PART II

MASTER PLAN

CHAPTER 6

METHODOLOGY FOR BRIDGE CONDITION SURVEY AND ASSESSMENT

CHAPTER 6

METHODOLOGY FOR BRIDGE CONDITION SURVEY AND ASSESSMENT

6.1 STUDY BRIDGES AND SURVEY ITEMS

The Study Team has developed an inspection manual entitled "An Approach to Inspection and Condition Evaluation of Bridges" (hereinafter referred to as "the Manual). Survey and assessment of the study bridges were basically performed in compliance with the Manual.

6.1.1 Study Bridges

There are seventeen (17) bridge site locations under the Study, as presented in **Table 6.1.1-1.** Twelve (12) of the bridge sites cross Pasig River while five (5) of the site cross Marikina River. However, the total number of bridges structures on these sites total to twenty (20).

Table 6.1.1-1 List of Study Bridges

Bridge No.		Bridge Name	Description	Survey Level	Completion Year
1	Pa1.1	Delpan Bridge (Upstream)	PC Gerber Box Girder Bridge (5-Span)	II	1965
	Pa1.2	Delpan Bridge (Downstream)	PC Gerber Box Girder Bridge (5-Span)	II	1988
2	Pa2	Jones Bridge	3-Span Continuous Steel Plate Girder Bridge	II	1948
3	Pa3	Mac Arthur Bridge	3-Span Continuous Steel Plate Girder Bridge	II	1948
4	Pa4	Quezon Bridge	Single Span Steel Type Arch Bridge	II	1946
5	Pa5	Ayala Bridge	2-Span Simple Steel Truss Bridge	III	1935
6	Pa6	Nagtahan Bridge	3-Span Continuous Truss	II	1966
7	Pa7	Pandacan Bridge	PC I-Girder Bridge (5-Span)	I	1997
8	Pa8	Lambingan Bridge	PC Gerber I-Girder Bridge (3-Span)	II	1975
9	Pa9	Makati-Mandaluyong Bridge	PC Box Gerber with I-Girder Drop Span Bridge (3-Span)	I	1986
10	Pa10.1	Guadalupe Bridge (Central)	3-Span Continuous Truss Bridge	II	1962
	Pa10.2	Guadalupe Bridge (Both Sides)	PC Gerber Girder Bridge (5-Span)	II	1979
11	Pa11	C-5 Bridge	PC I-Girder Bridge (10-Span)	I	1997
12	Pa12	Bambang Bridge	PC I-Girder Bridge (3-Span)	II	1991
13	Ma1.1	Vargas Bridge (Upstream)	PC Gerber I-Girder Bridge (4-Span)	II	1992
	Ma1.2	Vargas Bridge (Downstream)	Steel Plate Girder Bridge(4-Span)	II	1973
14	Ma2	Rosario Bridge	PC I-Girder Bridge (6-Span)	II	1952
15	Ma3	Marcos Bridge	PC I-Girder Bridge (11-Span)	II	1978
16	Ma4	Marikina Bridge	PC I-Girder Bridge (5-Span)	II	1980
17	Ma5	San Jose Bridge	PC I-Girder Bridge (8-Span)	II	1980

The existing conditions of the study bridges indicated different levels of deterioration and damages that require appropriate level of field survey and analysis. Based on the initial findings on existing bridge conditions, three levels of survey as described in **Section 6.2.2,** were proposed for the bridges.

- Survey Level I (Ordinary Inspection); 3 bridges (Pandacan Bridge, Makati-Mandaluyong Bridge, C-5 Bridge)
- Survey Level II (Periodical Inspection); 16 bridges

- Survey Level III (In-depth Survey); 1 bridge (Ayala Bridge)

During the field inspection, the Survey Level II was practically adopted for all bridges except the Ayala Bridge which was inspected under Survey Level. With respect to Jones Bridge, Quezon Bridge, Lambingan Bridge, Guadalupe Bridge (Both Sides) and Vargas Bridge (Upstream Side), Survey Level III inspections were conducted in addition to Survey Level II because they were judged to require an in-depth survey under the Master Plan Stage, details of which are discussed in Chapter 20 through 24.

6.1.2 Survey Items

Table 6.1.2-1 gives the survey items required on major bridge components at different survey levels.

Table 6.1.2-1 Survey Items

Survey Level		I	II	III
Main Objectives		Inspection on Damage Type, Scale and Severity	Examination on Loading Capacity and Durability	Determination of Improvement Measures
Superstructure	Concrete Bridge	a) Visual Inspection b) Inspection on Structure Shapes c) Inspection on Damage Type, Scale and Severity	a) Visual Inspection b) Measurement of Structure Shapes. c) Inspection on Damage Type, Scale and Severity. d) Non-destructive Test (Schmidt Hammer Test)	a) Closed Visual Investigation b) Measurement of Structure Shapes/Dimension c) Non-destructive Test (Schmidt Hammer Test) d) Material Test (Core, Neutralization, Alkali Aggregate) e) Electromagnetic Wave Radar (Location of Reinforcing Bar)
	Steel Bridge	a) Visual Inspection b) Inspection on Structure shapes c) Inspection on Damage Type, Scale and Severity	a) Visual Inspection b) Measurement of Structure Shapes. c) Inspection on Damage Type, Scale and Severity. d) Damage Survey (damage Detection by Dye Penetrant Test)	a) Closed Visual Investigation b) Measurement of Structure Shapes/Dimensions c) Structural Survey d) Material Test (Chemical)l Analysis, Vickers Hardness Test) e) Damage Survey (Damage Detection by Dye Penetrant Test) f) Microtremor Measurement Survey
Substructure		a) Visual Inspection b) Inspection on Structure shapes c) Inspection on Damage Type, Scale and Severity	a) Visual Inspection b) Measurement of Structure Shapes. c) Inspection on Damage Type, Scale and Severity. d) Non-destructive Test (Schmidt Hammer Test)	a) Closed Visual b) Measurement of Structure Shapes/Dimensions. c) Displacement Survey (Vertical, Horizontal) d) Non-destructive Test (Schmidt Hammer Test) e) Stability Test (Impact Vibration Test.
Foundation		-	-	a) Stability Test (Impact Vibration Test) b) Scour Survey (Echo Sounder). c) Microtremor Measurement Survey d) Topographic and Geothechnical Survey
Loading Capacity of Superstructure		-	-	a) Static Load Test

6.2 GENERAL PROCEDURE OF BRIDGE INSPECTION

6.2.1 Needs of Systematic Bridge Inspection

Bridges are key elements of the road network. The strategic location and the high level of service of bridges, which the road user highly expects, require that particular attention be given to the systematic inspection of bridges.

The fundamental justifications of bridge inspection is in the need to ensure safe condition for traffic and to protect the public by reducing the risk of possible bridge failure as mush as possible.

The second primary aim of inspection is the protection of the capital invested in the bridge project. Timely and economic planning of remedial and preventive maintenance and repair works are precisely programmed through systematic and detailed inspection and assessment on existing bridges.

The legal liability requirements can be an important incentive for road and bridge authority to set up the bridge inspection system. The neglect of deteriorating or damaged bridges may affect public confidence.

Therefore, the capability to assess the physical condition, safety, and operating efficiency of bridges is vital and essential to address the needs mentioned above. Successful inspection is dependent on proper planning, technique, adequate equipment , and the experience and reliability of personnel performing the inspection.

6.2.2 Procedures and Types of Bridge Inspection

(1) Inspection Procedures

Inspection procedures are essentially a set of techniques intended to determine the physical condition and assess the soundness of bridges, covering all stages from construction to improvement.

The type of inspection may vary over the useful life of a bridge in order to reflect the objectives and intensity of inspection required at the time of inspection.

Figure 6.2.2-1 illustrates the general procedure of bridge inspection.

(2) Inspection Types

In the general rule of bridge inspection, the following inspection types are categorized.

- Bridge Inventory
- Ordinary Inspection
- Periodical Inspection
- Follow-up Inspection
- Emergency Inspection
- In-depth Survey (Detailed Inspection)

The survey method of follow-up and emergency inspection may vary depending on the objectives, scale and intensity of survey to be carried out for a specified bridge or damage.

Table 6.2.2-1 shows the general definition, frequency, inspection methods and diagnosis of bridge inspection survey. It is important that the inspections are carried out to a uniform standard, so that valid comparisons can be made between inspections done in different location at different times and by different personnel.

