社会開発調査部報告書

No. 143

GOVERNMENT OF MALAYSIA
MINISTRY OF WORKS
PUBLIC WORKS DEPARTMENT

THE STUDY ON THE MAINTENANCE AND REHABILITATION OF BRIDGES IN MALAYSIA

BRIDGE INSPECTION, MAINTENANCE AND REHABILITATION MANUAL

DECEMBER 1992

JAPAN INTERNATIONAL COOPERATION AGENCY

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JICA
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PREFACE

In response to a request from the Government of Malaysia, the Government of Japan decided to conduct the study on the Maintenance and Rehabilitation of Bridges in Malaysia and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Malaysia a study team headed by Mr. Hisashi OHSHIMA from Nippon Koei Co., Ltd., three times between September 1990 and October 1992.

The team held discussions with officials concerned of the Government of Malaysia, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of Malaysia for their close cooperation extended to the team.

December 1992

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

FOREWORD

It has been realized that bridge inspection, maintenance and rehabilitation should be systematically carried out in the whole country in accordance with standard and suitable bridge inspection, maintenance and rehabilitation manuals. In this regard, the Government of Malaysia requested the Government of Japan to provide technical assistance for the study on the Maintenance and Rehabilitation of Bridges in Malaysia. The aims of the Study which was entrusted to the Japan International Cooperation Agency (JICA) are to develop a systematic maintenance and rehabilitation program covering deteriorated or damaged bridges, about 200 in Peninsular Malaysia, and to establish a manual for bridge inspection, maintenance and rehabilitation works taking into account all the typical bridge features in Malaysia.

The bridge inspection, maintenance and rehabilitation manual is prepared to serve as a guide in a separate volume from the Study Main Report. The Manual presents several inspection methods, standard inspection forms, bridge assessment methods, bridge maintenance and rehabilitation methods and techniques as well as bridge management and organization.

It is hoped that this manual will be of value to all the Public Works Department's staff concerned with bridge management and consequently contribute to an effective and systematic bridge management in Malaysia. Finally, the JICA Study Team acknowledges with thanks the technical assistance and valuable comments provided by the counterpart personnel from the Bridge Unit in the Public Works Department during the preparation of the Manual.

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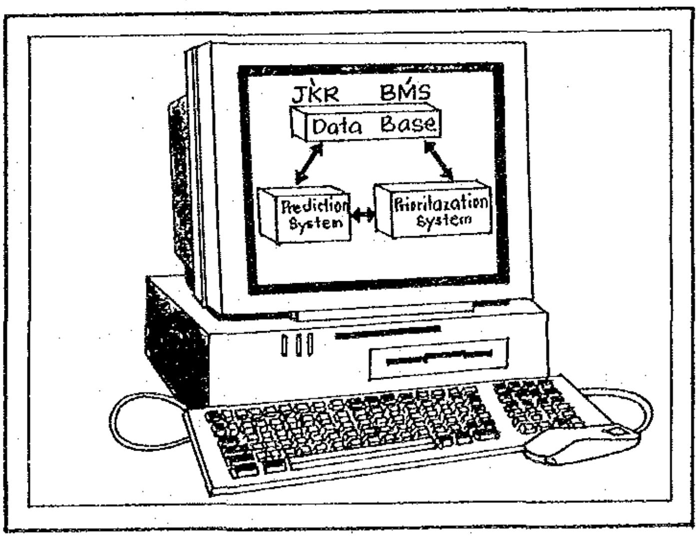
ABBREVIATION
(In Alphabetical Order)

B/C	Benefit/Cost Ratio
BS	British Standard
BMS	Bridge Management System
DID	Drainage and Irrigation Department
IRR	Internal Rate of Return
JICA	Japan International Cooperation Agency
JKR	Jabatan Kerja Raya
GOM	Government of Malaysia
P.C.	Prestressed Concrete
PRB	Precast Reinforced Concrete Beam
PVC	Polyvinyl Chloride
N/sq.mm	Newton per Square Millimeter
NALS	National Axle Load Study
NPV	Net Present Value
R.C.	Reinforced Concrete
RCB	Reinforced Concrete Beam
RCS	Reinforced Concrete Slab
RRLC	Reserved Residual Loading Capacity
SSAL	Substandard Axle Load
SBB	Steel Beam Buckle Plate
SBC	Steel Beam Concrete Slab

CHAPTER 1 : INTRODUCTION



CHAPTER 1 INTRODUCTION

1.1 General

The growth of the transportation and communication sector, especially the road network in the road transport sub-sector, is supporting the national growth and economic expansion of the country. However, as the nation's road transport has substantially matured and the nation has realized the necessity to alleviate transport-related problems, such as increasing transport costs and capital investment costs, the Public Works Department (Jabatan Kerja Raya (JKR) in Malay) is forced to take a second look into the role of transportation.

In this regard, as stressed in "Sixth Malaysia Plan 1991-1995", the emphasis has begun to shift from building new roads to maintaining and rehabilitating the existing facilities. On the road network, bridges are key elements because of their strategic location and the adverse consequences when they fail or when their capacity is impaired. Presently, the number of bridges in Malaysia is about 4500. However, deterioration of the bridges due to aging, an increase in the traffic volume and overloading as well as environmental effects is going to lead to serious problems, such as a decrease of traffic safety, an increased risk of bridge collapse and the large sums expenditure for bridge replacement.

Clearly, there is a need to establish a comprehensive policy covering all aspects of bridge management from the opening of new bridges to replacement, including bridge documentation, inspection, maintenance, rehabilitation and strengthening.

1.2 Background and Objectives of the Manual

In order to establish a more economical road transportation system in Malaysia, the National Axle Load Study (NALS) was initiated in 1985. During the course of the study, inspection and data gathering exercise for all the bridges on the Federal Roads in the Peninsular were carried out to determine their strength and general structural condition. In the process, the study discovered that a large number of bridges have been in distress either due to aging, overloading, deficient structural members, deterioration of bridge components, inadequate maintenance, or improper maintenance practice. Some of the bridges have been found to be deteriorated beyond economic repair while a significant number of bridges require urgent maintenance and rehabilitation. Faced with those study findings the Government of Malaysia (GOM) has promptly recognized the need to establish a comprehensive bridge management policy and took the following measures;

- Development and establishment of a bridge management system,
- Establishment of systematic bridge inspection, maintenance and rehabilitation,
- Setting up a Bridge Management Section in the Bridge Unit, JKR, and
- Replacement of bridges which were found to be beyond economic repair

For the first item above, the Bridge Unit developed and established the Bridge Management System (BMS) in 1987. However, for the second item above, GOM requested the Government of Japan (GOJ) to provide technical assistance for a study for this purpose and for the remaining two items above, GOM has taken appropriate action and implemented accordingly.

With regard to BMS, whose basic framework was completed in 1990, the Bridge Unit of JKR has been working towards the strengthening of BMS which will enforce a more efficient and effective management system of bridges in Malaysia. BMS, built on a micro based information system, consists of three major components: a prioritization model, a prediction model, and a data bank.

The function of the prioritization model is to assign priority to bridge structures for action and to indicate the type of improvement necessary. The prediction model provides information to support the prioritization model as well as to predict future needs for the purpose of long-term planning. The data bank stores information and data utilized in both prioritization and prediction models and includes such items as bridge costs and a national bridge inventory.

The technical assistance requested by GOM for establishment of a regular system for bridge maintenance and rehabilitation was formulated as "The Study on the Maintenance and Rehabilitation of Bridges in Malaysia" and GOJ entrusted implementation of the Study to the Japan International Cooperation Agency (JICA). The principle objectives of the Study are twofold:-

1) To develop a systematic maintenance and rehabilitation program for the bridges with condition rating 3, 4 or study category of SSAL (Substandard Axle Load) in Peninsular Malaysia, and

2) To establish a manual for inspection, maintenance and rehabilitation work covering all the study bridges consisting of a total of above bridges, 40 State bridges on the Peninsular and 30 bridges in East Malaysia.

The Manual was written with due consideration to the substance of BMS and submitted to the Government of Malaysia in accordance with Article III for the Scope of Work agreed upon between there both parties. In this context, the objectives of the Manual are to provide guidance on routine bridge maintenance and rehabilitation techniques and to provide comprehensive methods for bridge inspection, including equipment and staff required and detailed assessment methods for bridges.

1.3 Structure of the Manual

The subsequent chapters of the Manual are as follows:

CHAPTER 2 "BRIDGE INSPECTION"

The first part of this chapter describes the specific objectives of bridge inspection and defines its scope in terms of scale, frequency and elements to be inspected. The second part introduces suitable means of access including bridge inspection vehicle, traditional scaffolding and various inspection equipment consisting of conventional survey tools, equipment and non-destructive test equipment. The last part deals with the proposed organization and staffing in JKR and bridge documentation.

CHAPTER 3 "BRIDGE ASSESSMENT METHODS"

This chapter presents assessment methods for bridge conditions based on respective inspection results and full scale loading test methods for rehabilitation design. The assessment methods consist of structural condition rating, bridge functional assessment and analytic assessment including hydrological analysis. For the loading test, the procedures discussed include loading test planning and loading test implementation as well as an assessment method for the loading test.

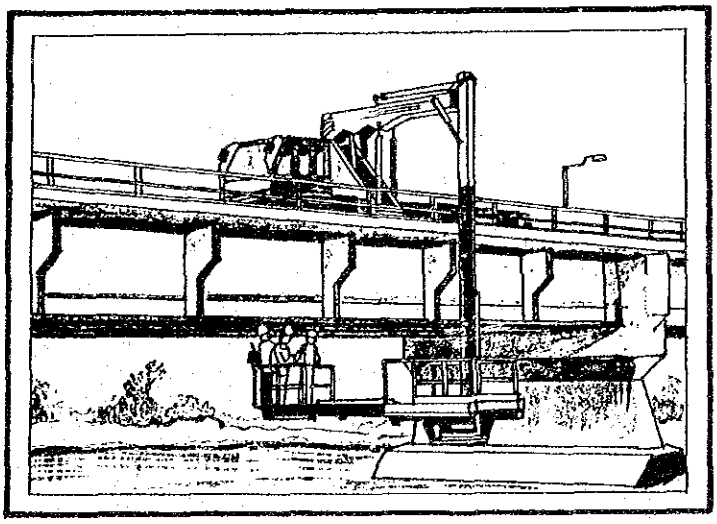
CHAPTER 4 "BRIDGE MAINTENANCE"

This chapter starts by placing the objectives and definitions of maintenance and goes on to introduce maintenance methods and techniques for various elements of the structures. Furthermore, the proposed management system and organization of the maintenance team in JKR are outlined with due consideration of national schemes and the present JKR practice.

CHAPTER 5 "BRIDGE REHABILITATION AND STRENGTHENING"

The first part of this chapter defines the specific objectives and scope of bridge rehabilitation and strengthening. The second part describes the criteria for selecting the rehabilitation and strengthening method and introduces the various techniques habitually applied for the works on concrete and steel bridges, foundations as well as on bridge components and accessories. The last part deals with management and implementation of the bridge rehabilitation and strengthening which include several major policy considerations: responsible agencies for detailed design, tendering activities, construction supervision, and bridge documentation.

CHAPTER 2 : BRIDGE INSPECTION



CHAPTER 2 BRIDGE INSPECTION

2.1 General

Road network is designed to ensure efficient movement of people and goods, in which bridges are integral elements because of their strategic location and the serious consequences when their capacity is impaired or, even worse, when they fail. Particular attention must be given to the systematic inspection of bridges as an essential part of the surveillance and management of the road network.

The main objectives of the bridge inspection are to identify and to quantify deficiency and deterioration caused by applied loads from various sources, by chemical influences exerted by the environment, etc. The other primary purposes of the bridge inspection are as follows:-

- To examine the safety of the structure.
- To identify any possible source of distress.
- To record systematically and periodically the condition of the structure.
- To provide the necessary information for any decision with regard to maintenance, rehabilitation, or replacement of bridges.
- To provide a feed-back of information to owners and designers on the features which often give maintenance problems, so that necessary attention could be given during the design and construction stage.
- To check on the effects of actual loads on bridges.

A bridge inventory survey for all the federal bridges in Peninsular Malaysia has been completed in NALS Phase I and II. The inventory data of those bridges have been recorded in two different standard forms: bridge cards and bridge inventory sheets. Both have been stored in the Data Bank of BMS.

Consequently, this chapter deals mainly with periodic or routine inspections which are the appropriate follow-up action to be taken after the inventory survey. In case of the inventory survey, it is recommended that the methods and the forms derived by NALS, which are enclosed in Annex A, shall be utilized consecutively taking into account the large amount of bridge inventory data available from NALS forms.

2.2 Classification and Frequency

The frequency of bridge inspections depends on the age, construction type, traffic volume, and the characteristics and availability of resources for carrying out an inspection.

On the other hand, deficiencies and defects also vary widely between structures. It is therefore difficult to detect and diagnose these through a single inspection.

To cope with the above context, an effective method is to carry out several types of inspections which differ in objectives, scope, scale and method. All aspects required in the inspection could be covered, hence leading to effective preservation of bridge investments and proper maintenance and timely rehabilitation programming.

Therefore, bridge inspections in this manual are broadly classified into (1) Superficial inspection, (2) Periodical inspection, (3) Detailed inspection, and (4) Special inspection. The interrelationship among them, as well as the relationship between inspection and maintenance/rehabilitation works are depicted in Fig.2-1. The scope and frequency of each inspection are briefly described as follows;

(1) Superficial Inspection

A superficial inspection is carried out regularly at least once a year for every bridge in each district by a team of JKR district road maintenance personnel including a structural technician who has a good practical knowledge about road structures and has been trained in bridge inspection. This type of inspection is aimed at visually detecting major damages or obvious faults to the structure using a simple standard check list. The inspection record covering any defects or damages has to be reported by the District Engineer to the Bridge Management Section in the Bridge Unit.

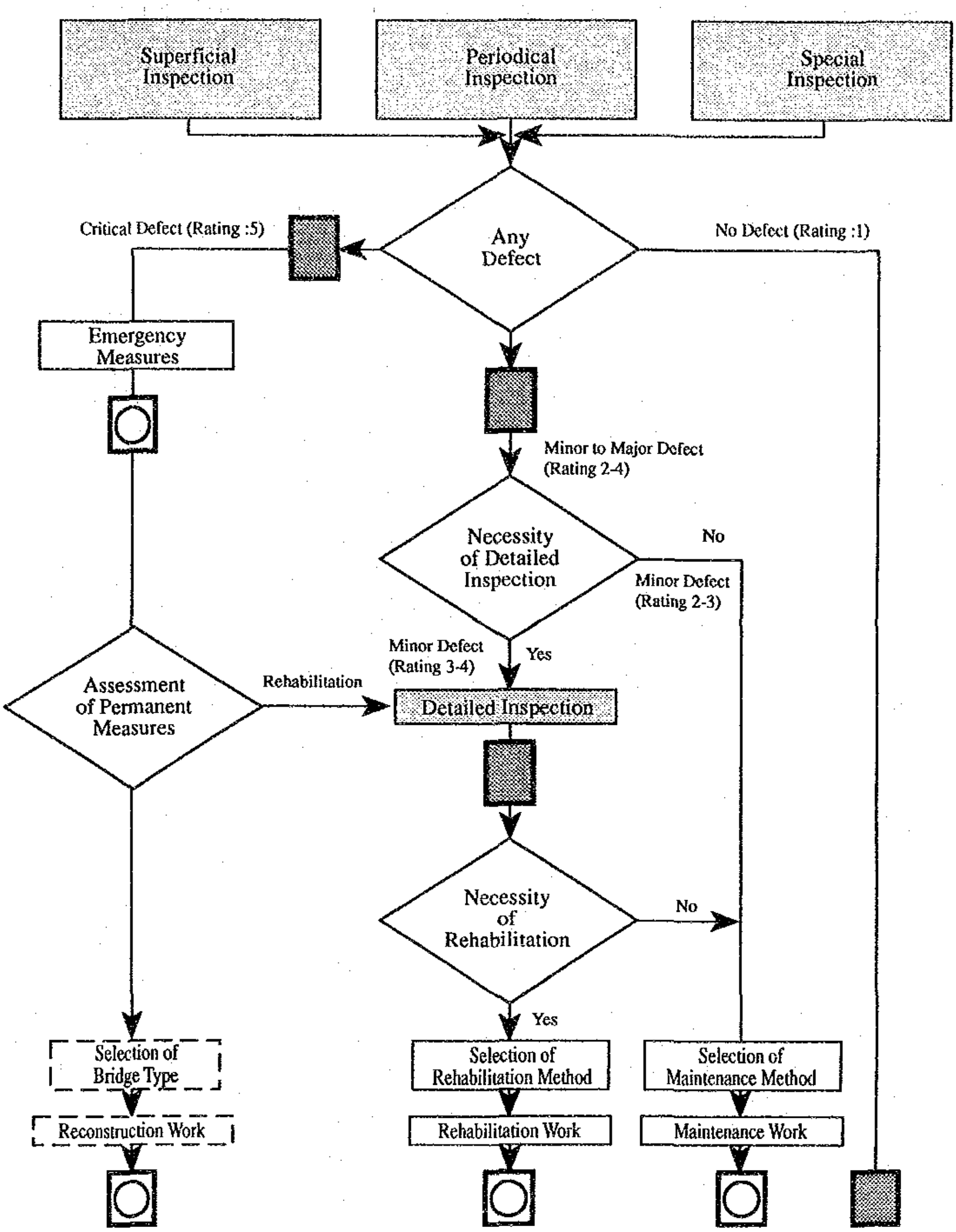
(2) Periodical Inspection

A periodical inspection is made by a qualified inspector with the assistance of two trained field technicians from the District Office. This inspection is carried out periodically at an interval of three (3) years to provide assurances that the bridge is safe for traffic. It is done by visual assessment of all the parts of the structure using standard instrument aids on and under the bridge, against the inventory sheet and detailed check list of structural condition rating.

