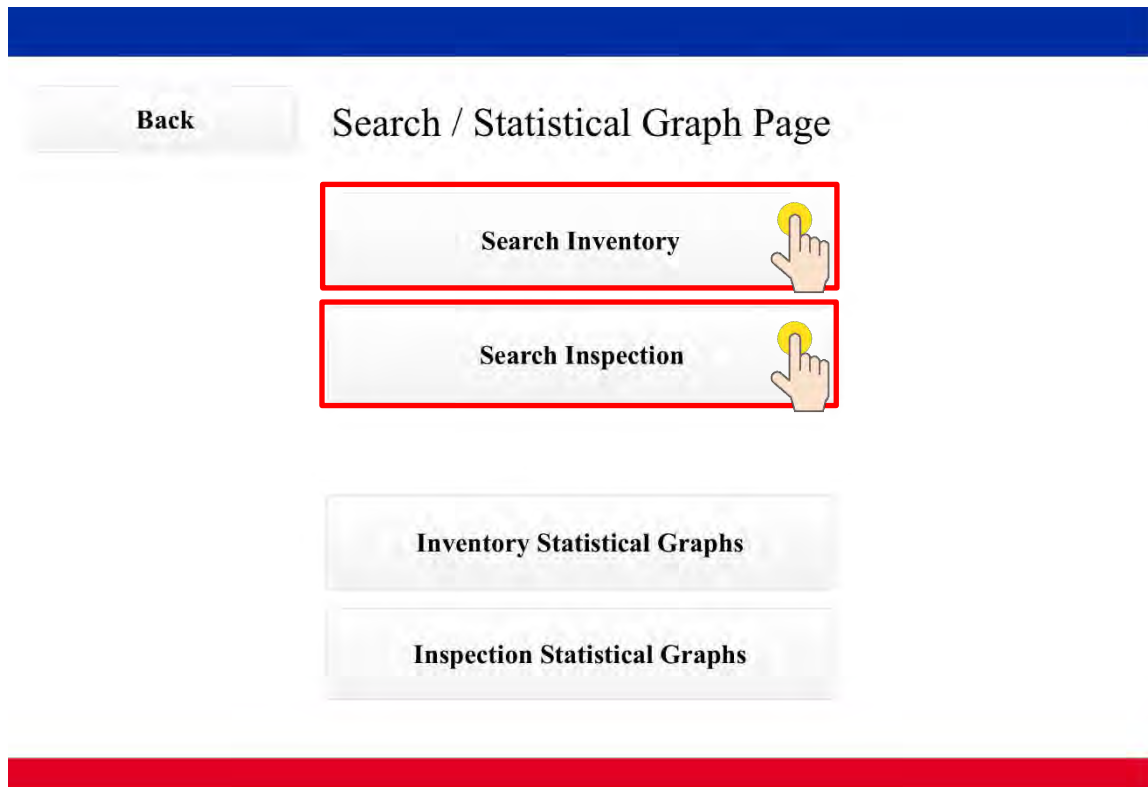
- To browse inventory data of a specific bridge
- To browse inspection data judged “SD” bridge
- To browse inspection data of the bridge with serious damage on superstructure
- Etc.

Tap the button of “SEARCH/GRAPHS” (Fig.4.2.15).



**Fig.4.2.15 Top screen of the database system**

And, the screen (Fig.4.2.16) will be displayed.



**Fig.4.2.16 To search a bridge inventory data by specifying conditions**

a) To search the bridge inventory data by specifying condition

To see bridge inventory data, tap the button of “Search Inventory” (Fig.4.2.16). Then, the screen of Fig.4.2.17 will be displayed.

When you want to see the bridge inventory data in Kandal province, select “Kandal” in the cell of “Province”, and tap the button of “Search”. Then, bridge list in Kandal will be displayed. It is possible to search under other condition in the same way.

## Search Bridge Inventory

[Back](#)

Search bridges that constructed in year 2000 and before  
Search bridges that length is longer than 50m

→ Input "< 2000" to "Constructed Year" field  
→ Input "> 50" to "Bridge Length" field

A. GENERAL										
Bridge Name	<input type="text"/>				Road Category	<input type="radio"/> National <input type="radio"/> Provincial				
Province	<input type="text"/>				Village/Commune	<input type="text"/>				
Road Name	<input type="text"/>	PK	<input type="text"/>	<input type="text"/>	PK Range	<input type="text"/>		Range	<input type="text"/>	
Location	Latitude	<input type="text"/>	<input type="text"/>		Longitude	<input type="text"/>				
Bridge Length	<input type="text"/>	m	Number of Span	<input type="text"/>	Max. Span Length	<input type="text"/>	m			
Left Sidewalk Width	<input type="text"/>	m	Carriageway Width	<input type="text"/>	m	Right Sidewalk Width	<input type="text"/>	m		
Total Width (including Curb)	<input type="text"/>	m	Number of Lane	<input type="text"/>	Constructed Year	<input type="text"/>				
Contractor	<input type="text"/>				As_built drawings	<input type="radio"/> Yes <input type="radio"/> No				
B. SUPERSTRUCTURE										
Material	<input type="text"/>				Superstructure Type	<input type="text"/>				
Number of Girders/Span	<input type="text"/>	<input type="text"/>			Continuous	<input type="radio"/> Yes <input type="radio"/> No				
C. SLAB/PAVEMENT										
Slab Material	<input type="text"/>				Pavement	<input type="text"/>				
D. ABUTMENTS										
Material	<input type="text"/>				StructureType	<input type="text"/>				
Foundation Type	<input type="text"/>				Height	A1	<input type="text"/>	m	A2	<input type="text"/>
E. COLUMNS AND PIERS										
Material	<input type="text"/>				StructureType	<input type="text"/>				
Size of Column/Pier	Rectangle	<input type="text"/>	mm ×	<input type="text"/>	mm	Circle	φ	<input type="text"/>	mm	
Foundation Type	<input type="text"/>				Number of Column / Pier	<input type="text"/>				
F. ACCESSORY										
Bearing	<input type="radio"/> Yes <input type="radio"/> No				Expansion Joint	<input type="radio"/> Yes <input type="radio"/> No				
Bridge Railing	<input type="radio"/> Yes <input type="radio"/> No				Attachment	<input type="radio"/> Yes <input type="radio"/> No				

Search

**Fig.4.2.17 To search a bridge inventory data by specifying conditions**

b) To search the SD bridge data

To see SD bridge data, tap the button of “Search Inspection” (Fig.4.2.16). Then, the screen of Fig.4.2.18 will be displayed.

Select “SD” in the cell in bridge soundness, and tap the button of “Search”. Then bridge list judged SD will be displayed.

Bridge Name: 

III : Urgent
II : Observation
I : Unnecessary

Back

				Score	Level
Road Surface	Pavement	Unevenness / Pot hole / Rutting / Crack	No Damage    Damaged	Q	I II III
			Unevenness / Pot hole		
			Rutting		
	Bridge Railing / Guardrail / Curb	Damage	No Damage    Damaged	Q	I II III
			Small damage (Lacking and/or Deformation)		
			Big damage (Partially collapse)		
	Expansion Joint	Step	No Damage    Damaged	Q	I II III
			Step under 20mm		
			Step over 20mm		
		Deformation / Damage	No Damage    Damaged		
			Abnormal expansion gap		
		Abnormal Sound	No Damage    Damaged		
	Abnormal sound				
	Drainage system	Clog of drainage pipe	No Damage    Damaged	Q	I II III
Partly no function					
Almost no function					
Underside	Superstructure (Steel)	Corrosion / Rust	No Damage    Damaged    Invisible	Q	I II III
			Corrosion on steel member		
			Steel member thickness is thinning		
		Crack, Deformation, Loss, Break	No Damage    Damaged    Invisible		
			Crack on steel member		
			Steel member deformation		
		Missing bolt	No Damage    Damaged    Invisible		
			Bolt is missing less than 10%		
			Bolt is missing more than 10%		
	Superstructure (Concrete)	Crack	No Damage    Damaged    Invisible	Q	I II III
			Crack on undersurface		
			Crack on side		
			Rust fluid from crack		
		Honeycomb / Flaking / Exposure of rebar	No Damage    Damaged    Invisible		
			Honeycomb		
			Lacking and/or Flaking concrete		
			Exposure of rebar		
			Rebar thinning		
	Superstructure (Wooden)	Rotting	No Damage    Damaged    Invisible	Q	I II III
			Rot of wood		
			Reduction of cross section		
	Crack / Damage	No Damage    Damaged    Invisible			
		Big damage / Impassable			
	Slab (Steel)	Corrosion / Crack	No Damage    Damaged    Invisible	Q	I II III
			Corrosion and/or Rust on steel member		
			Crack		
	Slab (Concrete)	Crack / Hole	No Damage    Damaged    Invisible	Q	I II III
			Crack on undersurface		
			Free lime		
			Rust fluid from crack		
		Honeycomb / Flaking / Exposure of rebar	No Damage    Damaged    Invisible		
			Honeycomb		
			Flaking and/or Lacking concrete		
			Exposure of rebar		
			Rebar thinning		
	Slab (Wooden)	Rotting	No Damage    Damaged    Invisible	Q	I II III
			Rot of wood		
			Reduction of cross section		
		Crack/Damage	No Damage    Damaged    Invisible		
			Big damage / Impassable		
	Vibration, Abnormal Sound	No Damage    Damaged    Invisible			
		Vibration and/or Abnormal sound at travelling			
Bearing	Sedimentation / Damage	No Damage    Damaged    Invisible	Q	I II III	
		Sedimentation			
		Corrosion and/or damage			
		No function			
Substructure (Pier/ Abutment)	Scouring / Settlement	No Damage    Damaged    Invisible	Q	I II III	
		Scouring around substructure			
		Settlement of substructure			
	Crack	No Damage    Damaged    Invisible			
		Crack			
		Free lime			
	Peeling / Flaking / Honeycomb	No Damage    Damaged    Invisible			
		Honeycomb			
		Flaking and/or Lacking concrete			
		Exposure of rebar			
		Rebar thinning			

Search

D
O

SD
N

Select "SD"

**Fig.4.2.18 To search a bridge inspection data by specifying conditions**



c) To search the bridges with serious damage on superstructure

To see the data of bridges with serious damage on superstructure, tap the button of “Search Inspection” (Fig.4.2.16). Then, the screen of Fig.4.2.18 will be displayed.

Select “III” in the cell of Level of Superstructure (Concrete). And tap the button of “Search”. Then the list of bridges with serious damage on superstructure will be displayed.

## **CHAPTER 5. NON-DESTRUCTIVE TESTING**

### **5.1 Outline**

Once a bridge has been inspected for its overall condition, it is necessary to carry out Non-Destructive Tests (NDT) in order to further refine the diagnostic process if the overall condition is poor or bad and if it is suspected that the bridge has been weakened in some way. Non-destructive testing in this context means that the structure is not destroyed though parts of it may be taken away for testing or inspection.

NDT are normally conducted to determine:

- The physical quality of the materials; and
- The position and extent of hidden defects, elements and material boundaries.

NDT are carried out in-situ to provide further information from which an improved diagnosis can be made to enable the bridge engineer to make decisions on the necessary remedial work.

## 5.2 Non–Destructive Tests

### 5.2.1 Types of Non–Destructive Tests

There are several types of Non–Destructive Tests. This manual describes some tests using.

<b>For Concrete Attributes</b>
N01 Rebound Hammer Test
N02 Carbonation Depth Measurement Test
N03 Ultrasonic Pulse Velocity Test
N04 Half–Cell Electrical Potential Test
N05 Rebar Detection Test
N05–01 Magnetic Type (For Superstructure)
N05–02 Radar Type (For Substructure)
N06 Infrared Thermal Image Test
N07 Compressive Strength Test
<b>For Steel Attributes</b>
N08 Paint Thickness Test
N09 Metal Thickness Test
N10 Magnetic Particle Testing
N11 Eddy Current Testing
<b>Special NDT</b>
S01 Ultrasonic Flaw Detection Test (For Cracks of Steel)
S02 Static Load Carrying Test
S03 Dynamic Load Carrying Test
S04 Ambient Vibration Test (For Superstructure)
S05 Impact Vibration Test (For Substructure)
S06 SONAR Test (For Scouring)
S07 Impact Echo Test (For PC structure)
S08 X Ray Test (For PC structure)
S09 In–Situ Stress Measurement Test (For PC Structure)

It should be pointed out that Special NDT of bridges may be costly in many cases but in general, their cost is insignificant compared to the construction of a new bridge. There are a great number of situations when the test results verify the negative results of calculations and the old bridge may be utilized without any or with only a few limitations without its replacement being necessary.

Special NDT can also show the parts of the structure required to be repaired or strengthened. Moreover, Special NDT usually provide information otherwise not obtainable e.g., concerning reduction of statistical uncertainties, ultimate load, deflection, vibration serviceability, data for fatigue analysis.

### **5.2.2 Reliability of NDT**

Concrete strength, rebar status, painting conditions, etc. on existing bridges and other structures can be checked by NDT.

NDT result may not always be perfect. There is a possibility that the accuracy of NDT outcome could differ depending on the degree of compliance of the prescribed preparatory works and the technical operation of the NDT apparatus. NDT operator has to undergo proper training.

The result therefore of NDT has to be sufficiently evaluated by the Engineer from the objective and technical point of view.

## 5.3 NDT for Concrete Attributes

### 5.3.1 Rebound Hammer Test

#### 5.3.1.1 Fundamental Principles

The test method is based on the principle that the rebound of an elastic mass (the hammer piston or impact plunger) depends on the hardness of the material it strikes, and the assumptions that (a) the hardness is proportional to the materials strength and (b) the material is homogenous.

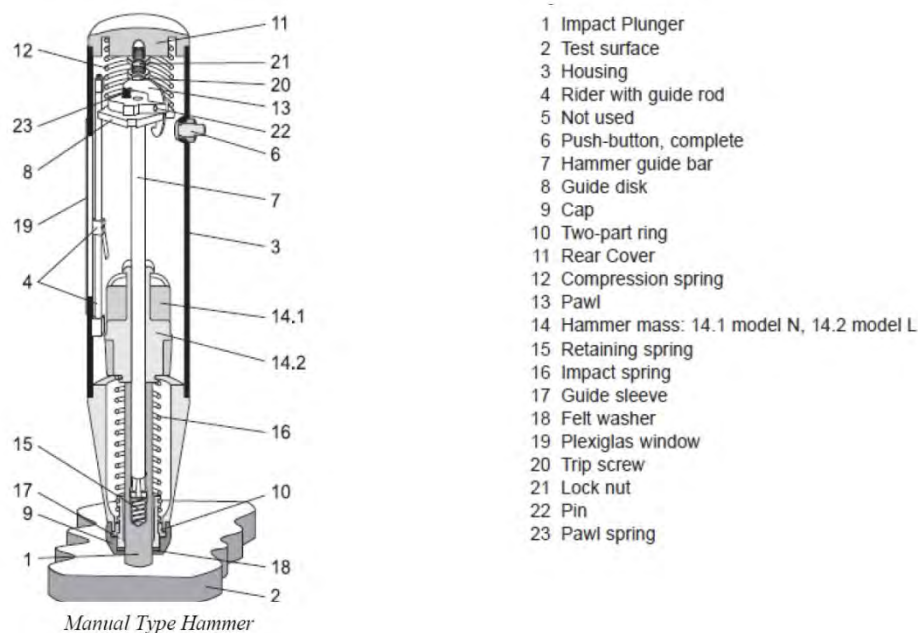
Rebound hammer test can only assess the compressive strength of the near surface layer of concrete in the zone of influence of hammer impact. It is useful in finding weak areas in concrete in a structure.

#### 5.3.1.2 Description of Apparatus

Typical of Concrete Test Hammers is shown in **Fig5.3.1.1**



**Fig 5.3.1.1 Typical Concrete Test Hammers**



**Fig 5.3.1.2 Mechanical Parts of a Concrete Test Hammer**

### **(a) Manual Type Concrete Test Hammer**

#### Description:

- 1 unit manual concrete test hammer (wt. – 1.7kg)
- 1 unit grinding stone
- 1 unit carrying case: 325 x 125 x 140mm

#### Specifications:

- Impact energy: 2.207 Nm or 2.207 Joules
- Measuring range: 10 to 70 Nm/mm<sup>2</sup> compressive strength

### **(b) Digital Type Concrete Test Hammer**

#### Description:

- 1 unit electronic concrete test hammer, battery operated, with alpha-numerical display 2x16 characters, keypad with 5 keys and connectors.
- 1 unit battery charger with lead
- 1 unit serial cable for connection of PC
- 1 unit grinding stone

#### Specifications:

- Impact energy: 2.207 Nm or 2.207 Joules
- Measuring range: 10 to 70 Nm/mm<sup>2</sup> compressive strength
- Dimensions: dia. 54x360 mm long
- Signal conditioning unit for linear potentiometric transducer
- Processor: 16 bit
- Memory ROM: 32 Kbyte
- Memory RAM: 32 Kbyte
- Memory Backup RAM: 16 Kbyte
- A/D resolution: 12 bit
- Accuracy rebound hammer reading: 12 bit
- Accuracy:  $\pm 1$  digit
- Standard RS232 Serial output (9600 baud, 8 data bit, 1 stop bit, no parity)

### **5.3.1.3 Procedures**

Explained below are general procedures when using rebound hammer.

#### **(a) Gather Reference Information on Structure**

Before testing, determine the following information on the structure to be tested:

- Design compressive strength



- Age of concrete (reckoned from date of construction)
- Concrete mix proportions

### (b) Set-up of Apparatus

After taking out the test hammer from the carrying case, press the plunger head until it is released. Check surface of plunger, and remove any dust or oil with cotton cloth to avoid scratching the surface.

Calibration of the rebound hammer is necessary for its proper operation. A steel anvil is used for verification. Refer to the manufacturer's instruction manual.

### (c) Preparation of Test Surface

If necessary, grout or plaster that covers the concrete surface should be ground smooth with abrasive stone.

Avoid testing near joints and areas exhibiting honeycomb, scaling and high porosity. In cases where carbonation is present or suspected, the surface layer maybe removed using power grinder to obtain rebound numbers representative of the interior concrete.

Try to avoid tests directly on top of bars. Where possible, use a cover meter to locate bars close to the surface before taking a test or setting out a grid for a number of tests.

Where tests are required on concrete members less than 100mm thick, members should be rigidly supported.

The number of test points shall be determined in the field. Minimum spacing between test points shall be 150 mm.

### (d) Testing

#### 1) Draw Grid on Concrete Surface to be tested

See test point example pattern below.

	A	B	C	D
1	25mm	25mm		
2	25mm			
3				
4				
5				

**Fig 5.3.1.3 Example of Testing Grid**

## 2) Take Measurements

At Cell A1 (**Fig5.3.1.3**):

- a) Rest the plunger head at right angles to the concrete surface
- b) Press the hammer until it strikes the surface  
(Note: Do not press push-button under any circumstances when taking readings)
- c) The hammer rebounds moving a reference pointer with it
- d) By pushing the button, the pointer is held at its maximum position. Record the reading
- e) Repeat procedures for next measurements until a total of 20 readings (Cells A1 to D5) are taken.



**Photo5.3.1.1 Testing Position-Mannal Type Concrete Test Hammer**

The hammer can be used to test surfaces at any inclination but only readings at the same inclination (horizontal, up, down, etc.) shall be compared. Test inclination shall be recorded on the test sheet.

## 3) Test Points

Conduct tests at three test points at each bridge element/attribute (Deck, Girder, Pier and Abutment). If rebound hammer test is conducted in conjunction with compressive strength test, the test result may be used as reference.

### 5.3.1.4 Operation and Analysis of Measurements – Manual Type Concrete Test Hammer

#### a) Operation

The operation of manual type concrete test hammer is explained in **5.3.1.3**.

#### b) Rebound Value and Cube Compressive Strength

The 'R' values of rebound have been defined in such a way that they can be converted, by means of diagrams, in terms of resistance to compression for tests carried out on a cube or cylinder. In the diagram below, 5 different curves have been reproduced for cube compressive strength, which take into account the angle of inclination of the hammer. The curves take into account the effect of gravity acting upon the impact shock. Thus the test can be carried out on floors, walls, ceilings and any other inclined surface.

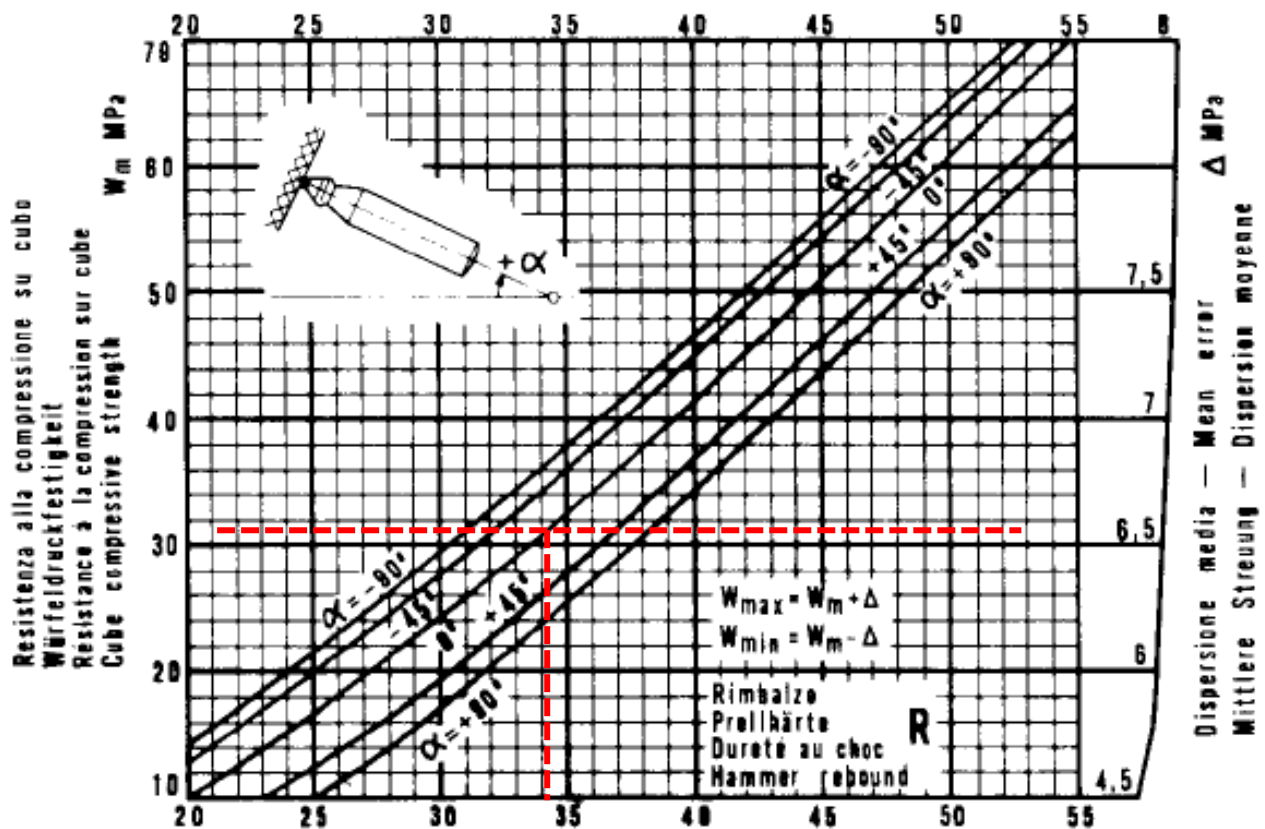


Fig 5.3.1.4 Rebound Value and Cube Compressive Strength Chart

### c) Cube Compressive Strength

In the example above,  $R = 34$  is the mean or average of 20 readings taken from the test of a vertical wall (angle of inclination  $\alpha = 0^\circ$ ). Projecting a vertical line at  $R = 34$  until it intersects the graph of  $\alpha = 0^\circ$  inclination, the resulting mean compressive strength,  $f_{c\text{mean}} (W_m)$  and  $\Delta$  (mean error) are obtained.

$$R = 34$$

$$f_{c\text{mean}} (W_m) = 31 \text{ MPa}$$

$$\Delta = 6.55 \text{ MPa}$$

$$f_{c\text{max}} = 31 + 6.55 = 37.55 \text{ MPa}$$

$$f_{c\text{min}} = 31 - 6.55 = 24.45 \text{ MPa}$$

### d) Cylinder Compressive Strength

Cylinder strength is 15% lower than that of relative cube strength. Above values are converted to cylinder strength as follows:

$$f_{c\text{mean}} (W_m) = 31 \times 0.85 = 26.35 \text{ MPa}$$

$$f_{c\text{max}} = 37.55 \times 0.85 = 31.92 \text{ MPa}$$

$$f_{c\text{min}} = 24.45 \times 0.85 = 20.78 \text{ MPa}$$

### e) Influence of Age of Concrete on Compressive Strength

The strength of concrete decreases as it ages. The time factor applied in calculating the compressive strength of the structure at the time of inspection that can be applied as follows:

**Table 5.3.1–1 Time Factor for Calculation of Compressive Strength**

Age (Days)	Time Factor ( $\alpha$ )
10	1.55
20	1.15
28	1.00
50	0.87
100	0.78
150	0.74
200	0.72
300	0.70
500	0.67
1000	0.65
3000	0.63
10000	0.57
20000	0.41

Example: If age of concrete is 20,000 days (54.8 years);

$$F_{c \text{ mean or } W_m} (20,000 \text{ days}) = 26.35 \times 0.041 = 10.80 \text{ MPa}$$

### 5.3.1.5 Operation and Analysis of Measurements – Digital Type Test Hammer

#### a) Introduction

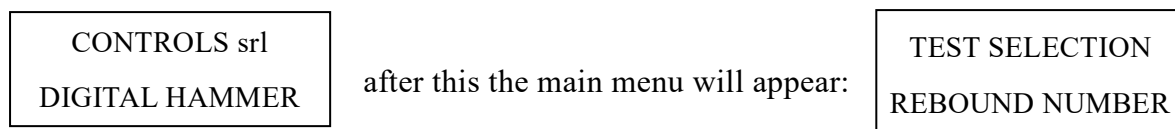
After extensive testing, research and development aimed at improving the accuracy and reliability of the results, manufacturers like CONTROLS have developed new digital test hammers managed by a microprocessor which can store up to 6000 readings and download these to a printer or PC through a RS232 Serial Port. The integrated Software offers the following options:

- Input via keyboard of number relative to the group of tests to be made (00 to 299) each of which can contain up to 20 tests.
- Selection of input angle (0, +90°, –90°, +45°, –45°).

- Display of present reading (rebound index) and relative compressive strength estimate.
- Selection of measurement unit of compressive strength (kg/cm<sup>2</sup>, MPa, Psi, N/mm<sup>2</sup>).
- 7 correlation curves rebound index/compressive strength (2 pre-set and 5 to be inserted by operator).
- Coefficients relative to age of concrete result to be obtained (cube or cylinder resistance) and operator experience allows the user to make corrections for errors related to the concrete under examination.
- Automatic processing of test results: calculation of the average value and standard deviation and verification of the significant of the readings.
- Real time display of all results
- Storage of all data and test results organized in groups which are also associated to the data and time of storage.
- Display, printing a selective cancellation and transfer to PC (via RS232 Serial Port) of stored data.
- Time-out for automatic switch-off of instrument after approx. 6 minutes from last operation.
- Easy calibration procedure.