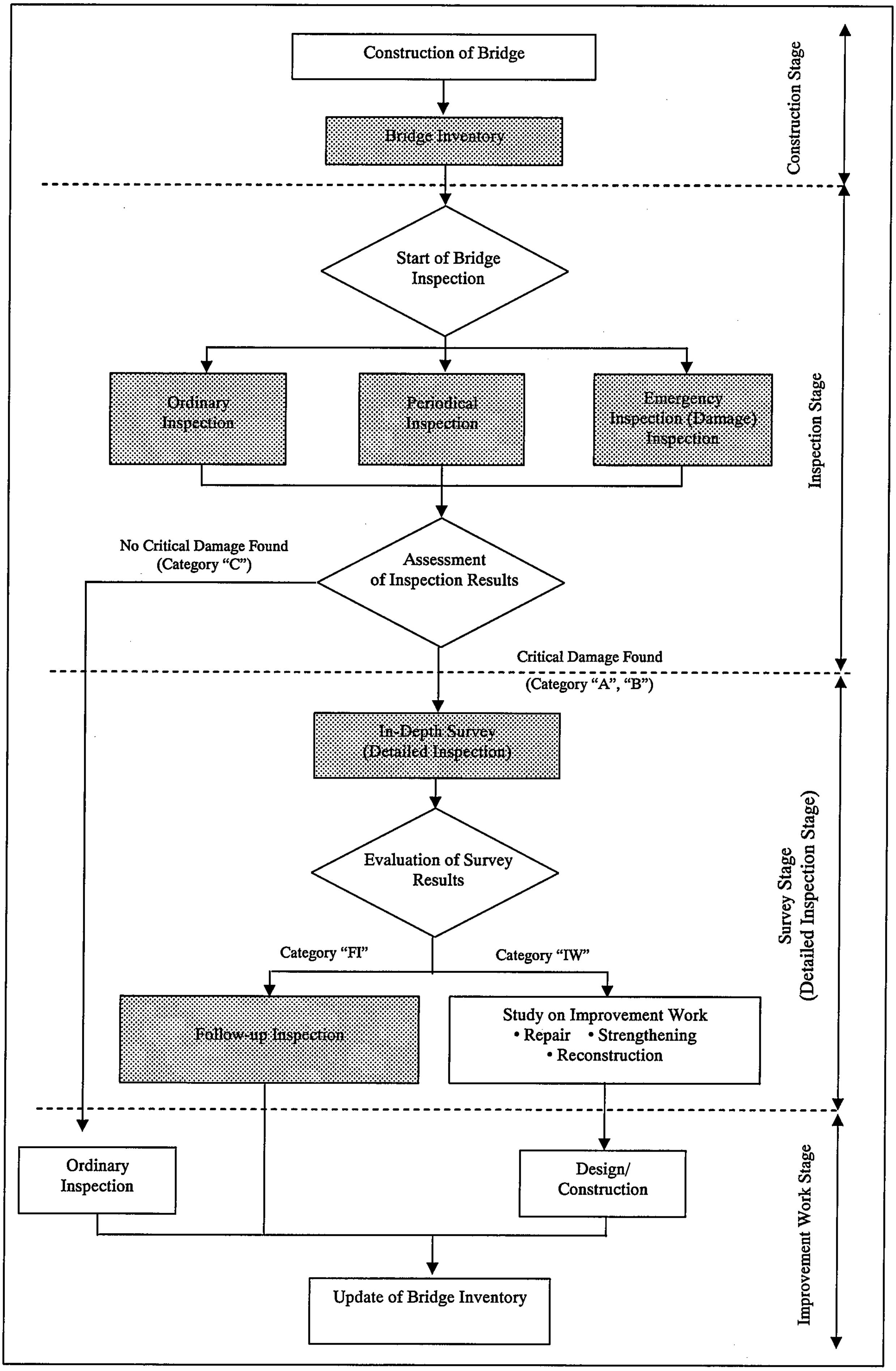

Figure 6.2.2-1 General Procedure on Bridge Inspection

Table 6.2.2-1 General Procedure on Bridge Inspection, Survey and Diagnosis

Survey Level	Type	Definition	Frequency	Major Inspection Methods	Main Inspection Members	Damage Rating Criteria	Diagnosis (Assessment/Evaluation)
Survey Level I	1. Ordinary Inspection	Regularly scheduled routine inspection				**Method 1 (X, Y, Z Method)** A damage is basically assessed based on the result of visual inspection depending on evaluation factors such as its location/pattern (X), depth (Y), and scale (Z), and primary or secondary member. (See **Section 6.4.1**) **Method 2 (H, M, S, Method)** A damage is basically assessed based on the result of visual inspection, depending on its severity (Heavy, Medium, Small) and primary or secondary member. The severity levels are established selecting the influential evaluation factor (primary and secondary evaluation factor) among X, Y and Z. (See **Section 6.4.2**)	**Category A / Heavy:** Urgent measures shall be applied, and then conduct the in-depth survey to decide whether improvement work is required or not. **Category B / Medium:** Urgent measures are not required, but conduct the in-depth survey to decide whether improvement work is required or not. **Category C / Small:** No immediate action are required. Ordinary inspection shall be continued.
	1.1 Inspection from the deck	Inspection by inspector's impression inside the moving car or visual inspection on the moving car	Daily	• Impression on moving car	• Members on the deck		
	1.2 Inspection from the ground	Distant visual inspection on foot, focusing on under-bridge	Yearly	• Distant visual inspection on foot	• Members under-bridge		
Survey Level II	2. Periodical Inspection	Regularly scheduled routine inspection					
	2.1 Partial Inspection	Distant or close-up visual inspection on damage-prone members	Every 5-years	• Combination of distant visual and close-up visual inspection	• Damage-prone members		
	2.2 Whole Inspection	Close-up visual inspection on whole structures of bridge using tools, equipment and facilities	Every 10-years	• Close-up visual inspection on whole structure • Equipment	• Whole members		
	3. Follow-up Inspection	• Inspection to observe the progress of damage which was found during other inspections, but repair work was not applied. • Close-up visual inspection using simple tools.	Preferably every 2-years	• Close-up visual inspection using simple tools such as crack gauge, video camera, etc.	• Specified members with damage, but no repair work was applied		
	4. Emergency Inspection (Damage Inspection)	• Inspection to confirm the durability of the bridge after the occurrence of incident or natural calamities. • Inspection method shall be selected depending on the nature of damages.	Occurrence of • vehicle collision • vessel collision • earthquake • typhoon • other events	• Methods to be selected depending on the nature of damages	• Specified members which were damaged		
Survey Level III	5. In-depth Survey (Detailed Inspection)	• Inspection to identify deficiencies not readily detected using routine inspection procedures. • Survey and analysis on type, scale, severity and pattern of damage by highly specialized methods and equipment.	When damage is ranked as Category "A" or "B" by inspection	• Close-up, hands-on survey and analysis using special equipment such as under-bridge inspection equipment, staging, workboat, etc.	• Specified members with high rank damage such as Category "A" or "B" by inspection	• Quantitative criteria are adopted to evaluate the damage of concrete and steel members, based on the survey and analysis. (See **Section 6.3.3**)	**Category "IW"** Improvement work is required. **Category "FI"** No improvement work is required, but follow-up inspection is required.

6.2.3 Survey Level and Methodology of Bridge Inspection

(1) Survey Level

The survey level and methodology of bridge inspection is discussed in compliance with the present situation and conditions of bridges. It is, however, understood that the level of detail and survey for physical inspection and the degree of testing will vary considerably for each type of damage to be studied.

The three levels of survey are summarized in **Table 6.2.3-1.**

(a) Survey Level I (Data Collection Level)

Main Objectives:

- To briefly check the physical and functional condition of the bridge by **"Ordinary Inspection"** method,
- To inspect and assess the damage types, scale and severity, if present, and
- To propose the probable and possible improvement measures for each defect or damage observed.

Survey Timing:

- When the data base for bridge management system are required, and
- When maintenance planning is required.

(b) Survey Level II (Master Plan Level)

Main Objectives:

- To evaluate damage types, scale and severity by **"Periodical Inspection"** method,
- To evaluate structural capacity of damaged members, and
- To prepare the preliminary improvement measures including cost estimation.

Survey Timing:

- When assessment of structural soundness of the bridge is required for planning of bridge rehabilitation and strengthening,
- When disaster/accident occurred or damaged members are found, and study on improvement measures is necessary.

Table 6.2.3-1 Level of Survey

Survey Level		I (Data Collection Level)	II (Master Plan Level)	III (Feasibility Study Level)**
Main Objectives		a) Checking/Assessment of physical and functional condition b) Inspection on Damage Type, Scale and Severity c) Proposal of Probable Improvement Measures	a) Evaluation of Damage Type, Scale and Severity b) Structural capacity evaluation c) Preparation of Preliminary Improvement Measures including Cost Estimation	a) Analytical assessment of Loading Capacity of Superstructure b) Estimation of Stability of Substructure including Foundation c) Determination of Major Improvement Measures
Survey Timing		When data base for bridge management system are required	When assessment of structural soundness is required for planning of bridge rehabilitation / strengthening and when damage due to disaster/accident need to be assessed	When serious damage are found, and a detailed study on major rehabilitation/strengthening is necessary
Superstructure	Concrete Bridge	a) Visual Inspection b) Inspection on Structural Shapes c) Inspection on Damage Type, Scale and Severity	a) Visual Inspection b) Measurement of Structural Shapes c) Evaluation on Damage Type, Scale and Severity d) Non-destructive Test (Schmidt Hammer Test)	a) Close-up Visual Investigation b) Measurement of Structural Shapes/Dimensions c) Non-destructive Test (Schmidt Hammer Test) d) Material Test (Core, Neutralization, Alkali Aggregate) e) Electromagnetic Wave Radar (Location of Reinforcing Bar)
	Steel Bridge	a) Visual Inspection b) Inspection on Structural Shapes c) Inspection on Damage Type, Scale and Severity	a) Visual Inspection b) Measurement of Structural Shapes c) Evaluation on Damage Type, Scale and Severity d) Damage Survey (Damage Detection by Penetrant Test)	a) Close-up Visual Investigation b) Measurement of Structural Shapes/Dimensions c) Structural Survey d) Material Test (Chemical Analysis, Vickers Hardness Test) e) Damage Survey (Damage Detection by Penetrant Test)
Substructure		a) Visual Inspection b) Inspection on Structural Shapes c) Inspection on Damage Type, Scale and Severity	a) Visual Inspection b) Measurement of Structural Shapes c) Evaluation on Damage Type, Scale and Severity d) Non-destructive Test (Schmidt Hammer Test)	a) Close-up Visual Investigation b) Measurement of Structural Shapes/Dimensions c) Displacement Survey (Vertical, Horizontal) d) Non-destructive Test (Schmidt Hammer Test)
Foundation		-	Depending on bridge condition, stability test and scour survey are required.	a) Stability Test (Impact Vibration Test) b) Scour Survey (Echo Sounder) c) Topographic and Geotechnical Survey
Loading Capacity of Superstructure		-	Depending on bridge condition, load test is required	a) Static Load Test

** Detailed Engineering Level is the same as Feasibility Study Level, that requires greater number of detailed survey points.

(c) Survey Level III (Feasibility Study Level)

Main Objectives:

- To analyze the loading capacity of superstructure based on the findings of **"In-depth Survey (Detailed Inspection)"**
- To estimate the stability of substructure and foundation, and
- To determine the major improvement measures.

Survey Timing:

- When serious damages are found and the structural soundness of the bridges is in question,
- When major rehabilitation/strengthening is needed.

(2) Methodology

The systematic methodology from the inspection stage to the stage of final decision on bridge improvement measures is recommended for each Survey Level.

In this study flow, the emphasis was given not only to the physical condition of the bridges, but also to other factors mentioned below.