(3) Special Inspection

A special inspection is made in connection with unusual circumstances such as exceptional loading, collapse, accidental damage, and major weakness, or with reassessment of the structure against revised specifications and regulations. A special team is usually headed by a senior bridge engineer of the Bridge Unit, JKR but often by a specialist. Nevertheless, the specific composition of the

Figure 2-1 Relationship Between Inspection, Maintenance and Rehabilitation Works



Note : Rating stated in above is only general guideline

Legend :
- Inspection covered in this Manual
- Documentation of Inspection Results and Filing in BMS
- Documentation of Field Works and Filing in BMS
- Work item not covered in this Manual
- Assessment based on the inspection results

team relies on the background of the occurrence since the purpose of the inspection is to assess the effect or reason in conjunction with the above occurrence. The method to be applied also depends on the objective defined, but generally is similar to the method for detailed inspections mentioned below.

(4) Detailed Inspection

A detailed inspection is made when either superficial or periodical inspections reveal its necessity and is carried out by a standard team comprising a chief inspector seconded from the Bridge Unit, an inspector and three trained field technicians from the District Office. This type of inspection is aimed to assess the structural safety and prepare rehabilitation methods based on the various results such as structural details, material strength, material deterioration, and loading test if required.

2.3 Inspection Procedure and Standard Inspection Forms

For each type of inspection, it is important to have a uniform or standard procedure and inspection form in order to ensure a thorough and complete inspection and to enable valid comparisons between the inspections conducted in different locations at different times by different personnel.

These procedures, however, vary depending on the condition of the structure, size and complexity of bridges and availability of personnel, equipment, present data and records. Therefore, in this manual, inspection procedures and standard forms are formulated based on those applied in the JICA study and taking into account the present situation in Malaysia.

(1) Superficial Inspection

The superficial inspection is to be carried out concurrently with routine road inspections without using any inspection aids. In the inspection, the incidental facilities such as drainage, railing, pavement, etc. are checked on foot on the bridge surface while main beams, abutments, piers, etc. are visually inspected from both sides of the river banks. A check list of the structural condition is attached in Annex-B. The items to be checked are as follows:

- Main Beam : Detecting corrosion, rupture, abnormal noise, deformation, sedimentation.
- Deck Slab : Detecting corrosion, deformation, etc.
- Pier/Abutment : Detecting corrosion, rupture, deformation, scouring, defects (section loss).
- Bearing : Detecting corrosion, freezing, etc.

- Drainage : Detecting water leakage, sedimentation, clogging defect (missing drainage pipes or inadequate pipe length)
- Sidewalk/kerb : Detecting sedimentation, defects (damaged or missing precast panels), etc.
- Railing : Detecting rupture, paint deterioration, deformation, etc.
- Pavement : Detecting pot holes, rutting, settlement, piping failure, etc.
- Expansion Joint: Detecting rupture, abnormal spacing, water leakage, abnormal noise, etc.
- River bank : Detecting erosion, defects (illegal waste disposal, shack, pen), etc.

Any other defects to be corrected in maintenance work and the inspector's special comments, if any, should be noted during the inspection and reported to the District Engineer.

(2) Periodical Inspection

Periodical inspection may involve the provision of special access facilities where necessary. The inspection is more intensive and requires close examination of all the structural parts to verify the level of safety and to check the functional service ability of the bridge. The inspection is primarily to detect any damages in accordance with the detailed structural condition check list forms attached in Annex-C and to rate the damages quantitatively. A full written report containing the check list and rating results, the engineer's comments, photographs and drawings, if required, shall be prepared.

(3) Special Inspection

Inspection procedures and inspection forms for the special inspections generally depend on the background of occurrence but it is similar to those used for the detailed inspection as described below.

(4) Detailed Inspection

This type of inspection is the most intensive and requires advance assessment techniques to analyze load carrying capacity of the bridge and to select an optimum rehabilitation method. The type of test and measurements to be carried out in the inspection are as follows:

Structural Detail Measurement

- Structural dimension survey
- Crack/Corrosion mapping survey
- Concrete cover, rebar size and spacing survey
- Steel thickness survey
- Pile length measurement survey

Material Strength Measurement
- Concrete strength
- Structural steel strength
- Reinforcement bar strength

Material Deterioration Degree Measurement
- Carbonation depth survey
- Chloride content survey
- Sulphate content survey
- Reinforcement corrosion degree survey (if required)
- Alkali aggregate reaction survey (if required)

Loading Test (if required)
- Static test
- Dynamic test

All the tests and survey results are compiled in a drawing form as attached in Annex-D.

A standard reporting cover form which should be filled-in after each inspection and attached together with the above mentioned documents is enclosed in Annex-H.

2.4 Means of Access and Inspection Equipment

One of the common problems in carrying out bridge inspections is how to access defective points or areas especially where decks or beams are located high above ground level or for piers located in a river. Since the erection of traditional scaffolding usually constitutes a major part of the cost in the bridge inspection, it could be unacceptable from an economic standpoint. It is therefore advantageous to provide built-in access such as ladders, platforms, etc. for new and major bridges. As to the existing bridges without provisions, means of access which should be safe, easy and convenient should be selected by considering the scale of bridge, level of inspection, possible traffic interruption and installation cost.

The conventional equipment and tools are normally adequate for various levels of bridge inspection. While, the recent technological renovation in mechanical, electrical and semiconductor fields has resulted in the invention of numerous advanced bridge survey and inspection equipment. Therefore, the optimum combination of inspection equipment and tools should be selected mainly in the light of the purpose and level of inspection.

Some possible means of access and suitable inspection tools and equipment in Malaysia are introduced below:

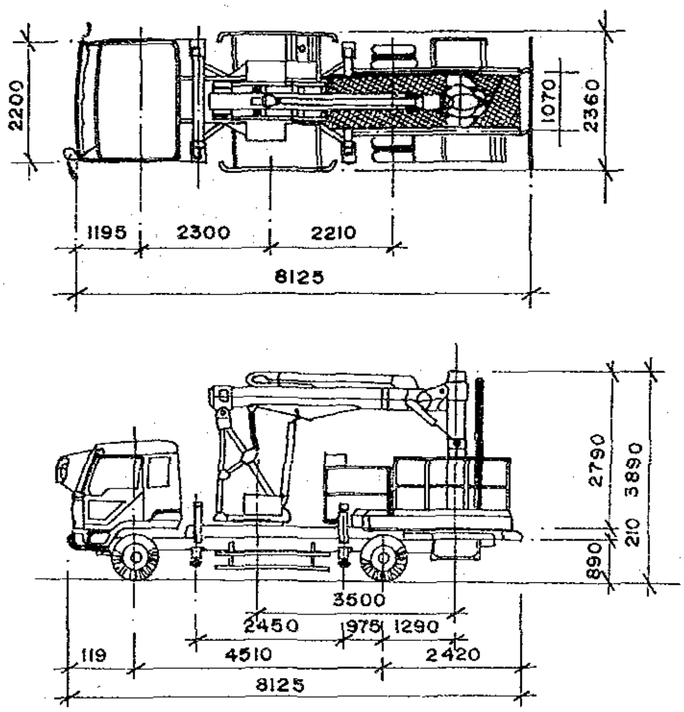
2.4.1 Bridge Inspection Vehicle

The best solution to the access problem is the use of mobile equipment. Among the various types of equipment recently developed, a bridge inspection vehicle operating from the bridge deck and specifically designed to inspect the intrados of decks and beams is the most suitable for the standard bridge geometry in Malaysia.

Presently, three bridge inspection vehicles are available in Malaysia, one is owned by Malaysian Highway Authority strictly for inspections of the Penang Bridge, the other two are owned by JKR and Sarawak State Government for general bridge inspections. These vehicles have proven to be an extremely versatile, efficient and useful means of access for visual assessment in all types of inspections. Among these, JKR's inspection vehicle is able to move along the structure and permit a small work crew to reach all points of the soffit with their testing equipment. This vehicle is Overhence Type II manufactured in Japan and its specification, dimension and working ranges are shown in Figure 2-2 and 2-3 respectively.

Figure 2-2 Specification and Dimension of JKR Inspection Vehicle

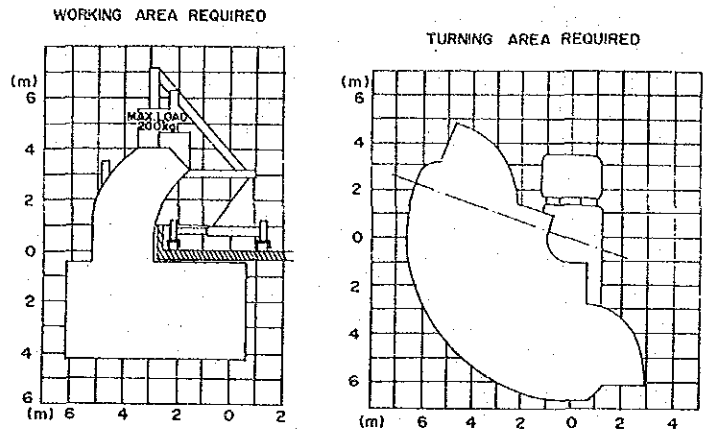
DIMENSION DRAWING



SPECIFICATION

BOOMS : BASKET (PLATFORM) :	
Elevating boom :	2 sections
Distance of cylinder slide	1200 mm
Verticle boom :	4 sections
Distance of cylinder slide	5400 mm
Extension time :	
Elevating boom	
Raise and Lower	25–45 sec
Extension and retract	25–35 sec
Swivel or turning	25–35 sec/110
Verticle boom	
Extension and retract	120–150 sec
Basket turning	15–25 sec/180
Angle of turning :	
Turn table	110
Platform	180
Elevating boom angle :	45
Max. clearance of elevating boom :	4350 mm
Basket and platform :	
Length	3390 mm
Width	920 mm
Height	1125 mm
Max. load	200 kg
FUEL TANK CAPACITY :	100
HYDRAULIC OIL TANK CAPACITY :	100
EMERGENCY GENERATOR :	Engine driven, A/C 240V,3KVA
Fuel tank capacity for emergency generator	11.5
TRUCK :	MITSUBISHI Model u-FK415JRC or any other truck with GVW of 9.900 kg or more
DIMENSIONS (TRAVELLING POSITION) :	
Length	8125 mm
Width	2360 mm
Height	3890 mm
Weight	App. 8950 kg

Figure 2-3 Working Ranges of JKR Inspection Vehicle



During the operation of the inspection vehicle, special attention shall be paid to the following:

- The truck driver should be at the driver's seat at all times during the operation to communicate with the bucket/platform operator.
- One flagman and a set of safety devices such as sign boards, rubber cones should be installed in front and at rear of the vehicle during the operation.
- The bucket/platform must be operated by a trained operator.
- The trained operator must have the operation manual at all times.

2.4.2 Scaffolding

The traditional method of providing adequate access for bridge inspection is the installation of scaffolding. It has some disadvantages compared with the inspection vehicle because it is not cost effective and is time consuming to erect and dismantle. Occasionally its usage is necessary where a bridge site is isolated without accessibility or is under very heavy traffic. In general, the scaffolding can be divided into two categories:-

a) Ground support scaffolding
b) Hanging scaffolding

The ground support scaffolding can be applied to a bridge that does not span over a deep river and where the vertical clearance from the ground to the beam soffit is less than about 5 meters.

On the other hand, the hanging scaffolding can be used for a bridge that spans a deep river or where the vertical clearance is more than 5 meters.

Typical example of each of the above is shown in Figure 2-4 and Figure 2-5.

Figure 2-4 Ground Support Scaffolding

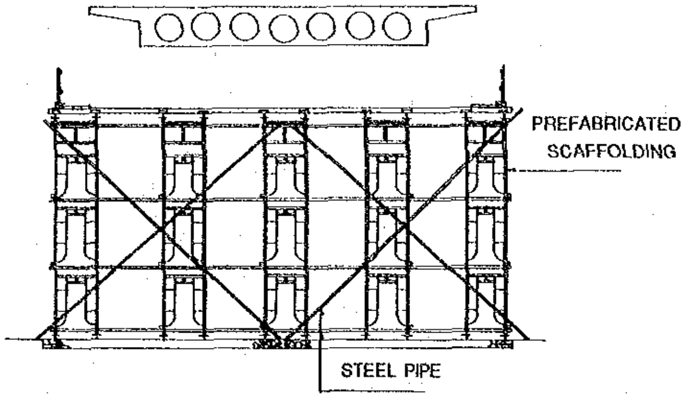
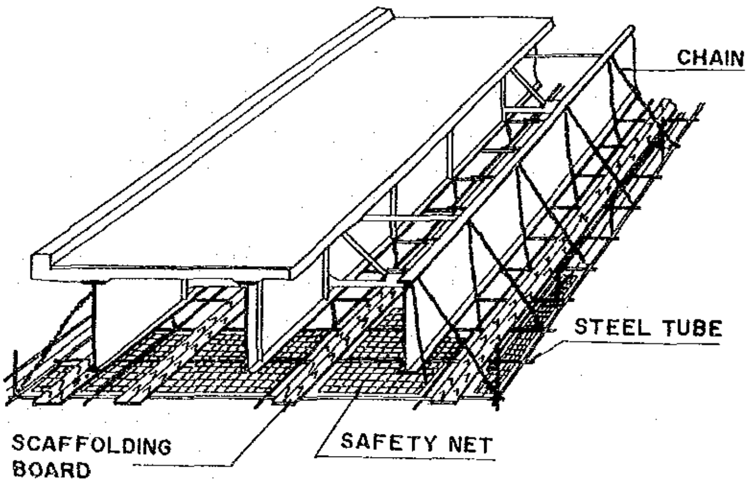


Figure 2-5 Hanging Scaffolding



2.4.3 Means of Access Under Water

Inspection under water is occasionally necessary in order to survey the riverbed in the vicinity of the structure or to detect any distress on the submerged part of the structure. This inspection differs from inspections above water in that more hazards are involved such as mobility, visibility and physical endurances. However, the quality of the inspection under water should be equal to the quality above water.

For means of access under water, diving is generally acceptable. Damage or deterioration is usually identified by a diver through his visual inspection instead of using sophisticated and expensive instruments such as echo-sounder, computerized tomography and closed-circuit underwater televisions.

The most obvious limitation to the visual inspection by diving is water clarity. When turbidity is high, i.e, underwater visibility is nearly zero, visibility may be improved by attaching a clear water mask to the face plate of diving gear. Small plastic bags (0.01 cu.m) can also be used as a clear water lens to inspect the submerged structure and to detect any damages.

2.4.4 Miscellaneous Means of Access

The other traditional means to access all parts of a bridge are usually required in proper bridge inspections. Those are heavy duty rubber boats, local rafts and rudders.

The criteria in selecting this equipment is that it should be portable. If it is required for only a few bridges, the access equipment available locally such as local boats or rafts and wooden ladders should be utilized as much as possible.

2.4.5 Inspection Equipment

The inspection equipment and tools shall be selected in order to provide accurate and reliable survey data for the assessment taking into account the level of inspection, the number of bridges to be inspected, the construction material used and availability of qualified personnel with appropriate professional training.