## b) Operation

Before proceeding to take measurements, the impact rod is placed in its rest position while releasing the hammer by applying pressure to the impact rod. For the test procedure, please refer to **5.3.1.4**. To switch on the instruments, press key "MODE I/O". The same key is used to switch off the instrument (keep pressed for at least 3 seconds). When switching off the instrument, release the "MODE I/O" key when the message "SWITCHING OFF" appears on the display. In any case the instrument will switch-off automatically if no operation is made for approx. 6 minutes after switching on the instrument, for a few seconds the display will show the message:



at this point the following selections can be made:

- REBOUND NUMBER is the test menu which allows testing and storage and processing of results.
- CALIBRATION is the calibration menu of the instrument.
- MEMORY/RS232 is the menu which allows access to stored tests so as to display the



results, download them via the serial port and delete them.

- SET CURVE is the menu which allows the operator to define a correlation curve based on his needs and experimental experience.

Select the desired function using the ‘\_’ and ‘^’ keys. Press ENTER to confirm the selection.

The desired function will flash on the display for a few seconds before becoming active.

### c) Rebound Number

Upon selection of this function the display will show:

Test XXX	Ang. YY
M= NEXT	ent = --->

Test ‘XXX’: XXX indicates the numerical code which identifies the group of readings in which the test results will be stored. The instrument has a memory which can store 299 test Areas, each of which can contain up to 20 rebound tests and all the test parameters relative to that group of readings. Thus the group refers to a memory cell identified by the assigned number. To input this number use the ‘-’ key to change the digit on which the cursor is positioned, and the ‘^’ to move from one digit to another.

Once the desired test has been selected press ENTER to move to the next field. ‘ANGLE YY’ which is the impact angle. Use the ‘-’ and ‘^’ keys to select an angle of +90°, +45°, 0°, -45° or -90° (+90° means hammer is vertically upwards, 0° horizontal and -90° downwards, the other values are intermediate).

Press ‘ENTER’ if you wish to return to ‘Test’. Press ‘MODE’ to move onto the next step. If the selected ‘test’ has already been used or contains data that has not been deleted, the following message appears:

AREA FULL
-----------

followed by:

OVERWRITE ?
Mode= NO ent=YES

Whereby the operator is advised of the presence of data in the test area and can overwrite and cancel such data (ent=YES) or select another test (mode= NO). The next display shows:

Test XXX	Ang. YY
M= NEXT	ent = --->

By pressing MODE it is possible to access the SET parameters menus which are as follows:

- AVERAGE: two selections are possible in the way the average is calculated: M1 calculates

the average of all the recorded readings; M2 discards the highest and lowest readings and calculates the average of the remaining readings.

- UNIT: allows the setting of the measurement unit in MPa, kg/cm<sup>2</sup>, psi and N/mm<sup>2</sup>. The compressive resistance is estimated by correlation with experimental tests and therefore is only an indicative value. A more accurate estimate can be made by plotting the characteristic correlation curve of the concrete being investigated with a series of destructive and non-destructive (rebound hammer) test on suitably selected samples.
- TIME FACTOR: is the proportional multiple time factor used in the calculation of the resistance to take into account of the age of the concrete. This is initially set as 1. **Table 5.3.1.1** suggests some factors that have been obtained by experimentation. They are offered as a guide and are not binding. It is possible, for the operator to establish his own time factors.
- CORRECTION FACTOR: is the proportional multiple factor used in the calculation of the resistance to take into account external factors such as humidity which could affect the readings. This is initially set as 1. The use of this factor is left to the discretion of the operator based on local experience. The factor can be set at a value between 0.10 and 1.99.
- TYPE: indicates the type of sample: Cube or Cylinder in which to express the readings in.
- CURVE: it is possible to select one of the correction curves, 7d or 28d and if inserted UD1, UD2, UD3, UD4 and UD5 which are the five personalized User Defined correlation curves.

To make selection use the ‘\_\_’ key to verify the displayed value and ‘←’ key to move from one figure to another. ENTER allows access to the successive selection whilst ‘ESC’ exits from the setting menu. Once the parameters have been set, the display will once again show:

Test XXX	Ang. YY
m= SE	ent = TEST

Then press ENTER to start a series of readings. The display will show:

Reb. XX.X	n. Y
S=****	Rm=**** ZZ

where:

XX.X is the rebound value of the last test made. When the instrument is in stand by the parameter is shown by ‘\_\_.’.

Y is the number of tests made within a group. This number is updated as the testing is performed.

S is the standard deviation of the readings. These parameters are calculated and displayed from the seventh measurement and above.

Rm is the mean rebound index calculated in basis of the selected mean. This parameter is calculated and displayed from the seventh measurement and above.

**Important:**

If the impact rod is not in its rest position when the instrument is switched on it will immediate register a reading which will correspond to the last reading made with the hammer.

Next make a reading with the hammer placed on the surface of concrete as described in **5.3.1.4**.

It should be noted that at least 9 readings should be made in test area so as to obtain reliable results.

The display is updated upon each hammer reading. The reading is updated when the impact rod is in its rest position.

As stated previously, the standard deviation and mean are only calculated from the seventh reading and above. The rebound readings (max. 20) and test parameters are memorized in the "test" and makes the calculations. This is also possible by pressing ESC before reaching 20 readings.



**Photo 5.3.1.2 Testing Position**

**Digital Test Hammer**

The screen will show:

**\*\*TEST RESULTS\*\***

followed by:

S=CCCC Rm=DDDD  
S=AAAA BBB

where:

AAAA is the compressive strength estimated as described above and in accordance with the pre-set parameters.

BBBB is the measuring unit of the compressive strength.

CCCC is the standard deviation of the readings.

DDDD is the mean rebound calculated as basis of the preset method.

The results remain displayed until the "ENTER" key is pressed and the following screen appears:

By pressing the mode key, the data is transmitted to the RS232 serial port (see chapter relative to RS232 port).

Test. XXX	Ang. YY
m= RS232	ent = END

Press ENTER to save all the readings made in that "test". The instrument will automatically increase the test number and is thus ready for the next set of readings.

### Error Messages

When the results are shown, one of the following error messages may appear:

- NO DATA!!! = no reading has been made
- NOT ENOUGH DATA!!! = less than 9 readings have been made
- OFF STANDARD!!! = where at least 20% of readings vary from the average by 6 or more units. In this case the International Standards indicate that the readings should be discarded and the test repeated. In any case the readings are stored along with the error message but the test data is not explained.

### d) Calibration function

This function is used to check, and if necessary adjust the calibration of the test hammer. The display will show:

Rebound n. XX.X
-----------------

Before proceeding, place the impact rod in its rest position by releasing the hammer by pressing on the rod itself. The display shows the rebound number. When one impact is made the display is updated and maintained until the hammer is released. By making tests on a reference sample (e.g. calibration anvil) it is possible to check the calibration of the hammer.

If the reading differs by a significant amount from the reference value ( $\pm 2.0$  units) it is possible to adjust the readings so as to bring them to within the limits. This is done with by adjusting the trimmer situated on the rear of the instrument. To access the trimmer the black plastic cover must be removed.

The adjustment is made as follows: make one rebound reading on the calibration anvil and block the release mechanism by pushing the button on the hammer itself. Check the rebound index number shown on the display and adjust it with the trimmer until the reference value appears. Make further tests and adjustments until the hammer is calibrated. Press ESC to exit the calibration function.

### e) Memory / RS 232 Function

The instrument has a memory for up to 299 Test Areas. Using the memory / RS232 menu it is possible to access all the data present in the memory, display them on the screen and download them to a PC through a RS 232 Serial Port. When this menu is accessed the screen shows:

MEMORY/RS232 Sel. Test: XXX
--------------------------------

XXX is the selected test from which it is possible, following the instructions given below, to display all the stored data with relative results and/or download them to a PC through the RS232 Serial Port. The test area can be selected using the '←' and '→' keys. The 'ESC' key is used to return to the previous menu. To confirm the desired test area, press 'ENTER', the screen will show:

TEST AREA: XX Download
---------------------------

XXX is the selected test area from which it is possible, following the instructions given below, to display all the stored data with relative results and/or download them to a PC through the RS232 Serial Port.

Using the '←' and '→' keys the following selections are possible:

- download – the PC via the RS232 Serial Port
- delete – cancel all data in selected test area
- view – to visualize all data of selected test area.

Once the desired mode has been selected, confirm with 'ENTER'. A further confirmation is requested via the 'MODE' key. The operation can be aborted at any time by pressing 'ESC'.

### f) Download Option

To download the data to a PC via the RS232 serial port the test hammer must first be connected using the cable supplied as standard with the machine. Connect the RS232 port to the serial port (COM) of the PC. Consult the instruction manual of the program used for its correct use.

The input parameters must be set as follows: 9600 baud, 8 data bit, 1 stop bit, no parity.

The PC must be ready to receive the data before the command is given to the instrument to transmit the data. The data is in ASCII format, thus once received by the PC, is accessible through any text editor (eg. Word®, Excel®, Notepad®, Wordpad®, etc.).



### View option

The view option allows the operator to visualize all the readings of a particular test Area with a format and management similar to the download option. Due to the limited space on the display it is necessary to use the '←' and '→' key to scroll the text. To return to the previous menu press 'ESC'.

### Delete option

The delete function allows the operator to cancel a test Area. Once the area has been selected press 'ENTER' to proceed with the cancellation. An extra confirmation is required by pressing 'MODE'. Then press 'ESC' to return to the previous menu.

### Error Messages

Selecting an empty test area, the screen will show the flashing message EMPTY for a few seconds. After this another test area may be selected.

### g) SET CURVE Function

This menu allows the operator to create up to five user defined (UD) curves of correlation between the rebound index and the compressive strength of the concrete to a maximum of the third degree, setting for each curve the four parameters A, B, C and D relative to the mathematical formula.

Two curves (7d and 28d) are factory set and refer to concrete with an age of 7 or 14 to 56 days. The UD curves have the following form:

$$f_c = A \cdot R_3 + B \cdot R_2 + C \cdot R + D$$

where:

$f_c$  = Compressive resistance (MPa)

A, B, C, D = Coefficient constants to be obtained by experimentation.

R = Rebound index at zero impact angle (i.e. horizontal).

When this menu is entered the display shows

UD X CURVE
m=SET      ent=BACK

where X is the number of the selected Curve which can be from 1 to 5 and selected with the '←' and '→' keys. Confirm with "MODE" to proceed to the input of the parameters. The display will

show:

A= +000.000000
m=NEXT    ent=BACK

Use the ‘-’ key to change the value of the digit on which the cursor flashes and the ‘ $\leftarrow$ ’ to pass from one digit to another. The MODE key is used to pass to the next selection, whilst the ENTER key allows the operator to return to the previous selection.

It is also possible to change the sign of the value when the cursor flashes on it. At the end of the setting, the instrument exits from the SET CURVE menu. Once a curve is defined, its parameters remain in the memory even when the instrument is switched off. All the user needs to do is select the curve in the test menu to use it for the data elaboration.

When a UD curve is selected during testing, all the parameters and coefficients that can be set by the user in the test menu as described above (group number, impact angle, type of mean, time factor, correlation factor, measuring unit, sample type...) are used in the same way as for the ‘7d and 28d’ curves.

Therefore, once a curve UDX has been defined relative to an impact angle of 0 and value expressed in MPa, it is possible to use this curve for tests at different angles and express results in different units by simply pre-setting the required parameters. Likewise it is possible to apply corrective factors after the test and to select between cube or cylinder resistance.

The UD correlation curves defined by the user are obtained by experimentation with rebound hammer and compression tests on concrete samples. MS Excel may be used to elaborate the results and calculate the equation of the relative interpolation curve.

#### 5.3.1.6 Evaluation and Recommendations

- Rebound hammer test is useful in finding weak areas in concrete structures
- Test results depend on angle of inclination of hammer to the horizontal, because of the influence of gravity on the amount of energy imparted to the impact.
- The test only gives indication of surface strength of concrete.

Based on the Manual for Load Rating of Bridges of the DPWH, the concrete design compressive strength used in Philippine bridges are as follows:

Concrete	Year of Construction	F <sub>c</sub> (MPa)
----------	----------------------	----------------------

Bending	Prior to 1959	17.2
	After 1959	20.7
	1977 to 1981	27.6*
	After 1981	31.0*

*\*for pre-stressed concrete*

The degree of damage of concrete member based on rebound hammer test results can be determined by the use of the following empirical formula developed in Japan:

Rebound Hammer Test/ Compressive Strength Test Degree of Damage	$F_c$ = Design Compressive Strength $F$ = Actual Compressive Strength from Test (in MPa)
I	$F \geq F_c$
II	$0.8F_c \leq F < F_c$
III	$F < 0.8 F_c$

Example:

Rebound Hammer Test Result (Cube Strength),  $f_c$  mean ( $W_m$ ) = 31 MPa

Conversion to Cylinder Strength,  $f_c$  mean ( $W_m$ ) =  $31 \times 0.85 = 26.35$  MPa

$F_c$  prior to 1959 = 17.2MPa, and  $0.80F_c = 13.80$  MPa

If bridge was constructed prior to 1959, age in days is about 20,000 and

$F_{(20000 \text{ days})} = 26.35 \times 0.41 = 10.80$  MPa

Comparing the values,  $F_{(20,000 \text{ days})} < 0.80F_c$  and the concrete is considered under Degree of Damage – III.

The test is the first step in the investigation. If the results are unreliable or less than the design compressive strength, detailed investigations including microcore test should be carried out. If the results show abnormal data between three (3) test points, lowest data is indicative of suspected defects in the concrete.

### 5.3.2 Carbonation Depth Measurement Test

#### 5.3.2.1 Fundamental Principles

Carbonation of concrete occurs when carbon dioxide, in the atmosphere in the presence of moisture, reacts with hydrated cement minerals to produce carbonates, e.g. calcium carbonate. The carbonation process is also called de-passivation. Carbonation penetrates below exposed surface of concrete extremely slow.

The significance of carbonation is that the usual protection of reinforcing steel generally present in concrete due to the alkaline conditions caused by hydrated cement paste is neutralized by carbonation. Thus, if the entire concrete cover over the reinforcing steel is carbonated, corrosion of steel would occur if moisture and oxygen could reach the steel.

#### 5.3.2.2 Description of Apparatus

The 1% Phenolphthalein Solution is made by dissolving 1gm of Phenolphthalein in 90 cc of ethanol. The solution is made up to 100 cc by adding distilled water. The pH value indicates if a solution is acid or alkaline, and therefore corrosion of reinforcing steel bars is determined if possible or not.

- $\text{pH} < 7$  : acid
- $\text{pH} = 7$  : neutral
- $\text{pH} > 7$  up to 14 : alkaline



**Photo 5.3.2.1 Phenolphthalein  
Solution**

#### 5.3.2.3 Procedures

The freshly extracted core is sprayed with Phenolphthalein solution, and the depth of uncolored layer (the carbonated layer) from the external surface is measured to nearest mm at 4 or 8 positions, and the average is taken. If the concrete still retains its alkaline characteristic, the color will change to red violet. If carbonation has taken place pH will have changed to 7 (i. e. neutral condition) and there will be no color change.

If test sample is cored by coring apparatus:

- Phenolphthalein shall be sprayed on the concrete surface after cleaning.
- The phenolphthalein becomes red-violet when it comes in contact with normally alkaline concrete

- If phenolphthalein becomes colorless, the concrete is carbonated.
- The depth of carbonated concrete shall be measured.

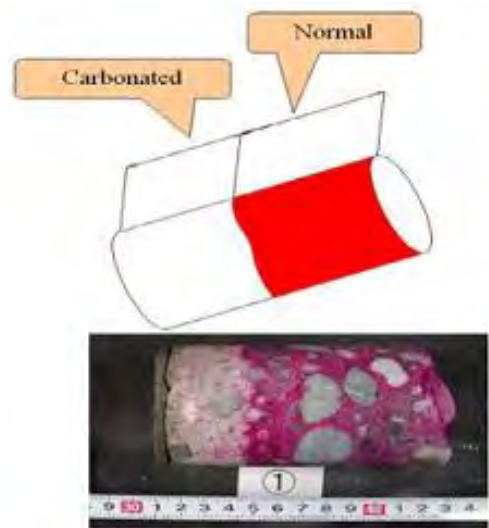
Note: When cored sample is used, point load test shall also be carried out on the sample. After coring, the hole shall be sealed by mortar.

If test is to be done in a chipped hole, the dust is first removed from the hole using an air brush and again the depth of uncolored layer is measured at 4 to 8 positions and the average taken. If the concrete still retains its alkaline characteristic, the color will change to red violet. If carbonation has taken place pH will have changed to 7 (i. e. neutral condition) and there will be no color change. See diagram below:

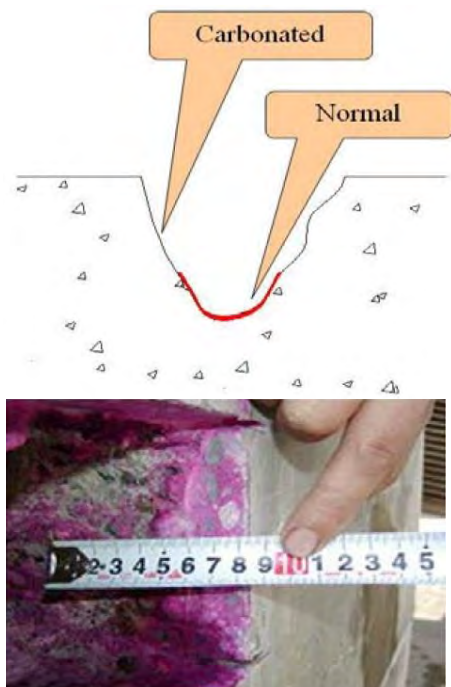
If concrete surface is chipped off by hammer, breaker or other apparatus:

- Spray Phenolphthalein Solution on the chipped surface after cleaning.
- If colorless, the concrete is carbonated.
- The depth of carbonated concrete shall be measured.

Note: Chipped concrete shall be sealed with mortar after testing



**Fig 5.3.2.1 Test for Cored Concrete**



**Fig 5.3.2.2 Test for Chipped Concrete**

Conduct one test when reinforcing steel bar is suspected of corrosion. Therefore, locate test point near defective site. Test core should not be located where removal of core will affect strength of member (web to end of girder etc.) In such a case, locate test core at another point (curb, etc.).

#### 5.3.2.4 Analysis

##### a) Compute Carbonation Rate Coefficient and Carbonate Survival Period

It is advisable to determine the carbonation rate coefficient from the carbonation depth



measurements, utilizing the fact that the carbonation depth is proportional to the square root of the carbonation period.

$$y = b\sqrt{t}$$

Where:

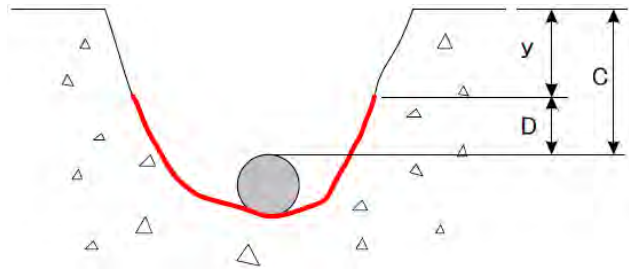
y: carbonated depth (mm)

b: carbonation rate coefficient (mm/√year)

t: carbonation period (year)

D: Un-carbonated depth (mm) = C-y

C: Cover



**Fig 5.3.2.3 Un-carbonated Depth**

### 5.3.2.5 Evaluation and Recommendations

The result of test is evaluated based on un-carbonated depth as follows:

**Table 5.3.2-1 Degree of Damage**

Degree of Damage	Un-Carbonated Depth (D)	Status
I	$D \geq 25\text{mm}$	Rebar will be corroded in the future. Monitoring is required.
II	$D < 25\text{mm}$	Rebar may be corroded. Repair is required.

If the Degree of Damage is II, the concrete structure may be affected by chloride deterioration.

### **5.3.3 Ultrasonic Pulse Velocity Test**

#### **5.3.3.1 Fundamental Principles**

##### **a) General**

A pulse of longitudinal vibrations is produced by an electro–acoustical transducer, which is held in contact with one surface of the concrete under test. When the pulse generated is transmitted into the concrete using a liquid coupling material such as grease or cellulose paste, it undergoes multiple reflections at the boundaries of the different material phases within the concrete. A complex system of stress waves develops, which include both longitudinal and shear waves, and propagates through the concrete. The first waves to reach the receiving transducer are the longitudinal waves, which are converted into an electrical signal by a second transducer. Electronic timing circuits enable the transit time ‘T’ of the pulse to be measured.

##### **b) Applications**

The ultrasonic pulse velocity tester is used to measure the velocity of propagation of ultrasonic pulses through concrete for determination of the following:

- Uniformity and homogeneity of concrete;
- Presence of cracks or voids;
- Spalling, delamination, deterioration due to fire, frost or chemical attack;
- Determination of dynamic elastic constants (E and  $\nu$ ); and
- Estimating time for formwork striking

The use of ultrasonic pulse velocity technique to define the extent of internal defects should be restricted to well–skilled personnel.

When an ultrasonic pulse travelling through concrete meets a concrete–air interface, there is negligible transmission of energy across this interface. Thus any air filled void lying immediately between transducers will obstruct the direct ultrasonic beam when the projected length of void is greater than the width of transducers and the wavelength of sound used. Thus the pulse is diffracted around the periphery of the void and transit time will be longer than in similar concrete with no void.

Tests for inspection of delamination, spalling and cracks are described in this section.

### 5.3.3.2 Description of Apparatus



#### Specifications

##### A. Ultrasonic Pulse Velocity Tester

- Microprocessor incorporated
- Transit time measurement : from 0.1 to 1999.9  $\mu$ s
- Pulse Rate: from 1 to 10 per second, selectable
- Accuracy: 0.1  $\mu$ s
- Transmitter output: 800 v
- Frequency Range: 24 to 150 kHz
- Power Supply: Two 1.5 V Alkaline "D" Type Batteries

##### B. Tester is supplied complete with:

- Two 54 KHz Transducers (Transmitter and Receiver) with 2 meter cable
- Coupling Agent (250 cc bottle)
- Nylon Carrying Case

Fig 5.3.3.1 Ultrasonic Pulse Velocity Tester

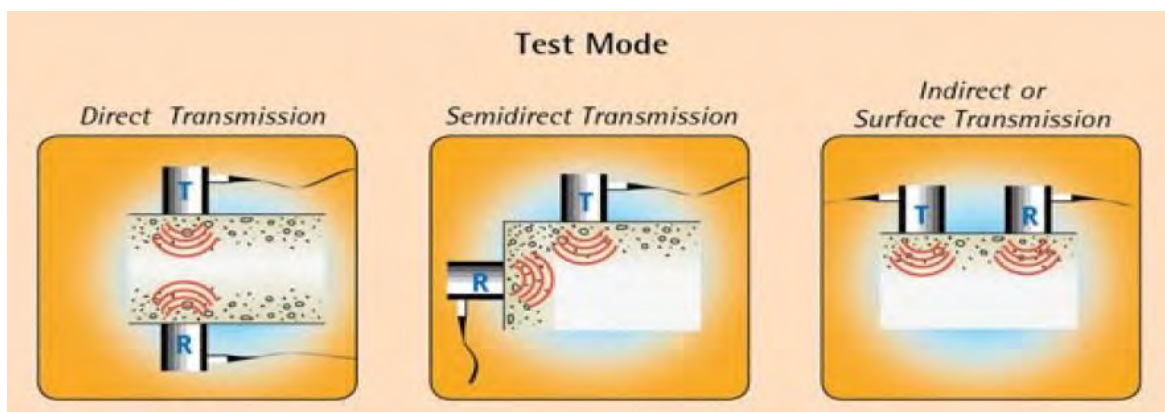
### 5.3.3.3 Procedures

#### a) Arrangements of Transducers

The receiving transducer detects the arrival of that component of the pulse, which arrives earliest. This is generally the leading edge of the longitudinal vibration. Although the direction in which the maximum energy propagated is at right angles to the face of the transmitting transducer, it is possible to detect pulses, which have travelled through the concrete in some other direction. It is possible therefore to make measurements of pulse velocity by placing the two transducers on either:

- Opposite faces (direct transmission),
- Adjacent faces (semi-direct transmission); or
- The same face (indirect or surface transmission).

These three arrangements are shown in the figure below.



*T – Transducer, R-Receiver*

Fig 5.3.3.2 Arrangements of Transducers

### **a.1) Determination of Pulse Velocity by Direct Transmission**

Where possible direct transmission arrangement should be used since the transfer of energy between transducers is at its maximum and the accuracy of velocity determination is therefore governed principally by the accuracy of path length measurement. The couplant to be used should be spread as thinly as possible to avoid any end effects resulting from the different velocities in couplant and concrete.

Longitudinal pulse velocity is given by:

$$v=L/T$$

where: V is the longitudinal pulse velocity in km/s or m/s

L is the path length, in mm

T is the time taken by the pulse to traverse that length, in  $\mu$ (s)

### **a.2) Determination of Pulse Velocity by Semi-Direct Transmission**

The semi-direct transmission arrangement has a sensitivity intermediate between those of the other two arrangements, and, although there may be some reduction in the accuracy of measurement of the path length, it is generally found to be sufficiently accurate to take this as the distance measured from center to center of the transducer faces. This arrangement is otherwise similar to direct transmission. The formula for direct transmission is also used for determining pulse velocity for semi-direct transmission.

### **a.3) Determination of Pulse Velocity by Indirect (Surface) Transmission**

Indirect transmission is used when only one face of concrete is accessible, when depth of surface crack is to be determined or when the quality of the surface concrete relative to the overall quality is of interest. It is the least sensitive of the arrangements and, for a given path length, produces at the receiving transducer a signal which has an amplitude of only about 2% or 3% of that produced by direct transmission. Furthermore, this arrangement gives pulse velocity measurements which are usually influenced by the concrete near the surface. This region is often of different composition from that of the concrete within the body of a unit and test results may be unrepresentative of that concrete. The indirect velocity is invariably lower than the direct velocity on the same concrete element. This difference may vary from 5% to 20% depending largely on the quality of concrete under test. Where practicable, site measurements should be made to determine this difference. With indirect transmission, there is some uncertainty regarding the exact length of the transmission path because of the significant size of areas of contact between transducers and the concrete. It is preferable to make a series of measurements with the transducers at different distances apart to eliminate this uncertainty.

1. To do this, the transmitting transducer is placed in contact with concrete surface at a fixed point “P” and the receiving transducer shall be placed at fixed increments “x” along a chosen line on the surface. The transmission times recorded should be plotted as points on a graph showing their relation to distance separating the transducers. An example of such plot is shown in Fig. 5.3.3.3.
2. The slope of the best straight line drawn through the points (tan) is measured and recorded as the mean pulse velocity along the chosen line on the concrete surface. Where points measured and recorded this way indicate a discontinuity, it is likely that a surface crack or surface layer of inferior quality is present and velocity measured in such an instance is unreliable.