- Historical report
- Structural soundness
- Vulnerability to disaster
- Traffic condition
- Special issues such as squatter condition etc.
- Vessel collision

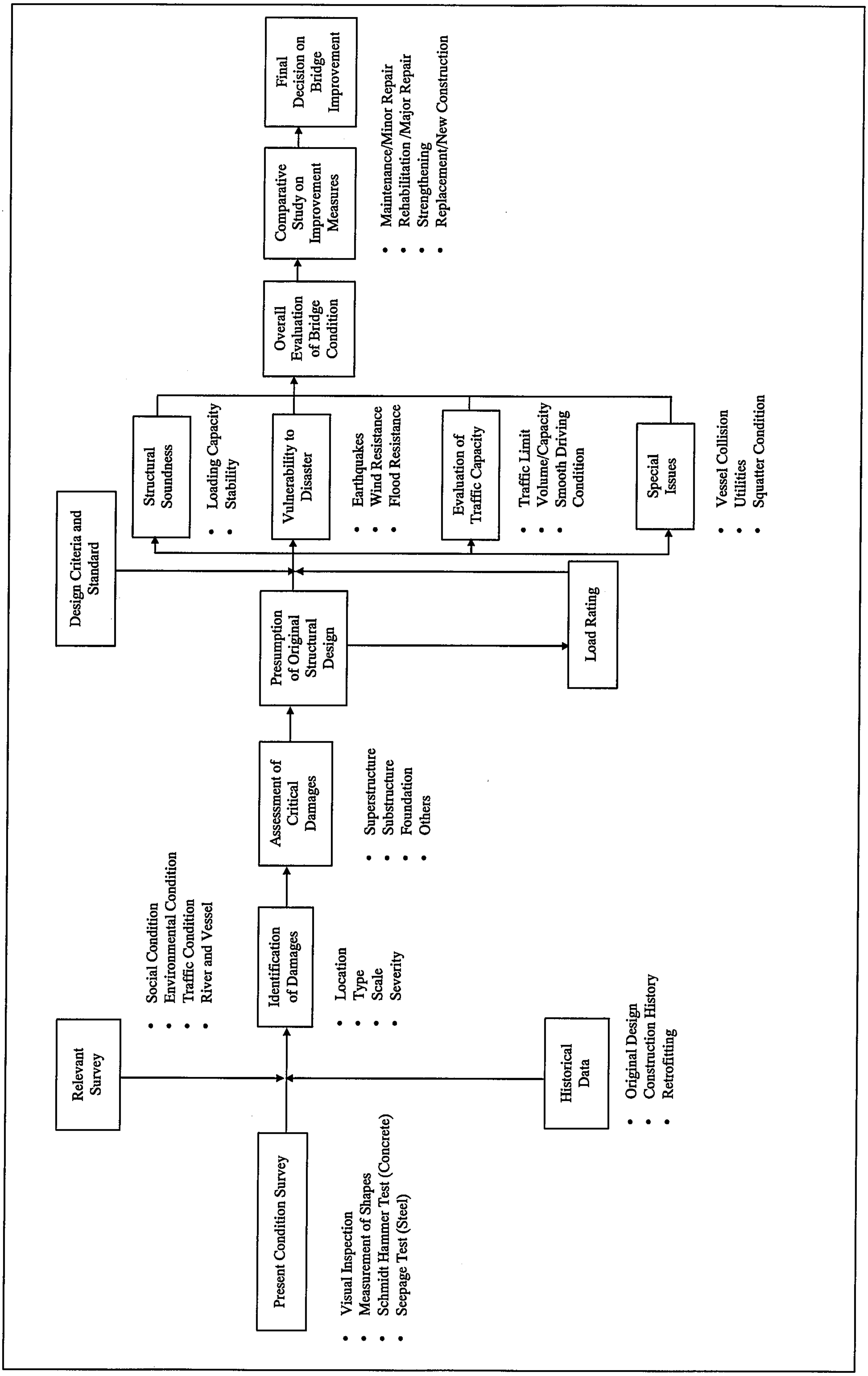

Figure 6.2.3-1 Study Flow of Bridge Condition Survey and Improvement Measures (Master Plan Level)

6.3 METHODOLOGY OF BRIDGE CONDITION SURVEY

6.3.1 Visual Inspection Method

(1) Visual Inspection Items

The visual inspection items include the primary and secondary members. **Table 6.3.1-1** presents the items to be observed in the field, while **Table 6.3.1-2** shows the inspection and examination contents.

Table 6.3.1-1 Items to Observed in the Field

	Members			Inspection Items
Primary Members	Super-Structure	Steel	Main Girder, Cross Beam Stringer, Sway Bracing	Corrosion, Cracks, Looseness and Missing Member, Break/Rupture, Painting Deterioration, Deformation, Abnormal Vibration, Missing Bolts and Rivets.
		Concrete	Main Girder	Cracks, Spalling, Exposed Rebars, Free Lime, Fracture, Honeycombs, Discoloration/Deterioration, Movement/ Inclination/Settlement/Displacement
			Slab	Cracks, Spalling, Exposed Rebars, Free Lime, Fracture, Honeycombs, Chipping-off, Damage of Joint, Leakage.
	Sub-Structure	Concrete	Abutment Pier	Cracks, Spalling, Exposed Rebars, Free Lime, Honeycombs, Wearing, Discoloration, Water Leakage, Loss of Member
		Foundation		Settlement, Movement, Inclination, Scour
	Bearing	Steel Bearing		Corrosion, Cracks, Loosening, Falling, Failure, Discoloration, Deformation, Settlement, Movement, Inclination
		Rubber Bearing		Discoloration, Water Leakage, Deformation, Failure
		Mortar		Cracks, Failure
		Anchor Bolt		Corrosion Damage, Cracks, Loosening, Falling, Failure, Deformation
	Unseating Prevention System	Steel	Restrainer Cable/Bar, Anchor Bar	Corrosion, Missing Bolts
		Concrete	Shear Block	Cracks, Spalling, Exposed Rebars, Free Lime, Fracture, Honeycombs, Discoloration
Secondary Members	Lateral Bracing	Steel		Corrosion, Cracks, Looseness and Missing Member, Break/Rupture, Painting Deterioration, Deformation, Abnormal Vibration, Missing Bolts and Rivets.
		Concrete	Intermediate and End Diaphragm	Cracks, Spalling, Exposed Rebars, Free Lime, Fracture, Honeycombs, Discoloration
	Sway Bracing	Steel		Corrosion, Cracks, Looseness and Missing Member, Break/Rupture, Painting Deterioration, Deformation, Abnormal Vibration, Missing Bolts and Rivets.
	Railing	Steel		Corrosion, Cracks, Looseness and Missing Member, Break/Rupture, Painting Deterioration, Deformation, Abnormal Vibration, Missing Bolts and Rivets.
		Concrete		Cracks, Spalling, Exposed Rebars, Free Lime, Honeycombs, Wearing, Discoloration, Leakage, Loss of Member
	Median Strip Curbstone	Concrete		Cracks, Spalling, Exposed Rebars, Free Lime, Fracture, Honeycombs, Discoloration
	Curb and Gutter	Concrete		Cracks, Spalling, Corrosion Damage, Free Lime, Honeycombs, Fracture
	Pavement	Asphalt		Potholes, Cracks, Rutting, Leakage
	Expansion Joint	Steel		Corrosion, Cracks, Loosening, Falling, Failure, Abnormal Opening, Abnormal Sound, Deformation, Water Leakage
		Rubber		Failure, Abnormal Opening, Abnormal Sound, Deformation, Loss of Member, Water Leakage
	Drainage Facility			Corrosion, Cracks, Loosening, Falling, Failure, Discoloration, Leakage, Deformation, Loss of Member.
	Lighting			Corrosion, Cracks, Loosening, Falling, Failure, Painting Deterioration, Deformation, Loss of Member.

Table 6.3.1-2 Inspection and Examination Contents

Examination Contents		Inspection and Test Method	Examination Items
Steel	Cracks	Penetrant test	Present Condition
	Corrosion	Eye inspection	Present Condition
Concrete	Cracks, Honeycombs, Reinforcement Corrosion	Photograph of damaged portions.	Present Condition
	Measurement of section	Measurement tape	Construction condition
	Crack width and crack length	Cracks scale and measurement tape.	Cracks
	Compressive strength	Schmidt hammer test,	Quality of Concrete

(2) Visual Inspection Form

The visual inspection of damages that are observed in the field were written in the Visual Inspection Form. The visual inspection form consists of three (3) sheets namely:

- Visual Inspection Sheet 1 of 3,
- Visual Inspection Sheet 2 of 3, and
- Visual Inspection Sheet 3 of 3 (Crack Sheet)

(a) Visual Inspection Sheet 1 of 3

The Visual Inspection Sheet 1 of 3 contains the basic bridge layout drawings including:

- Elevation and Cross-Sections,
- Table of Damage Types, and
- Visual Inspection Table indicating damages observed.

The types of damages observed shall be written in the drawings. This form is filled up with inspection items consisting of the road surface and the side and bottom of the bridge.

The kind of damages shall be written in abbreviation form which will be selected from the type of damages in the accompanying table. The severity of the observed damages shall be assessed and indicated in the form as:

H : Heavy / M : Medium / S: Small

An example of the Visual Inspection Sheet 1 of 3 form is presented in **Figure 6.3.1-1** with the following types of damages:

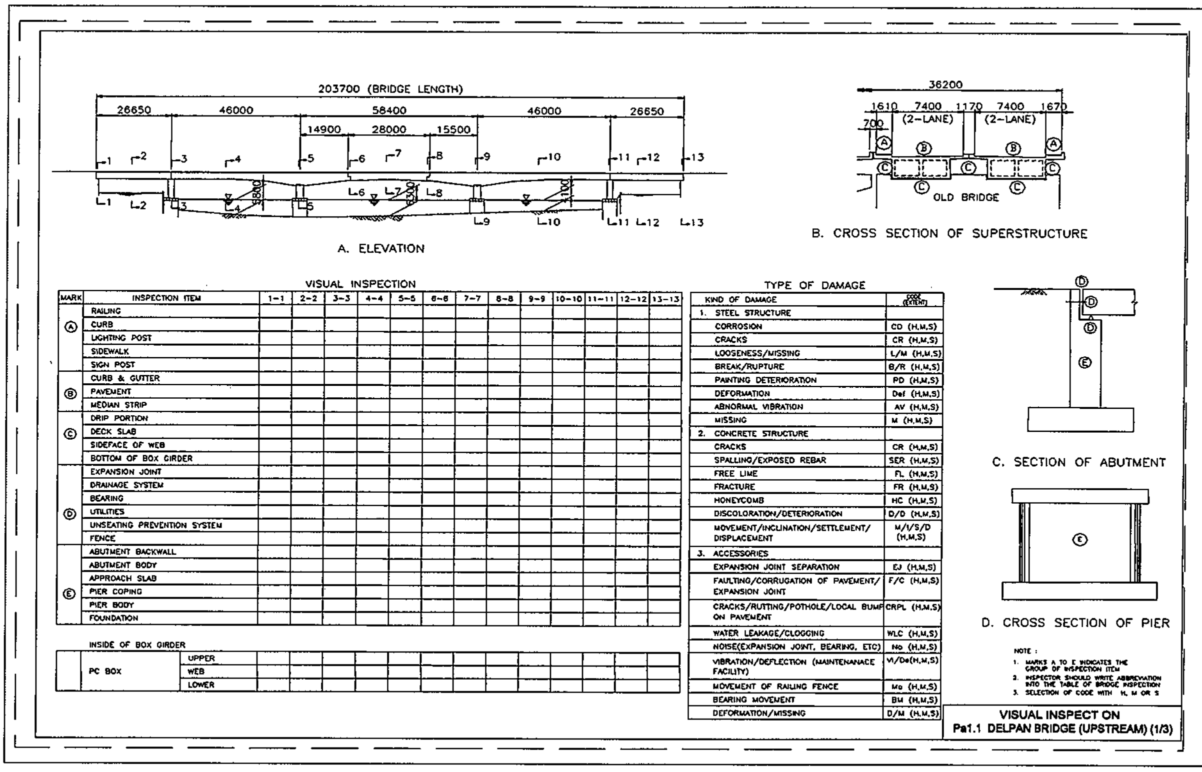

Figure 6.3.3-1 Visual Inspection Sheet 1 of 3

Steel Structures: Corrosion, Cracks, Looseness/Missing Members, Break/Rupture, Painting Deterioration, Deformation, Abnormal Vibration, Missing Bolts and Rivets.