It is deemed appropriate that the inspection equipment and tools be classified as follows, based on the type of inspection as defined in Section 2.2.

- Superficial inspection basically will not require the use of any equipment and tools, hence it will rely mainly on visual inspection.

- Periodical inspection will normally need standard traditional equipment and tools but still rely on visual inspection.

- Detailed inspection will have to utilize both non and semi-destructive testing equipment together with the above standard equipment and tools but still rely to a certain extent on visual assessment.

It should be noted that the equipment and tools for the special inspection rely on the background of occurrence.

It is acknowledged that reliable equipment and techniques, which are relatively expensive, have been recently developed to meet the need of assessing existing structures. It is, however, beyond the scope of this Manual to introduce all of the sophisticated equipment. Therefore, only inspection equipment and tools which had been used by the JICA Study Team and which are deemed to be useful and effective for inspections are described in this Manual.

(1) Standard Inspection Equipment and Tools For Periodical Inspection

The equipment and tools listed in Table 2-1 are recommended for the periodical inspection, considering the scope and intensity of the inspection.

(2) Standard Inspection Equipment and Tools For Special and Detailed Inspection

In addition to the above equipment and tools, the standard non-destructive equipment as shown in Table 2-2 is recommended for detailed inspections. The operation manuals and recording forms of this equipment are attached in Annex-E.

Table 2-2 List of Non-Destructive Equipment

Equipment/(Trade Mark)	Purpose
Ultrasonic steel thickness measurement equipment. /(Ultrasonic thickness meter)	To measure steel thickness. It can be used to measure thickness of a beam / girder web where vernier calipers can not be used.
Ultrasonic rebar detector./(Proformer)	To detect rebar location, concrete cover and rebar size. It also can be used to determine rebar spacing.
Concrete strength rebound test equipment. /(Schmidt hammer)	To measure the concrete strength.
Ultrasonic concrete strength test equipment. /(Pundit)	To measure the concrete strength and detect the defects.
Carbonation test equipment./(Conkit)	To measure the carbonation depth of the concrete
Corrosion degree of reinforcing bars measurement equipment./(Half Cell)	To determine the degree of corrosion of the embedded reinforcement bars.
Hardness tester./(Echo-tip)	To determine the hardness of steel and to estimate approximate steel strength
Concrete sampling equipment for chemical testing. /(Electric drill and plastic bag)	To collect concrete dust samples for sulphate and chloride test.
Concrete core sampling equipment.	To determine the strength and properties of concrete.

2.5 Organization and Staffing

A successful bridge inspection program will, to a considerable extent, rely on the organizational, managerial and training aspects of the operation. Therefore, this section deals with the appropriate government organization, staffing and training of the inspection.

Table 2-1 List of Conventional Equipment and Tools

(1) Measuring Equipment

Equipment	Purpose
3.0 m and 5.0 m measuring tapes	For measuring beam/girder dimensions such as beam heights, width, spacing, slab thickness and other short dimensions.
50.0 m and 100.0 m measuring tapes	For measuring span length, bridge width and other longitudinal dimensions.
Plumbob	For the measuring the degree of tilting or dipping of the structures.
Crack scale	For measuring the crack width.
Deep sounding	For measuring the river depth and local scouring depth from top of the deck. It also can be used to measure the tilting of a pier.
Levelling staff	For measuring the river depth or other parts of the structure which cannot be measured by the other equipment.
Spirit level	For measuring the perpendicular distance to any structural member.
Vernier scale with both inside and outside caliper	For measuring the steel thickness such as plate, beam flange, etc.

(2) Recording Equipment

Equipment	Purpose
Camera	To take photos of defects or damages to the structures.
Black board and chalk	Use to record bridge name, date of inspection, photo no. and type of structure when taking photograph.
Photo-scale	Use to measure the defects when taking photographs so that the exact scale of the defect can be determined from the photo.

(3) Access Equipment

Equipment	Purpose
Binocular	To be used when there is no access to the structure. Purpose is to detect any crack or damage to the structures such as beam/ girder, slab and abutment.
Tapping Hammer	For tapping the concrete surface in order to determine the soundness of the structure.
Chisel and electric power drill	For removing the concrete for semi-destructive tests and carbonation test.
Parang	For clearing all weed, branches and bushes which obstruct access to bridges.
Generator	For supplying electricity.
Ladder	For access to the soffit of the deck or bearing.
Rubber boat	For access to the river piers and spans.

(4) Safety Equipment

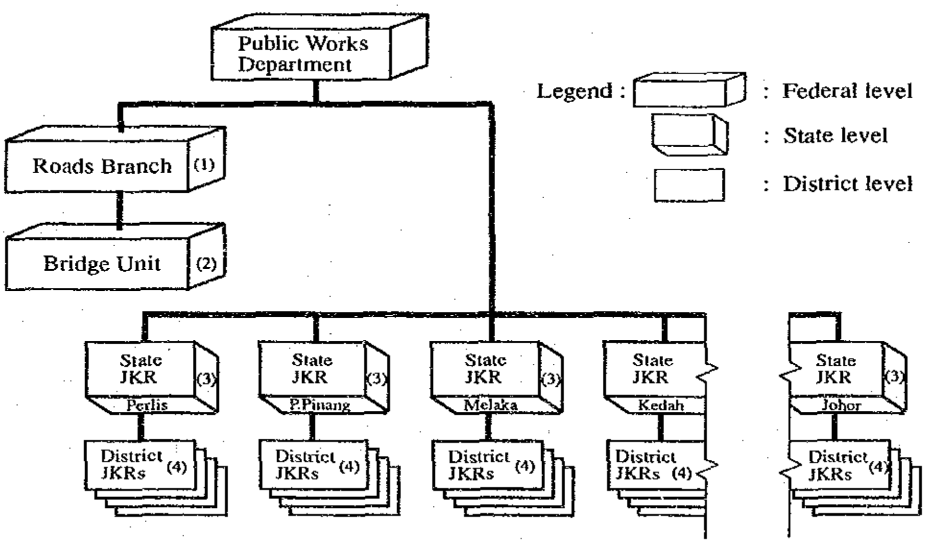
Equipment	Purpose
Life Jacket	To be used when assessing structures over rivers.
Safety belts	To be used when assessing structures using a ladder or an inspection vehicle.
Safety helmet	To be worn at all times during inspections.
Traffic sign board & Rubber cones	To be installed for traffic control.

With regard to organizational aspects in this Manual, it should be noted that only the federal bridges are considered as the objective to establish an organization and staffing for bridge inspections, while the organization of inspection for the state bridges is not described separately. Thus, readers who are interested in these for the state bridges are requested to replace the word of the Bridge Unit with the State JKR for their understanding and usage, since it is State JKR that is responsible for maintaining the state bridges.

2.5.1 Proposed Organization for Bridge Inspections

The JKR is the technological arm of the Government and serves as the main implementing agency for carrying out infrastructure projects in the whole country. The JKR is divided into three levels of management and organization structure; the Federal, State and District levels. The present JKR organization with regard to bridges and the maintenance is depicted in Figure 2-6.

Figure 2-6 Present Organization Related to Bridges and Maintenance



Notes:

(1) The roads branch is responsible for planning, construction and maintenance of Federal roads and bridges, and regional development schemes as well as formulating road standards, policies and advising the State JKRs on matters pertaining to State Roads.

(2) The Bridge Unit under the Roads Branch is responsible for establishing design standards and carrying out the design, construction and rehabilitation of Federal bridges.

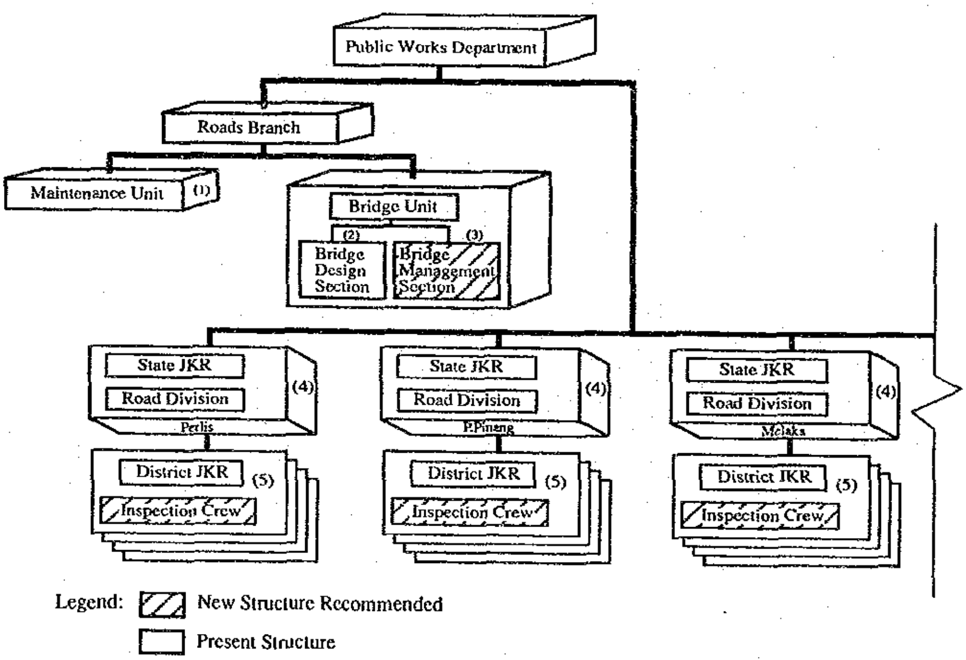
(3) The JKR has 13 State JKR Offices which are responsible for the planning, implementation and maintenance of state development projects as well as administration and monitoring of the federal projects carried out in the State.

(4) In Peninsular Malaysia, there are 72 District Offices. Each of these is under a District Engineer who is responsible to the State Director for implementation and maintenance of projects in that District.

Presently, design, construction and maintenance for Federal Bridges located on Federal Roads are under the responsibility of the Bridge Unit in the Roads Branch, while for the State bridges, the Road Division in the State JKR is responsible. In both cases, the actual bridge maintenance work is carried out as part of road maintenance which is entrusted to each JKR District Office.

However, there is no specific bridge inspection structure in the JKR organization at present. Accordingly, an organization structure for bridge inspections is recommended as depicted in Figure 2-7.

Figure 2-7 Proposed Organization For Bridge Inspection



Responsibilities of each structure depicted in the above Figure are as follows:

(1) Maintenance Unit
- Allocation of bridge inspection and maintenance funds

(2) Bridge Design Section
- Special and standard bridge design

(3) Bridge Management Section (New Structure Recommended)
- Implementation of special and detailed inspections
- Formulation of maintenance and rehabilitation works
- Rehabilitation design
- Coordination of rehabilitation works
- Scheduling and organizing training
- Development and maintenance of BMS

(4) Road Division
Inspection and maintenance of the Federal Bridges do not practically involve the Road Division of the State JKR. It is, however, necessary to establish a small scale Bridge Management Section in the Road Division for inspection and maintenance of the State Bridges. The immediate task of the State Bridge Management Section is to carry out bridge inventory surveys. The section's responsibilities will be the same as the Bridge Management Section in the Bridge Unit as assigned.

(5) Inspection Crew (A New Task Force)
Out of road maintenance staff presently available in District JKR, at least one engineer and three technicians shall be trained as bridge inspectors and inspection technicians. These trained staff will compose a new task force for whichever and whenever bridge inspections are required.

2.5.2 Composition of Inspection Crew

The staffing requirements for a specific bridge inspection crew depends on the type of inspection i.e. whether it is superficial, periodical, special, or detailed. It is, however, too difficult to specify the requirement for special inspections since they rely on the background of the occurrence. Thus, the following are the staffing requirements for the other three types of inspections.

Position	Section Belonged	Superficial Inspection	Periodical Inspection	Detailed Inspection
Chief Inspector (Sr Bridge Eng'er)	Bridge Unit	-	-	1
Inspector (Bridge Eng'er)	Bridge Unit L1	-	1	1
Technician	District	1	2	3
Labor	District	2	2	4
Flagman	District	-	2	2
Driver	District	1	1	2

Note: L1 At the initial stage, when a trained inspector who is responsible for the periodical inspection is not available in the District office, an inspector from the Bridge Unit is seconded to the crew. However, after training has been completed to a bridge engineer from the District Office, a full time inspector be available in each District Office.

- In addition to the above requirement for detailed inspections, a bridge inspection vehicle with a driver shall be provided.

- A superficial inspection is carried out by a team of road maintenance staff in each JKR District Office. The chief of the crew is responsible for all the activities including the reporting and is chief of superficial inspections.

2.5.3 Qualification and Responsibility of Key Crew Members

It is vital to clearly specify the qualifications and responsibilities of the key inspection crew members since they have controlled over the quality of the inspection results. Therefore, the key crew member who has been delegated the responsibilities for bridge inspection shall possess the following minimum qualification.

Position	Qualification	Responsibility
■Chief Inspector (Sr. Bridge Inspector)	▪Qualified professional Structural engineer with at least 7 years experience in civil works assignment. ▪Completed at least 3 years bridge design, construction and inspection in a responsible capability.	▪Thoroughness of the detailed inspection. ▪Analysis of all findings. ▪Recommendations for correction of defects. ▪Preparation of inspection reports.
■Inspector (Bridge Engineer)	▪Qualified structural engineer with at least 3 years working experience in a civil work assignment. ▪Completed at least one year on the job and comprehensive training on bridge inspection.	▪Thoroughness of periodical inspection. ▪Structural condition rating. ▪Preparation of engineer's comments. ▪Direction of technicians' field works. ▪Preparation of the inspection report.
■Technician	▪Qualified structural technician with at least 3 years civil work experience. ▪Completed bridge inspection training course for technician.	▪Conducting various field survey, measurement and testing. ▪Recording those results including photographing. ▪Direction of labors and flagmen's work.

2.5.4 Training

Training and technology transfer enhance the capability of engineers and technicians, which in turn directly affects quality of inspections. At present, there are more than 2600 Federal bridges in Malaysia. To inspect these bridges is not a simple task, but it is JKR's responsibility to keep these government investments in sound condition. Accordingly, the training is absolutely required not only to enhance the engineers and technicians' capabilities but also to find sufficient number of qualified inspectors.

The training which will be organized by the Bridge Unit should be held at the JKR Training Institute in Bangi, Selangor. The training course should include such subjects as general background information, basic bridge engineering, deterioration of bridge materials, etc. as listed in Table 2-3.

Table 2-3 List of Main Subjects for the Training Course

Main Subject	To Whom Intended
1. General Background Information	Eng. & Tech.
-JKR organization and highway system -Bridge type and history -Bridge nomenclature and structural components	
2. Basic bridge engineering	Eng. & Tech.
-Bridge elements -Simple structural mechanics -Properties of bridge materials -Brief bridge construction technique -Basic river engineering	
3. Deterioration of Bridge Materials	Eng. & Tech.
-Deterioration of steel -Deterioration of concrete -Deterioration of timber -Deterioration of rubber -Deterioration of paint	
4. Distress of bridge components	Eng. & Tech.
-Beams, girders, floor system, bracings and deck slab -Bearings, expansion joints, bridge drainage, railing, sidewalk and curbs. -Abutments, piers, foundation, bridge approaches wingwalls, river bank and waterways	

5. Bridge inspection Eng. & Tech.

- Inspection organization
- Duties and responsibilities of crew members
- Classification and scope of inspections
- Inspection procedure, check list and standard forms
- Inspection tools and equipment
- Reporting forms and flow

6. Assessment of bridges Eng.

- General structural assessment
- Structural theories
- Foundation analysis
- Full scale loading test

7. Maintenance and rehabilitation techniques Eng.

- Protection work for concrete and steel members
- Strengthening work for concrete and steel members
- Widening carriageway
- Adding sidewalk
- Raising grade
- Hydraulic rehabilitation works

Note: The training materials including lesson plans, work books and visual aids should be prepared and updated by the Bridge Management Section in the Bridge Unit.

All unqualified inspectors and technicians must undergo the formal training course mentioned above and on the job training for bridge field inspections for the minimum duration specified in Section 2.5.3 before they are allowed to lead the inspection team. From time to time, they should participate in special lectures, seminars and workshops on bridge inspections held in various countries throughout the world, so that they are aware of the state-of-the-art bridge inspection and assessment techniques.