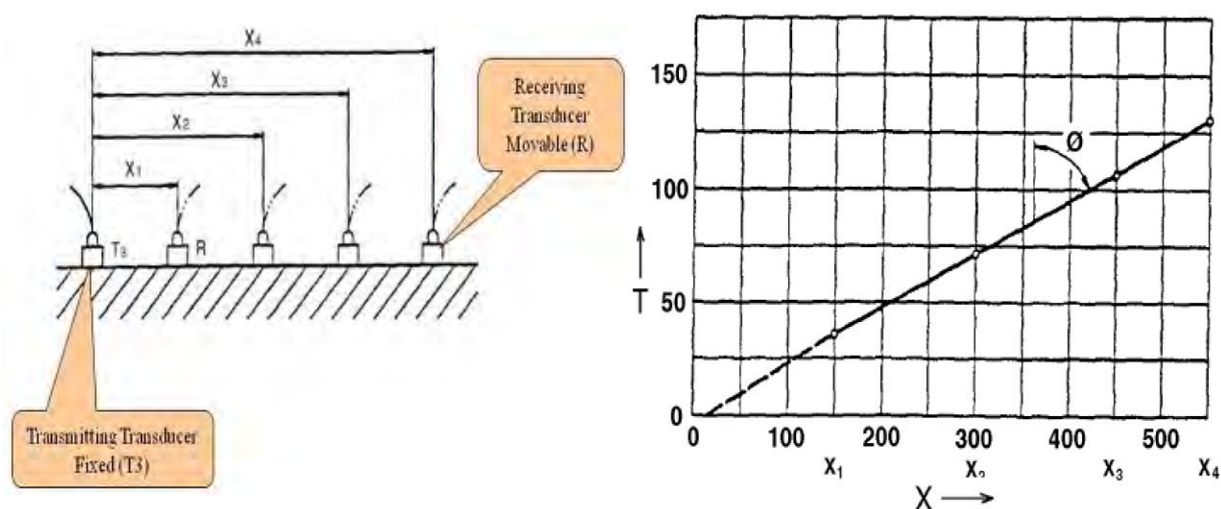
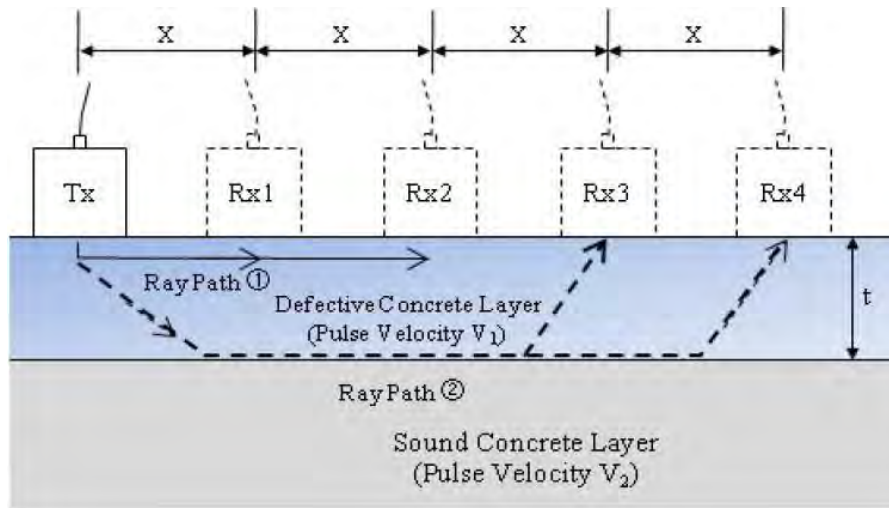


Fig. 5.3.3.3 Indirect (Surface) Transmission

#### b) Investigation of Scaling, Delamination, and Other Flaws

The depth of observed delamination and extent of scaling can be determined by this test. This test is suitable considering that pulse velocity in defective concrete layer (V1) is less than in the sound concrete layer (V2). Perform readings as shown in Fig. 5.3.3.4.

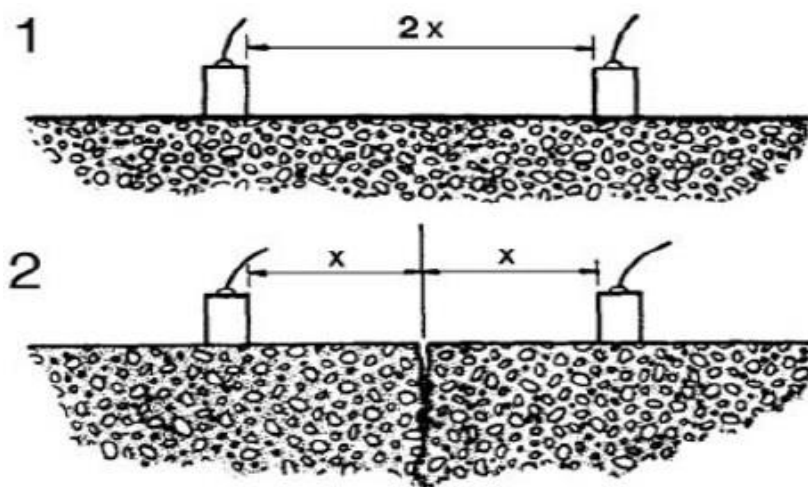
1. Set up apparatus. (Refer to Operation Manual)
2. Check rebar locations and mark area/locations for the test.
3. Place the transmitting transducer Tx as shown, then place receiving transducer Rx at distances x, 2x, 3x and 4x from Tx.
4. Distance “x” should be less than t/2 where “t” is the thickness of suspected damaged layer.
5. For each location of Rx make sure that couplant is applied. Record measured values of Transit Time (T) and Path Length (L) at each location.



**Fig. 5.3.3.4 Sampling Pattern for Investigation of Scaling, Delamination, Etc.**

### c) Depth of Cracks

Depth of cracks that are  $\geq 0.20$  mm wide should be inspected. When the depth of a crack has to be measured, perform two pulse transit time readings as indicated in Fig 5.3.3.5.



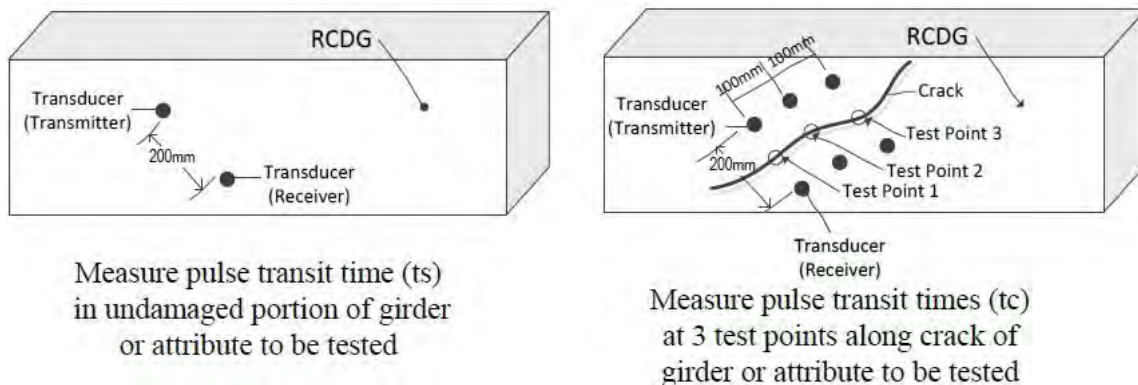
**Fig. 5.3.3.5 Transducers Positioning for Estimation of Crack Depth**

1. Set up apparatus. (Refer to Operation Manual)
2. Readings are taken with the transducers placed in several symmetrical positions with respect to the crack (Fig 5.3.3.5 diagram 2), another reading is with the same distance between the transducers but without any crack between them (Fig. 5.3.3.5 diagram 1) along the same attribute (for example girder).
3. Record the transit times for both cases. Make sure that the crack spaces are not filled with water during the testing since transit time will be affected.



#### d) Test Points

Along the line of crack, determine readings at every 100mm or shorter interval depending on the length of crack. Record maximum crack depth in the engineering inspection form (EIF).



#### 5.3.3.4 Analysis

##### a) Investigation of Scaling, Delamination and Other Flaws

1. Plot results of test graphically as shown in Fig. 5.3.3.6.

Ray path ① (Fig. 5.3.3.4) in surface layer of defective concrete is fastest/shortest path for test at Rx1 (x) and Rx2 (2x). Ray path ② in surface layer of sound concrete is fastest /shortest path for Rx3 (3x) and Rx4 (4x)

The velocity,  $V_d$  ( $= X1/T1$ ) in the defective concrete is less than  $V_s$  ( $= X2/T2$ ). Point A is the location of the boundary between defective and sound concrete

2. The thickness of the defective layer, “t” in mm, is estimated from the following relation:

$$t = X1/2(V_s - V_d)/(V_s + V_d)$$

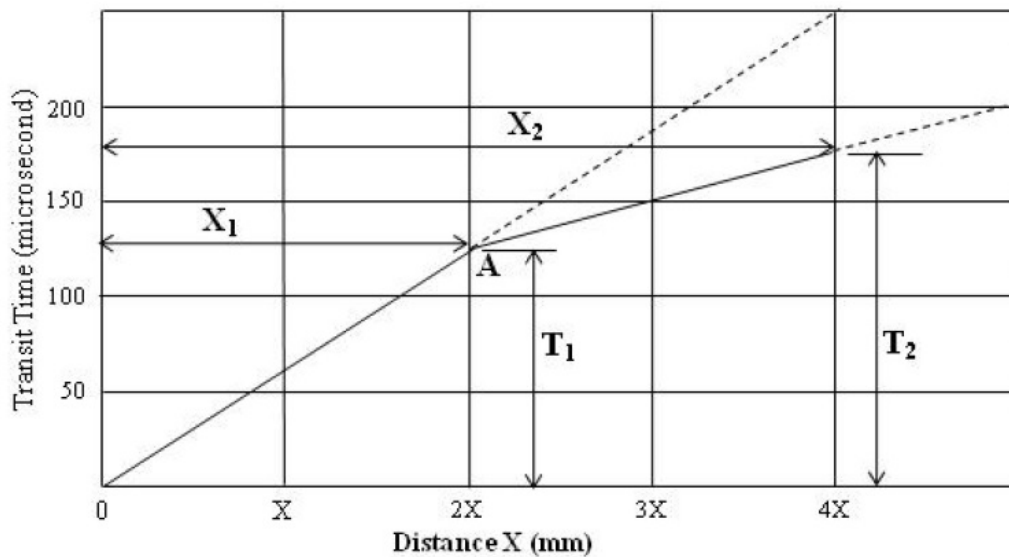
where:

$V_d$  = pulse velocity in defective concrete (km/s) =  $X1/T1$

$V_s$  = pulse velocity in sound concrete (km/s) =  $(X2 - X1) / (T2 - T1)$

$X1$  = distance at which the change of slope occurs

3. The first set of tests should be on trial and error basis, to confirm the approximate thickness of the defective layer. To investigate the maximum thickness “t” of the defective layer, the value of “x” may be measured in increments of 10 or 20% until maximum is found. This new value of “x” should then be used in further tests on grid basis to define the area affected



**Fig 5.3.3.6 Plot of Transit Time versus Distance**

#### **b) Depth of Cracks**

1. The following formula is used to calculate the depth “h” of the crack, provided that the crack space is not filled with water:

$$h = x \sqrt{\left(\frac{t_c}{t_s}\right)^2 - 1}$$

where:

x = half distance between the transducers (mm)

h = crack depth (mm)

tc = transit times across the crack of concrete structure (microsecond)

ts = transit time along the surface of portion of same concrete structure without defects (microsecond)

### **5.3.3.5 Evaluation and Recommendations**

#### **a) Scaling, Delamination and Other Flaws**

1. Confirm depth of suspected defective layer thickness and area affected by core test. Subject core sample to carbonation test to determine if rebars are likely to be corroded.
2. The procedure can also be used to investigate concrete damaged by fire, chemical attack, etc. where a surface or upper layer has less strength than the layer below.

## b) Depth of Crack

**Table 2.3.3-1 Degree of Damage**

Degree of Damage	Crack Depth (D in mm)	Status	Countermeasure
I	$C/2 > D$	Rebar will be corroded in the future.	Monitor
II	$C > D \geq C/2$ ( $C \geq 40\text{mm}$ )	Rebar may be corroded	Conduct periodic inspection
III	$C > D \geq C/2$ ( $C < 40\text{mm}$ )	Rebar may be corroded.	Conduct Carbonation Test
IV	$D \geq C$ C : concrete cover	Rebar must be corroded.	Conduct Half –Cell Test Conduct Carbonation Test Repair Damage

### 5.3.4 Half–Cell Electrical Potential Test

#### 5.3.4.1 Fundamental Principles

##### a) General

The corrosion (rusting) of steel rebar is an electro–chemical process, involving anodic (corroding) and cathodic (passive) areas of the metal. By measuring concrete–surface electrical potentials relative to a standard reference electrode on a pre–defined grid, the presence and location of corrosion and its probable future performance may be assessed.

To use this technique, it is necessary that a continuous electrical current is present in the reinforcing bars (this is normally achieved with a metal wire connecting the various reinforcing element, for example horizontal and vertical bars). A multimeter can be used to check that this electric current exists.

##### b) Applications

This technique is used to assess the durability of reinforced concrete members where reinforcement corrosion is suspected. The method has the advantage of being simple and it allows an almost non–destructive survey to produce equi–potential contour maps of surface of concrete member. Reported uses include the location of areas of high reinforcement corrosion risk in bridge decks and abutments.

The technique may be used to identify areas of reinforced concrete in need of repair or protective treatment and, by regular measurements, monitor the behavior of new and relatively new structures and thus minimize maintenance costs.

#### 5.3.4.2 Description of Apparatus



##### Specifications

- A. Name: Half-Cell Digital Corrosion Meter
  - Half Cell: Silver/Silver Chloride refillable probe (stable and low corrosive)
  - Measurements are automatically converted and displayed as copper/copper sulphate equivalent potentials
  - Range / Resolution: +1999 mV / +1mV
- B. Tester is supplied with:
  - Electrode complete with 100 ml electrolyte gel
- C. Unit conforms to BS 1881:201, ASTM C876, UNI 9535 standards

**Fig 5.3.4.1 Half-Cell Digital Corrosion Meter**

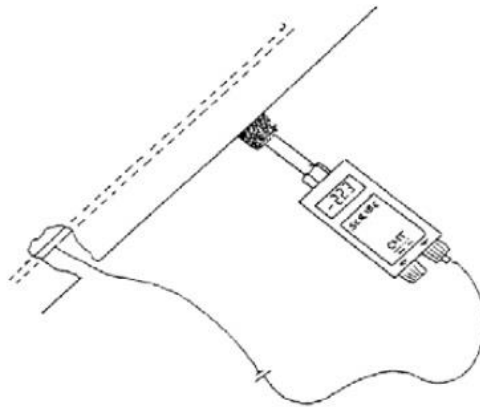
### 5.3.4.3 Procedures

#### a) Test Surface Preparation

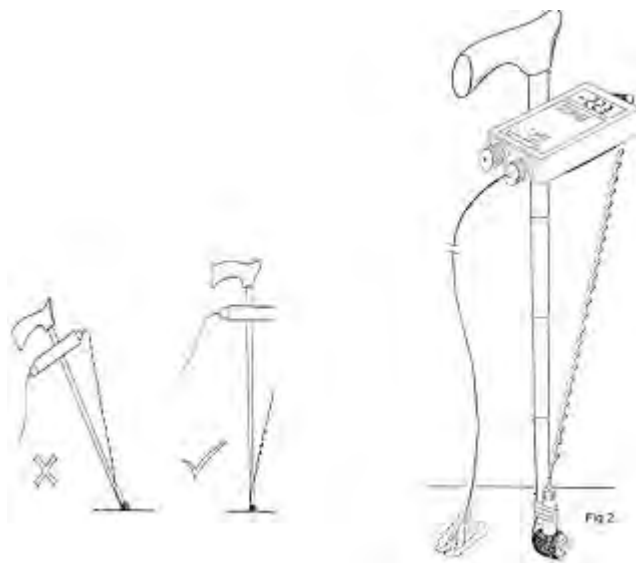
1. Mark out the desired grid on the surface to be surveyed. Grid spacing should be 100mm to 300mm. Use narrow spacing if the test will be carried out around surface crack.
2. Locate and expose a rebar approximately at the center of the area to be surveyed.
3. Clean the exposed rebar to bright metal to ensure good electrical contact and attach the reference cable using the crocodile clip. If the rebar is corroded, drill a small diameter hole into the steel and screw into it a T-bar Gimlet onto which to attach the cable.

#### b) Equipment Set-up

The Set-up equipment as shown in **Fig. 5.3.4.2** or **2.3.4.3** as appropriate. Apparatus must be calibrated before use. Refer to instruction manual on how to calibrate.



**Fig. 5.3.4.2 Set-up for Surveys on Vertical Surfaces and Soffits**



**Fig. 5.3.4.3 Set-up for Surveys on Horizontal Surfaces such as Bridge Decks/Slabs etc.**  
(To avoid fatigue when using this setup, lower the probe vertically onto test grid position)

### c) Testing

1. Replace the solid cap on the cell electrode with one of the sponge heads and moisten it with clean, slightly soapy water.
2. Dampen the concrete surface over its entire surface or grid points.
3. Place cell electrode probe on first test position. Position should be just above the rebar. Refer to diagram in Fig.5.3.4.4. Only light contact pressure of the sponge head is necessary.
4. The probe is precision equipment and should be treated accordingly. Inspector should follow manufacturer's recommendation in the instruction manual.
5. Allow reading to settle within 10mV (second least significant digit) and record reading.
6. Proceed to second test position and repeat testing procedure steps 3 and 4.

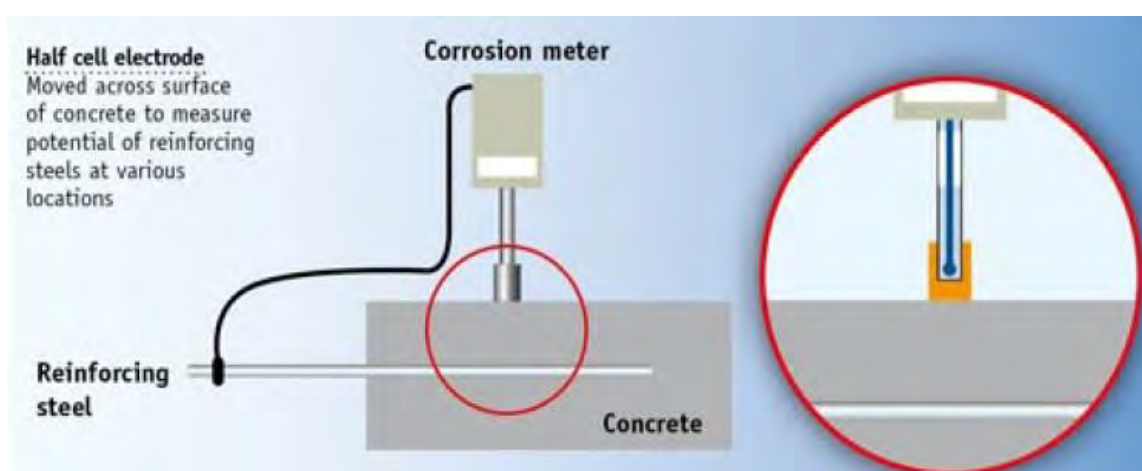


Fig 5.3.4.4 Testing Diagram

### d) Test Points

Perform tests near areas where there is corrosion potential of rebar. If the corrosion potential is higher or extensive, implement further testing within its surroundings.

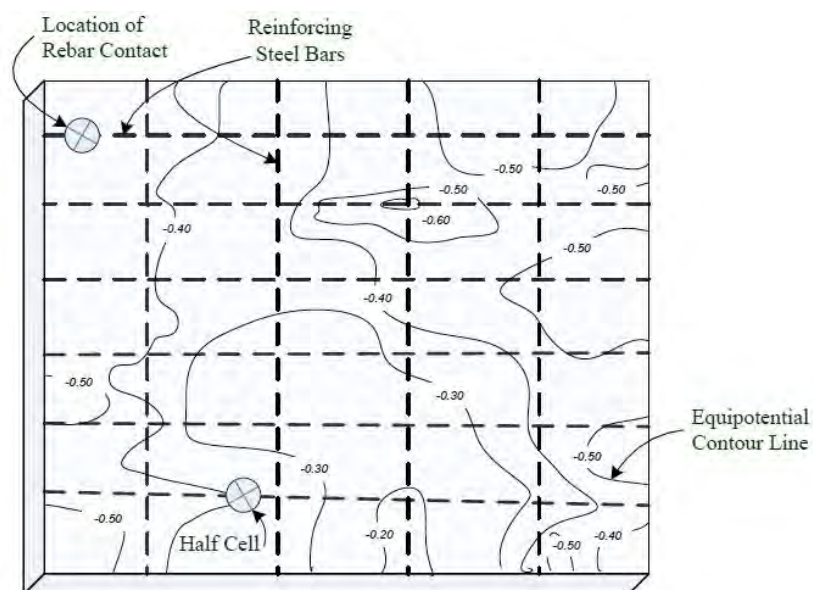
### 5.3.4.4 Analysis

Measurements are to be presented with an equipotential contour map which will provide a graphical delineation of areas in the member where corrosion activity may be occurring.

The contour map provides a graphical delineation of areas in the member where corrosion activity may be occurring.

The risks of corrosion based on potential difference reading are shown in **Table 5.3.4.1**. The data are based on the principle of Copper/Copper Sulphate electrode measurement technique as described in ASTM C876–80, in BS1881:201, in ASTM C876–80 and in a number of technical articles.





**Fig 5.3.4.5 Example of Equipotential Contour Map**

**Table 5.3.4.1 Risk of Corrosion Against the Potential Difference Readings**

Potential Difference Levels (mV) $\langle E \rangle$	Chance of Rebar Being Corroded
Less than $-500$ ( $E \leq -500$ )	Visible evidence of corrosion
$-350$ to $-500$ ( $-350 < E < -500$ )	95% probability of corrosion
$-200$ to $-350$ ( $-200 \leq E \leq -350$ )	50% probability of corrosion
More than $-200$ ( $-200 < E$ )	5% probability of corrosion

### 5.3.4.5 Evaluation and Recommendations

Depending on the analysis of results, the following degrees of damage are established:

**Table 5.3.4.2 Degree of Damage**

Degree of Damage	Potential Difference Levels (mV) $\langle E \rangle$	State
I	$-200 < E$	Rebars will be corroded in the future
II	$-200 \leq E \leq -350$	Rebars may be partly corroded
III	$-350 < E < -500$	Rebars are be corroded
IV	$E \leq -500$	Rebar are seriously corroded

Half cell electrical potential test should be carried out together with rebar detection test investigation and carbonation test at the same time.

A more detailed investigation is required especially around cracks.

It is generally accepted that corrosion potential measurements must be complemented by other methods, because although reliable relationships between potential and corrosion rate can be found in the laboratory for well-established conditions, these can in no way be generalized, since wide variations in the corrosion rate are possibly in very narrow range of potentials.

Values obtained can only provide information for corrosion probability and cannot indicate the rate of corrosion.

### 5.3.5 Rebar Detection Test

#### 5.3.5.1 Magnetic Type

##### a) Fundamental Principles

As a magnetic type scanning apparatus is turned on, it generates an electromagnetic field. When a reinforcing bar (rebar) or other metal object lies within this field, the lines of force become distorted. The disturbance caused by the presence of the metal in turn, produces a local change in field strength as detected by the search head and indicated by the meter. Both the orientation and proximity of the metal to the search head affect the meter reading. It is therefore possible to locate reinforcing bars and determine their orientation. Under ideal conditions, both bar size and cover can be estimated when neither is known.

With apparatus using magnetic induction, a multi-coil search is used with a lower operating frequency than eddy current type. The principle used is similar to that of a transformer. Such instruments are less sensitive to non-magnetic materials than those using eddy current principles.

##### b) Description of Apparatus



Photo 5.3.5.1 Magnetic Type Rebar Detector

##### Specifications

- Brand: HILTI PS200 Ferro-scan
- Scanner memory capacity: Up to 9 Image-scans plus up to 30 meters of recorded Quick-scans
- Monitor memory capacity / type: At least 150 Image-scans or 75 Quick-scans plus up to 15 min. of voice recording (32 MB)
- Battery life 8 hours on average
- Protection class IP 54 in accordance with IEC 529

- Operating temperature range –10°C to +50°C
- Dimensions / weight of scanner: 260 x 132 x 132 mm /1.4 kg
- Dimensions / weight of monitor: 264 x 152 x 57 mm /1.4 kg
- Minimum system requirements: Microsoft Windows 2000, XP, at least 50 MB free hard disk space, CD-ROM drive, for PC software USB V1.1 interface

### **Advantages**

- Immediate high resolution image for a clear picture of the reinforcement.
- Reduce wear on drill/core bits and tool motors when drilling through reinforcement.
- Reduce drilling times – important in repetitive drilling applications.
- Avoid potentially disastrous and costly hits on critical reinforcement.
- Cable less connection between monitor and scanner. No cable to snag or hinder inspector's movement.
- Includes powerful PC software for office analysis and easy creation of reports.

### **Limitations**

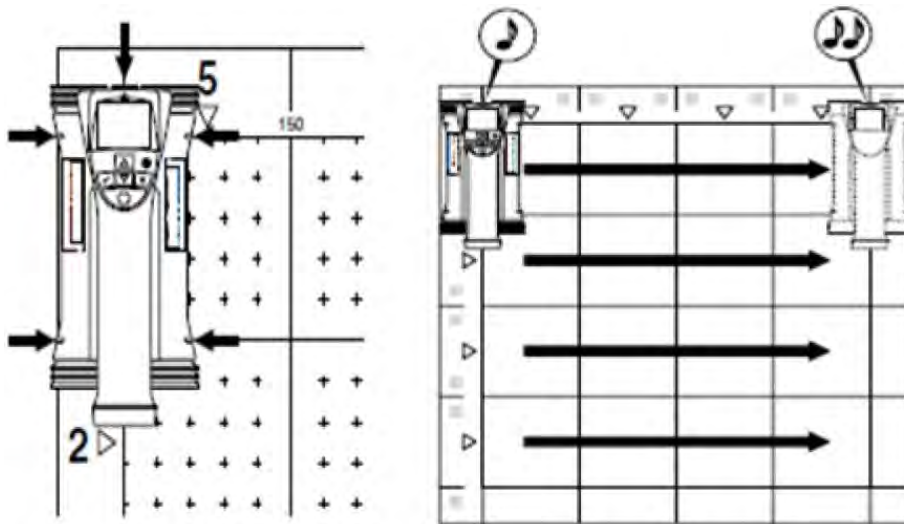
- The scanner only detects reinforcing bars that lie perpendicular to the direction of travel. Rebars that lie parallel to the direction of travel will not be detected. Therefore, ensure that the object is scanned in both the horizontal and vertical directions. An incorrect depth may be calculated for bars that lie diagonal to the direction of travel.
- Rebar spacing of 36 mm or less cannot be measured by the scanner.
- Rebar diameter measurement is possible only at minimum depth of 10 mm to a maximum depth of only 60 mm

## **c) Procedures**

### **c.1) Image Scan**

Image-scan is used to create an image of the reinforcement layout so that the depth and diameter of the bars can be determined.

- 1) Alternatively, a grid can be marked directly on the wall or girder/beam surface. Using a straight edge (ruler) as a guide, mark a 4 x 4 grid with 150mm spacing between parallel lines.
- 2) The scanner is switched on and set to Image-scan symbol. A representation of the grid appears on the screen with a suggested starting point. This is always upper left and will suffice for most scans. Image data will only be generated for areas of the grid that have been scanned both vertically and horizontally.
- 3) Place the scanner on the grid at the starting point. Ensure the alignment marks on the scanner are aligned correctly with the grid as shown below.

