Republic of Zambia
Road Development Agency
(RDA)

Republic of Zambia
The Bridge Maintenance Capacity Building Project in Zambia, Phase II

BRIDGE ROUTINE MAINTENANCE GUIDELINES

(Guidelines and Guidebooks for Bridge Maintenance/ Management, Vol.1)

February 2025

Japan International Cooperation Agency
（JICA）

Dia Nippon Engineering Consultants Co., Ltd.
Japan Overseas Consultants Co., Ltd.
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FOREWORD

The Road Development Agency (RDA) is responsible for the entire classified road network of 67,671 kilometres, including bridges and culverts. However, owing to limited resources, the Agency identified a rationalised network of 40,454 kilometres deemed as the Core Road Network (CRN). The CRN is defined as "the minimum network which when improved will spur socio-economic development and contribute to poverty reduction."

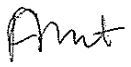
The CRN has over 460 bridges, most of which were constructed over 40 years ago, and have reached a critical stage, in need of repair. In an effort to implement bridge inspection, repair and maintenance, Guidebooks and Guidelines were produced under the Japan International Cooperation Agency (JICA), Technical Cooperation Project (TCP) on Bridge Maintenance Capacity Building in Zambia. These are the Bridge Repair Guidebooks, Bridge Routine Maintenance Guidelines and Bridge Inspection Guidebooks.

These Guidebooks and Guidelines will assist the officers in carrying out bridge inspections and maintenance activities and also offer repair Methods, which will in turn allow for the continued long-term use of the existing bridges.

Our profound gratitude goes to JICA for the technical and financial assistance and the RDA personnel that worked tirelessly to formulate and publish the Guidebooks and Guidelines.

I implore all those charged with the responsibility to inspect, repair and maintain bridges to utilise the Guidebooks and Guidelines as they undertake their work.

April, 2024



Eng. Grace Mutembo
Director and Chief Executive Officer
ROAD DEVELOPMENT AGENCY

ACKNOWLEDGEMENT

This Guideline on Bridge Routine Maintenance had been prepared by the Japan International Cooperation Agency (JICA) and the Road Development Agency (RDA) as a part of the Technical Cooperation Project for the Bridge Maintenance Capacity Building in Zambia.

In Phase I of this project, Routine Maintenance Guidelines for General Bridges were created. (Chapter 1 to 4)
In Phase II, Routine Maintenance Guidelines of Special Bridges (Chapter 5) and Responses to Emergencies (Chapter 6) were additionally created.

Recognition is given to the staff of RDA, and also a heartfelt thanks to the Technical Working Group and Counterpart Working Group members designated for the Project, who had rendered utmost support for the completion of this undertaking.

The following have been instrumental to be development of these guidelines on Bridge Routine Maintenance:

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ABBREVIATIONS

ASTM	:	American Society for Testing and Materials
AASHTO	:	American Association of State Highway and Transport Officials
B/C	:	Benefit/Cost Ratio
BMS	:	Bridge Management System
BS	:	British Standard
CRN	:	Core Road Network
EA	:	Emergency Action
FS	:	Feasibility Study
HTB	:	High Tension Bolt
ISO	:	International Organization for Standardization
JICA	:	Japan International Cooperation Agency
kPa	:	Kilo-Pascal
kVA	:	Kilo-Volt-Ampere
LCC	:	Life Cycle Cost
MM	:	Major Maintenance
MO	:	Monitoring
MPa	:	Mega-Pascal
OJT	:	On-the-Job Training
PC	:	Prestressed Concrete
RC	:	Reinforced Concrete
RDA	:	Road Development Agency
RM	:	Routine Maintenance
SADC	:	Southern African Development Community
SATCC	:	Southern Africa Transport and Communications Commission
SHMS	:	Structure Health Monitoring System
TWG	:	Technical Working Group
US$	:	United States Dollar
W/C	:	Water and Cement Ratio

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CHAPTER 1 GENERAL

1-1 INTRODUCTION

The present total length of the national road network in Zambia is about 67,000 km and about 40,000 km of those are maintained by RDA. These 40,000 km RDA-maintained roads are parts of the Core Road Network (CRN). There are over 460 bridges on the CRN. Most of these bridges were constructed in the early seventies or much earlier, and has not been maintained and repaired in a coherent and consistent manner. About 15% of these structures are reportedly in bad condition wherein urgent maintenance and repair works are needed. As a part of activities of the Bridge Maintenance Capacity Building Project, considering the above mentioned background, this guideline is intended as a reference for routine maintenance activities applicable to the bridge structures owned and maintained by RDA. The target users are RDA staff engaged in bridge maintenance and the contractors of bridge routine maintenance to be outsourced. This guideline is designed to address the most common types of bridge structure distress by outlining practical procedure for corrective and preventive maintenance. These procedures are not meant to be all-inclusive, or to rule out other maintenance procedures. This guideline also includes routine inspection which is vital to carry out routine maintenance activities in a cyclic manner.

1-2 BRIDGE MAINTENANCE MANAGEMENT CYCLE

Bridges are important valuable assets in Zambia. RDA has the responsibility of road and bridge maintenance. Asset management should be implemented by RDA to achieve the required target level of service.

Some of existing bridges may be already deteriorated with the performance being degraded. For such cases, cause of damages should be accurately grasped and identified as initial defects, damage, or deterioration. Main causes of damages should also be identified as much as possible for selecting appropriate remedial countermeasures. Initial defects and damage should be treated promptly and appropriately including emergency treatments. On the other hand, when bridge deterioration affecting its performance has occurred, the deteriorating mechanism should be identified as much as possible, and appropriate maintenance should be carried out based on the prediction as well.

It is becoming increasingly important to systematize the maintenance of bridges in Zambia because of their advancing age, increasing traffic volumes, heavier weight of freight cargo, limited resources and various modes of structural aging and deterioration. In order to implement bridge maintenance appropriately, design and construction data, inspection data, prediction of deterioration, evaluation and judgment, and remedial measures shall be recorded. Thus, it is necessary to consider appropriate bridge maintenance strategies and tools. The activities for improvement of maintenance management cycle aim to ensure the effectiveness of the above-mentioned systems.

The maintenance work usually proceeds by these steps: [Collecting current condition data]➔ [Inspection]➔[Evaluation]➔[Analysis]➔[Repair Plan]➔[Budget plan]➔[Implementation of Repair work]➔[Record]➔ [Collecting current condition data] and smooth movements are always required. In case there are some obstacles against the smooth movement in the management cycle, the above-mentioned effectiveness will be reduced.

This figure shows the Bridge Maintenance Management Cycle for expanding of life of bridge.