In order to retain capable inspectors and technicians who in turn maintain the government bridge investment in sound condition, Qualified Bridge Inspectors Registration should be introduced in the national bridge inspection system. Moreover, frequent personnel turnovers must be avoided so that working on a bridge inspection team does not become merely a stepping stone to another job.

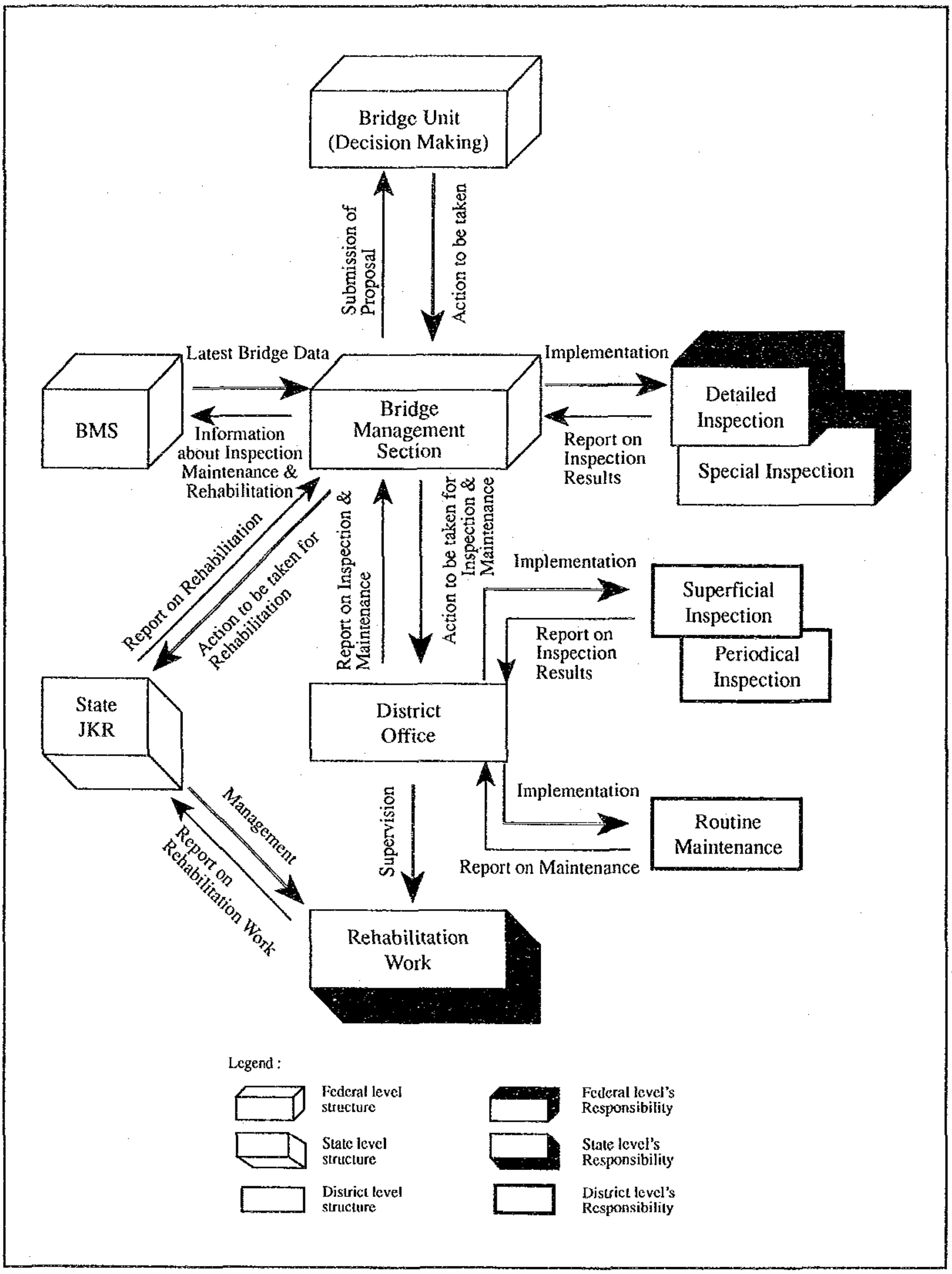
2.6 Bridge Documentation

Bridge documentation covering systematic collection, filing, updating and retrieving of the relevant data, information, records and documents should be considered as indispensable for assessing bridges for managerial and engineering purposes. Thus it will provide all the information needed for making decisions on engineering, economic and policy matters and adequate documentation will help to make bridge inspections more efficient.

It is vital for bridge documentation which includes all the inspection results, maintenance and rehabilitation records to be centralized so that bridges can be managed systematically. For this purpose the Bridge Unit in JKR has been establishing BMS based on a micro-based information system consisting of three major components: a prioritization model, a prediction model and a data bank.

Schematic flow for the bridge documentation is depicted in Figure 2-8 which indicates the flow of the inspection results and reports on maintenance and rehabilitation records, responsibility and function of the agencies involved and interrelationship of the agencies concerned.

Figure 2-8 Schematic Flow of The Link Between Inspection and Bridge Management



CHAPTER 3 : BRIDGE ASSESSMENT METHODS

CHAPTER 3 BRIDGE ASSESSMENT METHODS

3.1 General

There are no universal assessment methods for the overall structural behavior of existing bridges. Various researches are still being carried out at institutes and universities in many countries. However, a proper assessment method is essential in formulating the bridge inspection and rehabilitation program to provide quantitative bridge condition data for bridge management, to assess functional requirements of bridges and to analytically examine structural components for selecting optimum rehabilitation methods.

Under such situation, this chapter presents several assessment methods that have been practiced in Japan and which were applied to JICA Study on the Maintenance and Rehabilitation of Bridges in Malaysia.

3.2 Assessment Method of Inspection Results

The assessment method of inspection results is broadly divided into three categories; the first and the second categories are structural condition rating and assessment of bridge function resulting from superficial and periodical inspections, while the third is analytic assessment based on the detailed inspection results. The main purpose of the condition rating is to quantitatively rate the bridge with a simple figurative indicator based on the visual assessment of each bridge component using the structural condition check list. The assessment of the bridge function is aimed to identify bridges that have an inadequate functional requirement. On the other hand, the analytic assessment is intended to diagnose all the structural components by means of structural analysis, i.e. to identify which bridge members are inadequate or adequate to carry applicable loading based on the assessment criteria and the detailed inspection results, including structural details and all the test results.

(1) Structural Condition Rating

It is essential to rate a damage or defect in various members as quantitatively as possible during the superficial and periodical inspections so that comparison of the rating between the present and the previous years will indicate the development of damage, if any.

To this end, the structural condition rating check list, that was quoted from "Bridge Inspection Manual"(ISSN 0386-5878) issued by the Ministry of Construction, Japan, was introduced in Section 2-3 of this Manual, after some modifications were made to meet the local Malaysian conditions. All the damages detected which were marked on the condition rating check list can be rated referring to "Rating Criteria of Damages" attached in Annex-F. The damage is graded into five ranks and the general criteria for ratings are defined below:

Rating	General Definition
1	*No damage found and no maintenance required as a* result of the inspection.
2	Damage detected and it is necessary to record the condition for observation purposes.
3	Damage detected is slightly critical and thus it is necessary to implement routine maintenance work.
4	Damage detected is critical and thus it is necessary to implement repair work or to carry out a detailed inspection to determine whether any rehabilitation works are required or not.
5	Being heavily and critically damaged and possibly affecting the safety of traffic, it is necessary to implement emergency temporary repair work immediately or rehabilitation work without delay after the provision of a load limitation traffic sign.

Procedures for member rating, component part rating and overall rating per bridge are explained below.

Step-1 Member Rating

Among several damages detected in a member, the most critical damage will govern structural soundness of the member. Therefore, grade of the worst damage among the others should be applied as the rating of the member.

Step-2 Component Part Rating Per Span

Bridge component parts such as girder, bearing, abutment, pier, etc. are composed of several of the same structural members. The most critical member will govern the structural soundness of the component part, in general. Accordingly, the grade of the worst member should be applied as the rating of the component part per span.

Step-3 Component Part Rating Per Bridge

In a multi span bridge, the worst rated part among the other same parts in all spans will govern the bridge safety from a structural view point and will represent the necessity for maintenance and rehabilitation work. However, this rating result does not represent priority or an emergency for maintenance and rehabilitation work. For instance, if a multi span bridge has critical component parts in all spans it should take priority over an other similar type of bridge which has a critical part on only one span.

Component part rating per bridge is broadly divided into two parts: one which rating is assigned to the worst part rating among the other parts of the bridge, it will represent the degree of bridge safety from structural view point and the other in which rating is assigned from an arithmetic averaged rating of each span, it will indicate the priority of maintenance and rehabilitation work.

Step-4 Overall Rating Per Bridge

It is essential to present a simple figure for the overall rating per bridge indicating the overall bridge condition based on a visual inspection. For this purpose, two types of figures are introduced based on the reason mentioned in Step 3: one is an overall rating of bridge safety from the structural view point, and the other is an overall rating from the maintenance view point.

Overall rating from the bridge safety view point can be worked out by a weighted average of each main part rating. While overall rating from bridge maintenance view point shall be figured out by a weighted average of all the parts rating. The weighted factors given to each component part are as follows:

Component	**Weighted Factor**
*Abutment	1.0
*Pier	1.0
*Bearings	0.7
*Beam/Girder	1.0
*Deck	0.8
Surfacing	0.5
Wingwall	0.5
Expansion Joint	0.5
Railing	0.5
Drainage	0.3
Bank slope	0.5

Note; The component with * is defined as a main component part.

(2) Assessment of Bridge Function

The main function of a bridge is to cater for vehicle traffic, pedestrian flow and to accommodate flood discharge of a river if the bridge spans a river/creek. The bridges shall be assessed from these three aspects; traffic capacity on the bridge, pedestrian flow capacity and bridge opening capacity. Each method of the assessment is described below.

■ **Traffic Capacity on a Bridge**

The main objective of this exercise is to determine traffic capacity on a bridge and whether or not to cater for the present traffic demand on the existing carriageway on the bridge. The assessment is carried out using bridge width data given in the inventory survey and traffic data obtained from "Traffic Volume Malaysia" issued by the Highway Planning Unit (HPU).

Traffic capacity on a bridge is calculated based on the total service flow rate in both directions for a 2 lane highway and is worked out by the following formula given in "Highway Capacity Manual" Special Report 209 (Refer to page 8-1)

$$SFi = 2{,}800 \times (v/c)i \times fd \times fw \times f_{HV}$$

Where:

SFi = total service flow rate in both directions for prevailing roadway and traffic conditions, for level of service i in vph;

(v/c)i = ratio of flow rate to ideal capacity for level of service i, obtained from Table 8-1 in the Manual (v/c)i = 1.00 (Level of service = 'E' & level terrain are assumed for all the bridge locations in general)

fd = adjustment factor for directional distribution of traffic, obtained from Table 8-4 in the Manual *fd* = 0.97 (55/45 split)

fw = adjustment factor for narrow lanes and restricted shoulder width, obtained from Table 8-5 in the Manual. It is a function of lane width of bridge approach road, effective width of bridge approach road, effective width of bridge between curbs and assuming level of service "E".

f_{HV} = adjustment factor for the presence of heavy vehicles in the traffic stream, computed as :

$$f_{HV} = 1/[1 + P_r(E_r - 1) + P_R(E_R - 1) + P_B(E_B - 1)]$$

where:

P_r = proportion of trucks in the traffic stream, expressed as a decimal. P_r at bridge site is obtained from total proportion of Medium Lorries & Heavy Lorries, in section where bridge is located, given in "Traffic Volume Malaysia".

P_R = proportion of RV's in the traffic stream, expressed as decimal : $P_R = 0$

P_B = proportion of buses in the traffic stream, expressed as decimal P at bridge site and is obtained from proportion of buses in the section where the bridge is located, figured out from Traffic Volume Malaysia.

E_r = passenger car equivalent for trucks, obtained from Table 8-6 in the Manual $E_r = 2.0$

E_R = passenger car equivalent for RV's, obtained from Table 8-6 in the Manual $E_R = 1.6$

E_B = passenger car equivalent for buses, obtained from Table 8-6 in the Manual $E_B = 1.6$

While, V/C (current demand volume/traffic capacity on bridge ratio) and capacity year are calculated using the following formula based on data obtained from "Traffic Volume Malaysia" and the calculated traffic capacity on bridge (SFi);

$$Cy = \text{Year of Traffic Volume Data} + \frac{\log C - \log V}{\log (1 + G)}$$

Where:

Cy = Capacity Year
C = Traffic Capacity on Bridge
V = Current demand volume
G = Annual growth rate, expressed as decimal

If V/C ratio is more than 1.00, it means the traffic capacity on the bridge is inadequate, widening of the carriageway is required as a rehabilitation plan. Conversely, if the V/C ratio is less than 1.00, it means the traffic capacity on the bridge is adequate. However, traffic capacity on the bridge will be saturated on the capacity year and thus widening of the carriageway shall be implemented before the year estimated.

Pedestrian Flow Capacity

In principal, federal bridges should have sidewalks for the safety of pedestrian. If the bridge is located without sidewalks in urban areas or near public facilities such as schools, mosques and other land marks, a considerable number of pedestrians will cross the bridge using the carriageway. This condition causes traffic hazards, in other words, it is dangerous for pedestrians.

During the superficial or periodical inspections, surrounding areas within one km of a bridge which has no sidewalk shall be surveyed to identify whether the bridge is located in an urban area, or its proximity with institutional public facilities such as schools, hospitals, mosques and other landmarks. If the bridge is located in the above condition, then it is deemed to need a sidewalk.

Bridge Opening Capacity

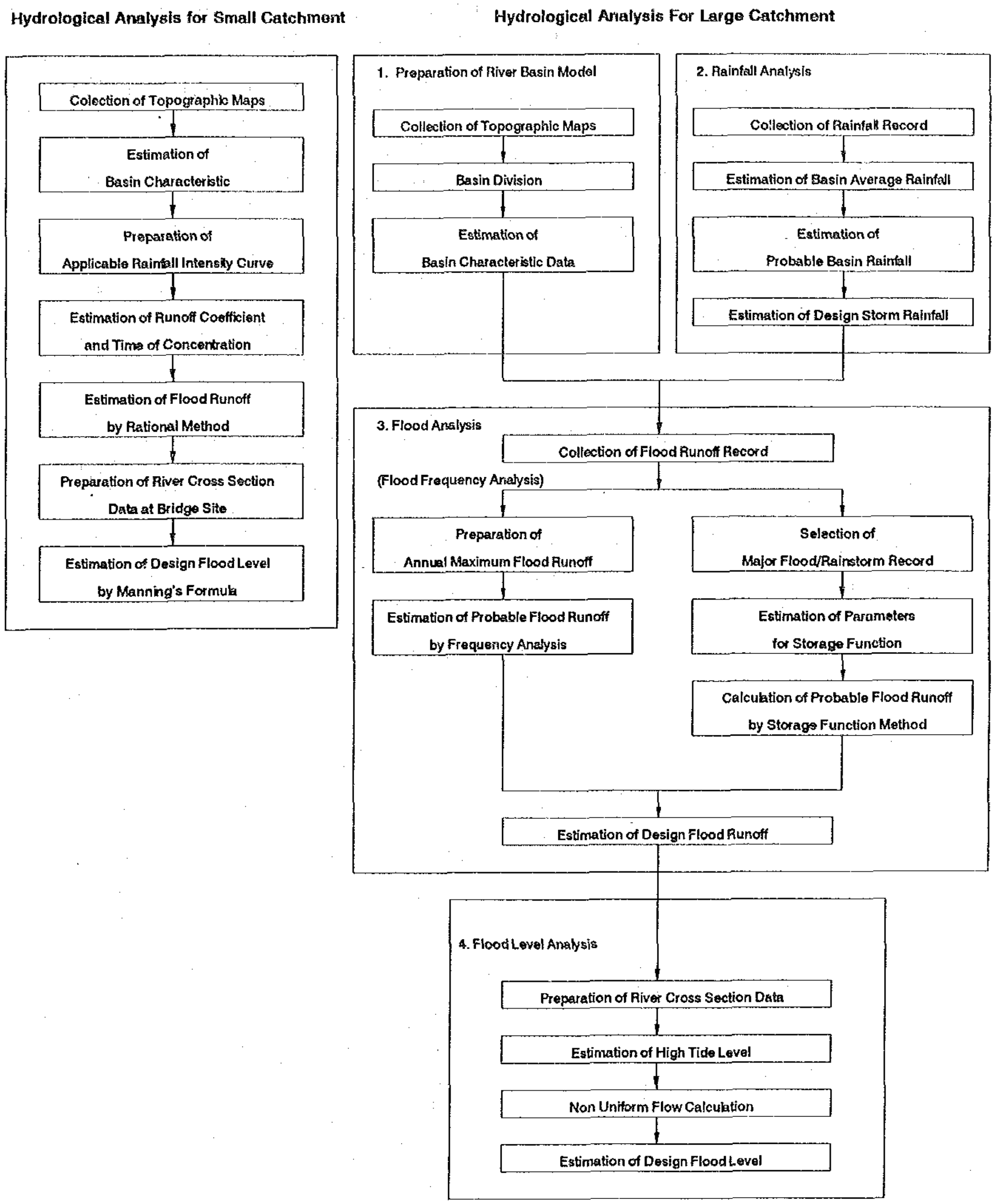
The purpose of this assessment is to confirm whether the bridge opening can accommodate flood runoff discharge or not, in other words, whether the bridge will be submerged or not during floods.