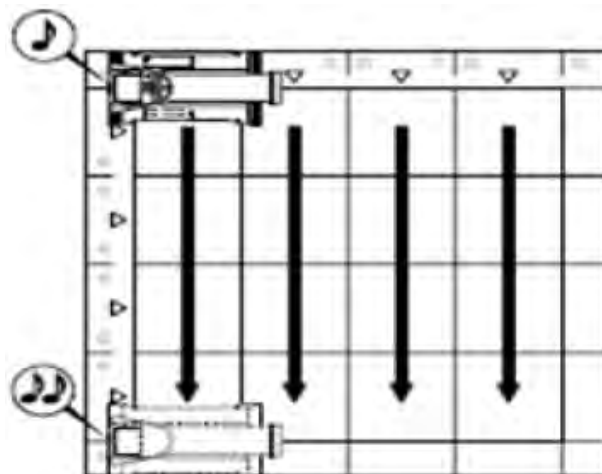


**Fig. 5.3.5.1 Starting Point of Horizontal Scan**



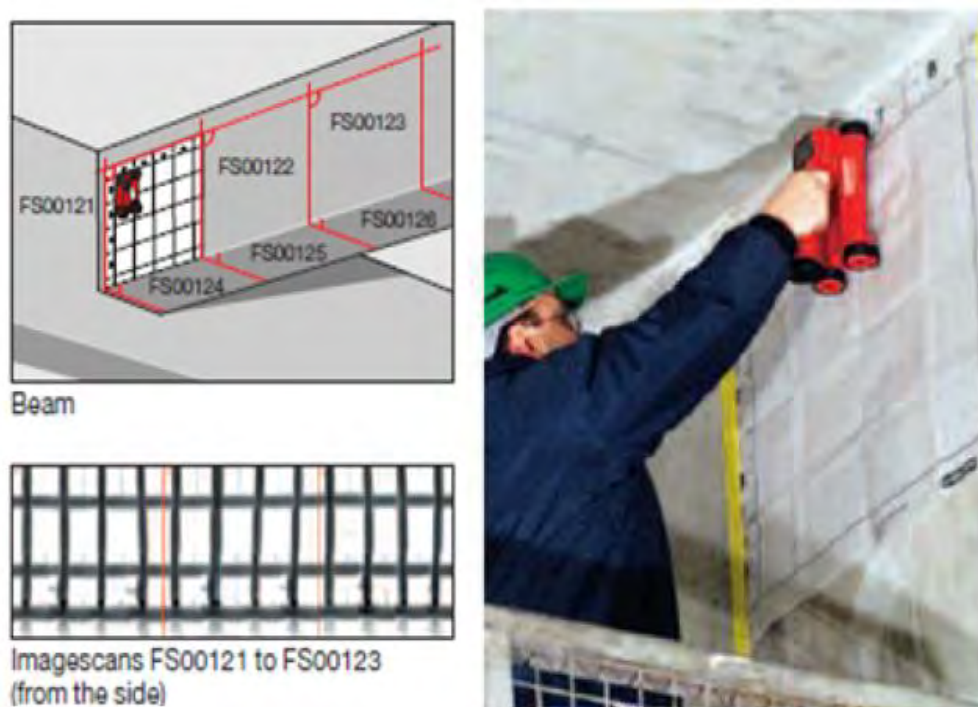
**Photo 5.3.5.2 Sequence of Horizontal (Rows) Scan**

4) When all rows are complete, scan the columns in a similar way.



**Fig 5.3.5.2 Sequence of Vertical (Columns) Scan**

- 5) When the scan is complete, the data may then be transferred to the monitor for viewing and evaluation.
- 6) If a large section of a wall or length of girder/beam has to be investigated, block scan is undertaken. In a block scan a series of Images-cans are taken and the data are recorded in the monitor.
- 7) After scanning, scanned data is transferred to the computer for analysis.
- 8) Rebar location and concrete cover are analyzed by the computer using a software.
- 9) The following diagrams show the procedures for image-scan on a beam/girder.



**Fig 5.3.5.3 Image-scan Process**

### **c.2) Quick-scan**

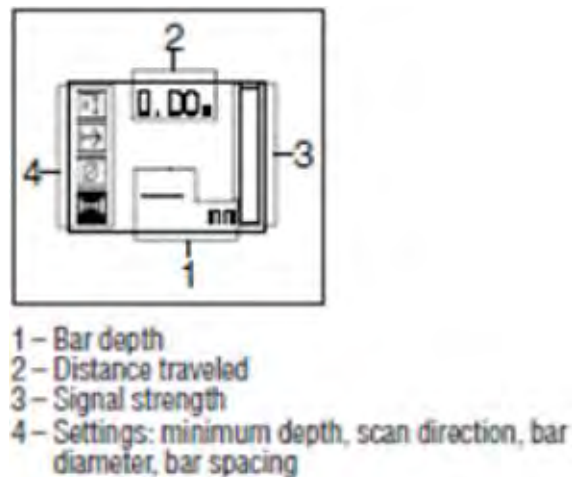
Quick-scan is used to quickly detect bar positions and depths that are then subsequently marked on the surface. This procedure is called Quick-scan detection. Accurate depth measurement is another Quick-scan function in which values for bar diameter and bar spacing must be previously entered.

Alternatively, the data can be recorded and evaluated on the monitor or in the PC application. In this way, the average depth of cover over the reinforcement over large stretches of the surface can be easily determined. This is termed Quick-scan recording.

Quick-scan settings are detailed in the instruction manual of the apparatus and are not shown in this document.

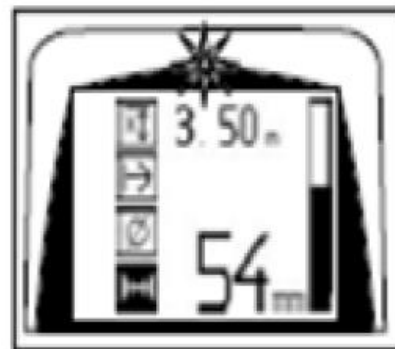


## 1) Quick-scan Detection



**Fig 5.3.5.4 Quick-scan Display**

- (a) Switch on the scanner. The Quick-scan icon is automatically selected first. The Quick-scan screen is then displayed.
- (b) Move the scanner over the surface. Reinforcing bars that lie perpendicular to the direction of travel will be detected. The distance covered by the scanner is recorded. The maximum scanning speed should be 0.5m/s (20 inches/sec.).
- (c) When approaching a reinforcing bar, the signal strength increases and depth values may appear in the display. When the scanner is at the center of a reinforcing bar the following occurs:
- the red LED lights,
  - the scanner beeps,
  - the signal strength bar is at maximum,
  - and the approximate depth of the bar is indicated (Lowest depth value indicated = center of the bar).
- (d) The bar is positioned along the center line of the scanner and may be marked on the surface using a marker. The accuracy of the depth measurement can be increased by switching to accurate depth measurement measuring mode.



**Fig. 5.3.5.5 Display of Results**

## 2) Quick-scan with Accurate Depth Measurement

- (a) The measuring mode 'Quick-scan with Accurate Depth Measurement' is selected by pressing the 'Confirm button' on the main menu of the scanner.
- (b) The diameter must be known and previously entered.

- (c) In addition, the value for the spacing between bars must also be entered if it lies between '>36' and '<120' mm. If the spacing is known, the value is entered manually.
- (d) The spacing can be calculated automatically using the Quick-scan detection function by searching for the center of the bar and pressing the red Record button when the scanner is over the midpoint of the bar. Next, search for the midpoint of the next bar and again press the Record button.
- (e) Bar spacing is then calculated automatically and recorded.
- (f) After setting the bar diameter and bar spacing, the scanning procedure is identical to the procedure described in **1) Quick-scan Detection**.

### **3) Quick-scan Recording**

Always carry out an Image-scan prior to Quick-scan recording in order to: establish the direction of the uppermost layer of reinforcement, minimize the risk of measuring on a spliced bar, and immediately see if there are any ferrous materials in the concrete that may affect the accuracy of the result.

- (a) To record the position and depth of all reinforcing bars detected, place the scanner on the surface and use Quick-scan detection to find a position where there are no bars present.
- (b) Mark the starting point with a marker and press the Record button. The diskette symbol appears on the screen, indicating that the scanner is recording data.
- (c) Move the scanner over the surface. At the end of the scan, take care to ensure that the end point is not directly over a rebar. To stop recording, press Record again. Use a marker to mark the end of the stretch that has been scanned.
- (d) Reinforcing bars that lie perpendicular to the direction of travel will be detected and automatically recorded. Ensure that the settings are correctly set before beginning recording is started.

### **d) Analysis**

- 1) The calculations for bar sizes and concrete cover are described in the procedures and / or are available as direct read out from the digital display.
- 2) Rebar location and thickness of concrete cover are analyzed by the computer by using a software.
- 3) Care should be taken to record other details such as direction of rebar and location of area of investigation supported by time-dated photos whenever possible.
- 4) The detection range and accuracy of depth measurement for Image-scan and Quick-scan is

typically accurate to within  $\pm 10\%$  of actual depth. Refer to table below for detection range and accuracy of the HILTI PS200 Ferro-scan when bar diameter is given.

**Table. 5.3.5.1 Detection Range and Accuracy**

**Imagescan**

Bar Diameter	Depth									
	20	40	60	80	100	120	140	160	180	
6	$\pm 2$	$\pm 3$	$\pm 3$	$\pm 4$	$\pm 5$	0	X	X	X	
8	$\pm 2$	$\pm 2$	$\pm 3$	$\pm 4$	$\pm 5$	0	0	X	X	
10	$\pm 2$	$\pm 2$	$\pm 3$	$\pm 4$	$\pm 5$	0	0	X	X	
12	$\pm 2$	$\pm 2$	$\pm 3$	$\pm 4$	$\pm 5$	$\pm 10$	0	X	X	
14	$\pm 2$	$\pm 2$	$\pm 3$	$\pm 4$	$\pm 5$	$\pm 10$	0	0	X	
16	$\pm 2$	$\pm 2$	$\pm 3$	$\pm 4$	$\pm 5$	$\pm 10$	0	0	X	
20	$\pm 2$	$\pm 2$	$\pm 3$	$\pm 4$	$\pm 5$	$\pm 10$	$\pm 11.5$	0	X	
25	$\pm 2$	$\pm 2$	$\pm 3$	$\pm 4$	$\pm 5$	$\pm 10$	$\pm 11.5$	0	X	
28	$\pm 2$	$\pm 2$	$\pm 3$	$\pm 4$	$\pm 5$	$\pm 10$	$\pm 11.5$	0	X	
30	$\pm 2$	$\pm 2$	$\pm 3$	$\pm 4$	$\pm 5$	$\pm 10$	$\pm 11.5$	0	X	
36	$\pm 2$	$\pm 2$	$\pm 3$	$\pm 4$	$\pm 5$	$\pm 10$	$\pm 11.5$	$\pm 13$	0	

Bar diameter given. Value indicates accuracy of depth measurement in mm.  
 0 - bar can be detected at this depth but no depth calculated  
 X - Bar cannot be detected at this depth  
 Valid for bars conforming to DIN 488

**Quickscan Recording**

Bar Diameter	Depth					
	20	40	60	80	100	
6	$\pm 1$	$\pm 1$	$\pm 2$	$\pm 4$	$\pm 5$	
8	$\pm 1$	$\pm 1$	$\pm 2$	$\pm 4$	$\pm 5$	
10	$\pm 1$	$\pm 1$	$\pm 2$	$\pm 4$	$\pm 5$	
12	$\pm 1$	$\pm 1$	$\pm 2$	$\pm 4$	$\pm 5$	
14	$\pm 1$	$\pm 1$	$\pm 2$	$\pm 4$	$\pm 5$	
16	$\pm 1$	$\pm 1$	$\pm 2$	$\pm 4$	$\pm 5$	
20	$\pm 1$	$\pm 1$	$\pm 2$	$\pm 4$	$\pm 5$	
25	$\pm 1$	$\pm 1$	$\pm 2$	$\pm 4$	$\pm 5$	
28	$\pm 1$	$\pm 1$	$\pm 2$	$\pm 4$	$\pm 5$	
30	$\pm 1$	$\pm 1$	$\pm 2$	$\pm 4$	$\pm 5$	
36	$\pm 1$	$\pm 1$	$\pm 2$	$\pm 4$	$\pm 5$	

Bar diameter given. Value indicates accuracy of depth measurement in mm.  
 0 - bar can be detected at this depth but no depth calculated  
 X - Bar cannot be detected at this depth  
 Valid for bars conforming to DIN 488

## e) Evaluation and Recommendations

The test is useful for:

- Verification of reinforcement: locate rebar when plans are missing, for acceptance inspections, before structural repair or change of loads on a structure.
- Verification of concrete cover over reinforcement: obtain concrete cover information over large areas for acceptance inspections, before renovation or for quality control.
- Avoidance of accidental hitting of rebars: avoid cutting through critical reinforcement or costly rebar hits.
- Determination of bar depth and diameter.
- Easy determination of average concrete cover over large areas.
- Investigation of concrete members of which records are not available or need to be checked.

### 5.3.5.2 Radar Type

#### a) Fundamental Principle

Electromagnetic waves are transmitted from the antenna toward the concrete as shown in diagram below. The electromagnetic waves are reflected by an interface with the reflecting objects (e.g., reinforcing steel bars or cavities) whose electrical property is different from that

of concrete. The waves are reflected back into the surface of concrete and received by the receiving antenna placed near the concrete surface. The distance to the reflecting objects can be calculated from the time the reflected waves need to reach the receiving antenna. The horizontal locations of the objects can be detected by moving the main unit on the surface of concrete. Since this radar is designed to probe objects with high resolution that are near from the surface of concrete, it transmits pulse waves having a width of only about one nanosecond (one-billionth of a second) or less.

The velocity  $V$  of electromagnetic waves in concrete is obtained from the following formula:

$$V = \frac{C}{\sqrt{\epsilon_r}} \text{ (m/s)}$$

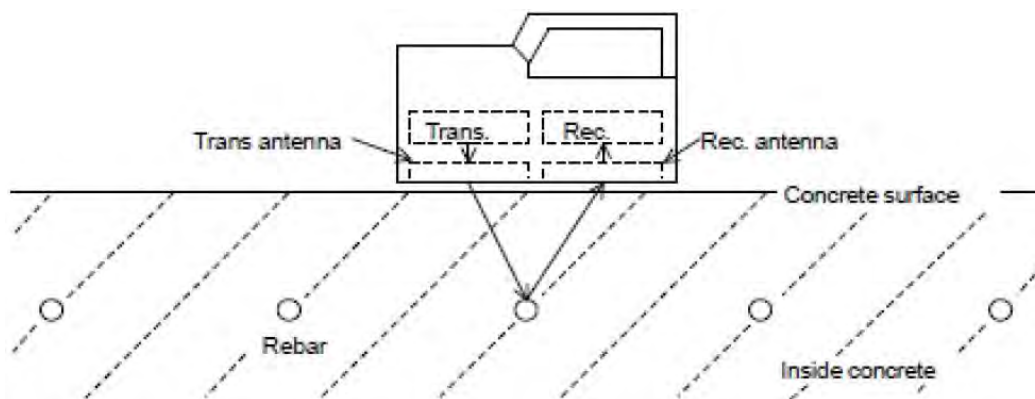
where:

$C$ : Velocity of electromagnetic waves in vacuum (in air) ( $3 \times 10^8$  m/s)

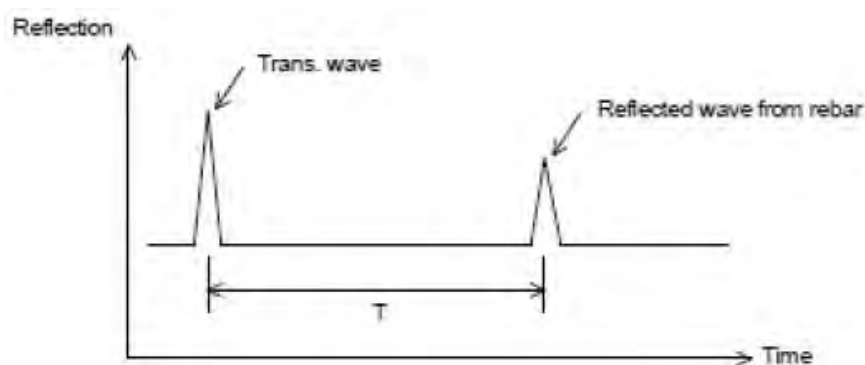
$\epsilon_r$ : Relative dielectric constant of concrete (6 to 11)

The distance  $D$  to the reflecting object is obtained from the following formula:

$$D = \frac{1}{2} V T \text{ (m)}$$



**Fig. 5.3.5.6 Diagram of Principle**



**Fig. 5.3.5.7 Diagram of Reflected Wave Form**

## b) Description of Apparatus



**Photo 5.3.5.3 Radar Type Rebar Detector**

### **Specifications**

Brand	JRC NJJ-105 Handy Search
System	Electromagnetic radar
Search target	Reinforcing steel bars, pvc pipes, cavities, etc.
Covering Thickness	5 to 300 mm (for top reinforcement while relative dielectric constant of concrete is 6.2 and rebar diameter is 6 mm or more)
Display	TFT color LCD (640 x 480 bits)
Max. scanning rate	About 40cm/s with overspeed alarm buzzer
Output function	Dedicated printer output function (IrDA)
Search data recording function	Data saved in compact flash memory. Approximately 200 passes (15-m search data saved in binary format) when using 1-GB memory
Memory capacity	
Temperature range	0°C to +50°C
Power supply	Battery pack, AC adapter
Continuous use time	About 1.5 hours (with the battery pack being fully charged)
Structure	Splash/rain resistant
Dimensions	About 149 (W) x 147 (H) x 216 (D) mm

### **b.1) Applicable measuring conditions**

- Scan test depth (covering depth) within 0.5 ~ 30 cm (case where relative permittivity of concrete is 6.2 and the diameter of the rebar is at least 6mm)
- Objects to be probed that are at a depth of less than 75 mm have an interval spacing of at

least 75 mm and where the depth of the object to be probed is greater than 75 mm, the interval spacing of the objects is more than the depth

- Quality of concrete: Uniform
- Direction of reinforcing steel: Orthogonal to the Handy Search's traveling direction

### b.2) Inapplicable Measuring Conditions

- Scanning of reinforcing steel bars or the like in concrete whose surface contains objects such as metal that reflect radio waves
- Presence of reinforcing steel bars that are parallel to the Handy Search's traveling direction
- Concrete that has a narrow (pitch) arrangement for the interval of rebar in the horizontal direction

(Depth less than 75 mm with spacing between rebar less than 75 mm

Depth greater than 75 mm with spacing between rebar less than depth)

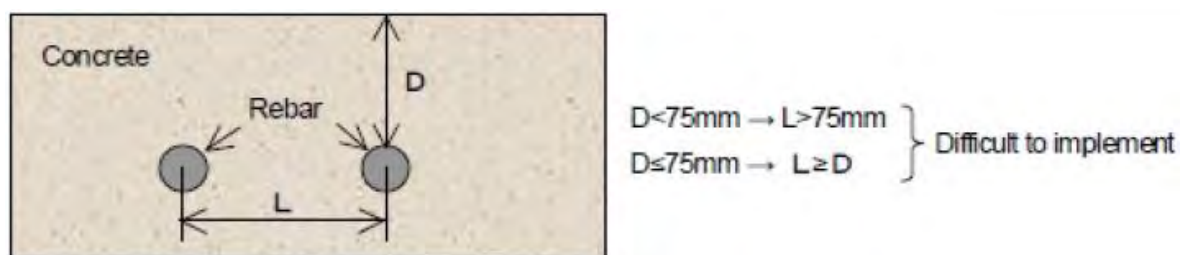


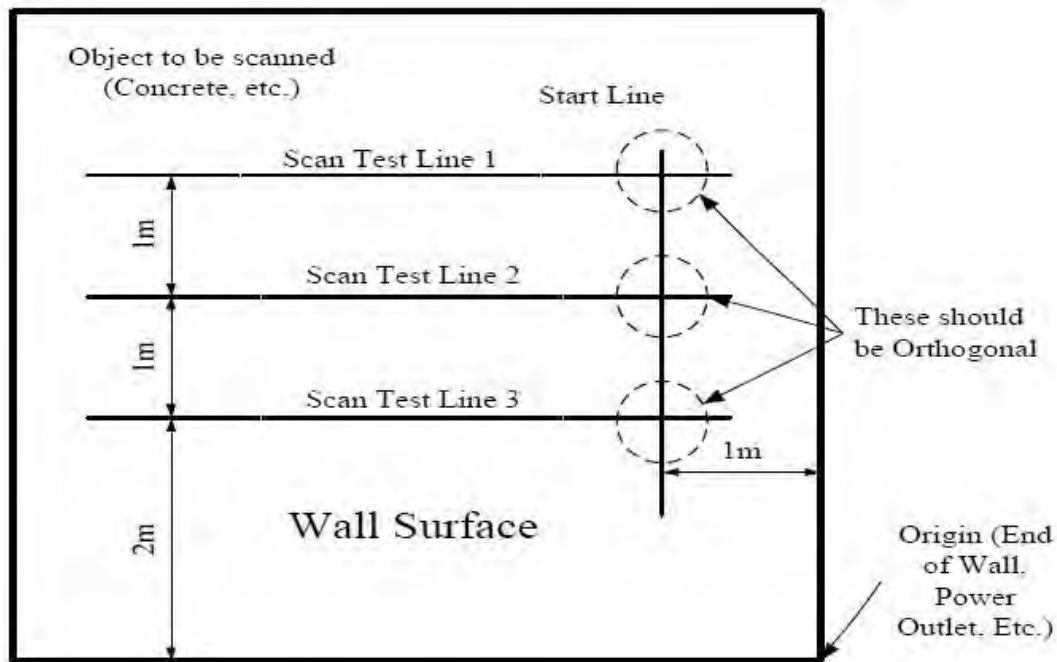
Fig. 5.3.5.8 Inapplicable Measuring Conditions

### c) Procedures

#### c.1) Preparation for Scanning

- 1) Using chalk (or similar tool) make markings on the concrete surface to indicate where to start testing (starting line) and where to scan (scan test line).
- 2) Make sure the start line and the scan test line are orthogonal (perpendicular to each other). (As necessary, in order to perform a retest, use an endpoint of the wall as a reference standard for the start line and scan test line).
- 3) A scan test applicable set up example is shown in Fig. 2.2.5.9.





**Fig. 5.3.5.9 Example of Scan Test Set-up**

## **c.2) Scanning**

### **c.2.1) Power-on Procedure**

- 1) The liquid crystal display lights up roughly 5 seconds after the power is turned on by turning on the power switch, and the initialization screen is displayed.
- 2) After the initialization screen completes, the scan test screen is displayed.
- 3) After confirming that the scan test screen is displayed on the liquid crystal display, start the scan test.

### **c.2.2) Scan Test**

- 1) Place the unit over the intersection of start line and the scan test line.
- 2) After about one second after pressing START, a short single buzzer sound is generated, the fixed cursor is displayed at a position of about 10cm of the movement distance scale on the screen, and then scan test preparation is complete.
- 3) Move the unit on top of the scan test line at a speed of less than 40 cm/s by rotating the wheels.
- 4) Press START again to finish. A double buzzer sound is generated and the scan test is stopped.
- 5) However, if the scan distance reaches 15 m, the buzzer sounds twice and the scan test automatically finishes.

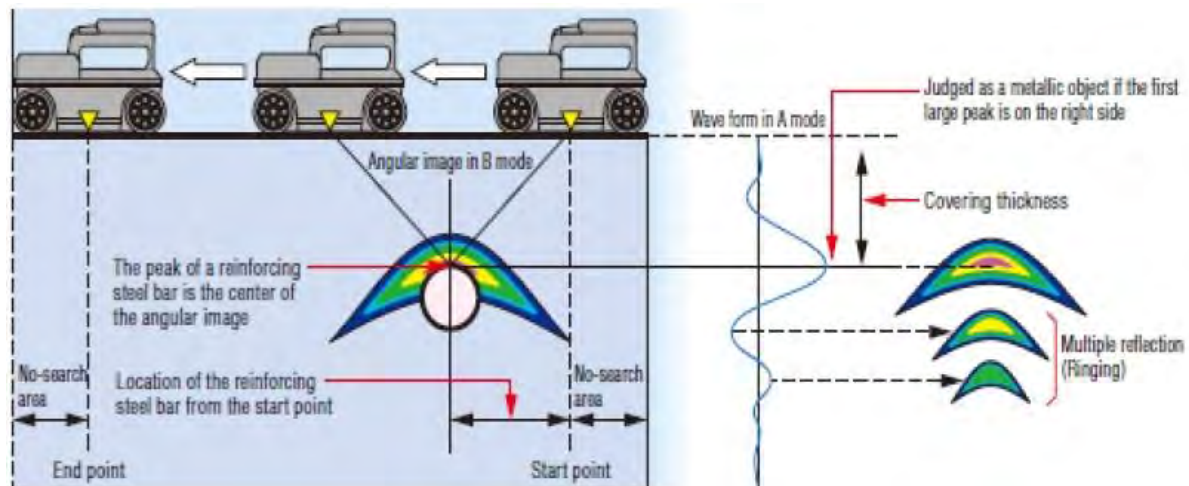


Fig. 5.3.5.10 Scanning Diagram

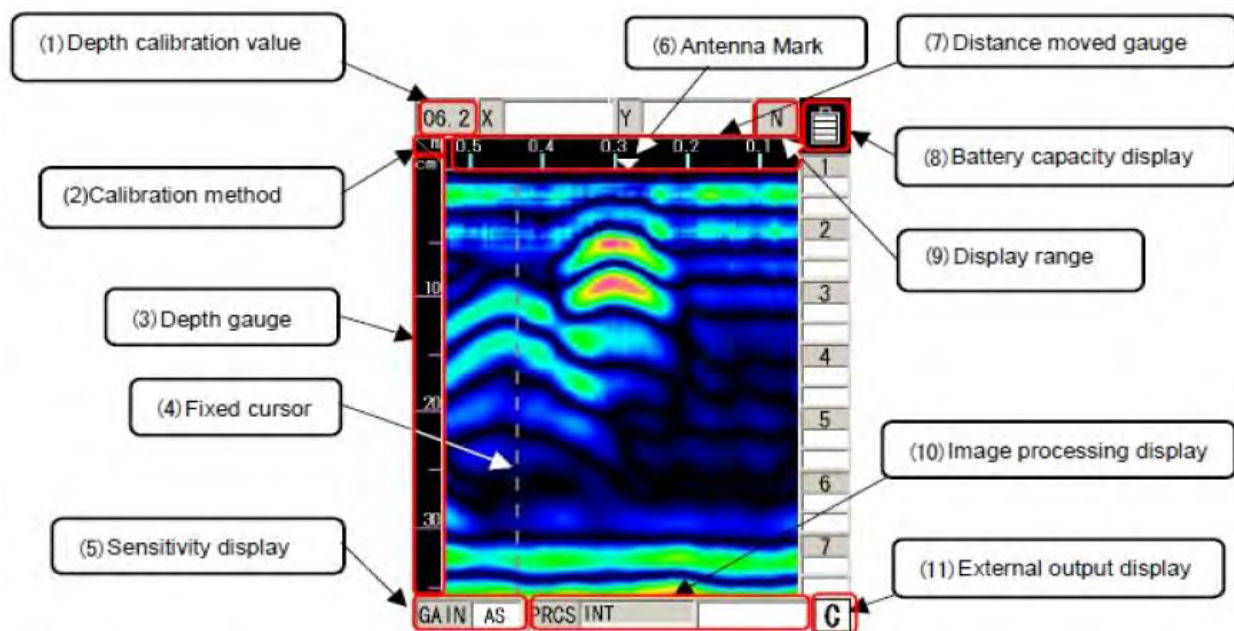


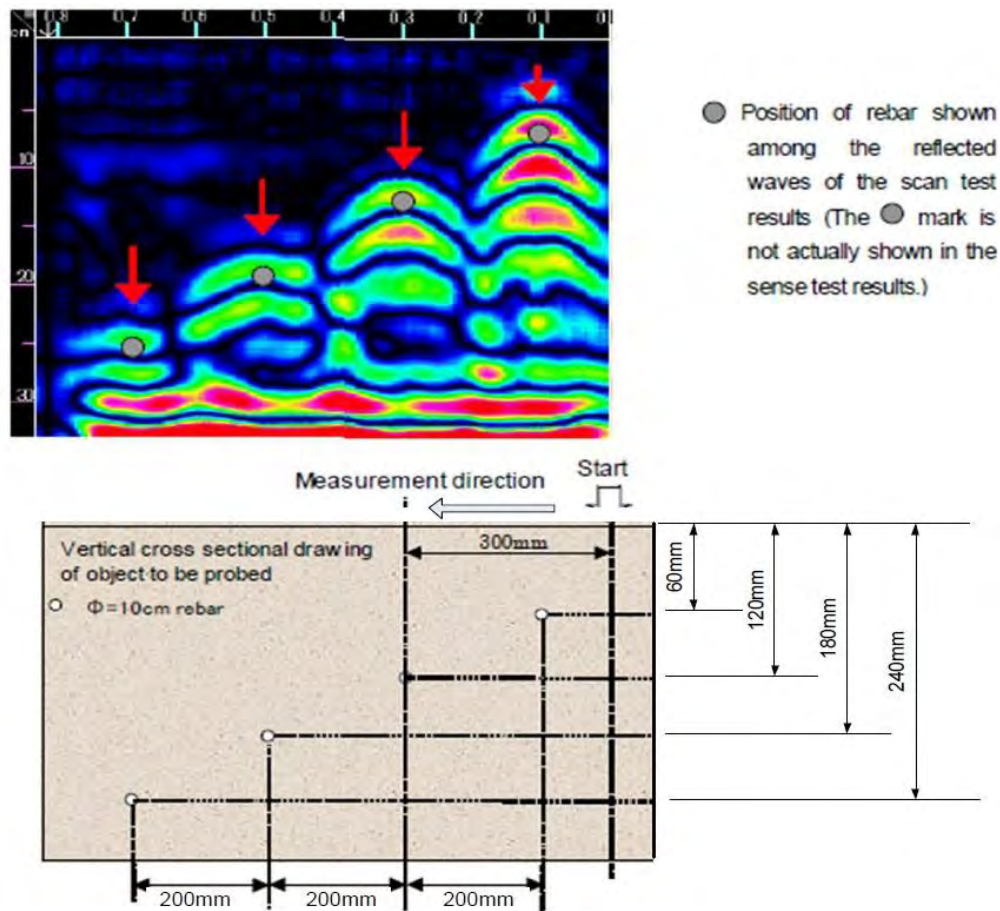
Fig. 5.3.5.11 Example of a Test Scan

#### d) Analysis (Interpretation of Data)

- The reflected waves shown in the scan test example in figure above are reflections of rebar. (↓ position)
- The position of the object to be probed (e.g., reinforcing steel bar) in the traveling direction is determined as the peak of the reflected wave.
- An approximate depth (covering depth) of the object to be probed (e.g., reinforcing steel bar) is determined as the center of the reflected wave.
- Perform depth calibration to reduce the error in the depth (covering depth) of the object being probed (such as rebar). The position of the object to be probed (such as rebar) is

shown by the peak on the right side of the A mode waveform.