Damages for Concrete Structures: Cracks, Spalling with Exposed Rebars, Freelime, Fracture, Honeycomb, Discoloration/Deterioration of Members, Movement/inclination/Settlement/ Displacement.

Damages for Accessories: Expansion Joint Separation, Faulting/Corrugation of Pavement/Expansion Joint, Cracks/Rutting/Pothole/ Local Bump on Pavement, Water Leakage/ Clogging, Noise of Expansion Joint/Bearing, Vibration/Deflection of Maintenance Facility, Movement of Handrail, Bearing Shoe Movement, Deformation/Missing.

(b) Visual Inspection Sheet 2 of 3

The Visual Inspection Sheet 2 of 3 contains the basic bridge layout drawings including plan, elevation, and sections and the location of damages and tests conducted on the bridge.

The main purpose of this inspection sheet is to:

a) Plot the location of damages,

b) Plot the location of Schmidt Hammer and Other Tests performed, and

c) Locate the type and size of utilities.

An example of the Visual Inspection Sheet 2 of 3 form is shown in **Figure 6.3.1-2**.

The location of visual inspection is not necessarily restricted to the cross-sections indicated in the general elevation. It is important to observe carefully all the defects along the bridge.

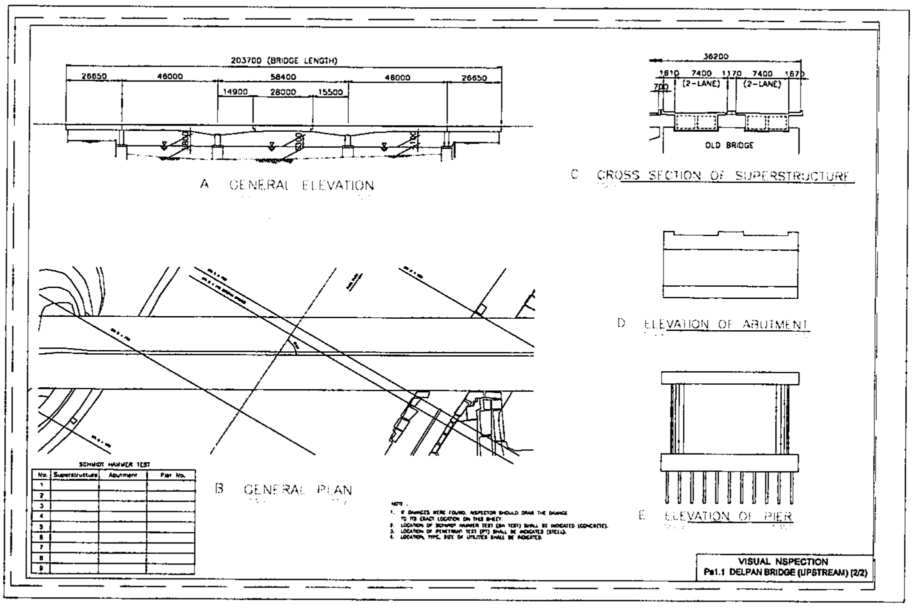

Figure 6.3.1-2 Visual Inspection Sheet 2 of 3

(c) Visual Inspection Sheet 3 of 3 (Crack Sheet)

Information on serious damages is presented on this sheet. The location and direction of cracks will be plotted as shown in the example **Figure 6.3.1-3**.

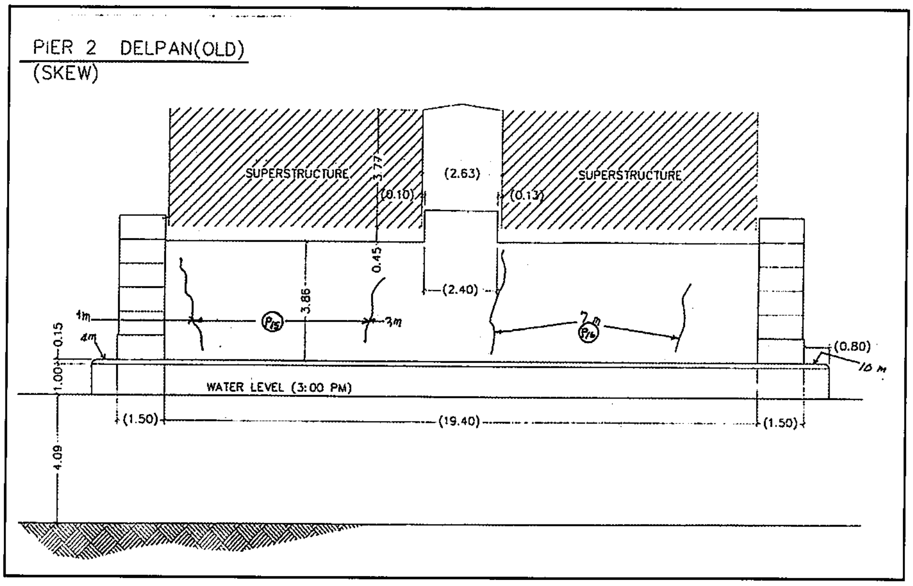

Figure 6.3.1-3 Visual Inspection Sheet 3 of 3 (Crack Sheet)

(3) Visual Inspection Report

Field inspection data which can be found on Visual Inspection Sheet (1 to 3) are the basis of preparation of Visual Inspection Report.

The details of damages will be included on the Visual Inspection Report and recorded in the different bridge inventory and inspection sheets as illustrated in **Figure 6.3.1-4** to **6.3.1-7.**

This includes: (1) Summary of Observed Damages, (2) Condition of Structural Members, (3) Condition of Accessories, and (4) Photograph of Damages.

BRIDGE INVENTORY AND INSPECTION FORM - 2

SUMMARY OF OBSERVED DAMAGES

Date of Inspection ______
Inspector ______
Name of Bridge : ______ Checker ______

Damage No.	Span No.	Name of Member	Type of Damage	Rank of Damage	Description of Damage (Nature, Location/Pattern, Scale, Severity, No. of Damages)	Remarks (A, B, C)	Photo No.
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							

Remarks : A : require urgent remedial measure
B : require maintenance work
C : others

Figure 6.3.1-4 Summary of Observed Damages

BRIDGE INVENTORY AND INSPECTION FORM - 3

CONDITION OF STRUCTURAL MEMBERS

Date of Inspection ______
Inspector ______
Name of Bridge : ______ Span : 1, 2, 3, 4, 5 Checker ______

Superstructure	Type		Bridge Length		Span Length	
Abutment	Type		Height		Foundation	
Pier	Type		Height		Foundation	
River Bank	Type					

Structural Member			Damage / Girder		Damage / Girder		Damage / Girder		Damage / Girder		Damage / Girder	
			Type	Rank	Type	Rank	Type	Rank	Type	Rank	Type	Rank
Superstructure	Deck Slab											
	PC	Upper & Girder										
		Side of Web										
		Bottom of Girder										
	Steel Girder	Main Girder										
		Cross Beam										
		Stringer										
		Sway Bracing										
		Lateral Bracing										
	Steel Truss & Arch	Upper Chord										
		Lower Chord										
		Vertical Member										
		Diagonal Member										
		Cross Beam										
		Stringer										
		Sway Bracing										
		Lateral Bracing										
Substructure	Abutment											
	Pier											
	Foundation											

Figure 6.3.1-5 Condition of Structural Members

BRIDGE INVENTORY AND INSPECTION FORM - 4

CONDITION OF ACCESSORIES

Date of Inspection ______
Inspector ______
Name of Bridge : ______ Span 1, 2, 3, 4, 5 Checker ______

Accessory	Damage		Damage		Damage		Damage	
	Type	Rank	Type	Rank	Type	Rank	Type	Rank
Railing								
Curb								
Lighting Post								
Sidewalk								
Sign Post								
Curb & Gutter								
Pavement								
Median Strip								
Expansion Joint								
Drainage System								
Utilities								
Fence								
Noise Barrier								

Figure 6.1.3-6 Condition of Accessories

BRIDGE INVENTORY AND INSPECTION FORM - 5

PHOTOGRAPHS OF DAMAGES

Date of Inspection ______
Inspector ______
Name of Bridge : ______ Checker ______

	Photo No. Span No. Member Damage Type Damage Rank Description		Photo No. Span No. Member Damage Type Damage Rank Description
	Photo No. Span No. Member Damage Type Damage Rank Description		Photo No. Span No. Member Damage Type Damage Rank Description

Figure 6.3.1-7 Photographs of Damages

(4) Methods of Schmidt Hammer Test and Dye Penetrant Test

(a) Schmidt Hammer Test

The Schmidt Hammer is a test method for determining compressive strength of hardened concrete. This device takes the reading depending on the hammer rebound of the equipment.

Schmidt hammer test shall be conducted by placing the equipment in contact with a structural member at a certain degree of inclination, i.e. 0^0, 45^0, 90^0 and 180^0 angles, a reading is then obtained. The graph in **Figure 6.3.1-8** converts the reading to a concrete strength in kg/cm^2. **Table 6.3.1-3** shows the Ratio ($\propto_n$) as a function of Concrete Age.