During the superficial or periodical inspection, field interviews concerning the flood level shall be conducted with at least three local residents who are living in the vicinity of the bridge site. Furthermore, a hydrological survey shall be conducted to identify flood marks at the bridge site, so that information from the interviews can be verified.

In the assessment of the detailed inspection results, hydrological analysis shall be conducted to estimate flood level and flow capacity of the river at the bridge site. For these estimation purposes, the rational formula recommended by DID in "National Method of Flood Estimation for Rural Catchments in Peninsular Malaysia" can be applied to a river which has a catchment area less than about 100 sq.km.

The storage function method and thiessen method are recommended for runoff calculations and rainfall analysis respectively for a river with a catchment area which is more than about 100 sq.km. Non-uniform flow methods should be adopted to analyze the flood level of a river which is affected by tidal levels. The overall flow diagram for hydrological analysis as described above is depicted in Figure 3-1.

Figure 3-1 Overall Flow for Hydrological Analysis



(3) Analytic Assessment

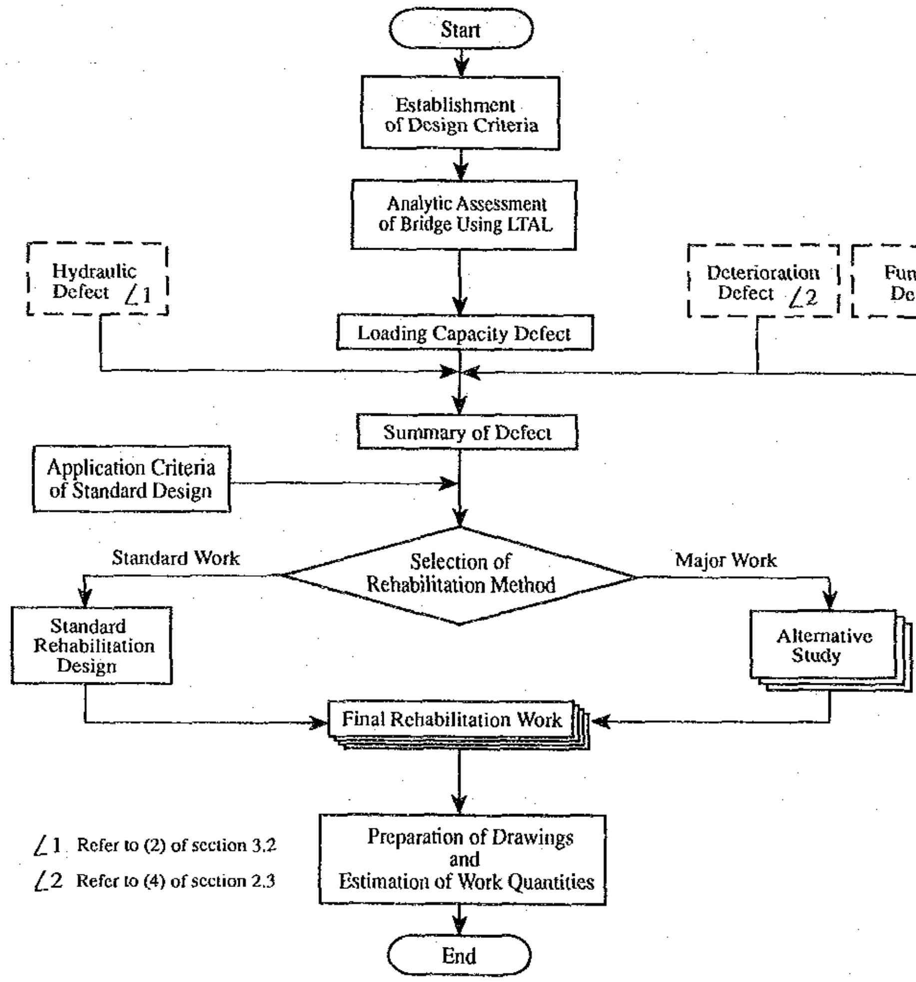
In the assessment of the detailed inspection results, it is essential to diagnose all defects in terms of material deterioration, load carrying capacity, bridge function and hydraulic adequacy together with the corresponding cause of the defect so that a suitable rehabilitation method, which will effectively rectify the cause of the defects, can be selected.

In this regard, material deterioration shall be assessed in accordance with those test methods mentioned in Section 2.4. The bridge functional and hydrological assessments are carried out according to the methods mentioned above.

Therefore, in this section, the remaining assessment item, i.e. analytic assessment method from load carrying capacity view point is described. The main purpose is to diagnose which main bridge member is inadequate to carry applicable loading based on the detailed inspection results.

Overall assessment flow based on the detailed inspection is depicted in Fig.3-2. Subsequently, all the defects together with respective causes from the above four view points can be identified to assist in selecting the most suitable rehabilitation method.

Figure 3-2 Overall Assessment Flow on Detailed Inspection



■ The Assessment Method

The assessment shall be carried out based on the available structural data taken from the detailed inspection. These consist of structural details such as dimension details i.e. size of various members, size and numbers of rebars and their arrangement, and material properties such as strength and elastic modulus.

In principle, the assessment of the existing bridge shall be carried out in accordance with the elastic design method (allowable stress method) stated in JKR Bridge Design Manual. While for rehabilitation plans such as adding sidewalks which are not attached to the existing bridge or complete bridge replacement, the structural analysis shall be carried out using the limit state design method prescribed in BS 5400. The assessment criteria for detailed assessments is attached in Annex-G.

Generally, most of the existing bridges were designed in accordance with lower live load intensity than the present applicable one. Thus it is obvious that most of the working stresses due to the present applicable live loads will exceed the allowable stresses applied in the original design, if the present loading standard is simply applied in the structural assessment without special consideration.

It has been, however, proven by the full scale loading test carried out in the JICA Study that most of bridge members have inherent residual loading capacity resulting from bridge behavior differences between in design and in actual, i.e. this factor mitigates actual working stress due to several effects such as composite action, built up action, lateral load distributions action and so on. Eventhough the exact value of each bridge should be derived from a corresponding full scale bridge loading test, this mitigating factor could be applied in the assessment when comparing the allowable stresses with the working stresses deducted by a certain percentage. The practical assessment method using the stress mitigating factor which was derived from the JICA Study is explained below for reference.

-Steel Beam and R.C Bridges

In the assessment of steel beams, the maximum working stress theoretically calculated due to the most severe live loads condition including dead loads is compared with the allowable stress of the structural steel. If the working stress after a reduction of 20 % which is applied as the inherent residual loading capacity value of steel beam is within the allowable stress, then loading capacity of the steel beams is considered adequate.

The same method described above is also applied in the assessment of R.C beams and R.C slabs. However, the mitigating factors of working stress, 20 % for R.C beam and 10 % for main slab, are applied.

-Prestressed Concrete Structures

On most of the P.C. beams, effective prestressing forces are unknown in general. Due to this lack of data, the assessment method to be applied is by comparison of the difference between sectional forces (bending moment and shear force) due to the assessment total load and those due to the design total load. Then if the difference is not more than 20 % which is the reserved residual loading capacity of the P.C beam, the P.C beam has adequate loading capacity.

-Substructure

Subsoil profile, pile length and size of footing are requisite data in the assessment of the substructure. However, these data are usually not available. Then, the assessment method to be applied is also by the comparison of the difference between reaction forces due to the assessment total load and those due to the design total load. If the difference is not more than 20 - 30 %, the substructure is considered adequate since the substructure has been designed with a safety factor of about 3.

3.3 Full Scale Bridge Loading Test

In most cases, the actual load carrying capacity of bridges is higher than that obtained by theoretical calculation. This phenomena is caused by the difference between design and actual bridge behavior due to the result of material properties deviation, the degree of difference in lateral load distribution, the extent of composite action etc. This difference is termed as reserved residual loading capacity, the value of which depends on type of structure, construction materials and extent of defects or deterioration.

It is, however, difficult to estimate the reserved residual loading capacity by analysis alone, particularly from the effects of defects or deterioration to the overall performance of an existing bridge, but it is important to make it a requisite in the assessment of the existing bridges. In order to overcome the difficulty, a full scale loading test is useful to determine the reserved residual loading capacity of the bridge instead of analysis.

The primary purpose of a full scale loading test is, therefore, to estimate the structural reserved/residual loading capacity of main component part of a bridge. To achieve this, comparison of stress and deflection is made between theoretically calculated values and those empirically measured. The other secondary purpose of the test is to ensure that structural theories and assumptions applied in the calculation are correct and suitable for use in structural bridge assessment work.

The loading test to be conducted is broadly divided into 2 types; static and dynamic loading tests. Static loading tests measure deflection and strain of main component parts under a known load. While, dynamic loading tests measure the actual working strain including the impact effect on the members under the existing traffic load.

3.3.1 Loading Test Planning

As preparatory work, the loading test planning consisting of structural detailed survey, selection of measurement points, determination of loading positions & loading cases and traffic count survey shall be conducted in advance to ensure that the final outputs meet the purpose of the test.

(a) Selection of Measurement Points

In general, the number and location of measurement points in a full scale loading test depend on the objective of the loading test i.e. whether it is proof test, behavior test or research test such as assessment of the ultimate loading capacity. Since the main objective of the loading test in the assessment is to assess the structural reserved/residual loading capacity of the main bridge components (ratio of empirically measured value and theoretically calculated one under the same known loading condition), the observation point on the main bridge component, where the measurement of strain and deflection is carried out, is to be selected so as to coincide with the maximum sectional forces induced.

The number and position of the measurement points at each selected observation point are determined mainly to enable the verification of the theoretical calculation and the measurement results.

(b) Determination of the Loading Position and Loading Case

The loading position and a number of trucks which will induce the most severe load effect to a member under consideration (i.e inducing the maximum moment, shear force or displacement at the selected observation point) shall be examined using relevant influence line diagrams. Based on this concept the loading position of each case together with a number of trucks to be used will be determined.

(c) Traffic Count Survey

A twenty four hour traffic count survey shall be carried out at a proposed bridge site to identify peak and low traffic hours (for both total traffic volume and heavy vehicles). Based on this traffic data, time and duration of the dynamic test and time of the static test will be decided in order to obtain the most severe load effect and to minimize any traffic interruption during the test period.

3.3.2 Method of Loading Test

A flow diagram showing the practical loading test procedure together with the above mentioned plan is shown in Figure 3-3.

(a) Preparation of loads

The load is normally applied by using loaded vehicles, occasionally by using dead load or load transferred through cable system, which are usually loaded with crushed aggregate or concrete blocks as counter weight. Before placing the load on a bridge, the configuration of the vehicle (usually a dump truck) including distance of axles and weight of each axle must be measured in advance using a conventional tape and a weigh bridge respectively. This data is necessary for determining the loading position on a bridge and for structural analysis. The exact position of the wheel shall be marked on the surface of the pavement using a specific color paint.

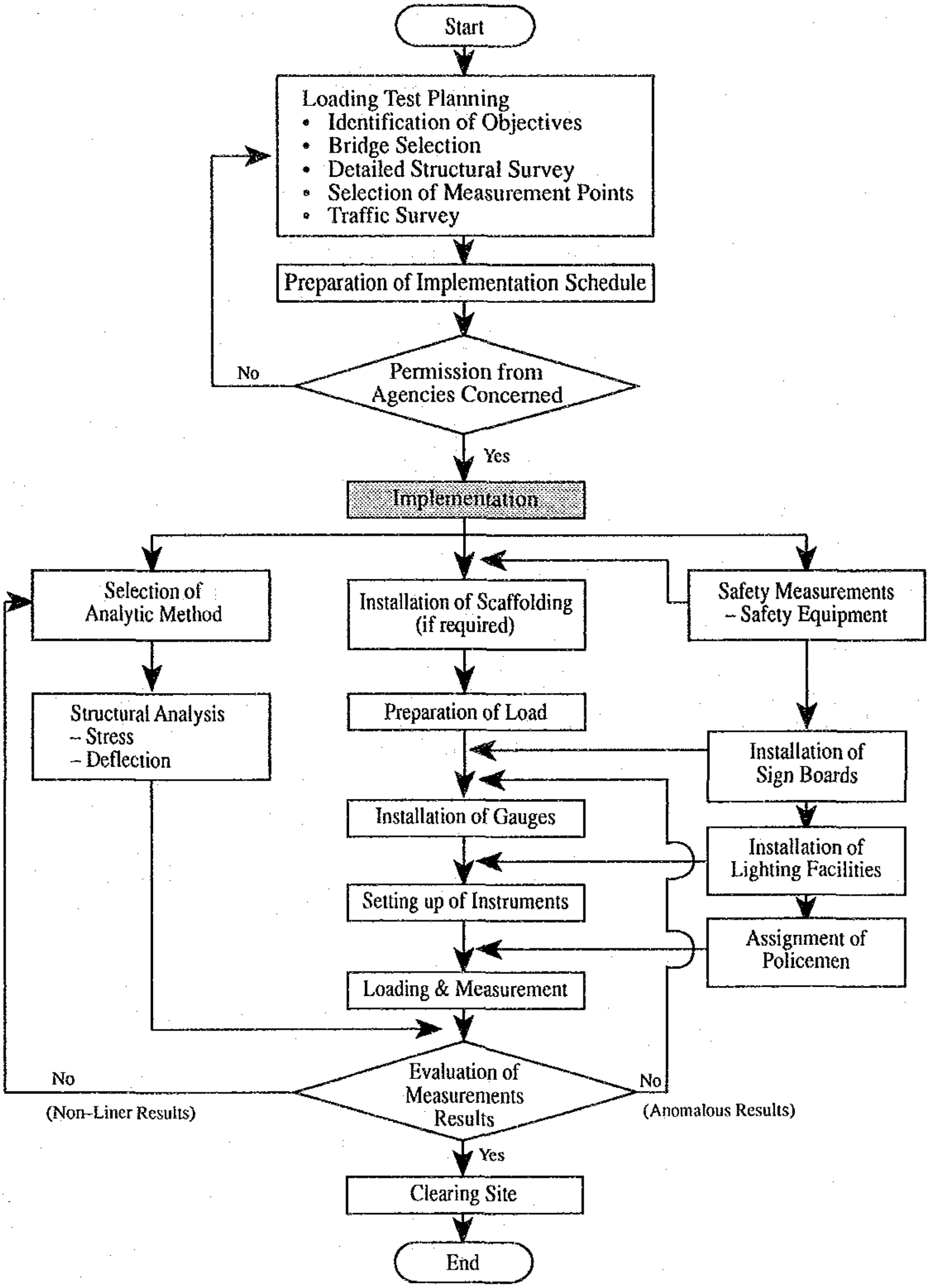
(b) Structural Analysis

Any damage to the bridges from the most severe loads during the loading test should be prevented. Hence, structural analysis using data collected through the detailed survey must be carried out in advance so as to ensure that no damages on the structure arise from the loading. The analysis method is made by comparison of the sectional forces due to the design live load and due to the most severe loading condition applied. The result of the analysis is also presented in terms of stresses and displacements at the measurement points due to the loads applied during the test.

(c) Safety Management

In a full scale bridge loading test, safety management is most important and shall be strictly executed in coordination with and assistance from the Government Agencies concerned. Out of the several important safety management items, traffic control shall be considered first and foremost. In order to properly and smoothly control traffic flow before, during and after the loading test, the following action shall be taken;

Figure 3-3 Flow Diagram of Loading Test



Installation of Traffic Sign Boards

The traffic sign boards such as public notice sign boards and regulative sign boards shall be prepared and installed in a timely manner by JKR district concerned.