- Match the cursor to the peak position to determine the depth.
- Refer to **Fig 5.3.5.12** for example of data analysis



**Fig. 5.3.5.12 Example Data Analysis**

### e) Evaluation and Recommendations

The test is useful in the:

- Verification of reinforcement: locate rebar when plans are missing, for acceptance inspections, before structural repair or change of loads on a structure.
- Verification of concrete cover over reinforcement: obtain concrete cover information over large areas for acceptance inspections, before renovation or for quality control.
- Avoidance of hitting rebars: avoid cutting through critical reinforcement or costly rebar hits.
- Determination of bar depth and determination of average concrete cover over large areas.
- Investigation of concrete members of which records are not available or need to be checked.

### 5.3.6 Infrared Thermal Image Test

#### 5.3.6.1 Fundamental Principles

##### a) General

Infrared Thermography is the process of using an instrument and a method to detect infrared energies emitted from an object, convert these emitted energies to temperature values, and display an image of the object showing the temperature distribution.

- Infrared was discovered by a British astronomer, Herschel, in 1800. When dispersing sunlight using a prism, Herschel accidentally found that there was an invisible energy just beyond the red color wavelength that increases with temperature.
- Infrared is an electromagnetic wave. Infrared wavelength is  $0.7\mu\text{m}$  or longer. For a wavelength of  $1\text{mm}$  ( $1000\mu\text{m}$ ) or less the frequency is  $300\text{GHz}$  or greater.

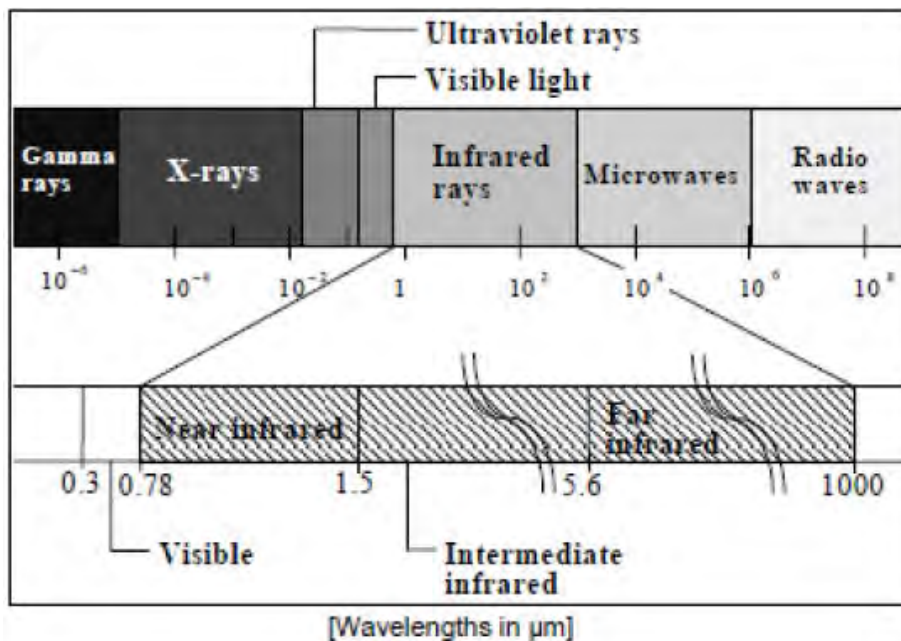
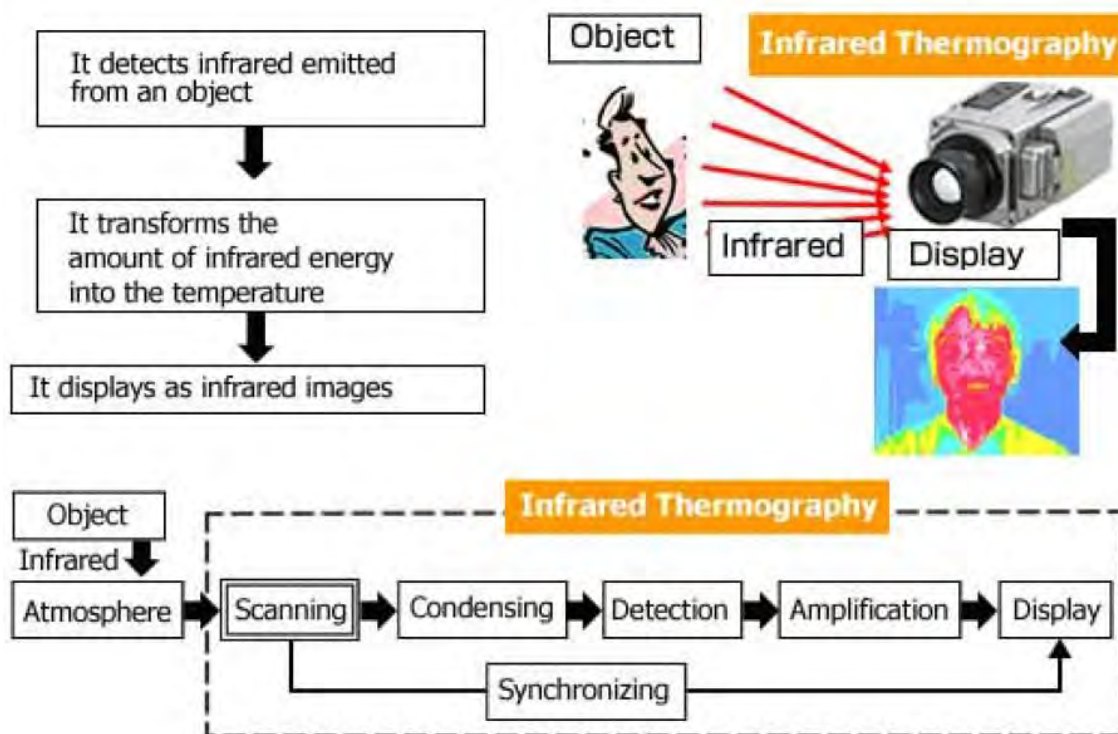


Fig. 5.3.6.1 Spectrum of Electromagnetic Radiation

Characteristics of Infrared:

- It is invisible since its wavelength is longer than visible light. It has nothing to do with brightness or darkness of visible light.
- It is emitted naturally from any object of which temperature is absolute zero (Zero Kelvin) or higher. Therefore, it can be applied to any field.
- It has a characteristic of heating an object. Therefore, it is sometimes called “heat wave”.
- Because it is a kind of light (electromagnetic wave) it is transmitted through a vacuum.
- There is a correlation between infrared energy and temperature of an object. Therefore, it can be used to measure the temperature of an object.



**Fig. 5.3.6.2 Process of Thermal Imaging**

Characteristics of Infrared Thermography Instrumentation:

- Captures a surface temperature distribution and displays it as visible information.
- Temperature is measured from a distance without contacting the measured object.
- Temperature is measured in real time.

### **b) Applications**

Used for detection of defects of concrete structure such as:

- Spalling
- Voids
- Delamination

The detectability of any internal structure such as voids, delamination or layer thickness depends on the physical properties (heat capacity, heat conductivity, density, and emissivity) of the materials of the test object. The interior 'structure' has an effect on temperature distribution on the surface. If the temperature changes on the surface, there is a delay before the effect of this change occurs below where a defect such as void occurs. The longer the times delay before the temperature changes, the greater is the depth of a defect below the surface. Generally anything deeper than 10 cm will only show after a long period of time (>1 hr) after the temperature change has occurred.



Since infrared system measures surface temperatures only, the temperature measured are influenced by three factors: (1) subsurface configuration, (2) surface condition; and (3) environment. As an NDT technique for inspecting concrete, the effect of subsurface configuration is usually the most interesting. All the information revealed by the infrared system relies on the principle that heat cannot be stopped from flowing from warmer to cooler areas; it can only be slowed down by the insulating effect of materials through which it flowing. Various types of construction materials have different insulating abilities or thermal conductivity values. For example, an air void has a lower thermal conductivity compared with surrounding concrete. Hence, the surface of a section of concrete containing an air void could be expected to have a slightly different temperature from a section of concrete without an air void.

When tests are performed during daylight hours, the defective concrete areas will appear warmer, while tests performed after dark, defective areas will appear cooler.

#### **5.3.6.2 Description of Apparatus**



**Photo 5.3.6.1 Infrared Camera and Accessories**

#### **Specifications**

Apparatus: Infrared Camera NEC Thermo Tracer

Detector Type: Uncooled Focal Plane Array (Microbolometer)

Measuring range:  $-40$  to  $+500^{\circ}\text{C}$ , in Three (3) ranges

Resolution: 320(H) x 240(V)

Thermal Sensitivity:  $<0.05^{\circ}\text{C}$  (at  $30^{\circ}\text{C}$ )

Accuracy:  $\pm 1^{\circ}\text{C}$  or  $\pm 1\%$  whichever is greater

Spectral Resolution: 8 to  $14\mu\text{m}$  ; Frame Rate: 60Hz

Spatial Resolution: (I.F.O.V) 1.21mrad

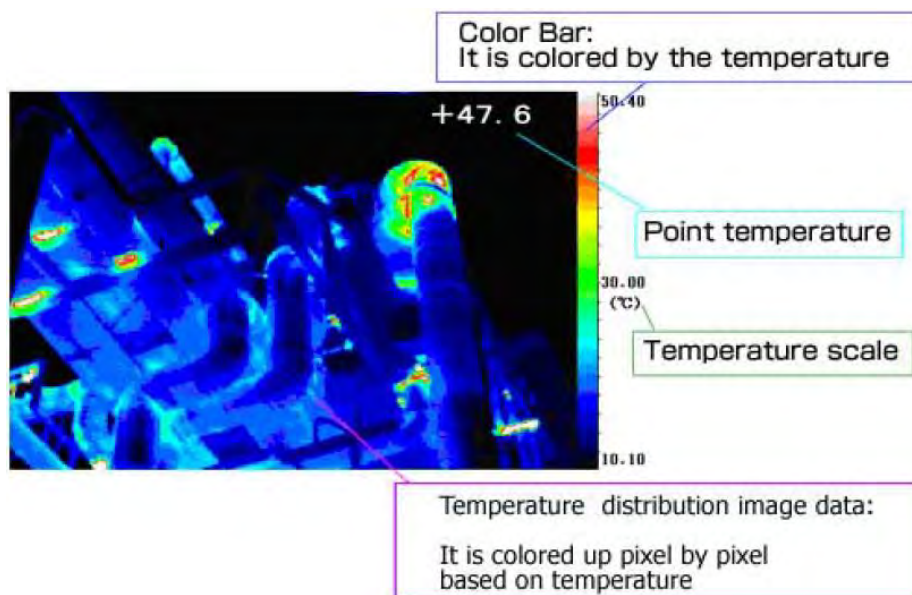


Focus Distance: 10cm to infinity (standard lens)  
Focus: Automatic  
Display Performance: Visual Image fusion display  
Display Unit: 3.5 inch Color LCD Monitor (320x240) with

### 5.3.6.3 Procedures

Refer to the Operation Manual on how to set-up, operate controls and commands in using the camera. The engineer should be trained in using this type of sophisticated apparatus.

A typical image produced by the camera is shown on **Fig. 5.3.6.3**.



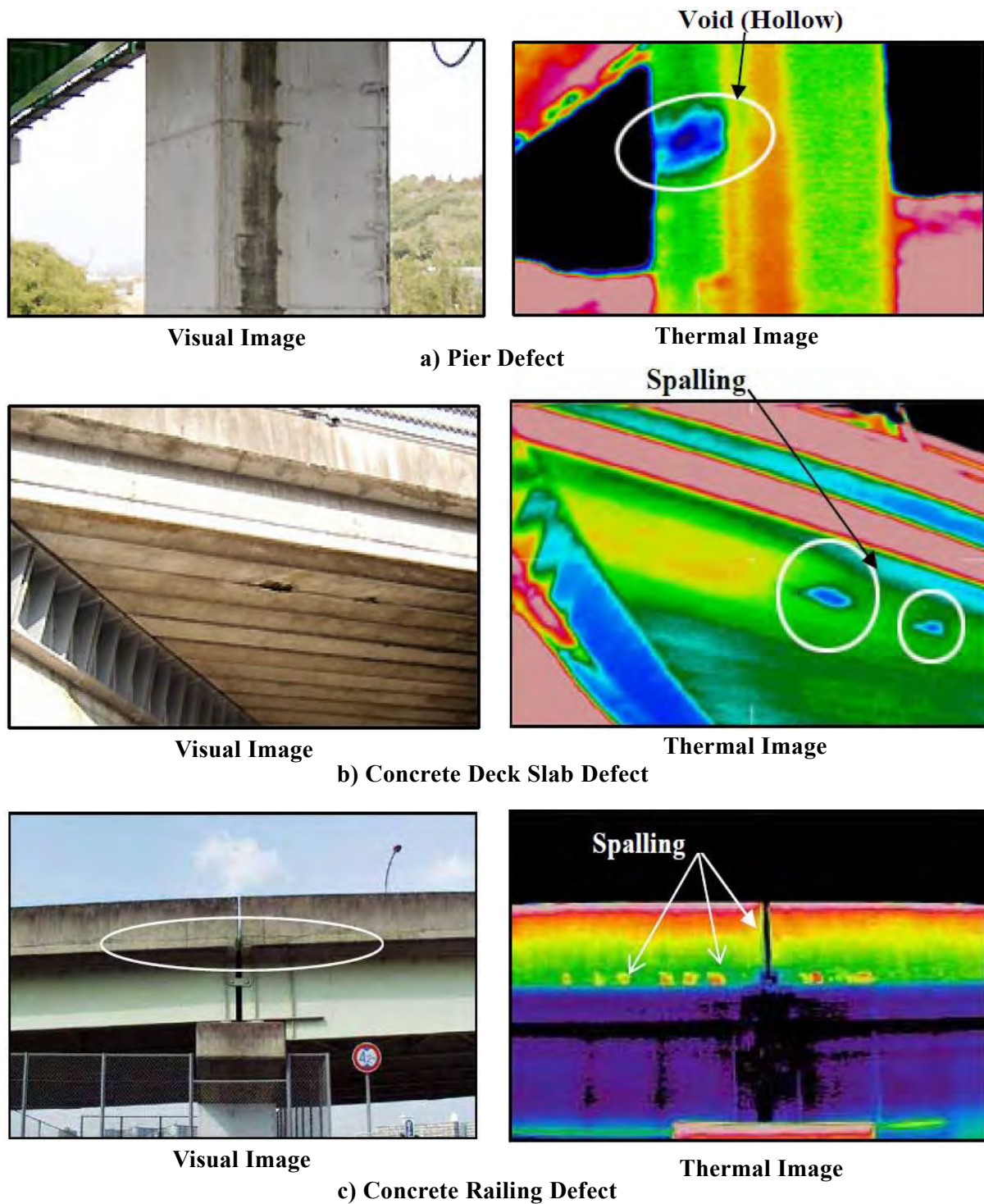
**Fig. 5.3.6.3 Sample Image from Infrared Camera**

Infrared Thermography instruments display temperature distribution image data using a matrix of pixels (each pixel being a miniature infrared energy detector). In the figure above, there are 320 horizontal x 240 vertical pixels (detectors).

### 5.3.6.4 Analysis

Images are uploaded to a computer for detailed analysis. With the use of software that interprets infrared images, the location and extent of voids, delamination and spalling of concrete structures are determined.

The following examples show results of infrared thermal imaging of structure defects.



**Fig. 5.3.6.4 Examples of Detection of Defects using Infrared Thermal Imaging**

### **5.3.6.5 Evaluation and Recommendations**

- Infrared thermographic analysis of large concrete areas does not require destroying concrete structure during testing. Only small calibration corings are used. This results in major savings in time, labor, equipment, traffic control, and scheduling problems.
- Infrared thermographic equipment is safe as it emits no radiation. It only records thermal radiation, which is naturally emitted from the concrete, as well as from all other objects. It is

similar in function to an ordinary thermometer, only much more efficient.

- Infrared thermography is an area testing technique, while the other NDT methods are mostly either point or line testing methods. Infrared thermography is capable of forming a two dimensional image of the large test surfaces showing the extent of subsurface anomalies.
- It is recommended that infrared thermography be used to survey large areas for problems. Once specific problem locations are established, radar can be used to spot check the anomaly for its depth and thickness. This combined technique would give the best combination of accuracy, efficiency, economy and safety.
- Temperature and weather are very sensitive. Therefore infrared thermography shall be useful the night time (around 9pm to 7am) or at day time (11am to 5pm). Because accuracy factor of temperature is  $\pm 2^{\circ}\text{C}$  or  $\pm 2\%$  of absolute temp in  $^{\circ}\text{C}$ .
- The test locations must be the point by solar radiation, temperature difference of the health point and damage point can be detected by infrared thermography.
- Infrared thermography must be avoided to test during rain, cloudy weather when there are slight changes in temperature after a few hours at the time of highest and lowest temperature ( approximately 3 hours).

### 5.3.7 Compressive Strength Test

#### 5.3.7.1 Fundamental Principles

Microcoring is the method chosen to obtain samples of existing concrete structures that are used to determine in-situ compressive strength of concrete. In concrete structures with a lot of reinforcement bars, it may be impossible to obtain a large core specimen from which compressive strength may be taken since reinforcing steel may be so prevalent in the concrete. Small cores extracted by microcore apparatus are used as substitutes for large cores to test concrete strength.

Compressive Strength Test in the form of The Point Load Test (PLT) is intended as an index test for the strength classification of rock materials and concrete core samples, but it may also be widely used to predict other material strength parameters with which is correlated. It can provide similar data at a lower cost due to its ease of testing and simplicity of sample preparation.

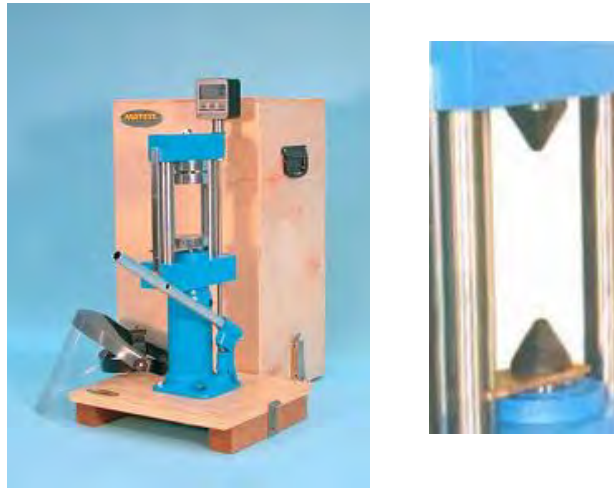
#### 5.3.7.2 Description of Apparatus

Microcore Apparatus is used for drilling holes (diamond core drilling) of 8–35 mm Ø in reinforced concrete, masonry and natural stone. It drills up to 300 mm depth with little vibration and low noise and can cut through reinforcing steel bars. Its water pump and extraction function are activated/deactivated automatically by the drilling machine.



**Photo 5.3.7.1 Microcore Apparatus**

Point Load Test Apparatus is used for compression test on small cylinder specimens and core samples up to Ø 60 x 100 mm. The load is applied by a hand pump and is measured by a precision digital display range 0–56kN, with an accuracy of  $\pm 1\%$ , resolution 65000 points. The compression platens have Ø 65 mm, the upper one has a spherical seat and vertical daylight of 110 mm. It comes with a set of two hardened conical points for point load testing.



**Photo 5.3.7.2 Point Load Test Apparatus**

### **5.3.7.3 Procedures**

#### **a) Coring**

- 1) Assemble the apparatus in accordance with instructions in the Operation Manual
- 2) Drilling
  - To begin drilling, press the control switch before the core bit has been brought into contact with the base material. Begin drilling the hole only when the water flow indicator shows that water is flowing through the core bit
  - Press the core bit gently against the base material. Take care to ensure that the core bit is perpendicular to the base material. The pressure applied to the core bit should be regulated so that the tool continues to run at its highest speed. Application of higher pressure does not increase the rate of drilling progress.
  - Hold the tool straight. Do not tilt it at angle as this may result in reduced drilling performance. Always ensure that the tool continues to run at a high speed.
  - Immediately after beginning drilling, check the water flow rate indicator to ensure that water is flowing.



**Photo 2.3.7-3 Microcore Drilling**



### 3) Removing the core from the hole

- Take the core removal tool out of the toolbox. Ensure that the diameter of the core removal tool corresponds to the diameter of the core bit used.
- Push the core removal tool into the hole as far as it will go while rotating it slightly.
- Break the core by applying slight lateral pressure to the core removal tool.
- Use the core removal tool to pull the broken core out of the hole. Turn the core removal tool through 180° and re-insert it in the hole.
- Use a ruler to measure the effective hole depth reached.
- Repeat this procedure, if necessary, several times until the entire core has been removed.



**Photo 2.3.7-4      Core Removal Tool and Core Sample**

## **b) Point Load Test (Reference standard ASTM D5731)**

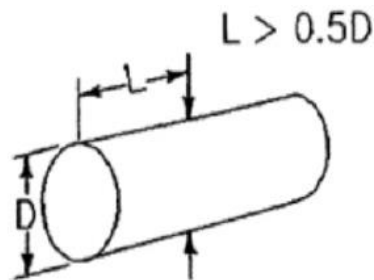
### **1) Diametrical Test**

- Mark the desired test orientation on the sample with lines along the surface. These lines are used for centering the sample before the test and checking the proper stress orientation along the compression to failure.
- Close the valve of the hydraulic circuit of the hand pump. Insert the extension rod into the jack lever and zero set the digital readout unit (make reference Instruction Manual for the use of the digital manometer).
- Insert the sample between the conical points along a direction perpendicular to the end faces of the core and act on the jack to close the platens to the core. The core surfaces generally consist of failure planes.
- Before starting compression, check that the conical points will contact the core sample along the diameter  $D$  and that the distance  $L$  between the contact points and the nearest free end of the core will be as follows:
- Use the graduated scale inserted on the frame of the machine to record the distance  $D$  of the points to the nearest  $\pm 2\%$ .
- Check that the digital manometer records a small load and operate with the pump to increase the load steadily such that the failure occurs within 10 to 60 sec.
- Record the maximum force displayed by the digital manometer (the peak load value is

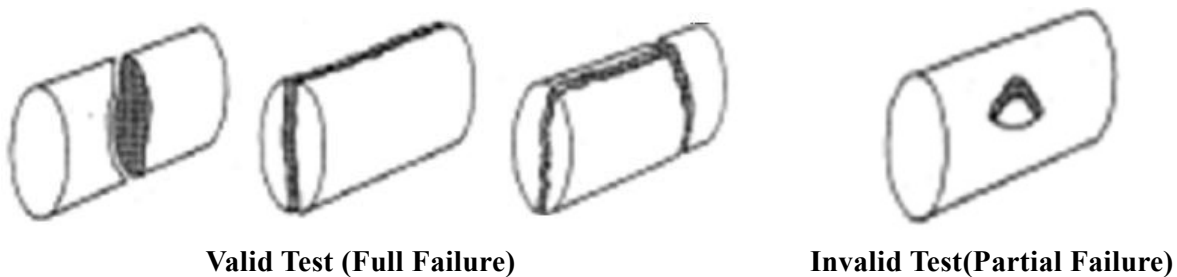


frozen on the display) and measure again the distance  $D'$  of the points. If a partial failure occurs, the test result is not considered.

- Open the hydraulic circuit of the pump and push down manually the loading piston, to start again with a new test of core samples. Where possible, the test is repeated with at least 10 core samples.



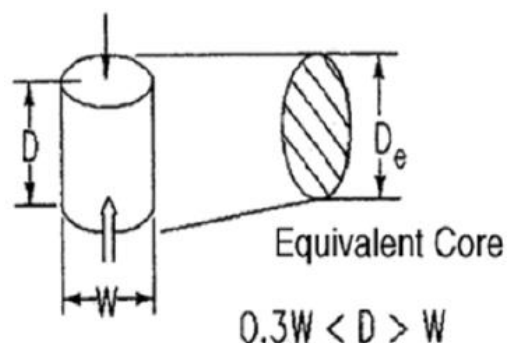
**Fig. 5.3.7.1 Core Configuration for Diametrical Test**



**Fig. 5.3.7.2 Valid and Invalid Diametrical Test**

## 2) Axial Test

- Measure first the size of the core sample, in order to check that the length/diameter ratio is between  $1/3$  and  $1$ . Mark the desired test orientation on the sample with lines along the surface. These lines are used for centering the sample before the test and checking the proper stress orientation along the compression to failure.
- Close the valve of the hydraulic circuit of the hand pump. Insert the extension rod into the jack lever and zero set the digital readout unit.