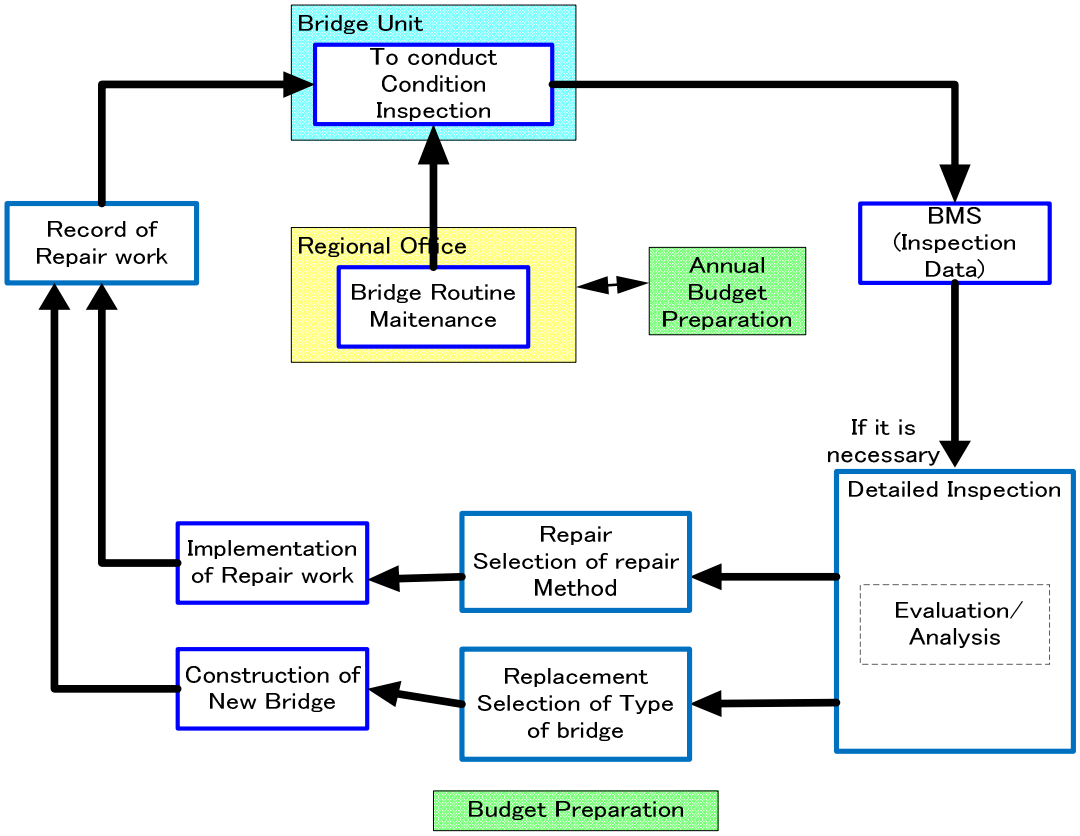


Figure 1-1 Bridge Maintenance Management Cycle

1-3 ELETEMT OF FRIDGE MAINTENANCE ACTIVITIES

Bridge Maintenance Activities can be grouped into two (2) categories; Bridge Inspection and Bridge Maintenance.

1-3-1 Bridge Inspection

Regular inspections are necessary for an effective maintenance program. It is recommended that bridge inspections be executed annually for all basic structures and more frequently for fenders and utilities.

The general types of bridge inspections are listed in Table 1-1.

Table 1-1 Bridge Inspection Types

TYPE	NAME	PURPOSE
1	Condition	- To obtain condition data on major maintenance needs of the bridges for operation of the BMS - To assess and rate condition of the structure
2	Detailed	- To investigate major maintenance needs of defective bridge identified by a condition inspection or other inspection - To determine the safe load capacity of the bridge - To test and evaluate the strength or quality of materials
3	Emergency	- To determine the emergency work needed for bridges after the occurrence of calamities in order to ensure its safety - To determine the severity of structural damage of bridges - To confirm safety of bridges and vehicular traffic
4	Inventory	- To obtain/update bridge inventory data for the BMS

1-3-2 Bridge Maintenance

As soon as a bridge is constructed and put into service, deterioration begins. The deterioration is due to aging and the impact from the environment, climate and the daily traffic. Bridge Maintenance is the recurrent day to day, periodic or scheduled work that is required to preserve or restore a bridge to such a condition that it can be effectively utilized for its designed purpose.

There are three type of bridge maintenance as follows;

1. Routine maintenance

   The purpose of recurrent maintenance, minor maintenance and cleaning is to ensure day-to-day traffic safety and serviceability. Routine maintenance covers minor works to the entire bridge, and includes cleaning, painting, minor repairs, and other minor works.

   The standard routine maintenance activities are listed in this Guideline.

2. Periodic Maintenance

   Periodic maintenance activities take place on a regular basis for several times per year.

3. Major Maintenance

   Major maintenance of bridge that is outside the scope of work handled under routine maintenance and which requires a separate allocation of funds. This category would include all works to prevent bridge deterioration, to address existing damage and to overcome conditions that may have impact on the bridges.

   Major maintenance can be grouped into four (4) categories as follows;

- Repair: Maintenance measures to restore or improve the durability of a structure and reduce hazards for third party.

- Upgrading: Widening, additional member of structure
- Strengthening: Maintenance measures to restore or improve the structural performance, such as the load-bearing capacity and/or stiffness, of a structure
- Replacement: Replacement of a new structure

1-3-3 Preventive Maintenance

Preventive maintenance is an approach for maintaining a structure by carrying out detailed inspection before deterioration manifest and taking appropriate measures to maintain it. This is the most advisable approach of maintenance. Preventive maintenance can also be defined as the act of keeping a structure in its as-built condition and/or protecting it from inevitable deterioration due to environment, traffic vibration and deicing chemicals. The bridge starts to deteriorate from the day its construction is completed, and it is the duty of the person in charge to slow the deterioration as much as possible using the best practical methods and materials. It is always more cost-effective in the long run to perform preventive maintenance activities than to allow a known condition get progressively worse until the entire member or structure has to be replaced. This methodology is similar to taking a medical check for one's body before the current condition gets worse and become a sickness. Similarly, at one's home, it is always cheaper to repair a minor leak in the roof as soon as noticed rather than to wait until the underlying roof sheeting is rotten.

In general, a bridge deteriorates from the deck slab. The deck slab is the first element of a bridge that is impacted by traffic. It also is in the worst environment due to deicing chemicals and temperature variations. The deck slab that remains dry on the bottom side with no cracks can protect the rest of the bridge indefinitely from most deterioration. Basis of Preventive Maintenance Technique is Life Cycle Cost (LCC). LCC consists of Initial cost + Maintenance cost + Renewal cost. Minimum cost of LCC is the best maintenance work. Regarding the LCC, there are two considerations.

The life-cycle cost can be minimized by implementing the countermeasures at the initial stage before damage worsen. In the figure below, blue lines show the large-scale repair and red lines shows the small-scale repair.

The Corrective Maintenance or large-scale repair model (blue line) requires a smaller budget to maintain the bridge at first but will continue for several years, thus, it will take much time and cost as well. Also, in case the bridge condition becomes serious due to damage, the bridge should be replaced immediately, therefore it will be needing extra budget.

On the other hand, the Preventive Maintenance or small-scale repair model (red line) requires a larger budget for bridge maintenance at first and several other times. However, the final total cost of maintenance can be reduced by extending the life span of the bridge. In the graph below, the total of the vertical axes shows the total repair cost during same service years. Therefore, the total cost of preventive maintenance is less than that of corrective maintenance.

CHAPTER 2 ROUTINE INSPECTION

2-1 PURPOSE

Routine Inspection is essentially visual and required to make an assessment of obvious defects of the bridge. This inspection is necessary to ensure that regular routine maintenance work is being planned and undertaken in accordance to the needs of the bridge. Routine inspection should also detect severe defects that may cause loss of stability of the structure and may result in injury or loss of life and damage to public property. In this context, routine inspection is important for taking emergency works to avoid collapse of the bridge and severe damage to a third party.

2-2 PROCESS

The process for conducting Routine Inspection is shown in Figure 2-1.