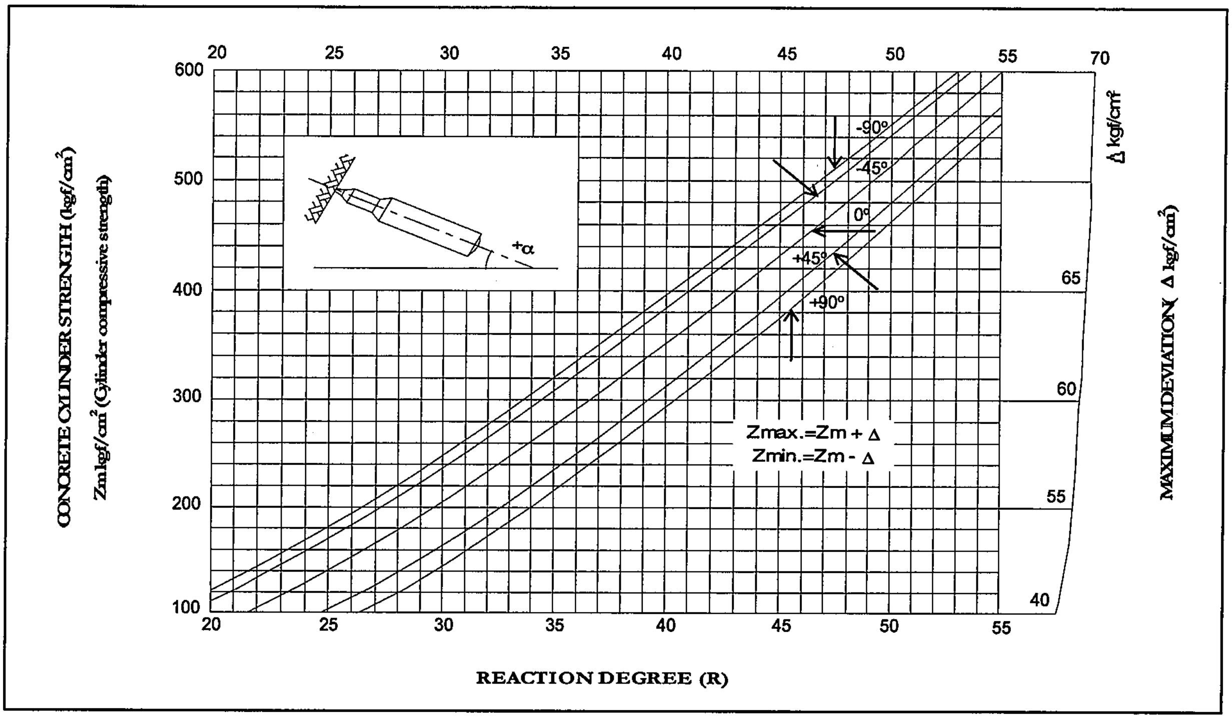

Figure 6.3.1-8 Curve Graph for Reaction Degree vs. Concrete Strength

Table 6.3.1-3 Ratio of Concrete Age

Concrete Age (Days)	10	20	28	50	100	150	200	300	500	1000	3000
Ratio (αn)	1.55	1.15	1.00	0.87	0.78	0.74	0.72	0.70	0.67	0.65	0.63

Using the graph in **Figure 6.3.1-8** with the corresponding reading and angle of inclination, a value Zm can be obtained. To calculate the average concrete strength, the following formula is to be used, $F = \alpha n * Zm$ (kgf/cm^2).

(b) Penetrant Test

Penetrant test on steel members shall be conducted on selected portions of the bridge. This type of non-destructive test is used to find and measure the crack on the steel components.

The surface area under test should be properly cleaned. A dye penetrant is to be sprayed uniformly on the area of interest. After allowing a certain period of penetration time, again the surface area is cleaned with a cleaner sprayed on a cloth to remove excess penetrant. A developer is sprayed uniformly on the same area of interest. Likewise, after a certain period or settling time, the visual inspection shall be conducted to detect the defect.

6.3.2 Shape and Dimension Measurement Method

(1) Shape and Dimension Checklist

In preparing the bridge inventory where none exist, or updating existing bridge inventory when alterations or modifications of the original bridge configurations have been made, it is necessary to conduct bridge shape and dimension measurements. The objective would be to prepare and/or update bridge inventory data which will serve as the base line for bridge maintenance and inspection.

The following items shall be included in the Shape and Dimension measurement:

- Approach Road,
- Superstructure, and
- Substructure

The inspector should be familiar with the following notes when performing shape and dimension measurement:

- Dimensions of approach road shall be measured approximately 100m from the abutment,
- Dimensions of section length of superstructure are measured perpendicular to the bridge centerline,
- θ is the skew angle at the bridge end,
- Fix or moving bearing shoe shall be indicated,
- ( ) means as-built drawings while (( )) means assumptions used for presumption of original design.

The data obtained from the shape and dimension measurement is used in the preparation of structural drawings of the existing bridges. These drawings are necessary for the analysis and overall safety evaluation of the bridge. In the absence of as-built drawings for the foundation, assumptions can be made regarding the kind and number of pile foundation or the type of foundation prevailing during the construction of the bridge. The length of pile was determined from the available geotechnical data and pile resistance.

The Basic Items and Location of Field Measurements are presented in **Table 6.3.2-1.**

(2) Shape and Dimension Measurement Form

(a) Basic Survey Form

The form consists of drawings of:

- Elevation
- Cross Section of Approach Road
- Cross Section of Superstructure
- Cross Section of Abutment
- Cross Section of Pier

Due to the difficulty of conducting measurements in the bridge site, some tables have already been filled with available information from as-built drawings. An example of shape and dimension measurement form is shown below in **Figure 6.3.2-1.**

Table 6.3.2-1 Basic Items and Locations of Field Measurements

Bridge Type			Item	Location	No. of Measurement (per span)
Basic Dimensions			Total Width	Center of Bridge	1/Bridge
			Sidewalk, Carriage Width	Center of Bridge	1/Bridge
			No. of Lanes	Center of Bridge	1/Bridge
			Bridge Length	Both sides of Bridge	2/Bridge
			Clear Span Length	Both sides of Bridge	2/Bridge
			Skew Angle (degree)	Both ends of Bridge	2/Bridge
			Bridge Deck Profile Survey	Abutment, Pier, Span Center	1/Bridge
Superstructure	Steel Plate Girder Bridge	Structural Dimension	Span Length	Both sides of span	2
			Spacing of Main Girders	At support points	2
			Main Girder Height	At support points	2
		Sectional Dimension	Main Girder Section	External and internal girders	2
			Cross Frame Section	At support points	2
	Steel Truss Bridge and Arch Bridge	Structural Dimension	Span Length	Both sides of the bridge	2
			Spacing of main Trusses	At support points	2
			Truss Height	1-Main Truss, Support Points	2
			Spacing of Panel Points	1-Main Truss	1
		Sectional Dimension	Upper Chord Section	Side/Center Main Truss, Arch	2
			Lower Chord Section	Side/Center Main Truss, Arch	2
			Diagonal Member Section	Side/Center Main Truss, Arch	2
			Vertical Member Section	Side/Center Main Truss, Arch	2
			Sway Bracing Section	Support Points	2
	PC I Girder	Structural Dimension	Span Length	Both Sides of Bridge	2
			Spacing of Main Girders	Support Points	2
			Main Girder Height	Support Points	2
			Confirmation of Girder Type No.	Support Points	2
	PC Box Girder	Sectional Dimension	Span Length	Both Sides of Bridge	2
			Spacing of Main Girders	Support Points	2
			Main Girder Section	Support Points	2
	I Girder + PC Box Girder		Follow I G., PC Box G. Bridge	-	-
Substructure	Support	Structural Dimension	Type, Fix or Movable	Support Points	-
	Pier		Dimensions	-	-
	Abutment		Dimensions	-	-
	Deformation Survey		Inclination of Abutments and Piers	2 axial directions	2/Pier, Abutment
Foundation	Pier and Abutment	Structural Dimension	Type	-	Each Foundation
			No. of Piles	-	Each Foundation

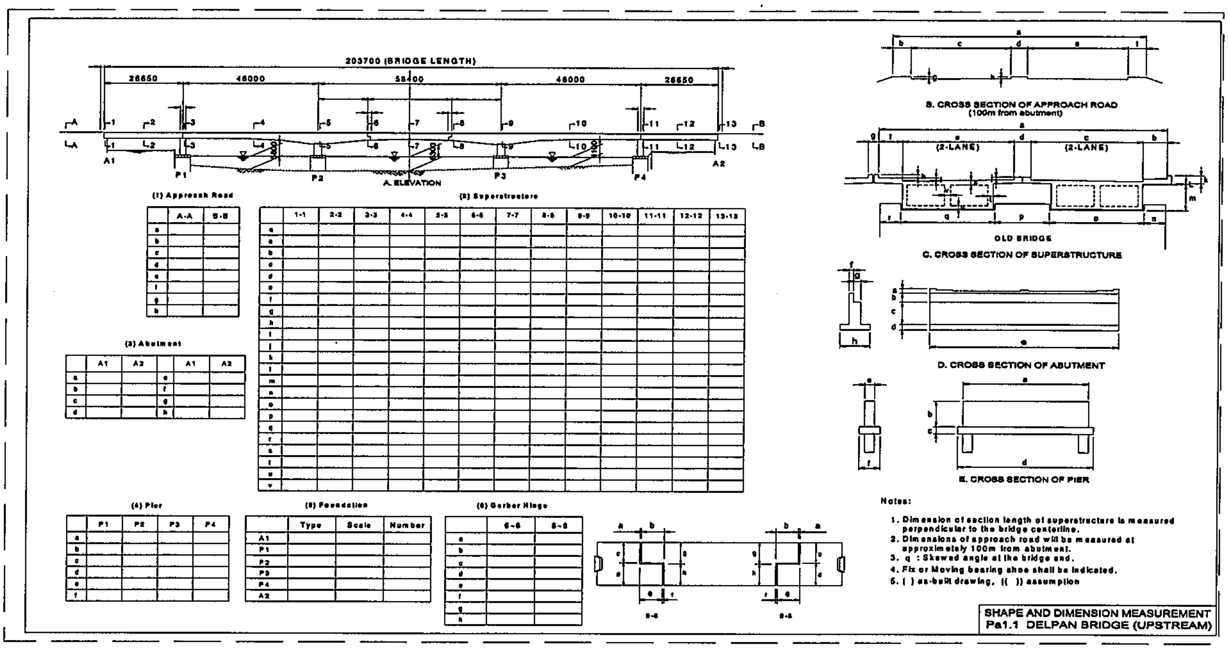

Figure 6.3.2-1 Shape and Dimension Measurement

(b) Bridge Deck Profile Survey

In case of large corrugation or deflection, deck slab profile survey is made to measure the deflection of the bridge.

(c) Inclination Survey of Substructure

Abutments and piers are plumb in the longitudinal and transverse direction. Two points along the vertical direction of the substructure are identified and marked as measurements points. The difference in horizontal distance between the marked points is measured and the angle of inclination calculated as $\theta = \tan^{-1} (\Delta x/y)$. **Figures 6.3.2-2** shows the determination of angle of inclination of an abutment.