**Fig 5.3.7.3 Core Configuration for Axial Test**

- Insert the sample between the conical points along a direction perpendicular to the end faces of the core and act on the jack to close the platens to the core. The core surfaces generally consist of failure planes.
- Use the graduated scale inserted on the frame of the machine to record the distance D of the points to the nearest  $\pm 2\%$ .
- Check that the digital manometer records a small load and operate with the pump to increase the load steadily such that the failure occurs within 10 to 60 sec.
- Record the maximum force displayed by the digital manometer (the peak load value is frozen on the display) and measure again the distance D' of the points. If a partial failure occurs, the test result is not considered.



**Valid Test (Full Failure)**

**Invalid Test (Partial Failure)**

**Fig. 5.3.7.4 Valid and Invalid Axial Test**

### 3) Test Points

- One test result needed for superstructure and one for substructure.
- One coring piece can be divided to two or three test pieces.
- Be careful so that coring does not affect structure.
- If test results are less than design compressive strength, then take another core and test again.

### 5.3.7.4 Analysis

1) Calculate Point Load Strength Index  $I_S$  (MPa) as follows:

$$I_S = P \times 1000 / D_e^2$$

where:

P : Peak resistance expressed in kN

$D_e$ : Equivalent diameter of the core expressed in mm

For diametrical test :  $D_e = \text{diameter}$

For axial test :  $D_e^2 = 4 \times A / \pi$

where :  $A = W \times D$

2) Apply size correction factor if core sample diameter is other than 50mm, as follows:

$$Is_{(50)} = F * IS$$

$$\text{where: } F : (De / 50)^{0.45}$$

3) Calculate Mean Value

To calculate the average point load index  $Is_{(50)}$ , at least 10 point load tests are required. From these tests reject the highest and the lowest strength value, and average the eight remaining test results to get the mean value.

4) Estimate Compressive Strength, as follows:

$$\delta_{uc} = C \times Is_{(50)}$$

where:

$\delta_{uc}$  : Uniaxial Compressive Strength

C: factor that depends on site-specific correlation between  $\delta_{uc}$  and  $Is_{(50)}$

$Is_{(50)}$  : Corrected Point Load Strength Index

**Table 5.3.7.1 Values of ‘C’**

Core Diameter, mm	Value of “C”
20	17.5
30	19
40	21
50	23
54	24
60	24.5

### **5.3.7.5 Evaluation and Recommendations**

- Microcoring has the advantages of cores being easily drilled and cut with minimum damage to structures and requires use of a portable lower-capacity machine.
- Cores also utilize for carbonation test.
- PLT is used as an index test for strength classification of materials such as existing concrete
- PLT requires smaller breaking force so that a small and portable testing machine may be used.
- Cores can be tested in the field without machining since apparatus is portable.

## 5.4 NDT for Steel Attributes

### 5.4.1 Paint Thickness Test

Coating thickness measurements are based on the fact that the inductance between an electromagnet and a metallic surface varies with the thickness of a nonmagnetic interface coating. Changes in the inductance are electronically transmitted to a digital measurement of the coating thickness.

#### 5.4.1.1 Fundamental Principles

##### a) General

When iron is moved toward or away from a steel core coil which carries electric current, self-inductance increases or decreases in accordance with distance. This change in inductance can be read as a deflection of needle of an ammeter, or a digital indicating signal connected as shown in Fig.5.4.1.1 below. This principle is utilized to measure the thickness of non-magnetic surface treated film (D) on iron substrate.

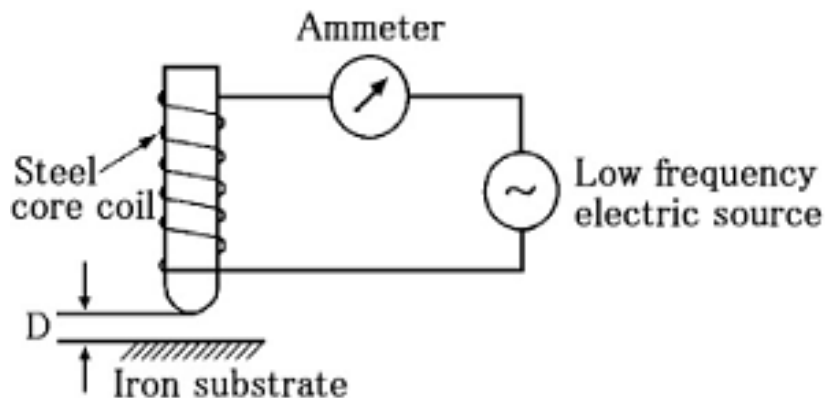


Fig. 5.4.1.1 Principle of Coating Thickness Measurement on Surface of Iron Substrate

##### b) Applications

The technique is applicable for non-destructive measurement of the thickness of a non-magnetic coatings, linings and plating applied to iron substrate including steel and ferritic stainless steel (SUS 430 etc.) such as:

- Paint films on machines, appliances, automobiles, furniture, bridges, ships, steel tubes, cast iron tubes, structures, etc.
- Lining films Resin, tar epoxy, rubber and enamel film etc.
- Non-magnetic plating such as chrome, zinc, copper, tin, electroless nickel, (excluding electrolysis nickel) etc.

- Metalikon, phosphoric acid films, oxide films, spray deposit films, etc.
- Resin films and non-magnetic metal sheets (on iron substrate)

#### 5.4.1.2 Description of Apparatus



**Photo 5.4.1-1 Paint/Coating Thickness Meter**

#### **Specifications**

Name – UNIBOY-M

Measuring Method – Electromagnetic induction

Measuring Range – 0 to 3.00 mm

Resolution – 1 $\mu$ m: within range of 0 to 999  $\mu$ m

0.01mm: within range of 1.00 to 3.00 mm

Accuracy –  $\pm$   $\mu$ m on uniform surface or  $\pm$  3% of reading

Display – LCD with display hold function

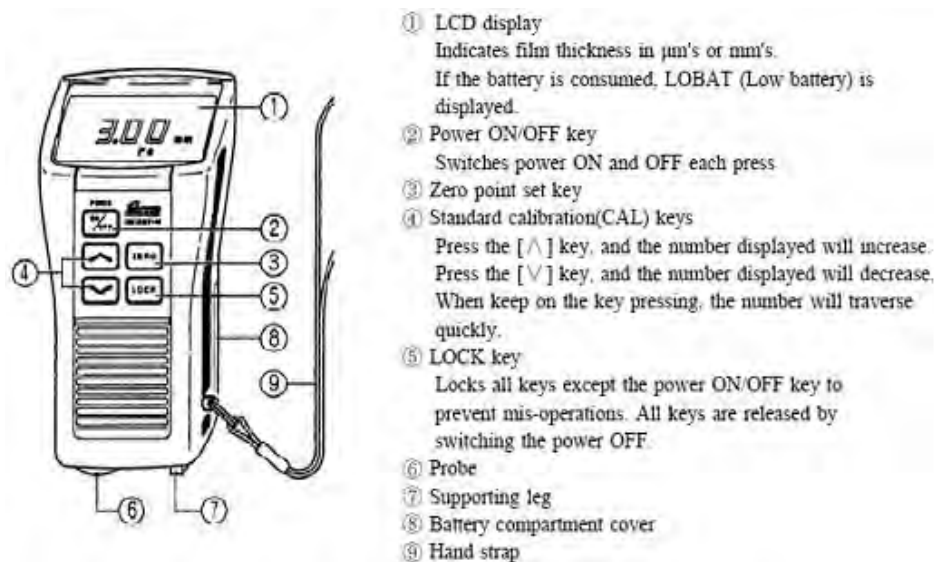
Probe – One-point contact pressure type with V-groove,  $\varnothing$ 17, Built-in electrode treated with CVD material of super abrasion resistance

Power Source – Dry batteries R03 (1.5V) x 2 pcs

Dimensions – 56 x 109 x 34 mm

Weight – 140 g (including batteries)

Accessories – Standard thickness plate x 2 pcs, Zero plate for testing



**Fig. 5.4.1.2 Parts Identification**

### 5.4.1.3 Procedures

#### a) Operating Instructions

Refer to Operation Manual for adjustments, calibration and proper usage.

#### b) Investigation

Before testing, the following items should be investigated:

1. Design film thickness
2. Paint material used
3. Painting work records (Date/s when the painting work was done.)
4. The latest test results (thickness)

#### c) Measurement

1. Press “Power On/Off”. When the buzzer emits beeping sound, the meter is ready.
2. Caution: Press the LOCK key during the measurement to avoid errors and hold the apparatus as shown in diagram below and press it vertically on surface to be measured.
3. Press the probe against an object to be measured and the buzzer emits a beeping sound and the measured value is indicated on the LCD.
4. When no beeping sound is emitted, measure again after moving the meter 4 to 5cm or more from the object and waiting for a little while.
5. Record measured film thickness





**Fig. 5.4.1.3 Measurement**

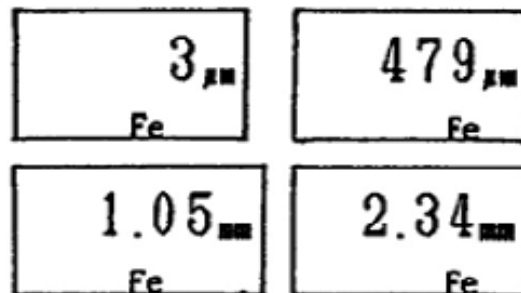
#### **d) Test Points**

1. Measure thickness of paint in good condition as reference.
2. Measure thickness of deteriorated paint areas

#### **5.4.1.4 Analysis**

When LCD read out appears as one of 0 to 999, unit of measurement is in  $\mu\text{m}$  (1/1000mm). For example: 0.2mm is 200 $\mu\text{m}$ .

When LCD read out appears as one of 1.00 to 3.00, unit of measurement is in mm.



**Fig. 5.4.1.4 Examples of Read Out**

#### **5.4.1.5 Evaluation and Recommendations**

- Control of the paint film thickness is important for steel structures. Condition of paint influences the service life of the structure. Therefore, paint film thickness should be inspected at fabrication shop immediately.
- Paint film thickness should be inspected periodically. To avoid paint damage, the surface should be cleaned regularly.
- If the existing film thickness is found to be less than the designed thickness but there is no damage, condition should be monitored. Additional painting will be required in case of new

fabrication.

- If damaged, the repair method should be planned based on the degree of damage.
- The coatings must be non-magnetic with a thickness preferably less than 1 mm. The method can be used on paint, plastic, vitreous, enamel, galvanized and hard chrome, to name examples of non-magnetic coatings
- The reliability of the readings depends on the calibration, the test item and the geometry of the item.
- With the exception of thin coatings (less than 0.005 mm), the accuracy is usually within  $\pm 3\%$  if the equipment is calibrated for the thickness to be measured. Otherwise, the precision is  $\pm 5\%$ . The minimum thickness that can be measured without special calibration is 0.003 mm.

### 5.4.2 Metal Thickness Test

The thickness gauge is used to determine the remaining thickness of corroded metallic items.

#### 5.4.2.1 Fundamental Principles

##### a) General

This ultrasonic nondestructive testing is used in characterizing material thickness, integrity, or other physical properties by means of high-frequency sound waves. It has become a widely used technique for quality control. In thickness gaging, ultrasonic techniques permit quick and reliable measurement of thickness without requiring access to both sides of a part. Accuracies as high as  $\pm 1$  micron or  $\pm 0.0001$  inch are achievable in some applications.

Precision ultrasonic thickness gauges usually operate at frequencies between 500 KHz and 100 MHZ, using piezoelectric transducers to generate bursts of sound waves when excited by electrical pulses. Typically, lower frequencies will be used to optimize penetration when measuring thick, highly attenuating, or highly scattering materials, while higher frequencies will be recommended to optimize resolution in thinner, non-attenuating, non-scattering materials.

A pulse-echo ultrasonic thickness gauge determines the thickness of a part or structure by accurately measuring the time required for a short ultrasonic pulse generated by a transducer to travel through the thickness of the material, reflect from the back or inside surface, and be returned to the transducer. In most applications this time interval is only a few microseconds or less. The measured two-way transit time is divided by two to account for the down-and-back travel path, and then multiplied by the velocity of sound in the test material. The result is expressed in the well-known relationship:

$$D = Vt / 2$$

where : d = the thickness of the test piece

V = the velocity of sound waves in the material

t = the measured round-trip transit time

##### b) Applications

Thickness of most engineering materials can be measured ultrasonically, including metals, plastic, ceramics, composites, epoxies and glass. In the field, it is used to determine remaining plate thickness of corroded steel bridge structures. In the fabrication shop, it is used to test uniformity of thickness of steel plates used in various structures

### 5.4.2.2 Description of Apparatus



**Photo 5.4.2.1 Ultrasonic Thickness Gauge**

#### **Specifications**

Name: Ultrasonic Thickness Gauge  
Display type: 4-digit LCD (128X64MM) with back light  
Display resolution: 0.001 inch or 0.01mm  
Measuring range: 0.040 to 15.75 inches (1 to 400mm) in steel  
Memory Capacity: 5000 readings  
Sound velocity range: 3280–32800 ft/s (1000–9999 m/s)  
Operating temperature: 32°F to 122°F (0°C to 50°C)  
Frequency: 5 MHz Output  
Connection to Computer: USB communication with software

#### **Standard Accessories**

Transducer 5 MHz  
Integrated Steel Calibration Plate 4.0mm

### 5.4.2.3 Procedures

#### **a) Operating Instructions**

Refer to the Operation Manual for adjustments, calibration and proper usage.

#### **b) Investigation**

Before testing, the following items should be investigated:

1. Design steel thickness
2. Repair work records
3. The latest thickness test results



**Photo 5.4.2.2 Operation of Ultrasonic Thickness Gauge**

#### **c) Measurement**

1. Press the probe against an object to be measured and the measured value is indicated on the LCD.
2. Record measured steel plate thickness and its location on the plan.
3. Repeat measurements at other locations as necessary
4. Measure thickness of both corroded and un-corroded steel for comparison. Be sure to remove rust on corroded surface by sanding before measuring

#### **d) Test Guidelines**

The transducer should be placed on the surface of the test item. The ultrasonic waves will then be reflected by the opposite surface. The thickness is shown digitally. For uneven or corroded surfaces, it may be necessary to grind the surface at the test positions to make proper contact. Possible rust on the opposite surface does not disturb the reflections. If steel plates are laminated, the measured thickness will only be the depth of the first layer.

Before starting the measurements, a contact liquid is applied to the test locations. Further, the equipment must be calibrated. For common steel alloys, the calibration is performed by means of test blocks. For unknown alloys (or if you are not sure), the calibration is performed by adjusting the sound velocity setting of the equipment until the equipment shows the same thickness as can be measured by a slide caliper at a free edge.

#### **e) Test Points**

1. Measure thickness of good condition metal for reference.
2. Measure thickness of deteriorated metal and analyze deterioration area.

#### **5.4.2.4 Analysis**

Record the measured thickness shown in the LCD screen at each test location on the drawings for easy analysis of results. The unit stores up to 5000 readings in its memory. Using USB interface and software, records are also transferred to the computer. Once transferred, records stored in unit can be erased for next use.

#### **5.4.2.5 Evaluation and Recommendations**

- Steel structures should be inspected regularly. To avoid damage, surfaces should be applied with appropriate paints.
- If the existing plate thickness is found to be less than the designed thickness due to corrosion, repair method should be planned based on the degree of damage.
- The method is generally applicable and is particularly efficient for measuring possible corrosion of structural elements with access only possible from one side. The gauge uses dual transducers to measure the thickness of corroded, pitted, scaled, granular materials from one side only.
- Thicknesses of between 0.50 mm and 200 mm can usually be determined within  $\pm 2\%$ .



### 5.4.3 Magnetic Particle Testing (MT) (JIS G 0565)

#### 5.4.3.1 Fundamental Principles

Magnetic Particle Testing (MT) is NDT process for detecting surface and slightly subsurface discontinuities in ferromagnetic materials such as iron, nickel, cobalt, and some of their alloys. The process puts a magnetic field into the part. The piece can be magnetized by direct or indirect magnetization. Direct magnetization occurs when the electric current is passed through the test object and a magnetic field is formed in the material. Indirect magnetization occurs when no electric current is passed through the test object, but a magnetic field is applied from an outside source.

MT is a visual testing about the crack length on surface or existence confirmation of crack by the magnetized target portion and the adhering magnetic particles to crack (Fig.5.4.3.1).

There is 'wet method' and 'dry method' in MT. In general, 'wet method' is adopted.

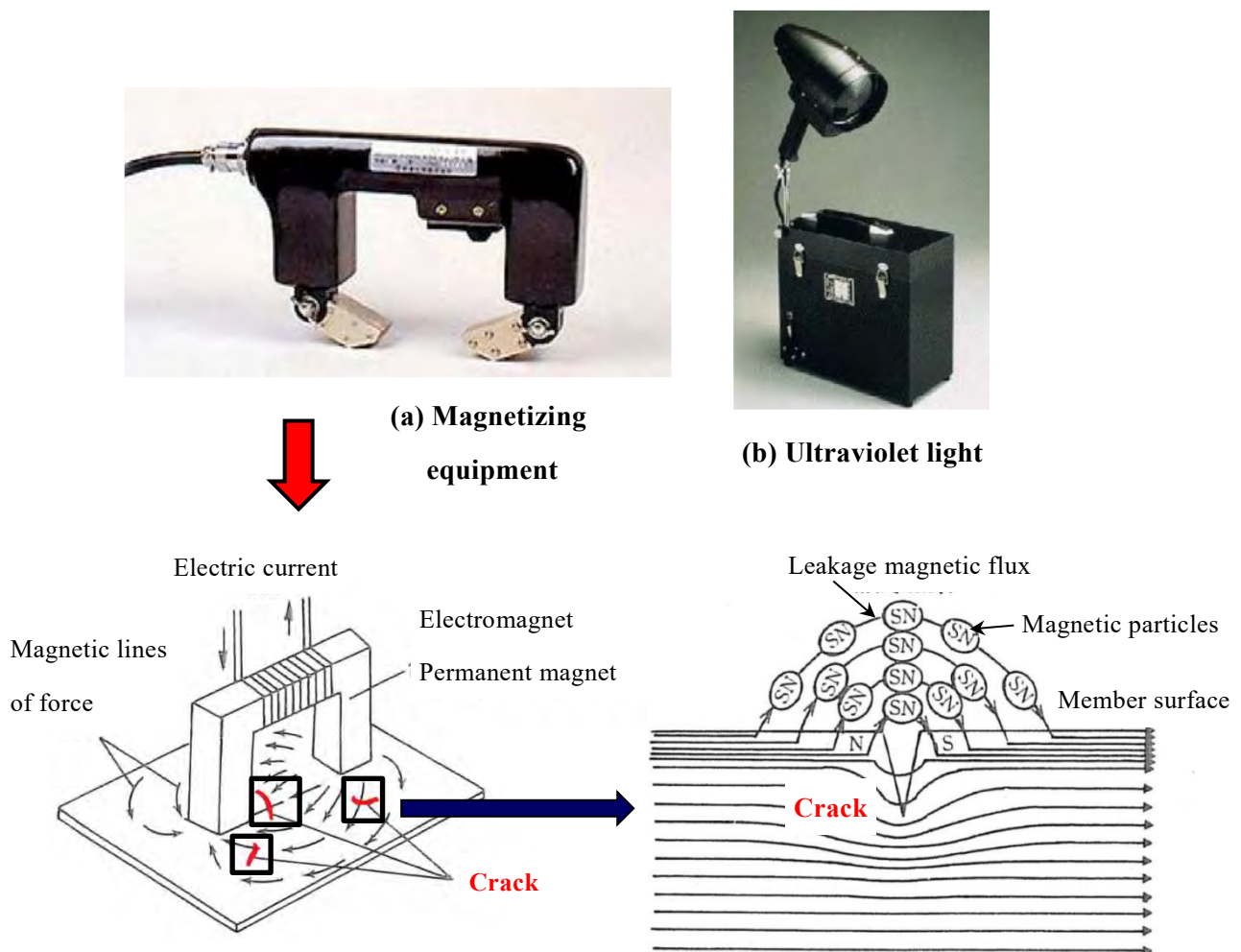
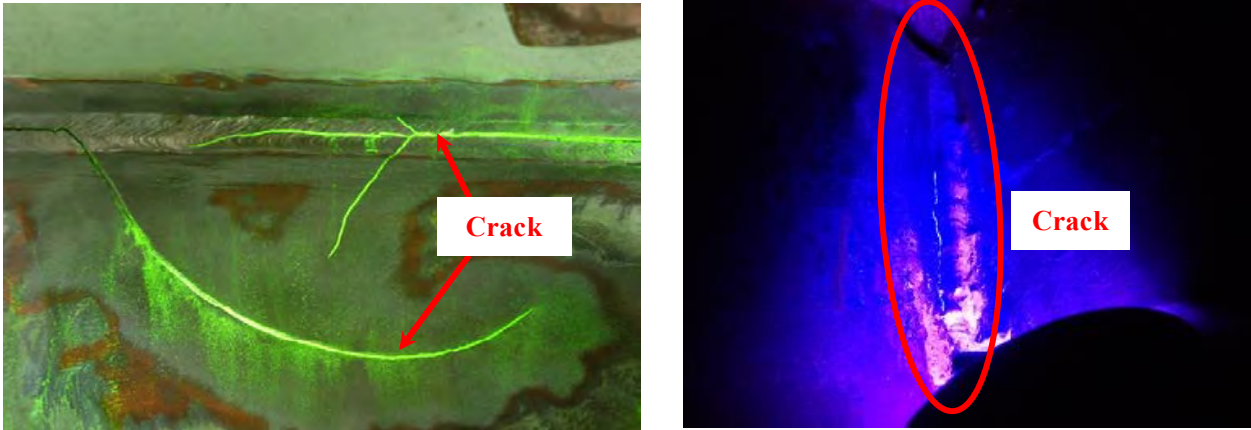


Fig.5.4.3.1 Magnetic Particle Testing

‘Wet method’ is that magnetic particles are dispersed in a liquid, and the magnetic particles are deposit to the magnetic flux leakage near the crack using liquid flow.

In generally, It is used to "fluorescent magnetic particles" which are contained a fluorescent paint. Fluorescent magnetic particles are good detection performance by applying ultraviolet light (Photo5.4.3.1).



**Photo.5.4.3.1 Detection of crack by MT**

#### **5.4.3.2 Procedures**

##### **(a) Preprocessing**

In case of attaching the oils, paints, rust and other foreign matter to the test member, the magnetic particles can't be only adhered to the adsorbed crack, but also magnetic particles adheres to non- crack part. Therefore, it is necessary to remove these by mechanical or chemical treatment before magnetization.

##### **(b) Magnetization**

It is important to properly magnetize the test member. In general, the test member is magnetized so that perpendicular to the direction of the crack and the direction of the magnetic flux.

##### **(c) The application of the magnetic particles**

The Magnetic particles must be excellent about the adsorption of magnetic. There are two methods about the timing of applying the magnetic particles;

Continuous method: Applying the magnetic particles at supplied current

Residual method: Using the residual magnetism of the test member

##### **(d) Crack confirmation**

In case of using fluorescent magnetic particles, it is easy to see the results detection if peripheral part is dark, because of using ultraviolet light.

#### **(e) Post-processing**

It is necessary to carry out the post-processing, such as Removal of magnetic particles and anti-rust treatment.

#### **5.4.3.3 Advantages and disadvantages**

Advantage of Magnetic particle Testing is as following;

- It can measure excellent accurately the shape and dimensions of surface-crack.

But disadvantage is as following;

- It is necessary to power equipment.
- It can't be detected internal defects.
- It is necessary to remove the coating.

#### 5.4.4 Eddy Current Testing (ET) (JIS G 0568)

##### 5.4.4.1 Fundamental Principles

When an alternating current is supplied to a coil of winding wire, the magnetic flux is generated. When the magnetic flux is absorbed to conductor, a current is generated on surface. If there is crack on the surface or the property of electronic and electromagnetic on the surface changes, the current which is generated on the surface changes. Eddy current testing is non-destructive inspection method about surface cracks by utilizing this phenomenon (Fig.5.4.4.1).

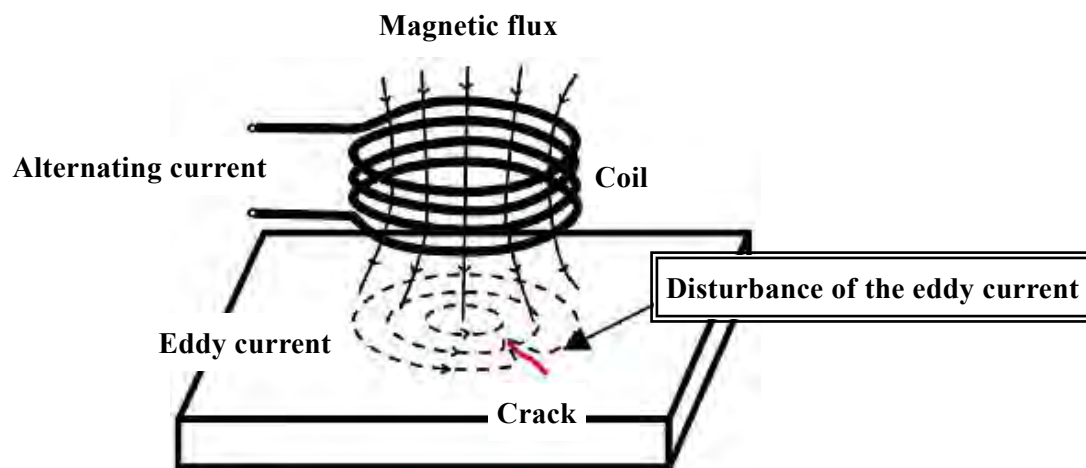


Fig.5.4.4.1 Eddy Current Testing



Photo.5.4.4.1 Equipment of eddy current testing

#### **5.4.3.2 Advantages and disadvantages**

Advantage of eddy current testing is as following;

- It can be a large amount of testing in a short period.
- It can check without peeling the paint.
- It is simple and inexpensive testing.

But the disadvantage is as following;

- It can't be detected internal defects.
- It is difficult to know the accurate crack shape and dimension.

## 5.5 Special Non–Destructive Tests

### 5.5.1 Ultrasonic Flaw Detection Test

#### 5.5.1.1 Purpose

Ultrasonic flaw detection test can detect surface and intentional defects using high frequency elastic pulse wave.

The ultrasonic flaw detection test is that a transmitter transducer introduces acoustic energy of high frequency inside the specimen which propagates in the form of waves. When there is a discontinuity (such as a crack) in the wave path, a part of the energy will be reflected back from the flaw surface. This reflected energy is picked up by a receiver transducer and is an indication of the size of the defect.

Ultrasonic flaw detection test is used to assess the quality of the steel structure in relation to:

- a) Locating and evaluating defects of welds
- b) Locating and evaluating other flaws such as crack and void
- c) Measuring thicknesses

#### 5.5.1.2 Description of Apparatus

This ultrasonic flaw detector has a frequency range from 0.5 to 20 MHz and a maximum calibration range of 10 m (steel), Probes connected by cables to the sockets at top right portion of the apparatus are used to send and receive ultrasonic pulses from test material which are then analyzed and displayed on the screen.