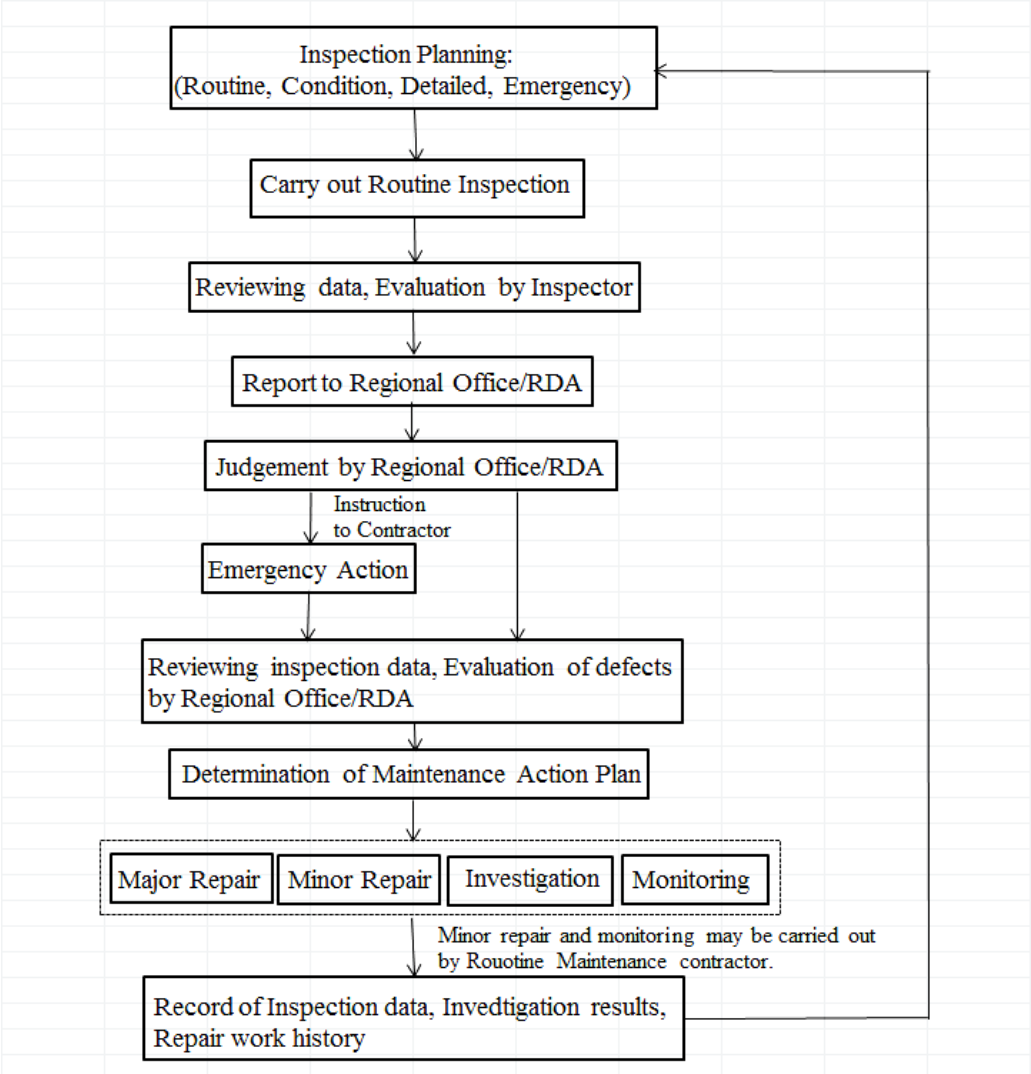


Figure 2-1 Routine Inspection Process

2-3 PROCEDURE

The procedure in accomplishing the Routine Inspection Forms and sketches is straightforward and involves visual inspection. The Routine Inspection Forms and is shown in Table 2-4. A copy of the previous Routine Inspection report should be brought to the site as reference. The bridge inspector of contractor, responsible for bridge routine maintenance, should review that the defects, actions and condition ratings for the bridge as listed in the previous inspection reports are accurate and without oversight. The contractor's inspector should check the defects and draw them on sketch drawings sheet, as needed, and photographs should be used to document any major defects or situations concerned. Upon returning to the office, the inspectors determine the Routine Inspection Condition Rating and required maintenance action plan based on the severity of defects. The result of inspection should be compiled as a deliverable and submitted to the regional offices/RDA. If there are any defects that require Emergency Action (AE), it should be reported immediately without waiting for the completion of report. Immediately judged by the regional office/RDA, the contractor will be instructed to carry out emergency repair including temporary work. The condition rating for Routine inspection and Required Maintenance Actions for each defect are shown in Table 2-1 and 2-2. Regarding inspection intervals, this routine inspection shall be in principle performed as frequently as every three months: e.g. 2 times in wet season and 2 times in dry season. In particular, the inspections related to waterways should be carried out after any significant storm events.

After receiving the Routine Inspection Report including the results of emergency repair works, the regional office/RDA will review all the inspection data and evaluate those defects and, based on such analysis, work out the maintenance action plan including such categorized maintenance actions as major repair, minor repair, investigation, and monitoring. The determination flow of these maintenance actions is shown in Figure 2-2. Among them, minor repairs and monitoring will be basically conducted by the routine maintenance contractor through the instruction of the regional office/RDA.

At the final stage, it is very important for RDA to keep the overall records including inspection data, investigation results and repair work history. Such feedback record shall be utilized to draw out following inspection plan including not only routine inspection but also other categorized inspections. The Bridge Routine Maintenance Schedule and Record Form shown in Table 2-6 may be used for the RDA's instruction to the contractor for each bridge and this would then form one part of maintenance record for the bridge.

Table 2-1 Routine Inspection Condition Rating

Condition Rating	Description
Good	No damage
Fair	With minor damage(s) not affecting the stability of the structure
Poor	With deteriorating damage(s) which should be monitored or could be repaired as a preventive action
Bad	With severe damage(s) that affects stability of bridge or that has possibility to harm a third party

Table 2-2 Required Maintenance Action

Required Actions	Description
MO: Monitoring	No repair work and keeping monitoring (Damage not progressing or very slow)
RM: Routine Maintenance	Should be maintained by Routine Maintenance
MM: Major Maintenance	Should be maintained by Major Maintenance
EA: Emergency Action	Need to take actions immediately to avoid bridge collapse or harm to a third party

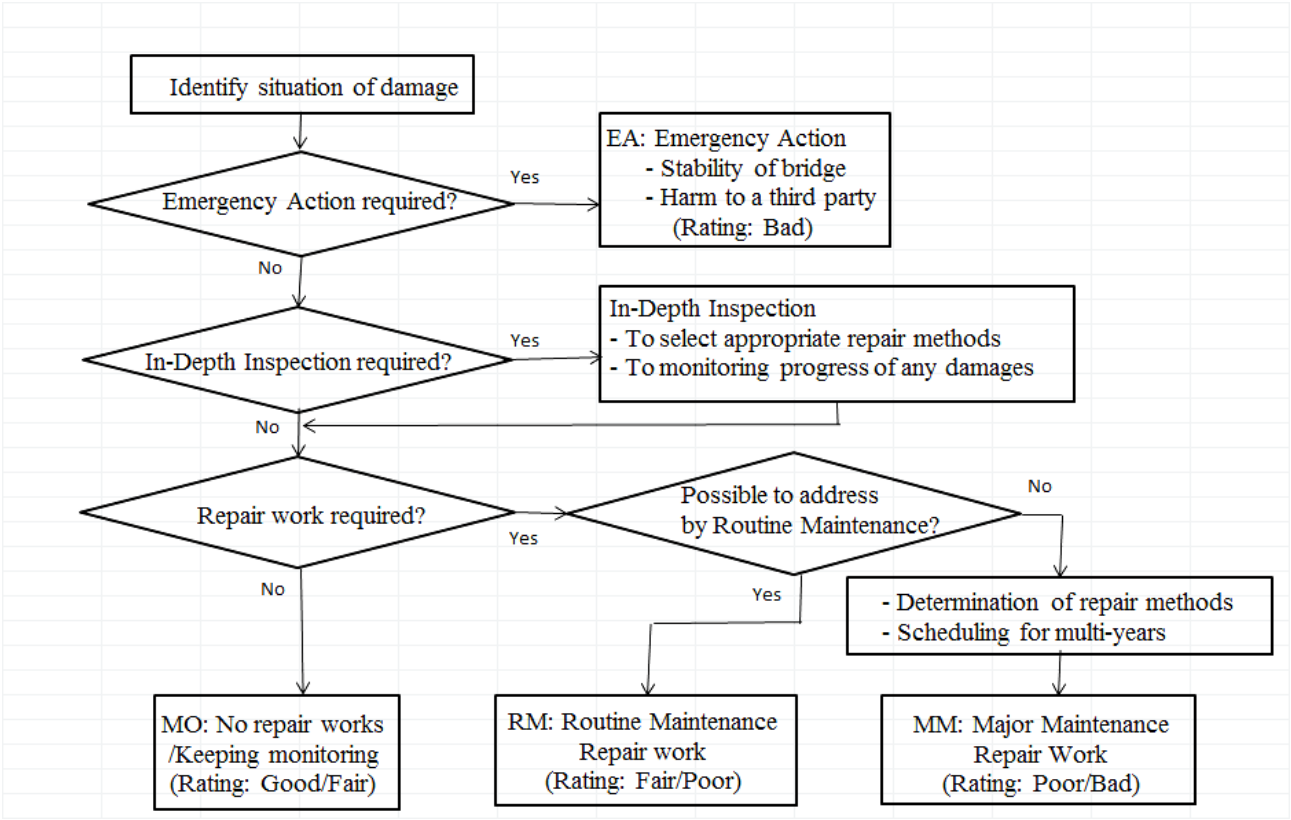


Figure 2-2 Determination Flow of Maintenance Action

2-4 DELIVERABLES

The deliverables of routine Inspection to be conducted by bridge routine maintenance contractor are as follows:

- Routine Inspection Report

  - Bridge Routine Inspection Form (See Table 2-4)
  - Sketch Drawings sheet (See Figure 2-3 and Figure 2-4)
  - Photo Record Sheet (See Table 2-5)
  - Routine Maintenance Record Schedule and Record Form (See Table 2-6)

The bridge Routine Inspection Reports shall be prepared by accredited bridge inspectors of the contractor. The reported data shall be checked and reviewed by the Regional Office/RDA for accomplishment and accuracy prior to finalization. When the Bridge Routine Inspection Report have been found to be complete, accurate and accepted, all the data shall be stored in the Bridge Management System (BMS).

In conjunction with such documentation and recording of bridge data, it is recommended to provide an individual name to every bridge for the convenience of bridge maintenance operations.

Table 2-3 (1) Defect Types of Bridge Component

Bridge Component	Sub-Component	Classification of Defects
Deck		1)Cracks, 2)Spalling/loose concrete, 3)Exposed/corroded rebars, 4)Cavity/honeycomb, 5)Free lime, 6)Rust seepage, 7)Deterioration/changed color, 8)Separation/swelling of repaired/strengthened part, 9)Water leakage
	Wearing course (Asphalt)	1)Potholes/spalling, 2)Bump, 3)Rutting, 4)Cracks, 5)Corrugtion, 6)Delaminated thin surfacing, 7)Ponding water
(Expansion joint)	Butt joint, Dummy joint	1)Damage to joint, 2)Damage to adjacent surfacing, 3)Water leakage, 4)Abnormal sound
	Finger joint, Sliding plate joint	1)Damage to joint, 2)Damage to adjacent post-cast part, 3)Water leakage, 4)Damage to waterproof system, 5)Abnormal sound, 6)Abnormal spacing, 7)Bump
(Railing/Curb)	Parapet, curb	1)Cracks, 2)Spalling/loose concrete, 3)Exposed/corroded rebars, 4)Free lime, 5)Rust seepage, 6)Deterioration/changed color, 7)Water leakage
	Metal rail	1)Deformation, 2)Corrosion
(Sidewalk)		1)Damage to sidewalk slab, 2)Ponding water, 3)Accumulation of garbage and debris
(Drainage)	Scupper	1)Damage to scupper, 2)Damage to cover, 3) Accumulation of garbage and debris
	Drain pipe	1)Damage to pipe, 2)Defect in connection, 3) Accumulation of garbage and debris
Superstructure	Steel members	1)Abnormal deflection, 2)Abnormal sound, 3)Abnormal vibration, 4)Abnormal spacing, 5)Displacement, 6)Water leakage/ponding, 7)Clearance under bridge, 8)Fatigue crack, 9)Deformation/buckling, 10)Loose/missing rivet/HTB, 11)Deterioration of painting, 12)Corrosion

Table 2-3 (2) Defect Types of Bridge Component

Bridge Component	Sub-Component	Classification of Defects
Superstructure	Concrete members	1)Abnormal deflection, 2)Abnormal sound, 3)Abnormal vibration, 4)Abnormal spacing, 5)Displacement, 6)Water leakage/ponding, 7)Clearance under bridge, 8)Cracks, 9)Spalling/loose concrete, 10)Exposed/corroded rebars, 11)Cavity/honeycomb, 12)Free lime, 13)Deterioration/changed color 14)Rust seepage, 15)Fracture/slipping out of tendon, 16)Separation/swelling of repaired/strengthened part
Substructure	Abutment/Pier	1)Cracks, 2)Spalling/loose concrete, 3)Exposed/corroded rebars, 4)Cavity/honeycomb, 5)Free lime, 6) Rust seepage, 7)Deterioration/changed color, 8)Separation/swelling of repaired/strengthened part
	Foundation	1)Scouring/lowering river bed
	Protection work	1)Settlement/displacement/washing away of rip-rap/retaining wall
(Bearing)	Metal Bearing	1)Damage to main part, 2)Corrosion of main part, 3)Damage to accessories, 4)Corrosion of accessories, 5)Damage to mortar/concrete seat, 6)Abnormal spacing, 7)Abnormal sound, 8)Accumulation of garbage and debris
	Rubber Bearing	1)Damage to main part, 2)Corrosion of main part, 3)Damage to accessories, 4)Corrosion of accessories, 5)Damage to mortar/concrete seat, 6)Abnormal spacing, 7)Accumulation of garbage and debris
Site/others	Waterway	1)Accumulation of driftwoods/debris, 2)Change of river direction/lowering river bed approx. 20m upstream and downstream
	Adjacent Bank to Abutment	1)Accumulation of vegetation/debris/garbage, 2)Damage to rip-rap/retaining wall, 3)Settlement of approach section/incorrect vertical alignment

Table 2-4 Bridge Routine Inspection Form (Example)

Date:	Contractor Name:	Contract Ref. No.:	Province:
Bridge No.:	Bridge Name:	Road No.:	Road Name:	Location:

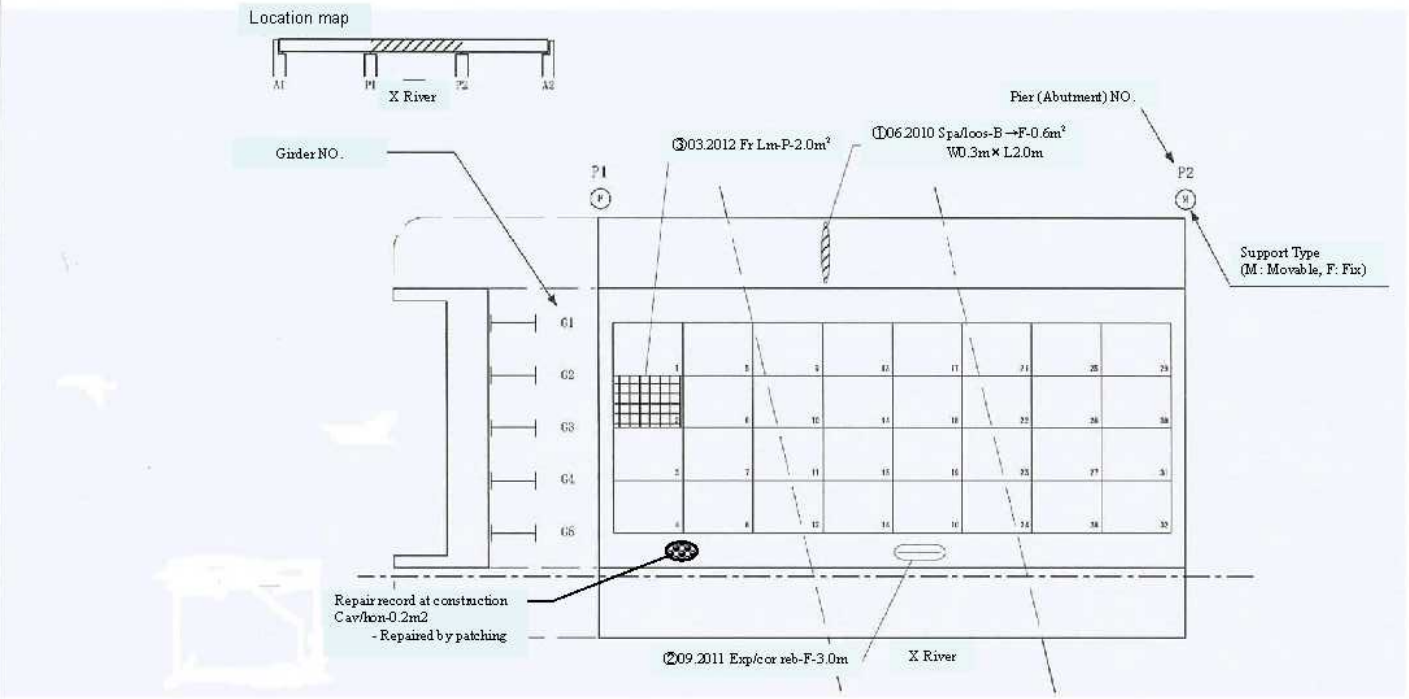
No.	(1) Bridge Component	(2) Sub-Component	(3) Defect Type	(4) Condition rating	(5) Quantity (Unit)	(6) Proposed Action	(7) New /Existing	(8) Date of Detection	(9) Remarks
1	Deck	(P1-P2)	Free lime	Poor	2.0m^2	In-depth inspection	New	07.03.2012	Free lime of large quantity observed. Cracks on pavement surface also observed in the same location. Further investigation incl. close visual inspection required. See Sketch 0-0, Photo 0-0.
2	Deck	(P1-P2)	Swelling	Poor	0.2m^2	Monitoring	Existing	At construction	Swelling of repaired part observed. Delamination of patching material suspected. See Sketch 0-0, Photo 0-0.
3	Substructure (P1)	Foundation (Cast-in-place pile)	Scouring	Bad	5.0m^3	RM Repair	New	07.03.2012	Prompt actions desirable until coming rainy season. Protection using gabions proposed. See Sketch 0-0, Photo 0-0.

Note: - To categorize (1) Bridge Component, (2) Sub-component and (3) Defect type, refer to the Table 2-3.

- To determine (4) Condition rating and (6) Proposed action, refer to the Table 2-1 and Table 2-2 with Figure 2-2, respectively.
- New/Existing means damage newly identified in this inspection/already identified in previous inspection.

Development Sketch for each span

(Superstructure)



Bridge Name	
Type of Bridge	
Span NO.	P00~P00
Span Length	00.0 m
Width	0.0 m
Crossing Condition	River/railway/road

Inspection History

Date	Inspector	Contractor
25.06.2010	aaa	bbb
10.09.2011	ccc	bbb
07.03.2012	ddd	bbb

Memorandum at Construction

Engineer:	Completion Date:	Contractor:
This is a continuous 3-span steel girder bridge. After casting deck concrete, honeycombs had been identified in the tip of cantilever deck. A part of them was chipped off to be repaired by patching method. Since there is a possibility that further defect can occur due to deterioration of concrete in future, this area should be continuously monitored in intensive manner. (D/M/Y)		

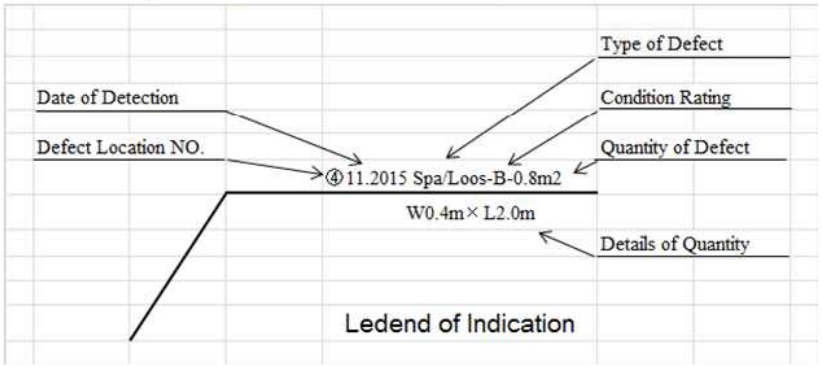
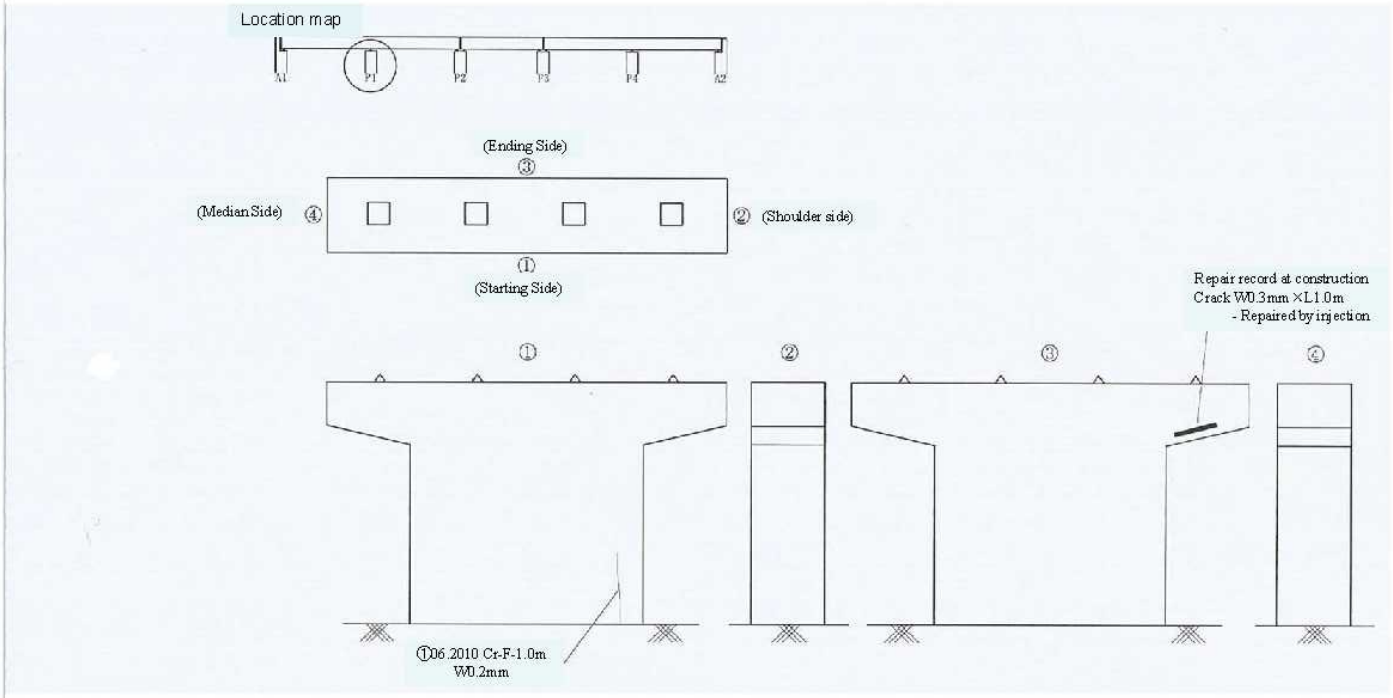


Figure 2-3 Sketch Drawing Sheet (Superstructure) (Example)

Development Sketch for each pier/abutment

(Substructure)



Bridge Name	
Type of Bridge	
Pier/Abut NO.	P00/A00
Type of Substructure	
Type of Support	
No. of Supports	