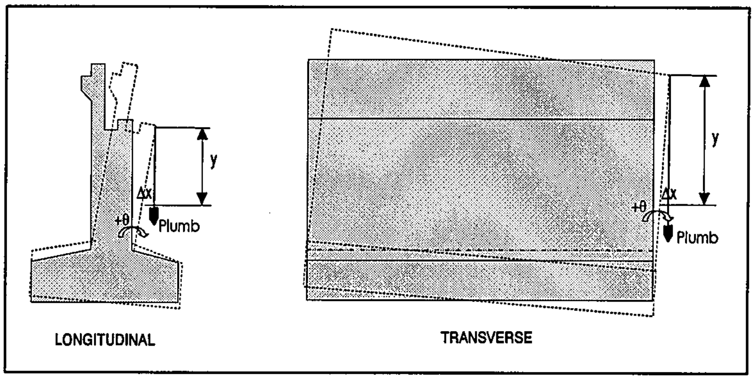

Figure 6.3.2-2 Angle of Inclination of Abutment

(3) Shape and Dimension Measurement Report

The Shape and Dimension Measurement results shall be reported following the format shown in **Figure 6.3.2-1.**

The bridge inventory survey results shall be summarized as shown in **Figure 6.3.2-3.**

BRIDGE INVENTORY AND INSPECTION FORM - 1

BRIDGE INVENTORY

Reference No. ____________
Inventory Date ____________
Inventory Office ____________

Name of Bridge : ____________

Bridge Type			Bridge Length		Span Length
Name of Road		Location		Chainage	
Approach Road	Road Width (m)		Abutment	Type	
	Lane	No. Width (m)		Body	Height (m), Width (m)
	Sidewalk	Type Width (m)		Footing	Length (m), Width (m)
	Median	Type Width (m)		Foundation	Type Length (m)
	Pavement	Type Thickness (cm)	Pier	Type	
	Traffic Volume	Both Direction/day		Coping	Height (m), Width (m)
Superstructure	Alignment	Skew Curve		Body	Height (m), size (m)
	Main Girder	Type		Footing	Length (m), Width (m)
		Height		Foundation	Type Length
		Number	Design	Specification	
		Space (m)		Live Load	
	Cross Beam	Type		Seismic Coefficient	
		No.		Design Date	
	Stringer	Type	Construction	Concrete	f'c
		No.		Reinforcing Bar	fy
	Pavement	Type Thickness (cm)		P.C. Material	f'c
	Slab	Type Thickness (cm)		Steel Material	fy
	Bearing	Type Reaction (t)		Construction Date	
	Expansion Joint	Type	Remarks		( ) As Built Data
	Railing	Type			(( )) Assumed Data

Figure 6.3.2-3 Bridge Inventory

The slab thickness is to be determined by obtaining a core sample from the slab, or taken from as-built drawings and assumptions.

(b) Field Data of Bridge Condition Survey

Structural drawings is made from Field Data of Condition Survey, As-Built drawings and presumption of substructures.

(c) Bridge Deck Profile Survey

Bridge Deck profile survey is performed on the bridge with large corrugation. Values obtained from the field shall be recorded accordingly.

(d) Inclination

The Angle of Inclination is shown in **Figure 6.3.2-2.**

6.3.3 In – Depth Survey Method

In-depth survey was applied to the survey of Ayala Bridge, Jones Bridge, Quezon Bridge, Lambingan Bridge, Guadalupe Bridge and Vargas Bridge, details of which are described in **Section 13.3.**

The inspection may include load rating to assess quantitatively the residual capacity of the member/s, depending on the extent of damage or deterioration. Non-destructive load test may be conducted to determine the safe load-carrying capacity of the bridge.

(1) Points in the Field Survey

The field In-Depth survey is conducted considering the following items below:

(a) The objectives of field in-depth survey should be made clear before its execution,

(b) Inspection items shall be selected by judging comprehensively the extent of damages obtained from the past inspection results and the desk-survey results,

(c) The following points should be kept in mind in conducting the field in-depth survey:

i) In the in-depth survey, bridge components and elements diagnosed to be Category "A", which is discussed in **Section 6.4.3**, in the initial inspection and meet site rehabilitation condition, shall be made a priority due to the urgent nature of damages. The survey is normally carried out after conducting a temporary emergency repair of the damaged component or element.

ii) For bridge components and elements diagnosed to be Category "B" in the initial inspection, the survey shall be conducted to provide data for judgment of the cause, scale and progress of damages. This survey will then become the basis for judging whether the bridge rehabilitation work in needed or not.

iii) For damages found to have progressive tendency to deteriorate, the survey shall be continued to confirm the progress of damage for a fixed period of time.

(2) Examination of Damage Causes

The causes of bridge damages, may be almost always in conjunction with many factors, making it difficult to specify the cause of such damages. In this section, there are five (5) major factors or causes of damages which can be classified as to either External or Internal factors as presented on **Table 6.3.3-1.**

The causes of damages for steel structures, concrete structure and bridge accessories are presented in **Table 6.3.3-2, 6.3.3-3** and **6.3.3-4**, respectively. The tables present the location and types of damages and refer to **Table 6.3.3-1** for the causes and factors giving rise to such damages.

Table 6.3.3-1 Factors Causing Damages

External Factors	Internal Factors
(a) External Forces (1) repeated loads such as vehicle loads (2) dead loads (3) collisions (4) uneven pressure / consolidation settlement (5) scour / erosion (6) earthquakes	(c) Material Deterioration (10) alkali-aggregate reaction (11) carbonation (12) poor quality (d) Fabrication / Construction (13) fabrication / construction faults (14) poor waterproof / drainage facility
(b) Environmental Factors (7) drying shrinkage/change in temperature (8) salt damage (9) chemical corrosion	(e) Structural Factors (15) structural deficiency

Table 6.3.3-2 Causes of Damages for Steel Structure

Location	Damage Type	Main Causes Estimated	
Steel Main Girder / Bracing / Steel Pier / others	Corrosion, Section Loss	Environmental	(8) Salt Damage, (9) Chemical Damage
		Material Deterioration	(12) Poor Quality
		Fabrication /Construction	(13) Fabrication/ Water Proof / Drainage Facilities
		Structural	(15) Structural deficiency
Steel Main Girder / Bracing / Steel Pier / Others	Crack Fissures	External Forces	(1) Repeated Loads, (3) Collision (6) Earthquake
		Material Deterioration	(12) Poor Quality
		Fabrication / Construction	(13) Fabrication / Construction Faults
		Structural	(15) Structural deficiency
Place of Bolts Installed	Looseness / Fallen-Off	External Forces	(1) Repeated Loads, (3) Collision (6) Earthquake
		Material Deterioration	(12) Poor Quality
		Fabrication/ Construction	(13) Fabrication / Construction Faults
		Structural	(15) Structural deficiency
Steel Main Girder / Bracing / Steel Pier / Others	Fractures	External Forces	(1) Repeated Loads, (3) Collision (6) Earthquake
		Material Deterioration	(12) Poor Quality
		Fabrication / Construction	(13) Fabrication / Construction Faults
		Structural	(15) Structural deficiency
Painted Area	Discolora-tion / Spalling	Environmental	(8) Salt Damage, (9) Chemical Damage
		Material Deterioration	(12) Poor Quality
		Fabrication / Construction	(13) Fabrication / Construction Deficiencies, (14) Poor Water Proof / Drainage Facilities
		Structural	(15) Structural Deficiency
Steel Main Girder / Steel Pier	Deforma-tion	External Forces	(1) Repeated Load, (3) Collision (4) Uneven Pressure/ Consolidation Settlement, (5) Scour/Erosion, (6) Earthquake
		Fabrication / Construction	(13)Fabrication / Construction Faults
		Structural	(15) Structural Deficiency
Steel Main Girder	Abnormal Vibration	External Forces	(1)Repeated Load, (6)Earthquake
		Fabrication / Construction	(13) Fabrication / Construction Faults
		Structural	(15) Structural Deficiency

Table 6.3.3-3 Causes of Damages for Concrete Structure

Location	Damage Type	Main Causes Estimated	
Main Girder / Slab Deck / Pier / Abutment / Railing Wall / Curb	Cracks	External Forces	(1) Repeated Load, (3) Collision, (4) Uneven Pressure / Consolidation Settlement, (5) Scour/Erosion (6)Earthquake
		Environmental	(7) Drying Shrinkage / Change in Temperature, (8) Salt Damage, (9) Chemical Corrosion
		Material Deterioration	(10) Alkali-Aggregate Reaction, (11) Carbonation, (12) Poor Quality
		Fabrication/ Construction	(13) Fabrication / Construction Faults, (14) Poor Water Proof / Drainage Facilities
		Structural	(15) Structural Deficiency
Main Girder / Slab Deck / Pier / Abutment / Railing Wall / Curb	Spalling / Exposed Rebar	External Forces	(1) Repeated Load, (3) Collision, (4) Uneven Pressure / Consolidation Settlement, (5) Scour/Erosion, (6) Earthquake
		Environmental	(7) Drying Shrinkage / Change in Temperature, (8) Salt Damage, (9) Chemical Corrosion
		Material Deterioration	(10) Alkali-Aggregate Reaction, (11) Carbonation, (12) Poor Quality
		Fabrication / Construction	(13) Fabrication / Construction Faults, (14) Poor Water Proof / Drainage Facilities
		Structural	(15) Structural Deficiency
Main Girder / Slab Deck / Pier / Abutment / Railing Wall / Curb	Discolora-tion	Environmental	(7) Drying Shrinkage / Change in Temperature, (8) Salt Damage, (9) Chemical Corrosion
		Material Deterioration	(10) Alkali-Aggregate Reaction, (11) Carbonation, (12) Poor Quality
		Fabrication / Construction	(13) Fabrication / Construction Faults, (14) Poor Water Proof / Drainage Facilities
		Structural	(15) Structural Deficiency
Slab deck / Railing Wall / Curb	Fallen-Off	External Forces	(1) Repeated Load, (3) Collision, (6) Earthquake
		Environmental	(8) Salt Damage
		Material Deterioration	(10) Alkali-Aggregate Reaction, (11) Carbonation, (12)Poor Quality
		Fabrication / Construction	(13) Fabrication / Construction Faults, (14) Poor Water Proof / Drainage Facilities
		Structural	(15) Structural Deficiency
Main Girder/ Slab Deck/ Pier/ Abutment/ Railing Wall/ Curb	Honey-comb Void	Material Deterioration	(10) Alkali-Aggregate Reaction, (11) Carbonation (12)Poor Quality
		Fabrication / Construction	(13) Fabrication / Construction Faults, (14)Poor Water Proof / Drainage Facilities
Main Girder/ Slab Deck/ Pier/ Abutment/ Railing Wall/ Curb	Discolora-tion	Environmental	(7)Drying Shrinkage / Change in Temperature, (8) Salt Damage, (9) Chemical Corrosion
		Material Deterioration	(10) Alkali-Aggregate Reaction, (11) Carbonation, (12) Poor Quality
		Fabrication / Construction	(13) Fabrication / Construction Faults, (14) Poor Water Proof / Drainage Facilities
Deformation/ Inclination/ Settlement/ Movement	Pier/ Abutment	External Forces	(1) Repeated Load, (3) Collision, (4) Uneven Pressure / Consolidation Settlement, (5) Scour/Erosion (6)Earthquake
		Material Deterioration	(12) Poor Quality
		Fabrication/ Construction	(13 Fabrication) / Construction Faults
		Structural	(15) Structural Deficiency