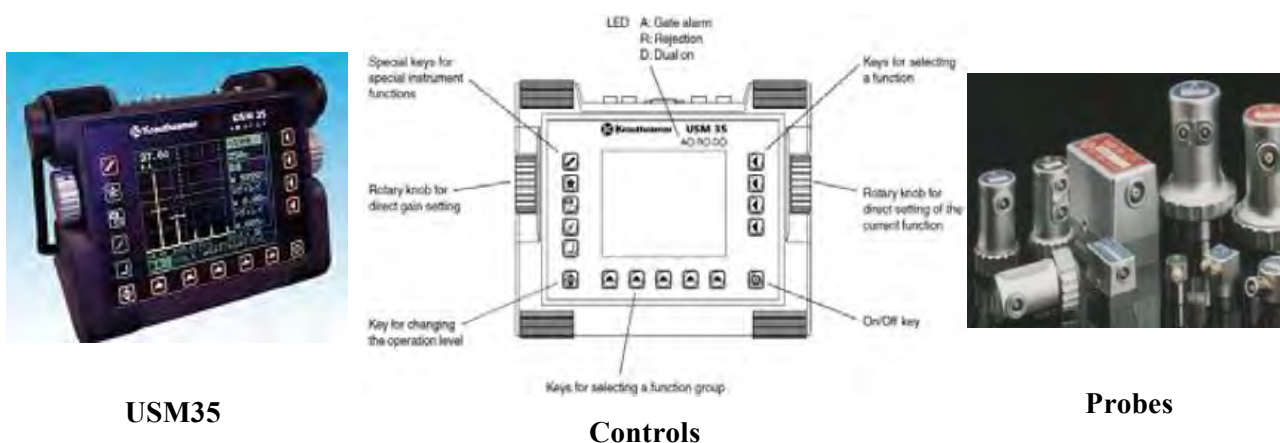


Fig 5.5.1.1 Ultrasonic Flaw Detector



### 5.5.1.3 Test Procedures

Ultrasonic Testing require following procedures:

#### a) Test Procedures

##### a.1) Testing of Welds

Before testing, the type of welding (full-penetrated or partial-penetrated groove weld, fillet weld, etc.) should be determined. Ultrasonic test can only assess the full-penetrated weld.

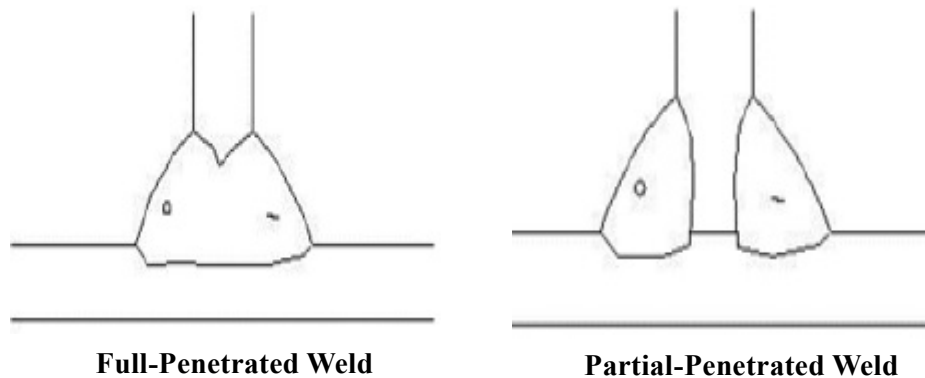


Fig 5.5.1.2 Types of Welding

##### a.2) Testing of Flaws

Use Straight Beam Probe which has a single transducer to transmit the ultrasonic pulses vertically into the test object and receive the returning reflections. They are suitable for detection and evaluation of flaws which reflect parts of the pulse back to the probe, e.g. shrinkage cavities, gas bubbles, inclusions or flat reflectors which are located vertically to the beam direction (cracks or bonding defects)

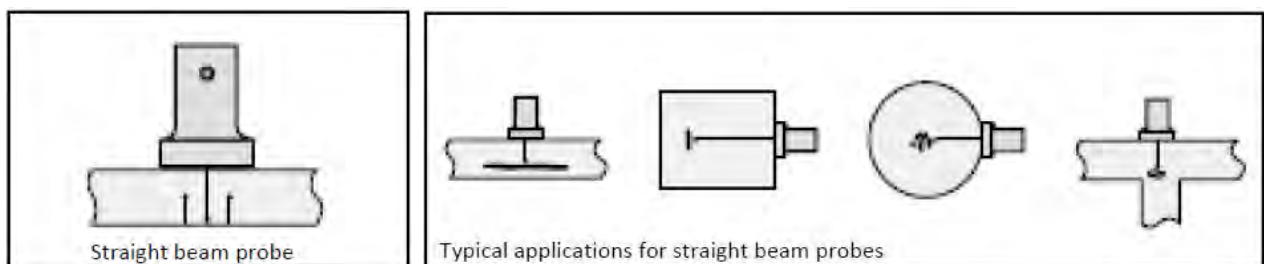


Fig 5.5.1.3 Types of Defects

In testing of the weld, the presence of defect (Flaw or “F”) is indicated by the spike in the graph. This is illustrated below:

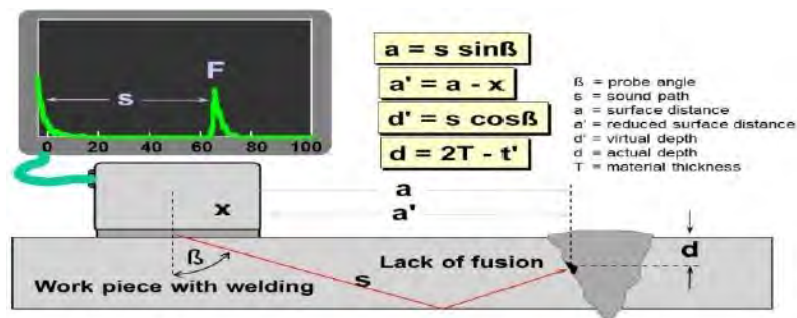


Fig 5.5.1.4 Testing of Flaws

In the detection of flaws, the presence of damage is explained by diagrams below.

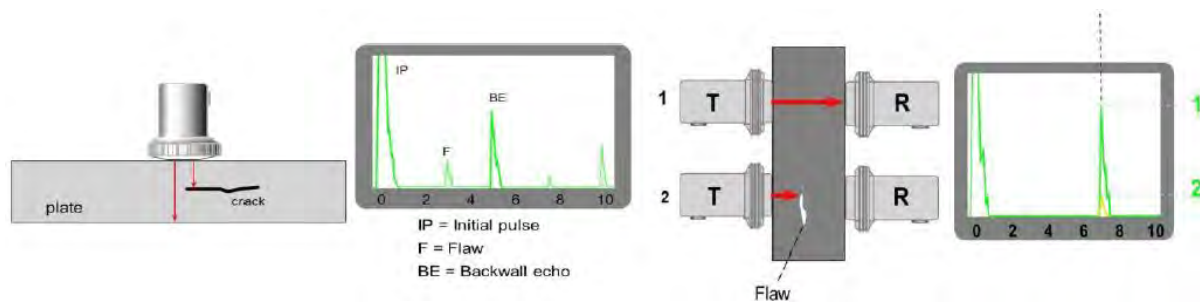


Fig 5.5.1.5 Detection of Flaws

#### 5.5.1.4 Evaluation and Recommendations

- This test method can assess the defect occurring only in the “Full-penetrated” weld.
- Ultrasonic test should be carried out during steel structure fabrication at the shop for the quality control.
- The inspector should be trained on proper use of the apparatus.
- Advantages
  - Thickness and lengths up to 30 ft can be tested.
  - Position, size and type of defect can be determined.
  - Instant test results.
  - Portable
  - Extremely sensitive if required.
  - Capable of being fully automated.
  - Access to only one side necessary.
  - No consumables required.
- Countermeasures
  - If there is defect on welding, the welding should be repaired in accordance with AWS1.1.

Basically, the defect should be removed and re-welded.

After repair, ultrasonic test should be carried out again.

## 5.5.2 Static Load Carrying Test

### 5.5.2.1 Purpose

Bridge Load testing consists of determining the safe load carrying capacity of structures, determining if specific legal or overweight vehicles can safely cross the structure and determining if a structure needs to be restricted and the level of posting required.

Where member strength cannot be adequately determined from the results of in-situ material tests, load testing may be necessary. Static load tests are useful in determining the maximum allowable loads on bridges. They can also be useful in discovering the mechanical properties of materials.

Static load tests are most likely to be needed in the following circumstances:

- Deterioration of structures, due to material degradation or physical damage.
- Structures which are substandard due to quality of design or construction.
- Non-standard design methods which may cause the designer, building authorities or other parties to require proof of the concept used.
- Change in occupancy or structural modification which may increase loading.
- Proof of performance following major repairs.

### 5.5.2.2 Test Procedures

#### a) Selection of Span and Method of Loading

In case of multi-span bridges, center span is chosen for load testing. The method of loading should be such as to either simulate the specific class of vehicles or induce in the members, the calculated forces or bending moments at critical sections.

Test loads may be in the form of mobile test vehicles (25 tons) and static loads.



20t Truck



Several Trucks



Measurement

**Fig 5.5.2.1 Equipment and Apparatus for Static Load Test**

### **b) Loading and Unloading Sequence**

In case of static loads, the test load shall be applied in stages so that timely action such as stopping the test can be taken if any untoward distress is observed at any stage. In most cases, design live load effect would be equal to or less than that due to dead load. The suggested stages of test load placement are 30%, 50%, 70%, 80%, 90% and 100%. Unloading should also be in same stages. The next incremental loading should be added only after the deflections under the previous load have stabilized and all stipulated observations are completed.

### **c) Preparatory Works**

- All visual defects should be measured, mapped and plotted.
- It should be ensured that bearings are functional
- Expansion gaps and joints should be cleared of all debris.
- It will be useful to give the surface of the superstructure a coat of white wash, so that appearance of cracks becomes immediately perceptible.

### **d) Observations**

The following are observed, measured and recorded at regular intervals of one hour over a period of 24 hours.

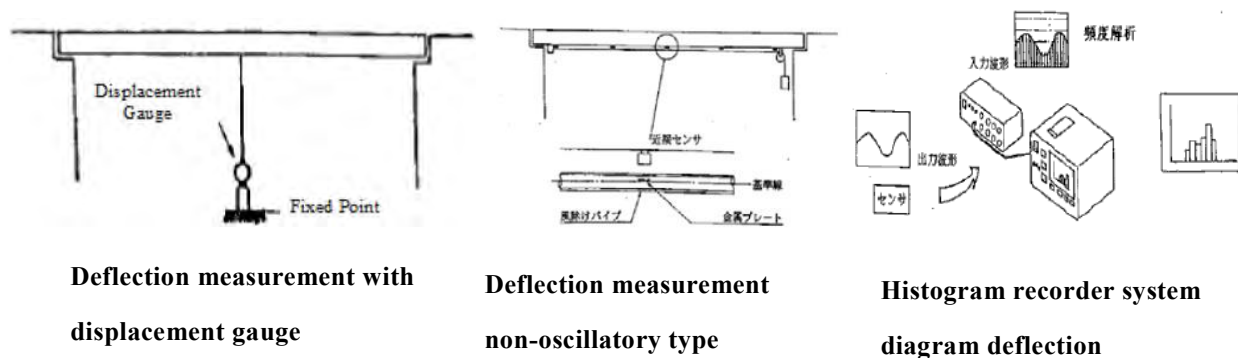
- Deflections at critical sections (for instance, for simply supported spans, at mid-span and at quarter span. In box girders, it will be useful to record deflections under each of the external ribs)
- Appearance of cracks and their development, length, width, location, and orientation correlated with load.
- Deformation of bearings.
- Ambient temperature and related temperature in the body of the structure.

### **5.5.2.3 Measurement of Deflections**

Deflections can be measured with the following devices:

- (a) Displacement Gauge
- (b) Ruler and Cursor
- (c) Deflectometer
- (d) Precision Level
- (e) Water Level

Methods (a) to (c) are used whenever dry river/stream bed is available under the span. Otherwise methods (d) and (e) can be used by using a reference station at the nearby abutment. When girder bridges are subjected to load tests, it is essential to clear debris in the expansion gaps and to lubricate steel bearings to permit free translation and rotational movements of the spans.



**Fig 5.5.2.2 Measurement of Deflections**

#### 5.5.2.4 Percentage Recovery of Deflection

The percentage recovery is calculated for values of deflection. The percentage recovery is calculated at 24 hours after removal of the load. The calculation is done after applying temperature and rotation corrections to the deflection data.

#### 5.5.2.5 Evaluation and Recommendations

Static load test can be direct calculation of the load capacity from the test results. It is assumed that the bridge assessment is carried out using the partial safety factor format and the load capacity is the value for which the rating live load should be multiplied to reach the failure limit state.

### **5.5.3 Dynamic Load Carrying Test**

#### **5.5.3.1 Purpose**

As a complement to static load carrying test, dynamic tests provide useful information about the actual behavior of the bridge under traffic. Dynamic load tests are identified in the following circumstances:

- Deterioration of structures, due to material degradation or physical damage.
- Structures which are substandard due to quality of design or construction.
- Non-standard design methods which may cause the designer, building authorities or other parties to require proof of the concept used.
- Change in occupancy or structural modification which may increase loading.
- Proof of performance following major repairs.

#### **5.5.3.2 Test Procedures**

Dynamic load testing is performed by exciting vibration of the bridge and by measuring its properties after the excitation vibration has ceased. Several methods are available to generate vibration on the bridge, in particular the passage of a loaded truck. This method is often preferred for the dynamic load testing of bridges because it gives, along with reasonably accurate values of the above mentioned quantities, a good approximation of the effect of the actual traffic on the structure. By varying the speed of the truck on the bridge, the full range of traffic speeds can be investigated. Furthermore, this method is easily implemented.

The measurements are taken and recorded by a dynamic data acquisition system, allowing an immediate interpretation of the results during the test. The trucks used for the dynamic excitation of the bridge are usually 3- axle trucks, with a total weight of 250 kN (total mass of 25 metric tons), traveling on the bridge at several speeds. The effect of a deterioration of the pavement is simulated by the introduction of a wood plank on the path of the truck. This induces a strong impact when the trucks passes at mid-span, that represents the effect of a pothole in the pavement, or the irregularity of the surface.





The dynamic tests can be performed using the following loadings:

- Normal traffic, test vehicle or engine
- Sudden release of deflection by realizing a load attached to the structure
- Sinusoidal exciter, energy input device, braking a vehicle or engine on the bridge
- Impact produced by a vehicle running through the standard bar (in case of highway)
- In general, the tests are most often performed under normal traffic or under the test vehicles.

#### **5.5.3.3 Recommendations**

Dynamic load testing is usually performed on bridges that have also been subjected to static load testing, comparisons can be made between the behavior of a bridge under static and dynamic loading.

By using a truck to induce vibrations on the bridge, it is possible to simulate the effects of pavement deterioration. Bridges that are especially sensitive to pavement deterioration are identified, and this information can then be used in establishing the maintenance program of the structure. Truck speed is shown as having a great importance on the dynamic response of the bridge, especially in the case of a deteriorated riding surface. There is correlation between the span and the natural frequency of a bridge and in a similar manner, there is some correlation between the bridge stiffness observed in a static load test and the dynamic properties of the bridge.

## 5.5.4 Ambient Vibration Test

### 5.5.4.1 Purpose

Ambient Vibration Test is used to determine the dynamic characteristics of structures through ambient vibration measurements. The ambient vibration behavior of a structure is recorded, evaluated, i.e. without artificial excitation, by means of highly sensitive velocity or acceleration sensors. For large and flexible structures, such as suspension bridges, cable-stayed bridges and other large structures, it becomes too difficult and costly to provide controlled excitation (forced testing) at levels which are significantly higher than the excitation provided by ambient sources. The method only requires the measurement of the response to ambient excitation which might be caused by wind, traffic, waves or micro-seismic activity.

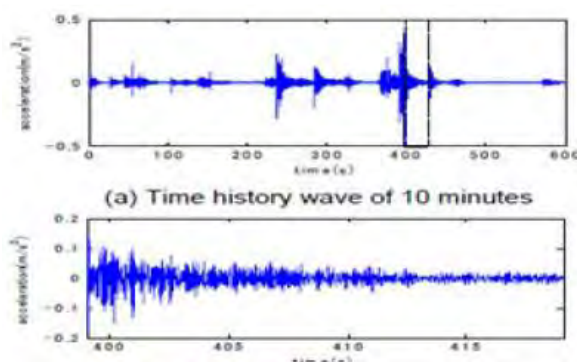
### 5.5.4.2 Test Procedures

Ambient vibration tests are conducted on the bridge using a channel data acquisition system with accelerometers. Measurements are taken continuously for three days, normally at the bridge center span.

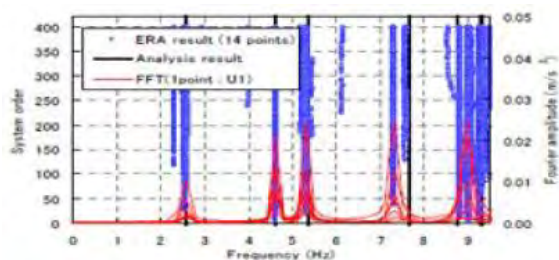
Damping coefficients are the third factor used for describing the dynamic response of a structure. The frequency dependent damping ratios are important criteria for structural assessment due to the fact that these ratios increase significantly when the structural resistance decreases – in other words, high damping ratios are an indicator for reduced safety.



Setup



Representative Wave Point



Comparison of Measured Frequency and Analytical values

Fig 5.5.4-1 Ambient Vibration Test Measurements

#### **5.5.4.3 Evaluation and Recommendation**

Ambient vibration test has an advantage of being simple, fast and cheap, which can be implemented simply by measuring the responses data. The ambient vibration test has been widely used in bridge structural detection.

The main advantage of this method is that normal operation, such as traffic, is not influenced or interrupted during testing. Traffic is a welcome source of excitation which usually provides good wide-band excitation.

The dynamic behavior of a structure depends on:

- a) Mode shapes corresponding to natural frequencies
- b) Vibration limits
- c) Damping coefficients

The real vibration shapes of a structure consist of the mode shapes corresponding to the natural frequencies. Therefore mode shapes are – beside the natural frequencies – the second important quantities that describe the dynamic behavior of a structure. Acceleration records are transformed to displacement values for each natural frequency at each measurement station.

The measured mode shapes are then compared to the computed ones

The consideration of vibration limits is important for the maintenance of structural integrity. Structural vibration limits for particular damage risks can be classified according to the level of vibration intensity.

### **5.5.5 Impact Vibration Test**

#### **5.5.5.1 Purpose**

Impact vibration test is conducted to determine effects of severe disasters on the soundness of a structure. When an earthquake or scouring occurs, the mass of the structure does not change, however, stiffness and spring constant values drops. Impact Vibration Test can analyze the bridge soundness by natural frequency accurately.

#### **5.5.5.2 Applications**

Test will be applied quickly and accurately for following situations:

1. Normal and emergency
  - Determination of structural soundness by deterioration
  - Determination of structural soundness by collision
  - Understanding of the influence by close-set construction
2. Disaster
  - Determination of damage by earthquake
  - Determination of damage by flooding
  - Selection of the degree traffic regulation individualized damage

#### **5.5.5.3 Test Procedures**

- Testing is done by recording the response wave caused by hitting the bridge pier with heavy steel ball (bob)
- After analyzing the wave response, the natural frequency level of the bridge is determined.
- Evaluation of bridge structural soundness is quantitatively analyzed without any damage to the structure.
- With drop in level of stiffness and spring constant values, the level of structure damage can be estimated.



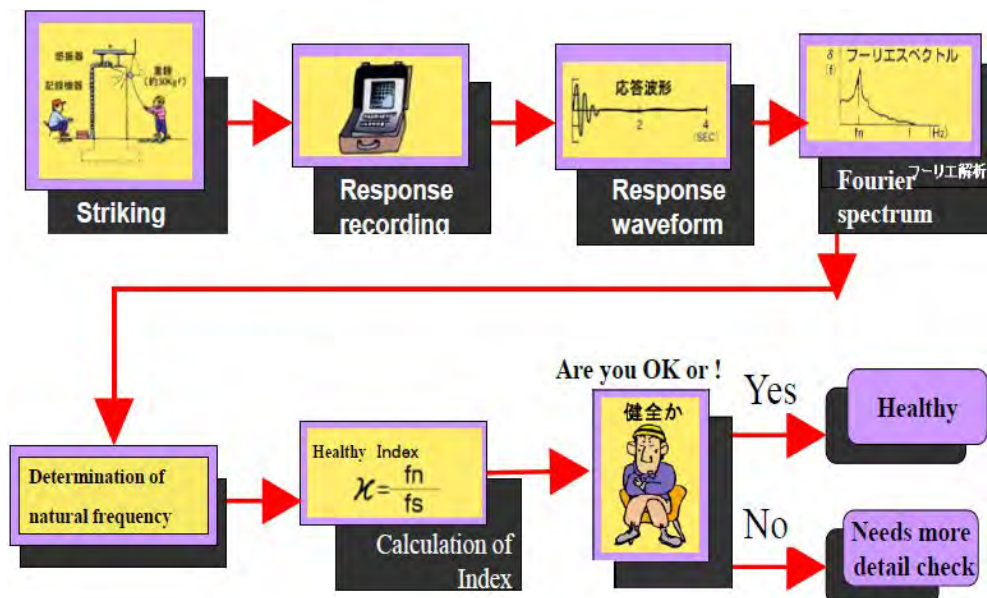


Fig. 5.5.5.1 Flowchart of Impact Vibration Test

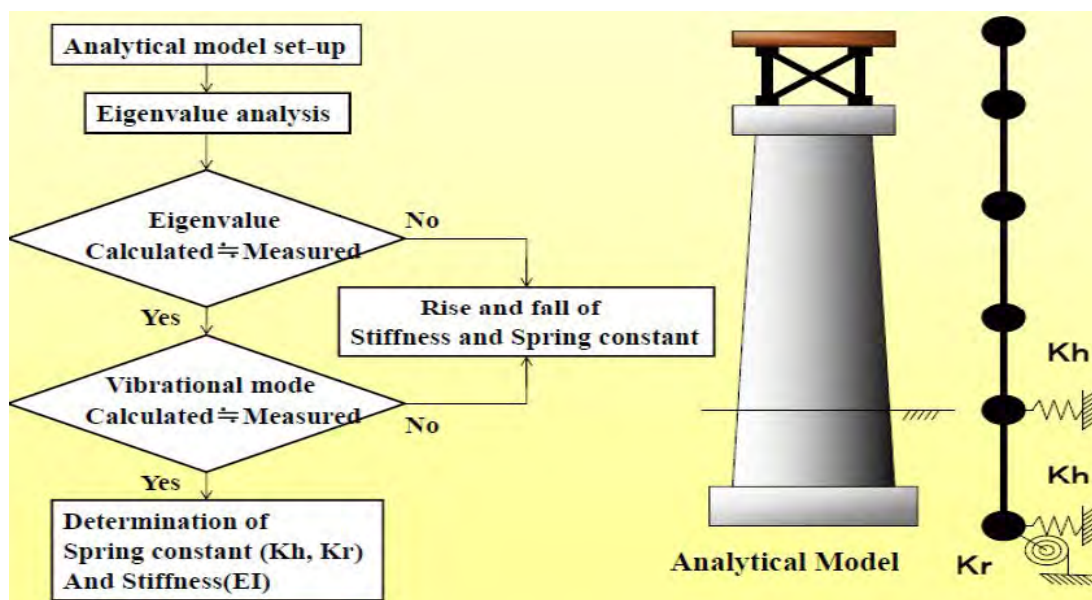


Fig. 5.5.5.2 Procedure of Estimation of Stiffness and Spring Constant



Photo 5.5.5.1 Impact Vibration of Bridge Piers





**Photo 5.5.5.2 Recording of Wave Response**

#### **5.5.5.4 Soundness**

The soundness of the bridge structure can be determined by comparing the measured stiffness value with design stiffness value as well as the measured spring constant values with the design value. For example, in a railway bridge, the following damage criteria have been determined:

When it is affected by disasters such as scouring or earthquake, the mass will not be changed, but stiffness will drop to a lower value and the spring constant of footing will also drop.

The natural frequency should be fixed by the mass and spring constant, therefore the natural frequency is dropped to a lower value. With dropping level of the stiffness and ground strength, the level of structure damage will be estimated.

**Table 5.5.5.1 Soundness of Structure (Railway Bridge)**

$a = (\text{Measured Stiffness Value}) / (\text{Design Stiffness Value})$		
Range of $a$	Class	Observation/Countermeasure
$1.00 \leq a$	S	Structure is sound
$0.75 \leq a < 1.00$	C	There are minor deformation or deflection of structure. Requires routine monitoring.
$0.50 \leq a < 0.75$	B	There are possible deformation or deflection of structure. Requires routine monitoring. Some actions may be taken requires appropriate actions.
$a < 0.50$	A2	There are possible deformation or deflection of structure. There is threat on safety of travelling public and operations. Actions to be taken

**Table 5.5.5.2 Soundness of Footing (Railway Bridge)**

$a = (\text{Measured Stiffness Value})/(\text{Design Stiffness Value})$		
<b>a</b>	<b>Class</b>	<b>Observation/Countermeasure</b>
$a < 0.50$	A2	There are possible deformation or deflection of structure. There is threat on safety of travelling public and operations. Actions to be taken
$0.50 \leq a < 0.75$	B	There is possible deformation or deflection of structure. Requires routine monitoring. Some actions may be taken
$0.75 \leq a < 1.00$	C	There are minor deformation or deflection of structure. Requires routine monitoring

#### **5.5.5.5 Evaluation and Recommendation**

Impact Vibration Test is used to:

- 1) Analyze the bridge soundness by natural frequency;
- 2) Take inspection easily;
- 3) Measure natural frequency accurately; and
- 4) Determine soundness even if there may be defects are hidden in the structure

## 5.5.6 SONAR Test (For Scouring)

### 5.5.6.1 Purpose

Earthquakes, flood scouring, and ground movement are the main causes of damage of bridge foundations. Scouring due to floods is the most common cause of bridge failures or severe damages which require repair or strengthening of bridge foundations. Consequently, it is absolutely necessary to investigate the scour condition as early and accurately as possible and to estimate the soundness of bridges in terms of keeping bridge foundations in good condition.

The use of SONAR (Sound Navigation and Ranging) to determine depth and extent of scour around bridge piers has been found to be an accurate and cost-effective technique. The equipment is a lightweight instrument and has capability to deal promptly with investigation since the work is conducted from the bridge deck or the inspection scaffold on the bridge inspection vehicle. Furthermore, the configuration of streambed is easily determined with display of an investigation results on a monitor screen with color image.