Inspection History

Date	Inspector	Contractor
25.06.2010	aaa	bbb
10.09.2011	ccc	bbb
07.03.2012	ddd	bbb

Memorandum at Construction

Engineer:	Completion Date:	Contractor:
This substructure is a wall type pier. Since crack of 0.2mm in width and 1.0m in length had been identified in a part of the concrete surface after the completion, it was treated by crack injection using polymer cement resin. (D/M/Y)		

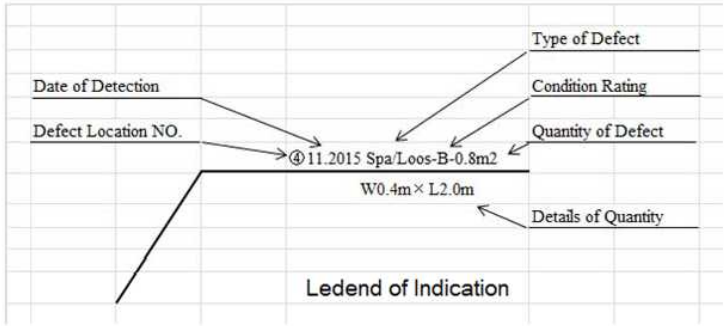


Figure 2-4 Sketch Drawing Sheet (Substructure) (Example)

Table 2-5 Photo Record Sheet

Contractor Name:		Contract Ref. No.:		Province:	

Bridge Name:		Bridge Name:		Bridge Name:		Bridge Name:	
Date:		Date:		Date:		Date:	
No.:		No.:		No.:		No.:	
Defect Type:		Defect Type:		Defect Type:		Defect Type:	
Description:		Description:		Description:		Description:	

Bridge Name:		Bridge Name:		Bridge Name:		Bridge Name:	
Date:		Date:		Date:		Date:	
No.:		No.:		No.:		No.:	
Defect Type:		Defect Type:		Defect Type:		Defect Type:	
Description:		Description:		Description:		Description:	

Table 2-6 Bridge Routine Maintenance Schedule and Record Form

Bridge No.:	Bridge Name:	Contractor Name:	Contract Ref. No.:	Province:

No.	(1) Contract Item No.	(2) Activities	(3) Description: Condition before maintenance	(4) Ref. No. of defect	(5) Estimated Cost	(6) Date: Instruction to Contractor	(7) Date: Work Completed	(8) Additional work required	(9) Remarks

Note: (4) Ref. No. of defect corresponds to No. with the inspection date in the Bridge Routine Inspection Form-e.g. No.01-26.11.2015

CHAPTER 3 ROUTINE MAINTENANCE

3-1 OBJECTIVES

The objectives of routine maintenance are to maintain the required level of traffic safety at all times, and to compensate for the effects of weather and traffic on the structures so that serious and costly damage is avoided. Durability and serviceability of the bridge should be provided through routine maintenance, fatal damages should be either prevented or postponed, recurrent defects occurring during regular service of the structure should be repaired.

3-2 ACTIVITIES

Routine maintenance consists of minor repairs that are frequently needed and can be carried out with simple tools and equipment (e.g. minor repairs on concrete, touch-up/re- painting, replacement of bitumen joints, cleaning). It also includes remedial measures in connection with aging or wear caused by climate or traffic. Routine maintenance work can be carried out directly by RDA's personnel or shall be put out to tender under multiple years' contract. This contract also comprises Emergency Works. Emergency Works include repairs of damage resulting from natural disasters, traffic accidents, etc.

The standard routine maintenance activities are listed in the Table 3-1 Routine Maintenance Activity List but by no means limited to this list. Other activity items not included are allowable as well subject to RDA's instruction or approval in order to achieve the above-mentioned original objectives of the bridge routine maintenance.

3-3 TREATMENT CATEGORIES

Routine maintenance treatments may be categorized into:

A) Preventive Maintenance –

Preventive maintenance is a planned strategy of cost-effective treatments to an existing bridge and its appurtenances that preserves the bridge, retards future deterioration, and maintains or improves the functional condition of the bridge.

B) Corrective Maintenance –

Corrective maintenance is maintenance which is carried out after failure detection and is aimed at restoring a bridge a condition in which it can perform its intended function.

3-4 PREVENTIVE MAINTENANCE

A constant program of preventive maintenance can extend the service life of bridge to ensure that the maximum value is realized from the initial capital investment. Additionally regular maintenance proves more cost effective than occasional major repair. Preventive maintenance is

defined as activities that will maintain components of the bridge and prevent development of a structural deficiency. Preventive maintenance activities can be classified into two groups: Cyclical and Condition Based activities.

1) Cyclical –

Activities performed on a pre-determined interval and aimed to preserve existing bridge element or component conditions. Bridge element or component conditions are not always directly improved as result of these activities, but deterioration is expected to be delayed. These activities include:

- Cleaning decks, seats, caps, and girders;
- Cleaning bridge drainage systems;
- Cleaning joints;
- Vegetation control and rubbish removal.

2) Condition Based –

Activities that are performed on bridge elements as needed and identified through the bridge inspection process and include:

- Touch-up/re- Painting of steel members;
- Crack repairs to concrete members;
- Erosion control.

A program of preventive maintenance is the most effective when applied to bridge elements on structures with significant remaining service life. The concept of preventive bridge maintenance is built on the understanding that a multiple relatively small repairs and activities will keep the bridge in good condition and thereby avoid the large expense of major rehabilitation or replacement.

3-5 CORRECTIVE MAINTENANCE

Despite even the most progressive preventive maintenance program, some deterioration or damage of elements will occur. To repair typical deterioration or damages, including damages from natural disasters and vehicle hitting, the corrective activities that can be performed in Routine Maintenance are as follows:

- Joint sealing;
- Patching on concrete members;
- Deck repair;
- Rail repair;
- Curb/sidewalk repair.

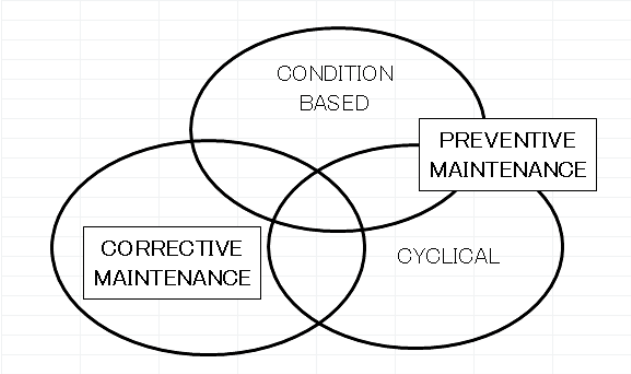


Figure 3-1 Treatment Categories

Table 3-1 Routine Maintenance Activity List

Activity No.	Activity Item	Frequency	Classification	Applied Item in Chapter 4
	(Deck)			
1-1	Clean deck and gutters	Yearly	Preventive(Cycl.)	4-1
1-2	Clean deck drains/scuppers	Yearly	Preventive(Cycl.)	4-1
1-3	Clean joint	Yearly	Preventive(Cycl.)	4-1
1-4	Joint sealing	As needed	Corrective	4-9
1-5	Deck repair – Coating on/injection/caulking into cracks	As needed	Preventive(CB.)	4-6/4-7/4-8
1-6	Deck repair – Pavement Patching	As needed	Corrective	4-2
1-7	Deck repair – Concrete Deck Patching	As needed	Corrective	4-3
1-8	Collision damage repair to railing/parapet	As needed	Corrective	4-10
1-9	Repair to damaged curb/sidewalk	As needed	Corrective	4-11
1-10	Drain extensions	As needed	Preventive(CB.)	4-12
	(Superstructure)			
2-1	Clean girders	2 years	Preventive(Cycl.)	4-1
2-2	Touch-up/re- painting on steel members	As needed	Preventive(CB.)	4-4
2-3	Coating on/injection/caulking into cracks	As needed	Preventive(CB.)	4-6/4-7/4-8
2-4	Patching on concrete members	As needed	Corrective	4-5
	(Substructure)			
3-1	Clean abutments/caps/bearings	2 years	Preventive(Cycl.)	4-1
3-2	Repairs to slope protection	As needed	Preventive(CB.)	4-15
3-3	Repair to scour protections around foundations	As needed	Preventive(CB.)	4-16
	(Site)			
4-1	Vegetation control and rubbish removal around substructures	Quarterly	Preventive(Cycl.)	4-13
4-2	Removal of debris/driftwoods from waterway	As needed	Preventive(CB.)	4-14

3-6 TYPES OF DEFECTS AND CAUSES

Routine maintenance is carried out by a contractor on the performance basis or with the instruction of RDA. Defects and its causes should be given special attention by the contractor and RDA's engineers.