Assignment of Traffic Policemen

During the period of the loading test, 2-3 traffic policemen shall be assigned at the site to ensure security and to control the traffic.

Systematic Arrangement of Loaded Trucks

In order to minimize the duration of the traffic interruption, the loading sequence of the dump trucks shall be carefully studied and determined in advance.

(d) Installation of Scaffolding

Installation of scaffolding is one of the major preparatory works in the loading test. Scaffolding is required to provide an access to the soffit of deck slab and girders in the case when a bridge clearance height to ground level is more than 3-4m.

The scaffolding is divided into two types, pipe support type and hanging type which have been commonly used in bridge maintenance and rehabilitation works. In the course of the loading test, the scaffolding will sustain the workers for the preparation works and for observation of concrete cracks. The scaffolding applied in the test shall be individually designed taking into consideration surcharge loads such as equipment and workers totaling 1500 N/sq.m and the dead load.

(e) Selection and Installation of Gauges

Several types of gauges can be used in conjunction with a bridge loading test. Resistance wire strain gauges are commonly applied in the loading test in which strains are measured by the changes in the electrical resistance of the gauges and can be measured very accurately. Gauges used in the test consist of a strain gauges for concrete structure, a strain gauge for steel structure and a dial gauge to measure deflection.

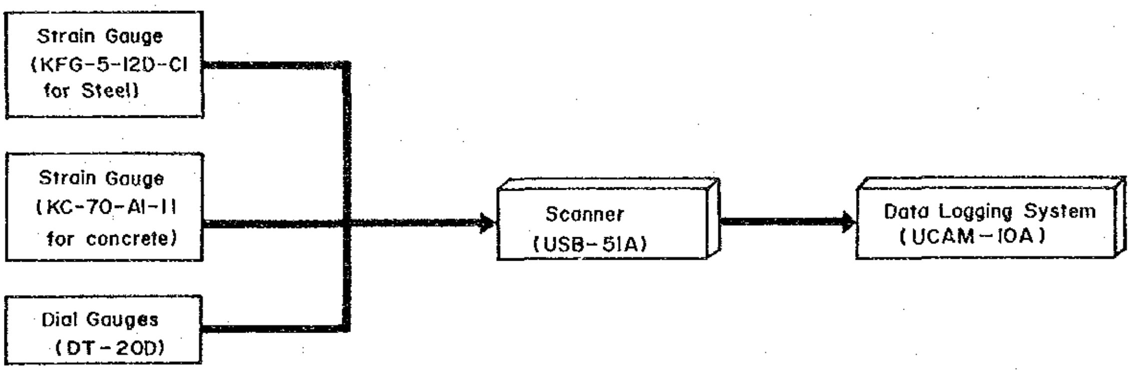
After completely cleaning the surface of structural members to be measured by sand-paper (#100-300) and thereafter by acetone, the strain gauge will be then bonded to the surface of the member using an exclusive adhesive. And later it is coated using butyl rubber material to prevent it from absorbing moisture in out-door condition. After bonding and coating the gauge completed, the lead wire is connected to the data logging system.

(f) Instrumentation and Equipment

Type of instrument and equipment used in the loading test specifically depend on the objectives. In the load test described in this Manual they are broadly divided into static and dynamic measurement equipment;

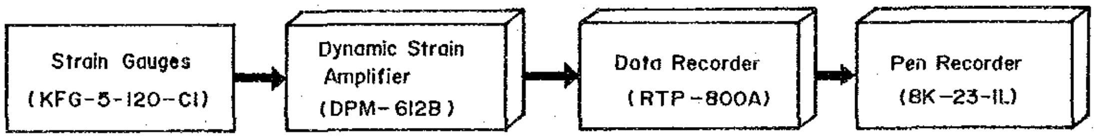
- Static Measurement

The measurement system shown in the following block diagram is generally applied to the static loading test.



- Dynamic Measurement

The objective of a dynamic loading test is to measure the dynamic strain of members under the existing traffic during peak hours. The results will reveal a fluctuation of the actual working strain. A measurement system shown in the following diagram is recommended for the dynamic loading test.



(g) Loading and Measurement

After completion of the above mentioned preparatory works, the trucks will be slowly moved to the designated points. Shortly after the complete decrement of the vibration, measurements will be read for the case of the static test. This practice will be repeated for all the loading cases.

During the dynamic test, dynamic strain due to the existing traffic will be automatically recorded over the period using a data recorder.

3.3.3 Assessment of Loading Test Results

Basically, assessment methods for the loading test results are by comparison of stress and deflection between empirically measured through the loading test and theoretically calculated using several structural theories.

(a) Assessment of Static Measurement Results.

The measured values obtained at the job site usually contain residual strain values or residual deflection values of the gauge itself. Thus measurement values to be used in the assessment should be adjusted by subtracting these values from the field values. Such values are usually stored in the Data Logger after removal of all the loads. They are about 3 micro millimeters in steel strain gauges (which is equivalent to 0.6N/sq.mm in terms of stress) and about 16 micro millimeters in concrete strain gauges (which is equivalent to 0.5N/sq.mm).

If variations of both stress ratio and deflection ratio (measurement value/calculation value) in each loading case is minimal, it can be concluded that both the test result and calculation results are reliable. Furthermore, it can be said that the theory applied in the analysis is suitable to theoretical assessment of the bridge.

If the variation is scattered, it is useful to carry out a reanalysis using different structural theories and to delineate stress distribution diagram and relation diagram between bending moment and stress or between deflection and bending moment in each loading case, so that anomalous measurement values can be revealed. These diagrams also indicate the reliability of the measurement results.

Through the above exercises aiming to confirm the reliability of the test and the calculation results, it is also to estimate the reserved residual loading capacity of a main structural member based on the difference between the test result value and the calculated value of the same measurement point.

(b) Assessment of Dynamic Measurement Results

The maximum, minimum and standard deviation of the working stress due to the present traffic load at each measurement point can be determined from the test results. Fluctuation diagrams and histograms of the working stress during the test period also can be depicted for the assessment purpose.

Based on these data, it can be concluded whether the bridge tested has adequate durability or not due to live loads derived from the existing traffic.

3.3.4 Application of Test Results to Rehabilitation Design

Based on the assessment of the load test results, it could be concluded that most of the bridges tested have some reserved residual loading capacity against maximum design stress, resulting from bridge behavior difference between design and actual, i.e. mitigating actual working stress due to several effects such as composite action, built up action, lateral load distribution action and so on.

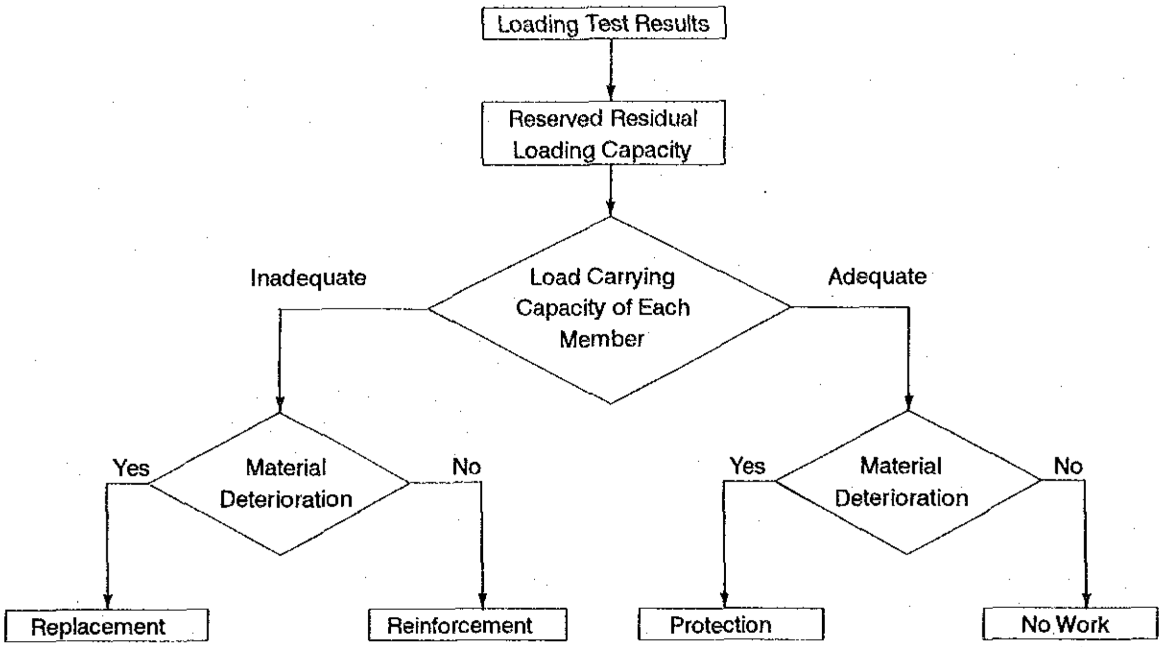
On the other hand, it is usual that most of the existing bridges have been designed for less live load intensity than that presently applicable. Thus, it is apparent that various members of the existing bridge could overstress, if present live load standard is simply applied in the structural assessment without special consideration.

Special consideration should be given to the reserved residual loading capacity (RRLC) which could cover the excess stress in the rehabilitation design. The bridge shall be theoretically assessed with due consideration of the reserved residual loading capacity to determine whether the bridge has adequate load carrying capacity. This result will be used as one of the criteria to determine a broad rehabilitation method i.e. whether minor work including protection work, strengthening work or replacement is required if a bridge has inadequate carrying capacity.

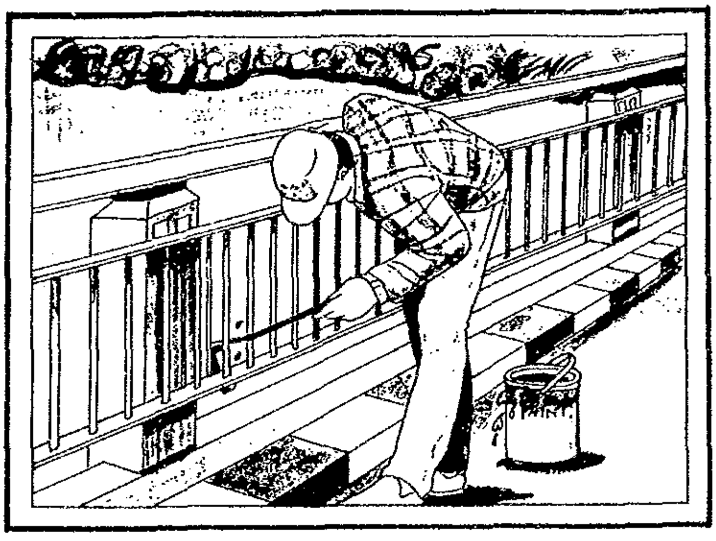
Following the above broad classification of rehabilitation methods, the most suitable rehabilitation method will be selected based on type, degree and extent of a damage detected as well as the cause of the damage, and cost comparison of several alternatives including type of material to be applied.

Conceptual flow of selecting rehabilitation method is illustrated in Figure 3-4.

Figure 3-4 Conceptual Flow of Test Results Application for Selection of a Rehabilitation Method



CHAPTER 4 : BRIDGE MAINTENANCE



CHAPTER 4 BRIDGE MAINTENANCE

4.1 General

Although maintenance of bridges is only one of the aspects of bridge management policy, it should be viewed in the context of the maintenance policy of the total road network. Bearing in mind the specific characteristics of bridges, the following main aspects shall be taken into account in determining a bridge maintenance policy:

- Bridges are sensitive points in the road because their strategic location;
- Bridge maintenance is a difficult art requiring good engineering knowledge and involving a wide range of techniques and advanced technology;
- The diversity of structures as there are many bridge types in existence, age, state of repair, changing regulations, and construction techniques have to be considered;
- Older bridges which are not suited to the present-day traffic not only because of increased loads, but also traffic operation techniques that are potentially damaging;

The prime objective of bridge maintenance is to keep structures in a serviceable condition in the interest of both public safety and economics. The other objectives are defined as follows:

(1) Avoiding damage or injury to third parties for which the bridge authority may be liable. Users of the bridge are not willing to accept any risk of bridge failure nor its consequences, even though it may in practice be technically impossible to fully satisfy this demand.

(2) Ensuring the best possible conditions for traffic. It is an essential objective since it is the very purpose for which a road network is built, therefore traffic limitations or closure of bridges must be avoided because the social cost is generally very high.

(3) Preserving national bridges as effectively as possible. Bridges represent capital assets, and the historical and cultural heritage of the country.

Taking into account the above objectives, bridge maintenance in this Manual is defined as the work needed to prevent deterioration or the development of incipient defects and other minor works which are repetitive and, in general, technically simple. The implementation of those works can be classified as work which will be carried out by the JKR District Office on a force account basis. Examples of the maintenance operations are cleaning the bridge and drainage system, localized repair of surfacings, repair of traffic damage to parapets, etc.

However, the following works which fall under a category of rehabilitation and strengthening works and which will be implemented on a contract basis are excluded from the definition.

(a) Any works leading to rehabilitation or betterment of the structure, whether by strengthening to carry heavier loads, by widening or by vertical realignment of the road surface.

(b) Any specialized or extraordinary repair works of deficiencies or defects which are critical or widely spread.

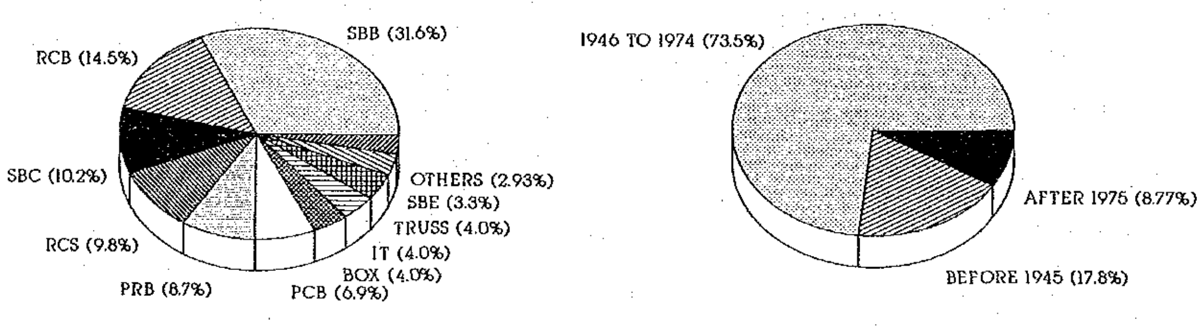
(c) Any restoration works of damages caused by landslide, flood, earthquake, fire and other exceptional causes.

4.2 Nature and Characteristics of the Bridges

As mentioned in Chapter 1, the nature and characteristics of the bridges covered in this Manual represent most of the typical bridges in Malaysia. In this regard, 205 Federal Bridges in Peninsular Malaysia, 15 Federal Bridges each in the states of Sabah and Sarawak and 40 State Bridges, 10 in Perak, 20 in Selangor and 10 in Negeri Sembilan, totaling 275 bridges, located throughout the country, have been selected by GOM and are defined as the representative bridges.

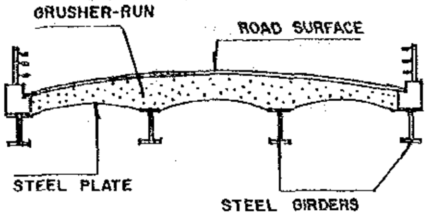
Statistical assessment of the representative bridges from bridge type and year built view points is presented in Figure 4-1.

Figure 4-1 Statistics of the Representative Bridges from Bridge Type and Year Built View Points

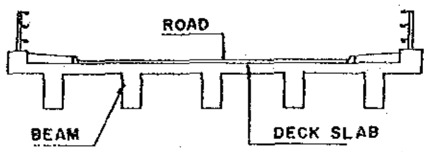


It revealed that the most dominant bridge is Steel Beam with Buckle Plate Slab (SBB) amounting to 31.6 % of all bridges. Reinforced Concrete Beam bridges (RCB) formed about 14.5 % of the bridges, while Steel Beam with Concrete Slab bridges (SBC) made up 10.2 %. The proportion of the rest of the bridges in decreasing percentage is as follows; Reinforced Concrete Slab bridges (RCS) 9.8 %, Precast RC Beam bridges (PRB) 8.7 %, Prestressed Concrete Beam bridges (PCB) 6.9 %, Pretentioned Inverted-T Beam bridges (IT) 4.0 %, Steel Truss bridges (ST) 4.0 %. The other bridge types involved are Steel Box Girder bridge, Prestressed Concrete Box Girder, Bailey Bridge, etc.