Table 6.3.3-4 Causes of Damages for Bridge Accessories

Location	Damage Type	Main Causes Estimated	
Expansion Joint	Abnormal Joint Gap	External Forces	(1) Repeated Load, (4),Uneven Pressure / Consolidation Settlement, (5) Scour/Erosion, (6) Earthquake
		Environmental	(7) Drying Shrinkage / Change in Temperature
		Fabrication / Construction	(13) Fabrication / Construction Faults
		Structural	(15) Structural Deficiency
Pavement/ Expansion Joint	Elevation Gap/ Corruga-tion	External Forces	(1) Repeated Load, (6) Earthquake
		Environmental	(7) Drying Shrinkage / Change in Temperature
		Material Deterioration	(12) Poor Quality
		Fabrication / Construction	(13) Fabrication / Construction Faults
		Structural	(15) Structural Deficiency
Pavement	Pavement Cracks/ Rutting/ Pothole/ Local Bump	External Forces	(1) Repeated Load, (6) Earthquake
		Environmental	(7) Change in Temperature
		Material Deterioration	(12) Poor Quality
		Fabrication / Construction	(13) Fabrication / Construction Deficiencies (14) Poor Water Proof / Drainage Facilities
		Structural	(15) Structural Deficiency
Drainage Facilities/ Expansion Joint	Water Leaking/ Clogged Water	External Forces	(3) Collision, (6) Earthquake
		Material Deterioration	(12) Poor Quality
		Fabrication/ Construction	(13) Fabrication / Construction Faults, (14) Poor Water Proof / Drainage Facilities
		Structural	(15) Structural Deficiency
Expansion Joint/ Seismic Restrainer	Abnormal Noise	External Forces	(1) Repeated Load, (3)Collision, (4) Uneven Pressure / settlement stemmed from soil consolidation, (5) Scour/Erosion, (6) Earthquake
		Environmental	(7) Drying Shrinkage / Change in Temperature
		Material Deterioration	(12) Poor Quality
		Fabrication / Construction	(13) Fabrication / Construction Faults
		Structural	(15) Structural Deficiency
Facilities for Inspection	Abnormal Vibration/ Abnormal Deflection	External Forces	(31) Repeated Load, (6) Earthquake
		Fabrication / Construction	(13) Fabrication / Construction Deficiencies
		Structural	(15) Structural Deficiency
Railing/ Guard Fence	Deforma-tion	External Forces	(1) Repeated Load, (3) Collision, (6) Earthquake
		Material Deterioration	(12) Poor Quality
		Fabrication / Construction	(13) Fabrication / Construction Faults
		Structural	(15) Structural Deficiency
Bearing	Movement	External Forces	(1) Repeated Load, (4) Uneven Pressure/ settlement stemmed from soil consolidation, (5) Scour/Erosion, (6) Earthquake
		Environmental	(7) Drying Shrinkage / Change in Temperature
		Fabrication / Construction	(13) Fabrication / Construction Faults
		Structural	(15) Structural Deficiency

6.4 METHODS OF DAMAGE RATING AND DIAGNOSIS

6.4.1 XYZ Damage Rating Method

This method was developed by Public Works Research Institute, Ministry of Construction, Japan in 1985. The method is mainly used as the close-up inspection method to evaluate the severity of damages of each member.

The damage rating method (X, Y, Z Method) presents a systematic guideline and overview to a structure under study. It has the ability to assess a particular damage immediately upon observation and it does not require complicated procedure of inspection. Using this method may enable an inspector to rate objectively the damage degree.

By this method, the location or pattern (X) is to be known through observation and familiarity on the location of the member. The depth of damage (Y) is identified by the type of damage to the member. Scale will provide an idea to the degree of damage. Such damage degree includes the following: Large/Many, Medium, Small, Few, Entire and many more. The scale (Z) varies depending on the type of structure and member under study.

The XYZ method classifies damages into 32 types, **Table 6.4.1-1** showing the damage type with respect to each member.

The XYZ Damage Rating Method are applied to the feasibility study bridges, details of which method are explained in the Manual.

Table 6.4.1-1 Classification of Bridge Elements

Bridge Element	Damage	Remarks	Bridge Element	Symbol	Remarks
1. Superstructure			5. Traffic Railings	Rs	Steel
Main Girder	Ms	Steel		Rc	Concrete
	Mc	Concrete	6. Wheel Guard	Fs	Steel
Cross Beam	Cs	Steel		Fc	Concrete
	Cc	Concrete	7. Center Median	Ns	Steel
Stringer	Ss	Steel		Nc	Concrete
	Sc	Concrete	8. Curb	Cu	-
Sway Bracing	Sw	-	9. Pavement	Ps	Steel
Lateral Bracing	Lb	-		Pc	Concrete
Floor Deck	Ds	Steel	10. Expansion Joint	Js	Steel
	Dc	Concrete		Jr	Rubber
2. Substructure			11. Drainage Facility	Dr	
Pier	Ps	Steel	12. Fall-Down Prevention Device	Fs	Steel
	Pc	Concrete		Fc	Concrete
Abutment	Ac	Concrete	13. Maintenance Catwalk	Cm	-
Footing	Fo	-	14. Noise Barrier	So	-
3. Bearing	Bs	Steel	15. Illumination	Il	-
	Br	Rubber	16. Traffic Guide Signs	In	-
	Ba	Anchor Bolt	17. Wing Wall	Ww	-
4. Pedestrian Railings	Es	Steel	18. Utilities	Ut	-
	Ec	Concrete			

6.4.2 HMS Damage Rating Method

This method was developed by the Study Team to be used easily and conveniently in evaluating the severity of damages of each member, based on the X, Y, Z method.

The principal concept of damage rating of this method is the same as the X, Y, Z method.

In the X, Y, Z method, there are three (3) factors to be considered, namely the Location or Pattern, Depth and Scale. However, in this method, only one primary or two secondary factors are considered, as indicated in **Table 6.4.2-1**.

The damages are then evaluated in three (3) basic damage ratings, namely H (heavy), M (medium) and S (small), as shown in **Table 6.4.2-1**. However, an additional rating "HH" equivalent to X, Y, Z Method rating "I" is used in the diagnosis. The damages with rating "H" are candidate for "HH" diagnosis rating but the decision to increase the rating rank shall not be made automatically from the inspection results but the Engineer (Responsible Person-in-Charge) after consultation with the Road Administrator or Official. An "HH" or "I" rating is a sensitive and crucial decision that should be made by a responsible person.

The details of the HMS Damage Rating Method are explained in the Manual.

Table 6.4.2-1 Summary of Damage Rating (H, M, S Method) (1/2)

DAMAGES		FACTORS AFFECTING INFLUENCE TO LOAD CARRYING CAPACITY AND DURABILITY			DAMAGE RANK		
		X	Y	Z	HEAVY (H)	MEDIUM (M)	SMALL (S)
DAMAGES TO STEEL MEMBERS	1. CORROSION	-	◎	○	• Advanced deterioration. Rust spreads over the whole section with heavy section loss = 30% of thickness. • Section loss due to location of corrosion warrants structural analysis of member when section loss is 10% < total thickness < 30%.	• Medium deterioration. Flaking, swelling with moderate section loss due to corrosion at 10% < total thickness = 30%. • Section loss does not warrant structural analysis	• Minor deterioration. Local peeling of paint, pitting or surface rust spots, etc. No measurable section loss or no evidence of active corrosion. • Minor section loss, = 10% thickness loss.
	2. CRACK	-	◎	-	• Crack on steel members are classified as heavy due to the nature of steel material.	Not applicable	Not applicable
	3. LOOSENESS OF BOLTS / RIVETS	-	-	◎	• Looseness of = 10% or 10 bolts/rivets in a splice area. •Looseness of bearing anchor bolt.	• Looseness of more than 5% or 2 bolts/rivets to less than 10% or 10 bolts/rivets.	• Looseness of = 5% or 2 bolts/rivets in a splice area.
	4. MISSING/FALLEN-OFF BOLT/RIVET	-	-	◎	• Missing more than four (4) pieces of bolts/rivets in a splice. • Missing bearing roller.	• Missing 2 – 4 pieces of bolts/rivets in a splice.	• Missing one (1) piece of bolt/rivet in a splice.
	5. BREAK / RUPTURE	-	◎	-	• Break or rupture of girders, etc., including railings and guard rails due to vehicle collision, corrosion, etc. • Break/rupture is always heavy since the member already lost its function	Not applicable	Not applicable
	6. PAINTING DETERIORATION	-	◎	○	Not applicable	• Deterioration of paint system over the whole member. • Painting system failed with corrosion starting to set-in.	• Paint system shows sign of discoloration, chalking, peeling, curling, etc. on local areas.
DAMAGES TO CONCRETE MEMBERS	7. CRACKS	○	◎	○	• Crack Width: Large RC: w = 1.00 mm PC: w = 0.30 mm • Distance between cracks: < 500mm	• Crack Width: Medium RC: 0.30 = w < 1.00mm PC: 0.10 = w < 0.30 mm • Distance between cracks: 500mm = d < 900mm	• Crack Width: Small RC: w < 0.30mm PC: w < 0.10mm • Distance between cracks: = 900mm
	8. SPALLING / EXPOSED REBAR	-	○	◎	• Concrete spalling with exposed rebar. Superstructure: $A = 0.10m^2$ Substructure: $A = 1.0\ m^2$	• Concrete spalling with exposed rebar. Superstructure: $A < 0.10m^2$ Substructure: $A < 1.0\ m^2$ • Without exposed rebar. Superstructure: $A = 0.10m^2$ Substructure: $A = 1.0\ m^2$	• Concrete spalling only. No exposed rebar Superstructure: $A < 0.10m^2$ Substructure: $A < 1.0\ m^2$
	9. FREE LIME / EFFLORESCENCE	-	-	◎	• Free lime Superstructure: $A = 0.15m^2$ Substructure: $A = 1.5\ m^2$	• Free lime Superstructure: $0.10 = A < 0.15m^2$ Substructure: $1.0 = A < 1.5\ m^2$	• Free lime Superstructure: $A < 0.10m^2$ Substructure: $A < 1.0\ m^2$

◎ – Primary ○ – Secondary

Table 6.4.2-1 Summary of Damage Rating (H, M, S Method) (2/2)