Defects and its corresponding measures are listed as follows:

3-6-1 Steel Bridge Superstructure

Location	Defects	Photography	Causes/Measure
Steel Superstructure	Paint Peel-off		Pinpoint rusting can occur at pinholes in the paint, which are tiny, deep holes in the paint exposing the steel. It can also be caused by thin paint coverage. Measure: Touch-up/Re- Painting

3-6-2 Concrete Bridge Deck Slab, Superstructure and Substructure

(1) Deck Slab

Location	Defects	Photography	Causes/Measure
Concrete Deck Slab	Spalling/ Disintegration, Scaling		Initially, scaling has occurred and then spalling was caused by corrosion of rebars due to ponding water. Measure: Patching

(2) Concrete Superstructure

Location	Defects	Photography	Causes/Measure
Concrete Superstructure	Spalling/ Disintegration		As spalling is located at or near a maximum moment of girder, overstress may have occurred because girder is crushed Measure: Patching

(3) Concrete Substructure

Location	Defects	Photography	Causes/Measure
Abutment/ Pier	Spalling/ Disintegration		Rebars are exposed by spalling caused by impact due to drift woods. Measure: Patching

3-6-3 Bridge Accessories

(1) Bearing

Location	Defects	Photography	Causes/Measure
Bearing	1. Paint Deterioration and Corrosion		Surface rusting can occur at pinholes in the paint, which are tiny, deep holes in the paint, exposing the steel. It can also be caused by thin paint coverage. Measure: Re-painting
	2. Debris Piling up around Bearing		Debris and sand is piled up around bearing due to opening on expansion joint Measure: Cleaning

(2) Expansion Joint

Location	Defects	Photography	Causes/Measure
Expansion Joint	1. Deterioration Sealant		The sealant joint is usually unprotected, when the edge of the deck is damaged the sealant deteriorates and peels-off. Measure: Cleaning and Resealing

3-6-4 Protection Works

Location	Defects	Photography	Causes/Measure
Waterway/ Embankments/ Slope Protection	1. Accumulation of Debris		Drift woods, shrubs and weeds are piled up around pier due to short span, river course and shape of pier. This affects the flow of water along the channel Measure: Removal of Driftwoods
	2. Material Loss /Scouring		Stone materials are missing from stone masonry wall and gabion mattress due to strong river flow7. Measure: Stone Masonry
	3. Damage on Gabion Wire		Gabion damage is generally due to destroyed wire mesh. Measure: Partial Replacement of Gabion Wire Mesh

3-7 ROUTINE MAINTENANCE ACTIVITIES

3-7-1 Responsible Office and Personnel

RDA is responsible for bridge routine maintenance through contracting out to competent contractors. The contractor organizes a maintenance team normally composed of 2 engineers and 6~8 skilled or semi-skilled workers. It is important that they are trained to perform such bridge maintenance activities in order to maintain the required level of traffic safety and to prolong the service life of the bridges. Routine maintenance is combined with bridge inspection and

maintenance/repair works including Performance-Based items and Day Work items. Major maintenance/repair activities are as follows:

For steel superstructure:

- Pressure washing on the beams/girders;
- Touch-up/re- paint to minor defects in the paint system such as scratches and small areas of corrosion;

For concrete superstructure/substructure:

- Pressure washing on the beams/girders;
- Patching of spalled/scaled areas on the concrete;

For protection works:

- Removal of mud, sand and debris on the pier and abutment and cleaning of bearing;
- Removal of debris and driftwoods materials from water channel.

3-7-2 Equipment and Repair Materials

Maintenance activity cannot be performed without appropriate equipment/tools**.** Hence**,** it is necessary that equipment/tools, as shown in Figure 3-2, are prepared for implementation of bridge routine maintenance works.

High Pressure Water Blaster

Electric Grinder

Handy Electric Chisel

Portable Generator

Figure 3-2 Standard Equipment for Routine Maintenance

The following materials necessary for routine maintenance works should be kept readily available through competent suppliers:

- Polymer cement mortar
- Anti-corrosion paint (Tolerant epoxy primer)

3-7-3 Repair Activities

For the repair activities during routine maintenance contract, the contractor and their staff should identify defects and consequent repair works which are classified under preventive maintenance to maintain the required level of traffic safety and to prolong the service life of a bridge. In this manner, such maintenance/repairs could be implemented at the early stage of defects. The following are the concept of repair activities under routine maintenance:

(1) Steel Structure

Steel girders and trusses should be washed using high pressure water once every two years during the dry season. This is important to prevent rusting on the steel surface as steel parts where contamination accumulates corrode easily.

If rust or peeled-off paint occurs on steel surface, touch-up/re- painting with anti-corrosion paint should be immediately applied during the dry season. It is important that the touch-up/re-painting is carried out while the steel surface is still in good condition and have not yet exhibited corrosion.

Severe corrosion with section loss is often observed at steel girder ends, around the bearings. This corrosion is due to water seeping through defective deck expansion gaps. If this condition is observed, anti-corrosion paint should be partially applied at the girder ends to prevent rust from progressing.

(2) Concrete Structure

Concrete girders should be washed using high pressure water once every two years during the dry season. Accumulated contamination on surface may have a harmful effect on concrete members and their inside reinforcement.

Regarding concrete structures, responsibilities of routine maintenance are limited only to minor defects such as spalling and scaling, and not severe cracks. Such defects can be easily repaired with simple tools and materials shown in Chapter 4.

Patching is applied to small defects due to spalling and scaling. The repair works is simple and less costly; however, if accessibility to the defects is difficult, depending on the configuration of the structure and its surrounding landscape. Then, the required scaffolding should be assembled prior to the commencement of repair works. In case the defects are located in deep water or at high elevations, a bridge inspection vehicle can be used.

(3) Bridge Accessories

If the expansion joint on the bridge deck is defective, debris, sand and water pass through the gaps and eventually deposited to piers and abutments. Hence, repair or replacement of expansion joint should be carried out. Prior to this, stocked contaminants should be washed out from the gaps using

high pressure water jet. Subsequent cleaning should be performed once a year, preferably during the dry season.

(4) Protection Works

The shortness of the span, nature of river course, shape and location of piers, may cause drifting woods, shrubs and weeds to pile up at the upstream side of the pier. Removal of debris and manual cleaning is recommended.

3-7-4 Safety Management

The occurrence of accidents during operations may cause suspension or delay of work and may lead to casualty of workers. Safety measures should be considered on site during routine maintenance work not only for the workers but also for the third party such as the motoring public and nearby residents.

1) Safety Gear

Proper use of safety gear depends on individual risks of the work site.

2) Equipment and Materials

- Check machines and tools before using;
- Handle electric powered machines and hazardous materials with care under established operations procedure;
- Operate vehicle-type construction machines and mobile cranes only after confirming safety of the surrounding areas;
- Only licensed equipment/machine operator is allowed to operate;
- Stockpile materials properly at site to prevent hazard to the motoring public.

3) Temporary Facilities

- Install proper temporary facilities (e.g. scaffolding) and regularly check firmness of the facility.