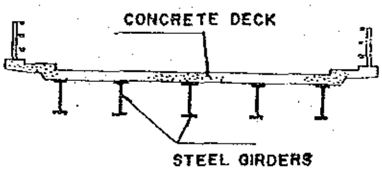
The cross sections of typical bridges discussed above are as follows;



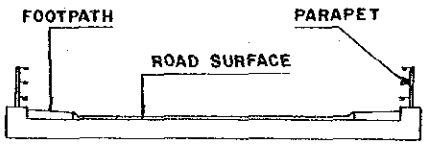
Steel Beam with Buckle Plate Slab



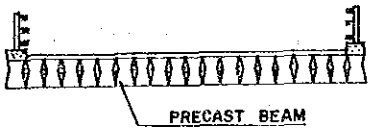
Reinforced Concrete Beam



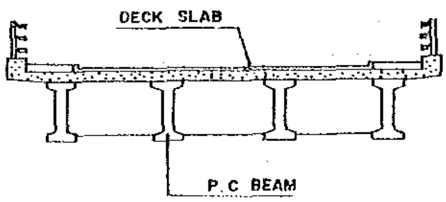
Steel Beam with Concrete Slab



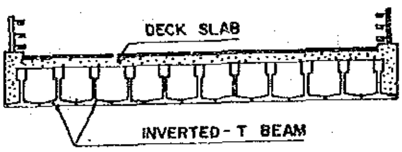
Reinforced Concrete Slab



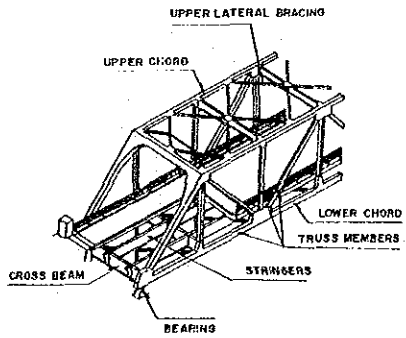
Precast RC Beam



Prestressed Concrete Beam

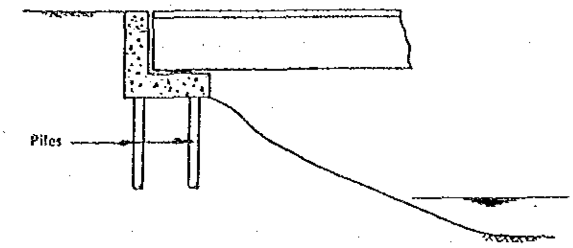


Pretentioned Inverted-T Beam

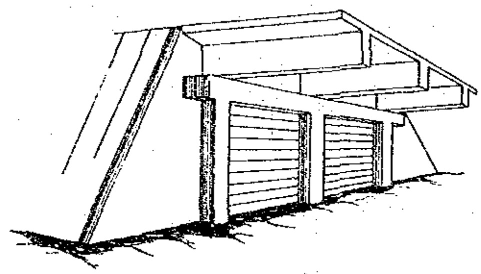


Steel Truss Bridge

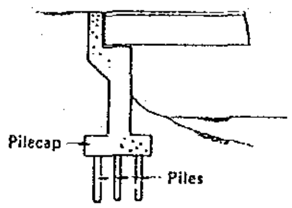
On the other hand, it is difficult to clearly classify the type of substructure in terms of abutment, pier and foundation because of the absence of as-built data. It is, however, presumed based on the limited data and the visual inspection that the followings are typical of the substructures.



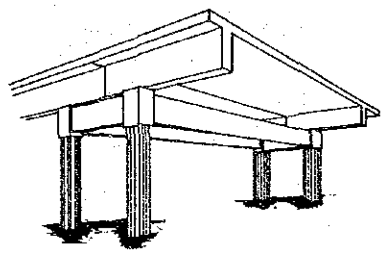
Bank Seat (Stub) Abutment
on Pile Foundation



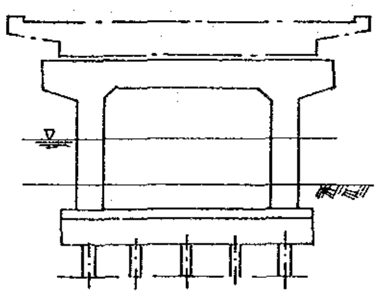
Pile Bent Abutment



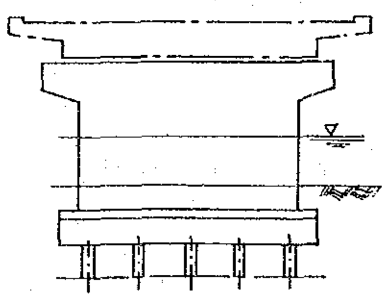
Inverted-T Abutment
on Pile Foundation



Pile Bent Pier



R.C. Frame Pier
on Pile foundation



R.C. Wall Pier
on Pile Foundation

From the bridge age view point, all the representative bridges can be divided into three age groups as shown in Figure 4-1. The figure indicates that 17.8 % of the bridges were built before 1945, 73.5 % were built between 1946 to 1974 and the rest 8.7% were built after 1975. Therefore 73.5% of the bridges are known to have been designed to HA load while 8.7% were designed to HA load and checked for 45 HB load (guided). On the other hand, there are 17.8% of bridges whose applied design load is unknown, but it could be suggested that they were built to BS 153 (1933 or earlier version) load.

In terms of the span length of the bridges, the majority of them are simply supported short span bridges with spans below 20 meter, as illustrated in Figure 4-2. However, there is a small proportion of multi-span simply supported bridges with an averaged span length between 30 to 40 meters and continuous span bridges with 3 spans with an averaged length of about 40-50 meters. These are drawn in Figure 4-3 and Figure 4-4 respectively.

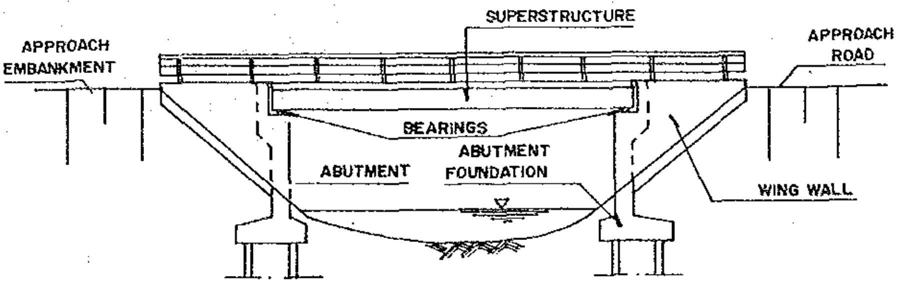


Figure 4-2 Simply Supported Single Span Bridge

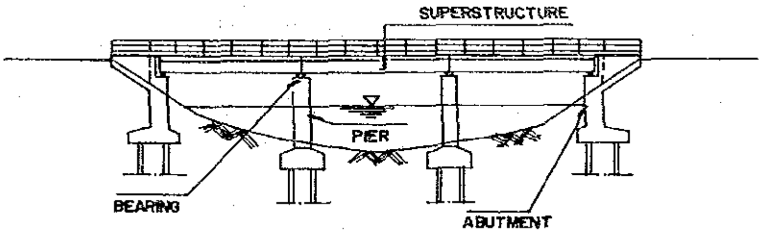


Figure 4-3 Multi-Span Simply Supported Bridge

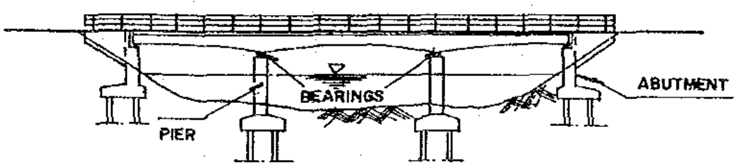


Figure 4-4 Three Span Continuous Bridge

4.3 Maintenance Operation and Techniques

The maintenance operation in this Manual has been formulated by taking into account the objectives and definitions as discussed in Section 4.1 as well as considering the implementation which is under the responsibility of the JKR District Office. The maintenance operation is broadly divided into the following categories:

- Simple cleaning operation; removal of foreign material such as trash, dirt, debris or parasitic vegetation by hand, and similar operations;

- Small scale removal and replacement operations; substitution of deteriorated elements such as deformed steel railing, damaged expansion joint, etc. by removal and replacement;

- Small scale restoration operation; repointing of stone masonry and brick work, reinstallation of traffic signs, railing and expansion joints;

- Localized repairing operation; repairs to potholes on bridge surface by bituminous materials and to concrete defects such as scaling, flaking, spalling, etc. by patching;

- Localized repainting operation; repainting of steel members such as beam, chord, bearing, railing and protective coating to concrete members;

- Lubrication and greasing operations.

Based on the broad maintenance operation defined above, each maintenance technique is discussed further by describing the possible cause of defects or damages and by recommending the corresponding correction method. The various maintenance techniques for the respective component elements are presented as follows;

(1) Beam, Girder and Chord

Beams and girders either of steel or concrete are structurally the most important elements in bridges. The steel beam which comes from the rolling mill as an integral unit of two flanges and a web is generally used for short span bridges. The steel plate girder as a structural member is applied for intermediate span lengths not requiring a truss bridge and yet requiring a member larger than a rolled beam. A plate girder consists of a web to which flanges are riveted or welded at the top and bottom edges.

On the other hand, concrete beams are usually reinforced to withstand the tensile stresses, whether resulting from bending, shear or a combination of both, in which stresses are taken up by the reinforcement bar or prestressing force. It is commonly rectangular or tee-shaped with its depth dimension greater than its stem width.

steel members in a through type bridge are susceptible to damage from roadway traffic, while the steel members on deck type bridges which are used for overpasses are also susceptible to collision damage from overheight loads. In most cases, the damage is relatively critical and it causes stress concentration in the deformed member.

extreme cases. However, minor damage can usually be repaired by strengthening using a strong back with jacks or by heat straightening while fractured members require partial or total replacement. Minor nicks and gouges due to accidents should not be allowed to remain as they can raise stress locally and often propagate cracks.

(1.2) Concrete Member

Problem

Local defect: Defects which are located only in a few parts such as honeycombing, flaking and scaling are defined as a local defect in a concrete member. Honeycombing is the formation of small holes or voids due to improper construction techniques or poor workmanship, while scaling is the surface pitting mainly resulting from usage of poor materials which produces a gradual decomposition of the cement paste; and flaking is caused by the corrosion of the reinforcing steel, or inadequate concrete cover, or porosity of the concrete which could cause pieces of concrete to break off. These defects even in a small scale accelerate corrosion of rebar and those with advanced defects could seriously reduce the safe load carrying capacity of the structures.

Correction

These defects can be corrected by patching work to prevent air, water or moisture penetration since their penetration into concrete accelerates deterioration of the concrete and corrosion of rebar and P.C. cables. For this purpose, the defective concrete must be removed until sound concrete is found (if an exposed rebar exists, it must be adequately cleaned and protected). Next, the affected areas must be thoroughly cleaned and a bonding agent should be applied. Finally, patching should be carried out using resin mortar patches. (Refer to Patching Work in Chapter 5)

(2) Decks

A slab which directly supports vehicle loads and distributes the loads to beams/girders or floor system is defined as a deck. The bridge decks are particularly vulnerable to deterioration due to direct impact loads, corrosive action and climate conditions.

(1.1) Steel Member

(a) Sediments on lower flange: Collecting and accumulating dirt or debris on a lower flange or chord is widely observed in the steel beam/girder bridges or in steel truss bridges. When they hold water, the dampness causes paint deterioration or even worse resultant corrosion. (Refer to Photo-1)

Periodic cleaning and removal of dirt or debris shall be made in order to prevent paint deterioration and corrosion. This maintenance operation in turn prolongs the life of the total paint system. Those which are dry can be removed using brooms while brushes and trowels are useful for the wet materials.

(b) Local corrosion One of the most common deficiencies in steel bridges is paint deterioration and its resultant corrosion. In general, a steel member is painted or galvanized to prevent corrosion. However, paint or galvanizing deteriorates due to air, water and bird droppings which if left unattended will cause the steel member to corrode. If corrosion is advanced, the edge of the steel plate can look as if it has split into thin layers. This phenomenon is called "Lamination". Under such condition, the steel has almost no structural strength left and this is structurally called "Section loss". (Refer to Photo-2)

Corrosion control by repainting is the most common maintenance operation to prevent advanced corrosion and costly rehabilitation in steel bridges. Thus, even though the defective area is isolated or scattered, it is appropriate to repaint the steel member without delay. Before repainting operation, thoroughly remove the rust completely. And after paint the surface with a suitable paint which has to be applied layer by layer. (For a detailed work sequence refer to Repainting Operation in Chapter 5).

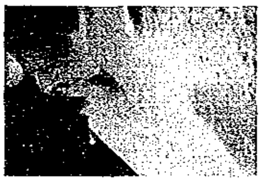


Photo-1 Sediments on lower flange

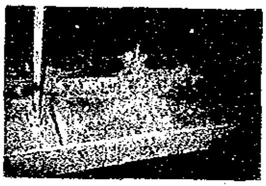


Photo-2 Local corrosion

(c) Local deformation: Local deformation of steel structural elements is defined as a collision damage caused by traffic or debris during floods. The

Repair of collision damage, whether caused by traffic or debris during floods, is often very difficult and involves member replacement in some

The main deck type in Malaysia is reinforced concrete, however, steel beams with buckle plates are widely used in short span steel beam bridges.

(2.1) Steel Beam Buckle Plate

Problem	***Correction***
Local corrosion: One of the most potential defects in the steel buckle plate is paint deterioration and resultant steel corrosion. These defects which require continual maintenance are caused by structural deficiency of the buckle plate. If appropriate maintenance is not timely applied, even though a defect is minor or localized, the paint deterioration will cause steel corrosion on wide area and ultimately lamination in the worst case.	Repainting of the defective areas is the most appropriate solution for this problem. For this purpose, corroded surfaces should be thoroughly cleaned (i.e. corrosion, foreign materials, etc. must be removed) and painted, according to the specifications by using appropriate coating materials (Refer to Repainting Techniques in Chapter 5). Paint deterioration and corrosion in the steel buckle plate is mainly caused by water leaking from the surface layer. Thus, this potential problem must be solved by the provision of a waterproof layer.

(2.2) Concrete Decks

Local defect: Defects which are located only in a few parts and such as honeycombing (Refer to Photo-3), flaking and scaling are defined as a local defect in a concrete slab. Definitions of each defect and its effect can be referred to in 4.3(1.2).	These defects should be corrected by patching work to prevent air or moisture penetration, since their penetration into concrete accelerates deterioration of the concrete and corrosion of rebar and P.C. cables. The repair procedure is the same as those for concrete beam/girder as discussed in 4.3(1.2).

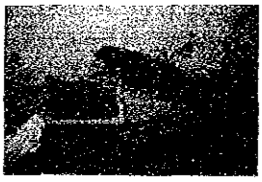


Photo - 3 Honeycombing with water leakage

(3) Abutment and Piers

The substructure of a bridge is composed of abutments and piers, which transmit the load from the superstructure to the ground. Abutments support the ends of a single span bridge or the exterior ends of a multi-span bridge, and in general, retain the approach embankment or fill. While, piers provide interior support for a multi-span bridge.