### 5.5.6.2 Outline of Testing

#### a) Scour Investigation around Piers

- a.1) Scour investigation around the pier on four (4) sides for each pier
- a.2) Periodic measurement: marking of sonar installation position is done on the bridge.  
(Time-dependent change is recognized directly)

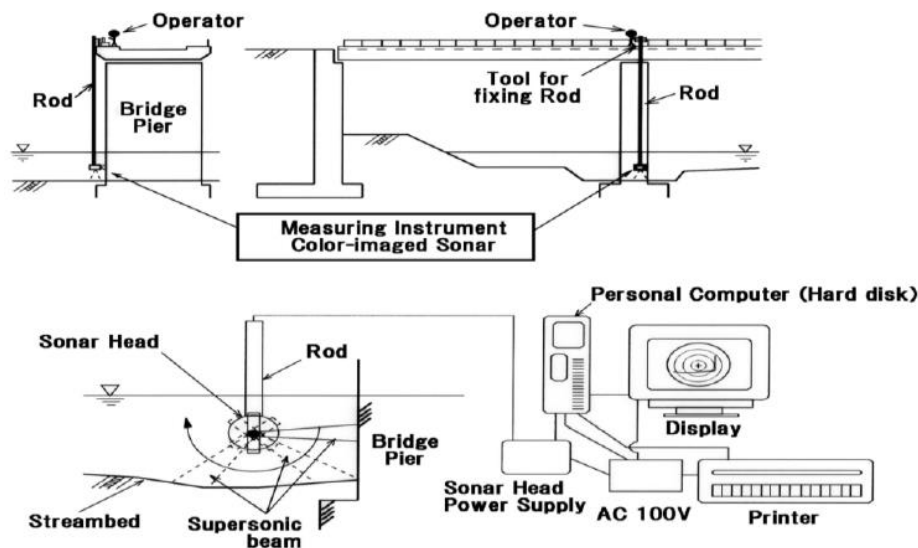


Fig 5.5.6.1 Outline of SONAR Testing

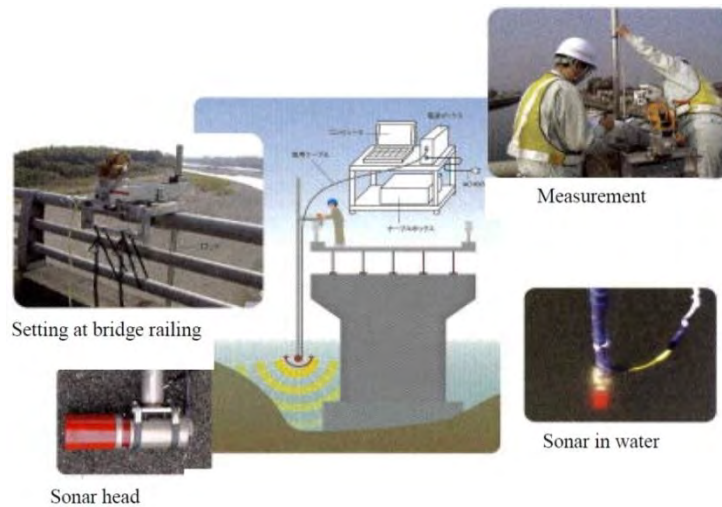
#### b) Procedures

First, a SONAR head attached to the edge of a sounding rod is brought down from the bridge deck or the inspection scaffold on the bridge inspection vehicle until about 1m under water, and then we can measure through going into a 360-degree roll of the sonar head.

### c) System Configuration

Sonar: sending and receiving ultrasonic wave

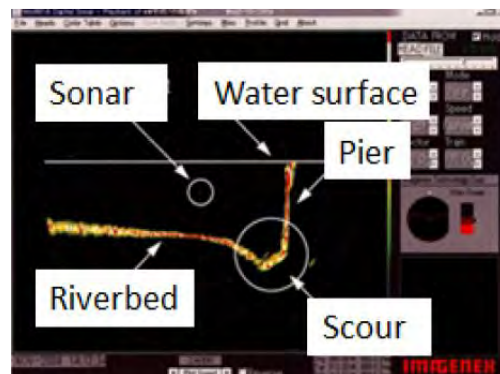
Computer: creates the picture on the basis of signal sent from sonar



**Fig. 5.5.6.2 System Configuration**

### d) Output

After SONAR testing, the scouring is identified near the pier.



**Fig 5.5.6.3 Screen Image of SONAR Test**

### 5.5.6.3 Evaluation and Recommendations

Since sonar can measure one topographic profile only at a time, investigation should be conducted to determine streambed conditions around piers by rotating the sonar around horizontally every 30 degrees. If there are dead angles due to pier's location, measurement can be done while the sonar head is moving.

## 5.5.7 Impact Echo Test

### 5.5.7.1 Purpose

#### a) General

Impact Echo Test can be used to detect voids in post tension tendon ducts of pre-stressed slab and beams. Impact-Echo Testing is a nondestructive testing technique used to evaluate the quality of the concrete by detecting internal flaws, including delamination, honeycombs, voids, etc.

Generally, the tendons are protected by the surrounding grout, which is injected into the tendon ducts. Voids in the grout can occur along the tendon trajectory due to blockages, improper grouting procedures, grouting material problems, and construction oversight. Inadequate grouting may allow water to penetrate into the ducts, causing corrosion of the tendons leading to failure of the structures.

Impact Echo Test is a method for non-destructive evaluation of concrete based on the use of impact-generated stress (sound) waves that propagate through the structure and are reflected by internal flaws and external surfaces. A small steel ball is used to produce the impact.

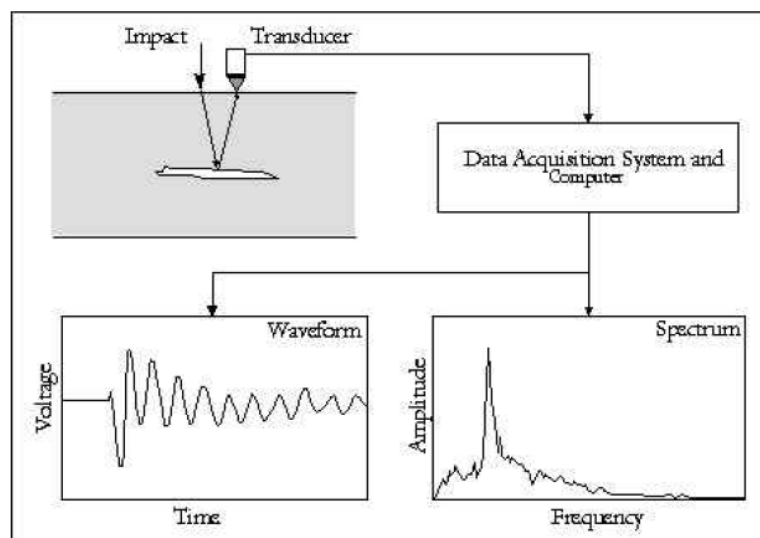


Fig. 5.5.7.1 Flowchart of Investigation by Impact Echo Test

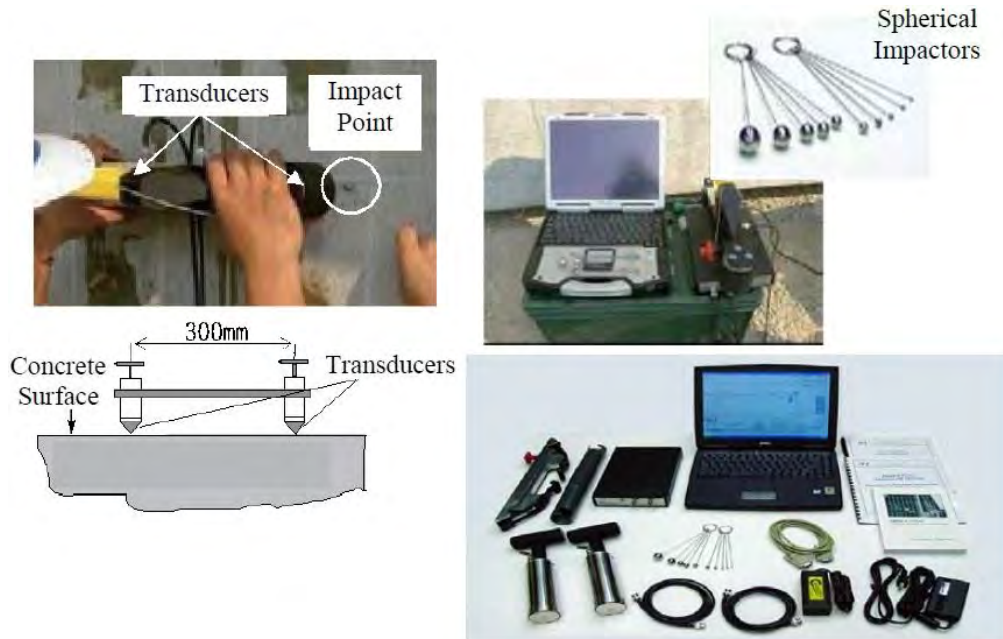
#### b) Applications

The successful outcome of this application depends on several factors, such as the geometry, shape of the test member, position and size of the tendon in the test member. For example, it is difficult to detect voids in tendon duct if the tendon duct is located within the flange of a typical I-beam. Similarly, if a small tendon duct is located in relatively deep portion of a slab or beam, detection is also difficult.

The applications of the impact echo technique include: determining both the thickness and

flaws in plate-like structure members, such as slabs, walls; detecting flaws in beams, columns and hollow cylindrical structural members; assessing the quality of bond in overlays; and detecting void in post tension tendon duct etc.

### 5.5.7.2 Outline of Testing



**Fig 5.5.7.2 Impact Echo Testing**

### 5.5.7.3 Evaluation and Recommendations

Advantages and limitations of this method are as follows:

- The equipment is relatively portable.
- Access to only one side of the structure is required.
- Provides the ability to collect and digitize large amounts of data.
- Field data acquisition is obtained and processed within a few seconds.
- Requires data interpretation and analysis, which typically requires an experienced operator.
- Relatively expensive equipment.
- Exact size of subsurface anomalies may be difficult to determine.



## 5.5.8 X-Ray Test

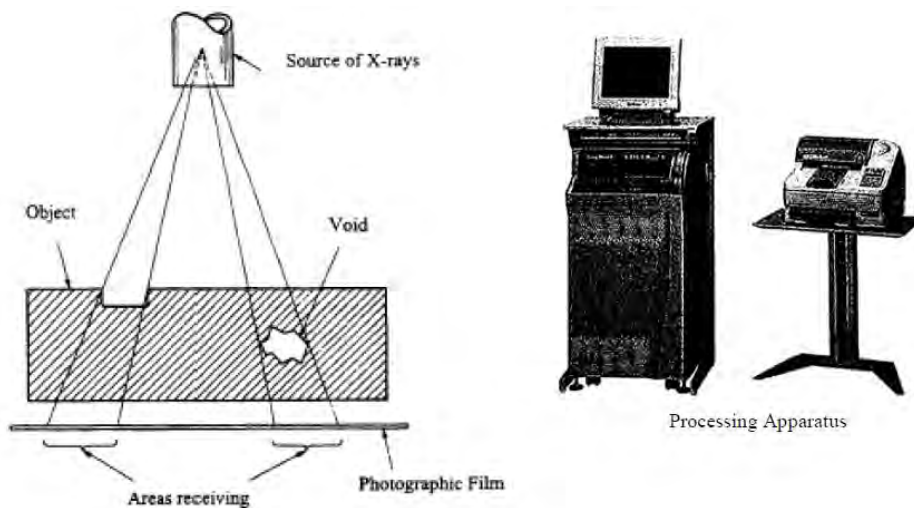
### 5.5.8.1 Purpose

Radiography technique is one of the non-destructive methods of testing concrete for obtaining information about concrete quality, defects within the pre-stressed concrete bridge.

X-Ray test of pre-stressed concrete girder bridges using high energy x-ray radiography is found to be useful in distinguishing grouted and un-grouted portions of cable sheaths; to find out the uniformity of the cement grout; to determine the condition of the cable sheath; and to determine whether the pre-stressing strands are ruptured or intact.

### 5.5.8.2 Description of Apparatus

X-Ray Test Method is used in civil engineering works notably to verify the integrity of pre-stressed wires in a pre-stressed concrete structure by using radioisotope sealed sources, X ray machines or linear accelerators. **Figure 5.5.8.1** shows a typical set up of radiographic testing.



**Fig. 5.5.8.1 X-Ray Test Set-Up**

### 5.5.8.3 Test Procedures

During the radiography X-rays penetrate through the material under inspection. While traversing through the material, these radiations experience modification by the internal structure of the material through absorption and scattering processes. If the internal structure is homogeneous, the absorption and scattering processes would be uniform throughout the material and radiations that escape from the material would be of uniform intensities.

These radiations are then recorded by a suitable recording medium, typically radiographic film. When the film is processed, a uniform dark image will appear on the film that indicates the homogeneity of the material tested. The situation is different for cases of materials containing

discontinuities or different in thickness. In general, the absorption of radiation by a material depends on the effective thickness through which the radiations penetrate.

Discontinuities such as cracks, slag inclusions, porosity, lack of penetration and lack of fusion reduce the effective thickness of the material under test. Thus, the presence of such discontinuities causes radiations to experience less absorption as compared with those in areas with discontinuity. As a result, in areas containing discontinuities more radiations escape, recorded by the film and forming a dark image that represents the internal structure of the material.

The appearance of radiographic images depends on the type discontinuities encountered by the radiation. For example, cracks will produce a fine, dark and irregular line, whereas porosities produce dark round images of different sizes.

Some discontinuities present in a material such as inclusion of tungsten in steel has a higher density than its surrounding. In this case, the effective thickness that needs to be traversed by radiation is somewhat greater. In other words, more radiation is absorbed in this area as compared with other areas. As a result the intensity of radiation that escaped after traversing this area will be lesser than that for other areas giving a lighter image bearing the shape of tungsten inclusion inside the material.

#### **5.5.8.4 Recommendations**

X-Ray Test is used throughout the bridge inspection. Its capability to produce two-dimensional permanent images makes it. However, radiation used for radiography presents a potential hazard to radiographers as well as members of public. Due to its hazardous nature, the use of radiation, including for industrial radiography is strictly controlled by Regulatory Authorities.

X-Ray Tests are fast; they are capable of viewing interiors of concrete sections up to 3 ft (1 m) thick; they can generate radiation at the optimum energy level for a given specimen thickness; and they require minimal shielding since radiation emission can be terminated by turning off the electrical power supply. On the other hand, X-ray equipment is expensive and must be operated carefully because of high voltages and high radiation levels. Until recent miniaturization of X-ray generators such as gamma radiography equipment has generally been more portable. Gamma ray equipment is less expensive and is easier to operate because electrical power is not necessary. The continuous radioactivity from the gamma ray sources requires more shielding and additional safety interlocks to prevent accidental exposures.

## 5.5.9 In-Situ Stress Measurement Test

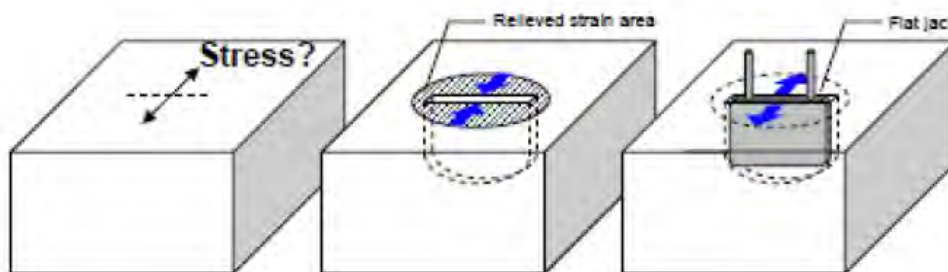
### 5.5.9.1 Purpose

In-Situ Stress Measurement Test is used for measurement of stress in concrete. It has been derived from the mining industry where it is used to measure stresses in rock masses. The method is also widely used in metals or plastics. Its principle is simple: the strain field is relieved by coring or slotting the material; the change of the strain in the relieved area is measured and the stress is calculated taking into account the elastic properties of the material and the geometry of the cut.

### 5.5.9.2 Description of Techniques and Procedures

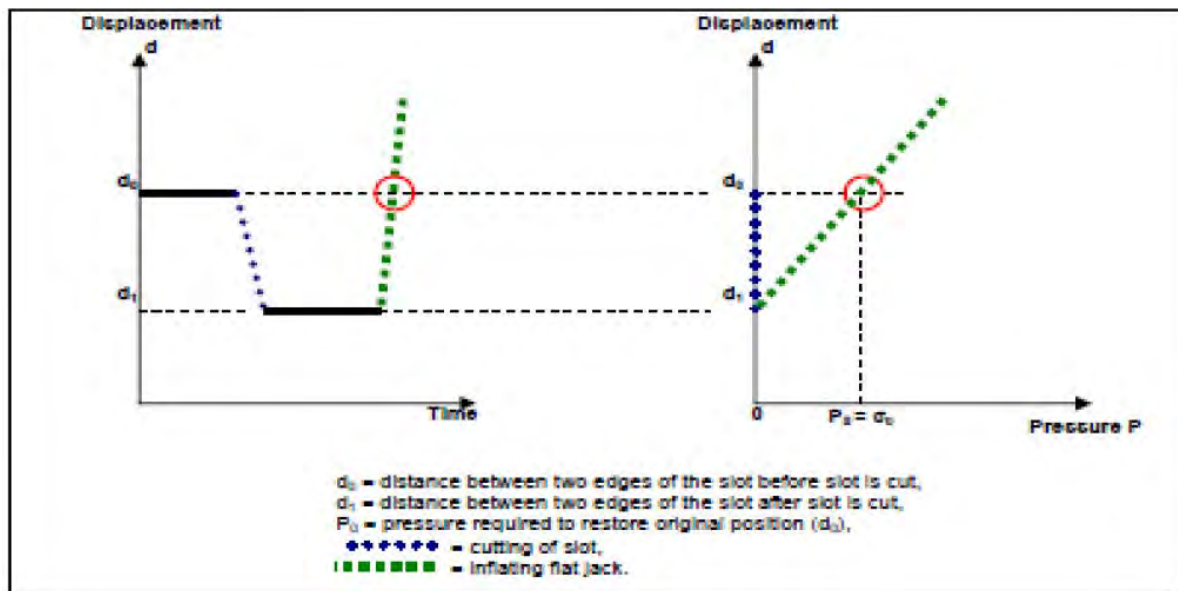
#### a) Strain Relief Method with Flat Jack Technique

In concrete, the modulus of elasticity varies with concrete mix, age, curing and environmental conditions. In order to eliminate the need to know the elastic properties of the concrete, a flat jack can be inserted into the slot and pressurized. As a result the initial strain field will be restored. The combination of the measured data on strain and pressure will give the value of the stress.



**Fig. 5.5.9.1 Principle of Strain Relief Method Combined with the Flat Jack Technique**

The stress in the concrete is estimated from the value of the pressure that restores the initial distance between the 2 points:

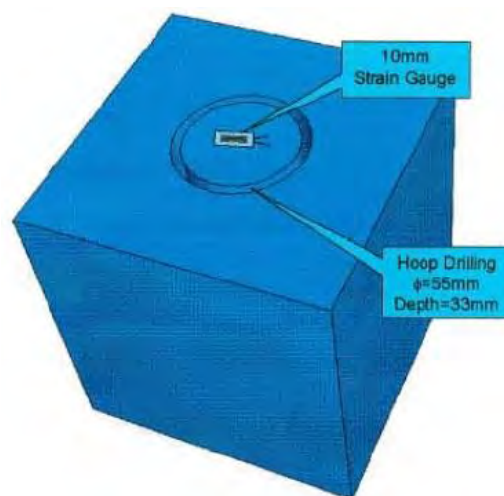


**Fig. 5.5.9.2 Basic Theory for Stress Calculation**

When the concrete is in compression, the edges of the slot will move together and the pressure required to restore them to their original position corresponds to the local compressive stress perpendicular to the slot direction.

#### **b) Hoop Stress–Releasing Technique**

The hoop stress–releasing technique is similar to hole drilling stress–release method which is used to measure residual stress in metal. In this method, a 10mm long strain gauge is mounted in the center of a hoop marked on the concrete surface. The strain is then measured while the concrete surrounding the strain gauge is cut by a coring machine slowly.



**Fig. 5.5.9.3 Diagram of Hoop Stress- Releasing Technique**

The released strain is equal to the inverse of the original strain locked in the structure (say girder of the bridge). By measuring the released strain from the strain gauge, the original strain in the girder is obtained. The calculated axial force is equivalent to the effective pre-stress force acting on the section. The loss of pre-stress is then determined by comparing the original jacking force with the calculated axial force.



Step 1- Locate the measuring point



Step 2- Mount the strain gauge



Step 3 - Release stress by coring using drilling machine



Step 4 - Measure the released strain every 5mm core depth upto 33 mm

**Photo 5.5.9.1 Procedures for In-Situ Stress Measurement Test Using Hoop Stress-Releasing Technique**

### 5.5.9.3 Recommendations

Stress Measurement Test is recommended to be used in determining the effective pre-stress force acting on a structure subjected to damage by fire, overloading, rupture of pre-stressed tendons, and other causes.

The existing state of stress in a structural member as determined by Stress Measurement Test can be used by the engineer as reference in estimating extent of deterioration, updating of safety factors, forecasting the state of the structure and in optimizing the design of strengthening or repair solutions.

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### **Sample of SD (Serious Damaged) Bridge**

Serious Damaged (SD: hereinafter, SD) Bridge is defined following situation,

- Impossible to pass
- Serious structural defect on slab deck
- Serious structural defect on main girder or truss girder
- Abutment or pier unstable by scouring
- Existence of many defects which is not SD.



**(A) Impossible to pass**



**(B) Serious structural defect on concrete slab deck**

**Fig.Ap Sample Photo of Serious Damaged Bridge (1)**



**(C) Serious structural defect on concrete girder (Shearing crack)**



**(D) Serious structural defect on steel slab deck (Fatigue crack)**



**(E) Serious structural defect on main girder or truss girder (Fatigue crack)**

**Fig.AP Sample Photo of Serious Damaged Bridge (2)**



**(F) Abutment or pier unstable by scouring**  
**(Settled due to back filled soil washed out by scouring)**

**Fig.AP Sample Photo of Serious Damaged Bridge (3)**

# Scoring Inspection Results



# Bridge Score

Results of bridge inspection should be evaluated appropriately based on bridge(soundness or damage) score.

Bridge soundness score 100 : No damage

>85: Good Condition

85>,<60: Damaged

60> : Serious Damaged



# Basis of Scoring

Score of each defect 0-15

Scoring every parts 0-100

Effect factor in Bridge

Road Surface 10%

Bridge Girder 30%

Bridge Slab 30%

Bearing 10%

Pier/Abutment 20%

Bridge Score is calculated automatically.

# Defect and Scoring

Location	Part	Inspection Item	Check point	Score	Score	Part	Part	Effect	Damage
					total	Score	Total	factor	Score
					a	b	c=b/a	d	c*d
Road Surface	Bridge Railing / Guardrail / Curb	Damage	No Damage	0	27		0	10%	0
			Damage	1					
			Damage (Possibility of harm third party)	10					
	Expansion Joint	Step	No damage	0					
			Step under 20mm	1					
			Step over 20mm	3					
		Deformation / Damage	No damage	0					
			Abnormal expansion gap (More than 2cm)	2					
			Deformation / Damage	3					
			Abnormal sound	3					
	Drainage System	Clog of drainage pipe	No Damage	0					
			Partial no function ( Impossibility flood )	1					
			Almost no function(stuffed, broken, etc)	3					

Defect should be repaired urgently (Urgent Repair)

Location	Part	Inspection item	Check point	Score	Score	Part	Part	Effect	Damage
					total	Score	Total	factor	Score
					a	b	c=b/a	d	c*d
Bridge Girder	Superstructure (Steel)	Corrosion / Rust	No Damage	0	36		0	30%	0
			Corrosion on steel members	1					
			Hole by corrosion	4					
			Invisible						
		Crack, Deformation, Loss, Break	No Damage	0					
			Steel members deformation	1					
			Crack on steel member	3					
			Steel member loss/broken (Secondary member)	5					
			Steel member loss/broken (Primary member)	10					
			Invisible						
		Missing bolt	No Damage	0					
			Missing less than 10%.	2					
			Missing more than 10%.	10					
			Invisible						
	Superstructure (Concrete)	Honeycomb / Flaking / Exposure of rebar /Crack	No Damage	0	17		0	30%	0
			Free lime/ Honeycomb/ Flaking and/or Lacking concrete	1					
			Exposure of rebar	1					
			Rebar rusting	2					
		(Crack width) RC: >about 0.3mm PC: >about 0.2mm	Rust fluid from crack	2					
			Crack on girder	3					
			Crack on girder (above Bearing)	8					
			Invisible						

Defect should be repaired urgently (Urgent Repair)

Location	Part	Inspection Item	Check point	Score	Score	Part	Part	Effect	Damage
					total	Score	Total	factor	Score
					a	b	c=b/a	d	c*d
Bailey Bridge	Superstructure (Bailey Bridge)	Missing pin	No Damage	0	75		0		0
			Loosing pin on bailey bridge	4					
			Missing pin on bailey bridge (Connecting part)	15					
		Truss Girder Corrosion / Rust / Crack / Deformation /Loss /Break	No Damage	0					
			Corrosion on steel member	1					
			Steel member deformation	1					
			Hole by corrosion	3					
			Crack on steel member	5					
			Steel member loss/broken	15					
			Invisible						
		Slab Corrosion / Crack	No Damage	0					
			Corrosion and/or Rust on steel member	1					
			Crack	15					
			Hole	15					
			Invisible						

Defect should be repaired urgently (Urgent Repair)

Location	Part	Inspection item	Check point	Score	Score	Part Score	Part Total	Effect factor	Damage
					total				
					a		c=b/a		
Bridge Slab	Superstructure (Wooden)	Rotting	No Damage	0	8		0	30%	0
			Rot of wood	1					
			Reduction of cross section	2					
			Invisible						
		Crack / Damage	No Damage	0					
			Damage ( Crack / Partial loss)	2					
			Big damage (collaspe risk / Impassable)	3					
			Invisible						
	Slab (Concrete)	Honeycomb / Flaking / Exposure of rebar Crack / Hole	No Damage	0	18		0	30%	0
			Free lime/ Honeycomb/ Flaking and/or Lacking concrete	1					
			Exposure of rebar	1					
			Rebar rusting	1					
			Rust fluid from crack	2					
		(Crack width) RC: >about 0.3mm PC: >about 0.2mm	Crack on undersurface (Longitudinal)	2					
			Crack on undersurface (Transversal)	3					
			Hole	8					
			Invisible						

Defect should be repaired urgently (Urgent Repair)

Location	Part	Inspection item	Check point	Score	Score	Part Score	Part Total	Effect factor	Damage Score
					total				
					a	b	c=b/a	d	c*d
Bridge Slab	Slab (Wooden)	Rotting	No Damage	0	14		0	30%	0
			Rot of wood	1					
			Reduction of cross section	2					
			Invisible						
		Crack / Damage	No Damage	0					
			Big damage (collaspe risk) / Impassable	5					
			Hole / Missing slab plate	5					
			Invisible						
		Vibration, Abnormal Sound	No Damage	0					
			Vibration and/or Abnormal sound at travelling	1					
Sub-structure	Bearing	Sedimentation / Damage	No Damage	0	9		0	10%	0
			Partial sedimentation	1					
			Corrosion and/or damage	2					
			Partial sedimentation (Cannot see bearings)	3					
			No function (Include rusting)	3					
			Invisible						

Defect should be repaired urgently (Urgent Repair)



Location	Part	Inspection item	Check point	Score	Score	Part	Part	Effect	Damage		
					total	Score	Total	factor	Score		
					a	b	c=b/a	d	c*d		
	Pier / Abutment	Scouring / Settlement	No Damage	0	30		0	20%	0		
			Scouring around substructure	4							
			Settlement of substructure	10							
			Invisible								
		Honeycomb / Flaking / Exposure of rebar / Crack  (Crack width) RC: >about 0.3mm PC: >about 0.2mm	No Damage	0							
			Free lime/ Honeycomb/ Flaking and/or Lacking concrete	1							
			Exposure of rebar	1							
			Rebar rusting	2							
			Rust fluid from crack	2							
			Crack on surface (Horizontal Direction)	5							
			Crack on surface (Vertical Direction)	5							
			Invisible								
			Total Damage Score							0.0	
		Total Soundness Score of Bridge							100.0		

 Defect should be repaired urgently (Urgent Repair)

Damage Level	Damage Score	Judgement	
Damage Level III	>40	SD	Defect should be repaired as emergency
Damage Level II	40> >15 or CD	D	Defect should be repaired as periodic
Damage Level I	<15	O	Defect should be observated

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