	DAMAGES	FACTORS AFFECTING INFLUENCE TO LOAD CARRYING CAPACITY AND DURABILITY			DAMAGE RANK		
		X	Y	Z	HEAVY (H)	MEDIUM (M)	SMALL (S)
DAMAGES TO CONCRETE MEMBERS	10. HONEYCOMB	-	○	◎	• Concrete honeycomb with exposed rebar. Superstructure: A = 0.10m^2 Substructure: A = 1.0 m^2	• Concrete honeycomb with exposed rebar. Superstructure: A < 0.10m^2 Substructure: A < 1.0 m^2 • Without exposed rebar. Superstr.: A = 0.10m^2 Substr.: A = 1.0 m	• Concrete honeycomb only. Superstructure: A < 0.10m^2 Substructure: A < 1.0 m^2
	11. WEAR / ABRASION / EROSION	-	○	◎	• With exposed rebar. Substructure: A = 1.0 m^2	• With exposed rebar. Substructure: A < 1.0 m^2 • Without exposed rebar. Substructure: A = 1.0 m^2	• Without exposed rebar Substructure: A < 1.0 m^2
	12. FALLEN-OFF	-	◎	-	• Fallen-Off concrete body damage is considered heavy, e.g. fallen-off deck with alligator cracks.	Not Applicable	Not Applicable
	13. DAMAGE OF JOINT AREA WITH STEEL PLATE	-	◎	-	• Stripping of almost entire seal area. • Extreme rutting and water leakage with looseness of concrete anchor. • Uplift or delamination of steel plate > ½ of steel plate area.	• Stripping of seal area, 1/3 = A < ½. • Rutting and water leakage < ½ of local area. • Uplift or delamination of steel plate ¼ = A < ½.	• Stripping of < 1/3 of seal area. • Rutting and water leakage on local areas only. • Uplift or delamination of steel plate < ¼ of steel plate area.
	14. CRACK OF FLOOR SLAB	○	◎	○	• Two-way cracks with heavy rusting, • Crack width > 1.0 mm • Distance between cracks < 500mm.	• One or two way cracks with water leakage or free lime, • Crack width, 0.3mm < w = 1.00mm • Distance between cracks: 500mm = d < 900mm	• One-way cracks, • Crack width < 0.30 mm • Distance between cracks > 900mm.
DAMAGES TO OTHER MEMBERS	15. ABNORMAL JOINT GAP	-	◎	-	• Joint gap too wide or too small compared to original design gap (greater than 2 times or less than ½ of the design gap) • Verify damage to bearing and parapets.	Not Applicable	Not Applicable
	16. FAULTING (ELEVATION GAP / CORRUGATION)	-	◎	-	• Remarkable corrugation or elevation gaps in the longitudinal direction, • Difference in elevation in the longitudinal direction : > 20mm	Not Applicable	• Corrugation or elevation gaps observed in the longitudinal direction, • Difference in elevation in the longitudinal direction : < 20mm
	17. POTHOLE ON PAVEMENT	-	○	◎	• Remarkably deep and wide potholes on deck slab. • Pothole depth > 50mm • Pothole diameter > 200mm	• Deep and wide potholes on deck slab, • Pothole depth 30mm < d = 50mm, • Pothole diameter ˉ 200mm	• Shallow and small potholes on deck slab, • Pothole depth = 30mm, • Pothole diameter < 200mm
	18. CRACK ON PAVEMENT	-	◎	-	• Crack width on pavement > 5mm	• Crack width on pavement 3mm < w = 5mm	• Crack width on pavement = 3mm
	19. RUTTING	-	◎	-	• Deep ruts with depth > 30mm in the transverse direction	• Moderate ruts with depth ranging from 20mm to = 30mm	• Presence of ruts with depth < 20mm in the transverse direction
	20. OTHERS	-	-	-	• Large barges/vessels docked at bridge piers pose danger caused by accidental collision	• Debris at bearings and expansion/movement joints • Illegal storage under bridge limits maintenance activities	• Informal dwellers on bridge pier • Debris/garbage on bridge members

◎ – Primary ○ – Secondary

6.4.3 Diagnosis of Damages

(1) Procedure of Diagnosis of Damages

The diagnosis is performed at the final stage to judge the serviceability of a bridge and decide the appropriate action to be taken based on the direct outcome of bridge inspection.

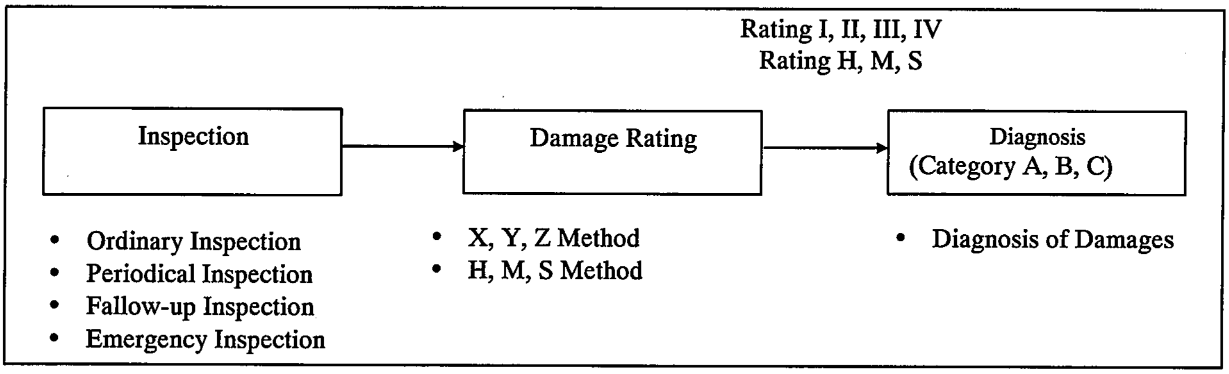

Figure 6.4.3-1 Procedure of Diagnosis and Procedure

The diagnosis of serviceability of bridges requires the rich experience of bridge engineering encompassing planning, design, construction and maintenance. Especially, the following qualifications are required:

- Familiarity with basic design and construction features of bridges to ensure a proper interpretation of findings of inspection,
- Ability to analyze loads and pursue structural capacity assurance,
- Ability to recognize and articulate structural deficiencies, assess their seriousness and recommend appropriate action, and
- Ability to recognize areas and sections where problems or damages are incipient so that preventive measure can be carried out.

Table 6.4.3-1 recommends an example of engineer class to perform damage rating and diagnosis.

Table 6.4.3-1 Engineers Responsible for Damage Rating and Diagnosis

Inspection Type	Damage Rating		Diagnosis	
	Rating Method	Responsible Engineer	Diagnosis	Responsible Engineer
• Ordinary Inspection	• X,Y,Z Method (I, II, III, IV) • H,M,S Method (H,M,S)	Chief Inspector	Category A, B, C,	Chief Engineer
• Periodical Inspection • Follow-up • Emergency		Chief Engineer		Director/ Inspection Program Manager
• In-depth Survey (Detailed Inspection)	• Quantitative Criteria	Chief Engineer	Category "IW" "FI"	Director/ Inspection Program Manager

(2) Diagnosis of Damaged Members

In accordance with the damage rating criteria mentioned above, the categories of diagnosis are prepared as presented in **Table 6.4.3-2.**

The category of diagnosis varies, depending on the damaged parts or elements and the location of bridge. If a bridge is located where people may enter or access under the bridge and a high possibility of failure of the damaged parts or members is anticipated, a higher rank of diagnosis is given. Except for the above cases, the standard rank of diagnosis is given.

The diagnosis are mainly classified focusing on traffic safety so that appropriate action could be immediately taken, as shown in **Table 6.4.3-3.**

The following cases are considered as Diagnosis Category "A" because urgent actions are needed and there is/are:

- Possibility of collapse of the bridge is anticipated due to the remarkable damages of superstructure and substructure,
- Possibility of falling of pedestrians or vehicles is anticipated due to fracture or section loss of railings,
- Possibility of driving accident is anticipated due to tire blowout caused by largely deformed expansion joints, or due to loss of expansion joints or due to corrugated pavement,
- Drop of concrete segments from curb, railing and slab deck is highly anticipated to harm pedestrians or vehicles passing under the bridge.
- Possibility of bridge falling down is anticipated due to damaged or loss of fall-down prevention devices or abnormal movement of a girder.
- Possibility of road surface caving is anticipated due to heavily damaged slab deck.
- Abnormal noise from a girder or inspection facilities is adversely affecting surrounding residents.

Table 6.4.3-2 Damage Location, Rating and Diagnosis

Location of Bridge	Damaged Parts or Elements	X,Y,Z Method Damage Rating	H,M,S Method Damage Rating	Diagnosis Category
Bridge or span where people may enter under the span.	[High danger of falling] • below floor deck, concrete girder, beams of pier. • concrete railing, out side of curb • bolts and joint area with steel plate • drainage facilities, noise barrier, guard fence, utilities, traffic guide signs • lighting facilities, expansion joint	I	HH*	A
		II	H	
		III	M	B
		IV		
		OK	S	C
	[Low danger of falling] • lateral bracing, sway bracing • pier except beams, abutment, foundation • pavement, curve, center median • bearing	I	HH*	A
		II	H	B
		III	M	
		IV	S	C
		OK		
Bridge or span where people may not enter under the span.	Main girder, cross beam, stringer, floor deck, lateral bracing, sway bracing, abutment, pier, foundation, bearing, falling prevention devices, pavement, railing, curb, center median, drainage facilities, noise barrier, lighting facilities, guard fence, utilities, traffic guide signs	I	HH*	A
		II	H	B
		III	M	
		IV	S	C
		OK		

* The Engineer shall decide conclusively through consulting with the Road Administrator/Official because the highest rank involves sensitive and crucial decision and not automatically decided from inspection result.

Note : A higher diagnosis rank shall be given to bridges with high possibility of falling damaged parts or elements and with possibility of people entering the bridge from under.

Table 6.4.3-3 Classification of Damage Rating and Diagnosis

Damage Rating			Diagnosis	
X,Y,Z Method	H,M,S Method	Condition	Category	Actions to be taken
I*	HH*	• Damage is serious • Traffic safety is in danger	A	• Emergency measures shall be undertaken immediately • Detailed study shall be conducted to decide remedial measures.
II	H	• Damage is big • Detailed survey is necessary to ensure traffic safety	B	• Detailed survey or follow-up inspection shall be done to evaluate the severity of damage and to decide necessity of remedial measures • Remedial measures shall be undertaken after evaluation of damages, if necessary.
III	M	• Damage is found • Follow-up inspection is required		
IV	S	• Small damage is observed • Damage is recorded	C	• No immediate action is necessary • Ordinary inspection shall be continued.
OK		• No damage is observed		

* The Engineer shall decide conclusively through consulting with the Road Administrator/Official because the highest rank involves sensitive and crucial decision and not automatically decided from inspection result.