Problem	***Correction***
(a) Sediment on bridge seat: Accumulation of dirt and debris on the bridge seat together with water that leaks from defective expansion joints, cause corrosion and deterioration of the bearings and decomposition of the seat concrete. In the worst cases, plants growing in these materials and their roots cause further damage the structures. (Refer to Photo-4).	Any sediment shall be cleaned and removed periodically. Furthermore, in this maintenance operation, repair of defective expansion joints would also be required to remedy any leaking materials. Photo - 4 Sediment on bridge seat 
(b) Local defect: Local defects on the abutments and piers include honeycombing, flaking (Refer to Photo-5), and scaling in concrete and mortar deterioration in the masonry and the brick structures. These defects are mainly caused by poor materials/workmanship, wet-dry cycle, impact loads, etc.	The local defects in concrete can be corrected by patching works using appropriate materials (Refer to 4.3(1.2)). Joints' repointing and replastering using mortar with mixing ratio of 1:3 (cement: sand) are appropriate for local defects on masonry and brick structures.
(c) Clogging bridge opening: All drift, logs, trees, banana trunks and other floating debris can lodge against river piers and they can catch more debris until the stream is partially damaged, especially in the pile bent type river piers. This accumulation of floating debris causes an increase in flow velocity at that point i.e. it increases	It is essential to remove the debris lodged on the piers at early stage during routine maintenance operations, otherwise it becomes more and more difficult to remove the accumulating debris which can increase the risk of bridge and river bank failure.

the stream's erosive ability and, in the worst case, this defect causes an overflow at the banks, wash out of bridge approaches and damage to the bridge itself. (Refer to Photo-6)

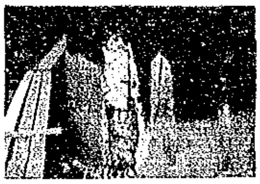


Photo - 5
Flaking

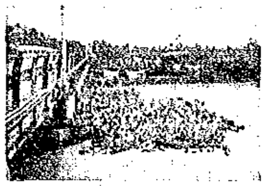


Photo - 6
Clogging bridge opening

(d)Vegetation: In the damp dirt and debris accumulated on the bridge seat, pile cap or joint, moss, plants and small trees can easily grow because of the tropical climate in Malaysia. The roots of these plants can cause cracks and scaling in concrete and deterioration of bearings installed on the bridge seat. (Refer to Photo-7).

Any vegetation growing on the structural member shall be removed whenever detected. This maintenance operation does not require any special techniques but depends on the maintenance team's discipline.


Photo - 7 Vegetation

(e)Local scouring: Local scouring is defined as washing around piers and abutments where the orientation of the pier or footing and flow direction differ. Local scouring may cause undermining of the footing and sub-sequent settlement in spread footing type piers and abutments. Moreover, it causes the reduction of friction pile stability.

Any scouring regardless of its scale shall be corrected without any delay, considering the importance of the substructures. It can be corrected by using wire mesh gabions, dumped stones, or stone-bags. Local scouring which could result in serious structural damage to the bridge can be prevented by frequent inspections and periodic river bed/bank maintenance.

(4) Bearings

Bridge bearings, either steel or rubber, are of vital importance to the functioning of the structure. If they are not kept in good working order, very high stresses may be induced in the structure. The function of bearings is mainly to transmit the superstructure load to the substructure and to provide for longitudinal movement and rotational movement. In Malaysia, sliding plate type, rocker type and roller type among other steel bearings are applied to long span bridges, while the elastomeric bearing using natural rubber is commonly used for intermediate span bridges. In most short span bridges, bearings have not been installed. Taking into consideration the present situation in Malaysia, the following is a typical maintenance operation requirement.

Problem

Freezing: Bridge bearings are designed to transmit loads to the substructure and to permit a certain amount of movement. If bearings are not able to accommodate movements of the bridge (this phenomenon is called "Freezing") due to dirt and debris accumulation and corrosion, the excessive friction forces placed upon the bearings will cause damage to the girders or the bridge seat. (Refer to Photo-8).

Correction

Routine clearing works on and around the bearings i.e. removal of dirt and debris is essential to prolong the function of the bearings. For sliding type and roller type bearings, lubricant should be applied after the bearings have been cleaned.

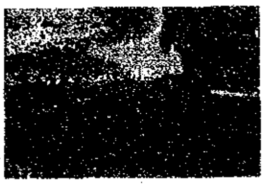


Photo - 8 Freezing

(5) Drainage Systems

It is no exaggeration to conclude that a good drainage system is the best preventive maintenance, since trapping, ponding and splashing of water can cause damage to various elements of the bridges over a period of time and represent serious traffic hazards, particularly in the rainy season in Malaysia.

Main components of the drainage system are surface inlets (or catch basins), drainage pipes and surface gutters along curbs. In the drainage system, accumulation of dirt and debris is the main cause of damage.

(5.1) Surface Inlets

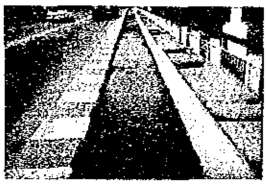
Problem

Clogging: The accumulation of dirt, debris, and other materials causes the inlets to become obstructed. Consequently, the water is trapped and impounded on the bridge surface. It makes the pavement slippery, and causes inconveniences for motorists and pedestrians. Moreover, since cracks are inherent to flexible pavements, the ponded water can penetrate through the overlay into the deck. (Refer to Photo-9).

Correction

Any dirt, or debris must be removed, i.e. all the surface inlets shall be thoroughly cleaned. If there are damaged inlets, they shall be replaced. The most important preventive measure is regular and frequent cleaning of the surface inlets in order to avoid any accumulation of dirt/debris.

Photo - 9 Clogging



(5.2) Drainage Pipe

Problem

Inadequate pipe length or missing pipe: Inadequate drainage pipe length or missing pipes cause water drained from the deck to splash directly to some structural elements of the bridge. If no appropriate maintenance is provided on time, this defect can cause paint deterioration and steel corrosion or scaling and flaking of concrete elements. (Refer to Photo-10)

Correction

The inadequate pipe length shall be extended up to about 30cm beyond the bottom of the beams using PVC or an appropriate material or a new drainage pipe. If accumulation of dirts and debris on lower flanges, paint deterioration or concrete local defects are observed, repair work shall also be carried out for these subsequent defects.

(5.3) Gutter

Sediments: Gutters located on some of the bridge surfaces are provided on the edge of the carriageway along both sides. Accumulation of dirt, debris and other foreign materials in the gutters is frequently observed due to lack of regular maintenance. This defect cause ponding of water on the bridge surface which is traffic hazards. (Refer to Photo-11).

The sediment must be removed from all gutter drains; and gutters shall be cleaned thoroughly.
It is recommendable to carry out cleaning works on gutters periodically (usually simultaneously with the roadway maintenance) in order to provide a free flow for water.

Photo - 10
Inadequate
pipe length

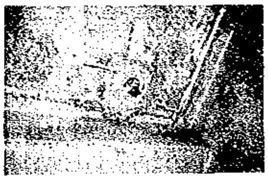
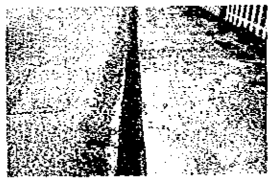


Photo - 11
Sediments
on gutter



(6) Sidewalks and Curbs

Sidewalks are the portion of the bridge floor area serving pedestrians and are commonly elevated above the portion used by vehicles to provide safety and convenience to users.

Curbs are barriers usually constructed parallel to the carriageway to guide the movement of vehicles while they safeguard railing, truss chords and other appurtenances existing outside the carriageway limits which also helps protect pedestrians on the sidewalk from vehicle collisions.

Concrete precast sidewalks and in-situ concrete curbs are common in Malaysia.

Problem	*Correction*
(a)Damaged precast panel slab : Precast panel slabs (about 150X50 cm) spanning the side-walk width are lined up on the sidewalk in most long span bridges. Defects commonly observed in these precast slabs are edge flaking, clattering noises under pedestrians traffic, broken or missing panels. These defects, mainly due to improper construction techniques, cause hazards to pedestrians. (Refer to Photo-12).	Minor damages such as edge flaking and other concrete defects can be corrected by patching work, while for clattering noises, the slab seat shall be adjusted by chipping or leveling. Major damage such as broken or missing slabs shall be replaced. Furthermore, sediments underneath the slabs and vegetation if any shall also be removed during this operation.
(b)Local defects: These defects including flaking, rebar exposure, cracks and scaling are mainly caused by impacts or collisions of vehicles with the curbs. Serious defects such as missing curbs or total distegration will affect traffic and pedestrian safety.	Minor local defects can be repaired by patching works. In the case of major local defects the damaged curbs shall be replaced within the earliest time.

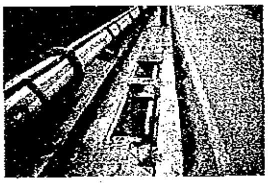


Photo-12 Damaged precast pannel

(7) Railing (Parapet)

Railings are barriers built at the outer-most edge of the roadway or sidewalk to guard/protect against accidents and to guide the movement of both pedestrian and vehicular traffic. Thus, even railings which normally do not contribute to the structural strength of the bridge, have a very high effect on public safety.

Typical types of railing in Malaysia are reinforced concrete and steel multiple railings.

(7.1)Concrete Railing

Problem	*Correction*
Local defect: Local defects for concrete railing are broadly divided into two types; one is minor defects including flaking, cracks, rebar exposu-	Minor defects shall be repaired by patching works as in the case of "local defects" on concrete elements as described in 4.3 (1.2). Major local

re, honeycomb, etc.; the other is major defects mainly caused by vehicle collision which are large scale flaking, rebar exposure and broken posts in the worst case. The latter defects threaten the safety of traffic and pedestrians. (Refer to Photo-13). defects shall be repaired by removing and replacing the damaged part of the railing, i.e. the damaged concrete shall be chipped off, then reinforcing steel must be strengthened or added and subsequently concrete shall be poured.

(7.2)Steel Railing

(a)<u>Local deformations and/or rupture:</u> As in the case of concrete railings, vehicle-impact is the main reason causing local deformation of the railing, or rupture in the worst case. In the worst case, the safety of traffic and pedestrians on the bridge will be threatened. (Refer to Photo-14). Reshaping of the deformed parts can be considered for minor deformations. However, in order to insure the safety of both vehicular and pedestrian traffic, more seriously damaged or ruptured railing parts must be replaced by an appropriate steel member. Also loose and corroded or loose nuts, bolts and connections must be repaired or replaced.

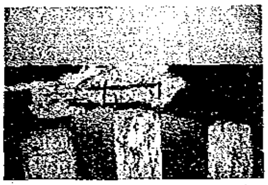


Photo - 13 Flaking

Photo 14 - Deformation

(b)<u>Paint deterioration:</u>Since steel railings are exposed to impact and collision of vehicles, weathering and other environmental agents, paint deterioration is widely observed. It should be noted that paint quality and cover thickness are determinant factors for the service life of steel railings. The deteriorated parts must be repaired by repainting work. For this purpose, defective paint and rusted or corroded surfaces should be thoroughly cleaned. Next, they must be painted according to the specifications as stated in repainting work in Chapter 5.

(8) Pavement

It is defined as the topmost layer or wearing surface applied on the structural deck and it provides a smooth and running surface. Moreover, this paving or wearing surface is placed to protect the deck from the effects of traffic, weathering, and chemical action.

Most of the bridges in Malaysia are provided with an asphaltic concrete pavement on the deck slabs.

It should be emphasized that in Malaysia asphalt overlay practices on a bridge surface have been being carried out without scarifying the previous layer(s). The additional dead load increased by the overlay has badly affected its structural condition. Therefore, asphalt overlay should be done after scarifying the existing layer(s).

(8.1) Bridge Surface

Problem	*Correction*
(a)Pothole: These are bowl-shaped holes of various sizes in the surface coarse resulting from localized disintegration. As a consequence of this pavement failure, impact load increases tremendously and the exposed deck is vulnerable to various damages. (Refer to Photo-15).	If only a few and small potholes are located on the bridge, a square or rectangular cut should be carried out with straight and vertical faces confining the potholes areas entirely. Then tack coat shall be applied, after which asphaltic concrete should be placed and compacted using a tamper. On the other hand, if the potholes number or their size were big enough (comparing to the total paved area), the pavement must be scarified and overlaid with a new layer.

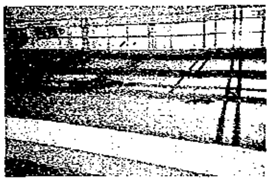


Photo - 15 Pothole

(8.2) Bridge Approaches

(a)Settlement: It is defined as a surface distortion mainly due to soil consolidation or compression. This defect in the bridge approach causes differential levels between the bridge surface and the approach road. Eventually, this will lead to an increase in impact load in various structural elements and hence induces traffic hazards.	In the bridge maintenance operation where the maximum settlement depth is not more than about 20cm, the distorted area shall be overlaid with asphalt concrete. Where the settlement depth is more than 20cm, total replacement including excavation, embankment, base and sub-base course work with appropriate compaction and surfacing shall be carried out under road maintenance.
(b)Piping failure: This defect is defined as a local depression or a deep hole in the embankment behind the abutment, as soil drops into the hole. Piping failures are mainly caused by water flow concentra-	This defect is normally repaired by filling with adequate compaction. On a small scale the piping can be repaired under bridge maintenance and its work sequence in order is excavation, filling with com-

tion and are a hazard to vehicle traffic and pedestrians.

paction, sub-base course base course work and surfacing. While the large scale piping should be rehabilitated under road maintenance.

(9) Expansion Joints

These are defined as joints placed between the gaps at the deck ends, or between the deck end and the backwall to mainly allow for longitudinal movement by structural members due to thermal effects as well as to prevent cracking in the surface layer and leakage of any foreign materials.

There are various types of the expansion joints presently available and selection of the type, technically, depends on the amount of gap required.

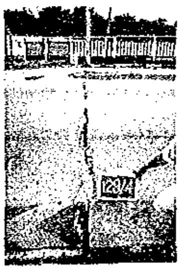
The most dominant types, in Malaysia are either elastomeric joints or sliding steel plate joints. The finger plate joint is also applied, mainly for long span bridges.

It is important to emphasize that in most short span bridges the joints are absent and also most of the joints have been covered entirely by the asphalt overlay.

Problem

(a) <u>Transverse open crack/ Water leakage</u>: Most of the joint surfaces have been overlaid by thick asphaltic concrete and open cracks or wide gaps along the slab ends are frequently observed. This defect causes the intrusion of dirt and grit as well as water through the open cracks and, accumulation of debris on the flanges and the bridge seats. (Refer to Photo-16). These deposits collect and hold moisture resulting in rusting of the steel members and deterioration of the bearings and the concrete surfaces.

Photo - 16
Open crack



Correction

First of all, removal of the asphalt overlay shall be carried out to identify what type of the expansion devices is used. In the case of an open joint, sealing the joint to prevent any leakage is essential. A compression joint sealant or a liquid polyurethane joint sealant may be utilized to waterproof the joint. If localized concrete edge crushing is observed, the damaged portion shall be chipped and patched using rapid hardening concrete. In the case of sliding plate type joints, a drain trough or sheet metal deflectors beneath the joint shall be installed to prevent water from draining onto flanges, bearings, etc.

(b) Damaged nosing: This defect is defined as crashing and flaking of slab concrete and asphalt surfaces adjacent to the expansion joint device. The failure is likely to be caused by loosened bolts or anchor bars under traffic loads, improper construction materials or poor workmanship. The vertical grade differential causes traffic to induce greater impact which further increases the damage. (Refer to Photo-17).

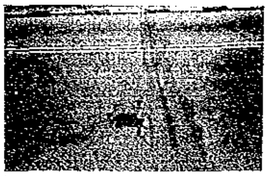


Photo 17 - Damaged noising

As a temporary measure, asphalt patching work shall be carried out to prevent further deterioration after removal of crushed asphaltic-concrete and concrete and thorough cleaning of the exposed surface. While a permanent measure is to reinstall the expansion joint. During the reinstallation work, it is very important to use a low shrinkage concrete with a high-early strengthening agent and to prevent any vibration during concrete curing.

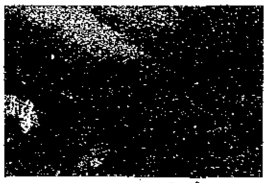


Photo 18 - Leaking water

(c) Abnormal noise (Pounding): Expansion finger plate or cover plates break loose at welds, producing abnormal noise and a hazard to traffic. Furthermore, loosened anchor plates or bolts cause movement of the expansion joint with abnormal noise (Pounding). Such failure will rapidly induce total expansion failure as well as critical damage of the concrete edge.

(d) Leaking water: Water leakage is a potential problem in the expansion joint and is inevitable and destructive to bridge elements beneath the joints. Due to clogging of the drainage trough or missing/defective drainage devices in the joints, surface run off will either bypass the clogged trough or will overflow or pass through the joint permitting water to reach structural members beneath the joint. (Refer to Photo-18)

The best solution for this defect is to reinstall the damaged joint. However if the defect is only local, the following correction methods can be applied; (1)Reposition and rewelding of finger plates or cover plates broken at the welds; (2)Removing of the loose or faulty bolts, and reposition of the joint by rebolting or rewelding.

If a drain trough was installed beneath the finger joint, cleaning and flushing of the drain trough will help to prevent clogging. For open joints, sealing the joint against leakage should be carried out periodically. Installation of drain troughs or sheet metal deflectors is a permanent counter measure for joints without a drainage system.