4) Traffic Safety

- Install proper traffic and site safety device. (e.g. Men at Work sign, Traffic control, Site base facilities) Refer also to the Standard Specifications for Road and Bridge Works, Sep. 1998 SATCC, Series 1000: General, Section 1500: Accommodation of Traffic, 1503 Temporary Traffic-Control Facilities.

3-7-5 Routine Maintenance Cost

If the regional office/RDA manages and properly implements the routine maintenance activities, the service life of the bridge can be prolonged without spending high costs for repair and reconstruction. Routine maintenance is mainly a preventive measure. It should be undertaken at an early stage which requires only minor repair tools and materials.

CHAPTER 4 ROUTINE MAINTENANCE AND REPAIR METHOD

4-1 CLEANING/DESILTING

4-1-1 Description of Method

To prevent deterioration of the bridge structure, cleaning works should be performed including removal of all accumulated foreign materials from the entire bridge such as its deck, sidewalk, curbs, top of pier, trusses and its web members, lower flanges of beams or girders, cleaning of expansion joints, bearing, wind bracing and drains. Areas which have been cleaned shall be ensured free from accumulated sand, gravel, dirt, and other foreign materials.

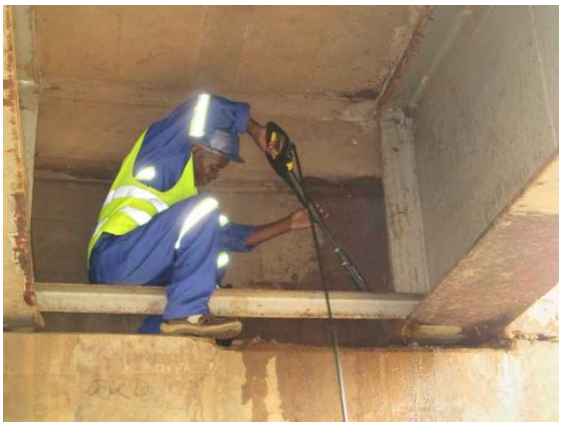


Photo 4-1 Cleaning of Bearing

Photo 4-2 Cleaning using Inspection Vehicle

4-1-2 Application Criteria

The bridge shall be maintained clean and in good condition to prolong its service life, as well as to provide safety and comfort to road users. Criteria for cleaning applied to the bridge including its superstructure, deck and substructure are recommended as follows:

(1) Surface of Superstructure

All surface areas of superstructures should be cleaned, including the undersurface of the slab, girders, and so on. High-pressure water shall be sufficient to remove dirt, dust, rust, scale, sand, and moss on the surface of the superstructure. The cleaning operation shall be discontinued if the foreign materials have not been easily removed or if cleaning operations are causing damages to existing bridge structures such as paint coating. In this situation, the high-pressure water shall be adjusted without damaging the paint coating. Bridge Inspection Vehicle (BIV) shall be utilized above crossing rivers or at a height difficult to access.

(2) Deck Slab Desilting

The deck slab should be cleaned every year, including expansion joints, drain pits, deck drain system, sidewalk, and other locations specified by the Project Manager's Representative. These shall be washed using high-pressure water blasting or manual shovelling/sweeping. The removable materials shall be collected and disposed of at an appropriate waste area in accordance with governing local regulations.

(3) Bridge Substructure

Substructures should be cleaned, including the bearings, the cap of the pier and abutment, and other locations specified by the Project Manager's Representative. These shall be executed using high-pressure water blasting or manual shovelling/sweeping. Bridge Inspection Vehicle (BIV) shall be utilized above crossing rivers or at a height difficult to access.

4-1-3 Procedures

(1) Surface of Superstructure

All foreign materials such as dirt, dust, scale, sand, and moss on steel and the concrete surface shall be completely removed manually. Steel and the concrete surface shall be cleaned by washing out chemical deposits known to accelerate corrosion and other deteriorations. Washing with high-pressure water bluster to completely remove all harmful substances is carried out from top to bottom and from end to the centre of the steel girder as shown in Figure 4-1.

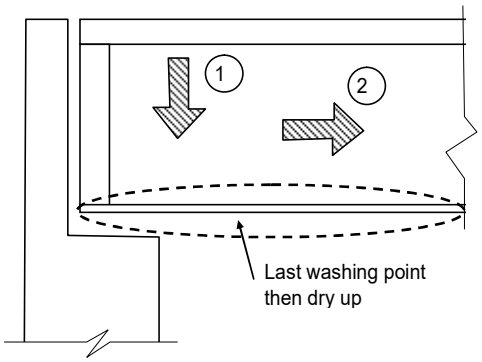


Figure 4-1 Sequence of Cleaning Girders

Photo 4-3 Cleaning of Steel Girder

(2) Deck Slab Desilting

All foreign materials such as dirt, dust, sand, rainwater and moss on concrete surfaces and at the gaps between girders shall also be completely removed manually and then washed using a high-pressure water bluster. The following areas on the deck should also be carefully cleaned:

- Expansion joints
- Drainage

Photo 4-4 Vegetation and Soil on the Girder

Photo 4-5 Joint is Clogged with Sand and dirt

Photo 4-6 Ponding Water and Mud on the Deck

Photo 4-7 Cleaning of the Deck Slab and Its Drainage Inlet

Photo 4-8 Cleaning expansion joint with high pressured water

(3) Cleaning of Bridge Substructure

All foreign materials such as dirt, dust, sand, ponding water, and moss on surfaces of the bearings, the cap of the pier and abutment, and other locations shall be completely removed manually and then washed using a high-pressure water bluster. Mud and sand deposits at the sides of the abutment shall be excavated to maintain its original distance from the river bank.

Photo 4-8 Mud, Debris & Sand on Bearing

Photo 4-9 Vegetation on the Substructure

Photo 4-9 Accumulated dirt around abutment may hamper the drainage

Photo 4-10 Nest and dropping of birds is a problem for bridge maintenance

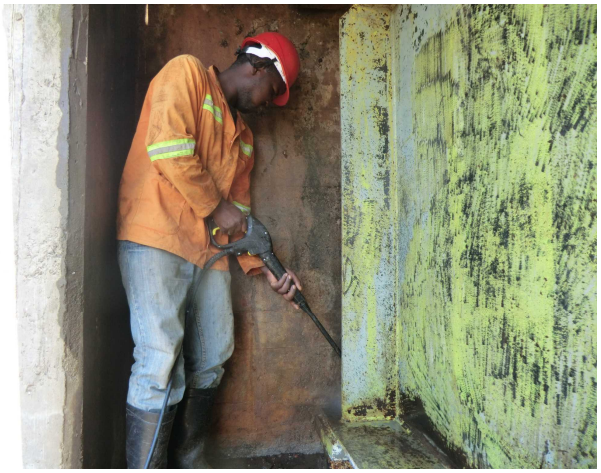


Photo 4-11 Cleaning of Bearings

4-1-4 Required Materials and Tools/Equipment

Cleaning equipment shall consist of hand tools, high-pressure water blasters, water tanks, and water pumps with associated delivery hardware necessary to properly flush, clean, and remove all foreign materials from the bridge structure. Other types of cleaning equipment may also be used subject to the approval of the Engineer. Clean water is recommended.

Other equipment such as a bridge inspection vehicle installed under the bridge, access trucks or movable scaffolding devices may be necessary to access the areas to be cleaned above the crossing river or at a height.

4-2 BITUMINOUS PAVEMENT PATCHING

4-2-1 Description of Method

Degradation of road surface conditions will not only affect ride comfort but also have a bad influence on the bridge superstructure. Therefore, it is important to identify such abnormalities immediately through sufficient inspection, to examine the real cause and to take proper actions timely. These abnormalities include cracks, loose concrete, pothole, etc. As for the repair method, patching is typically applied in routine maintenance.

4-2-2 Application Criteria

Some defects identified on the pavement surface of the bridge are caused not by the deterioration of the pavement itself but by deck damage. In this case, the superficial repair to the pavement may result in recurring defects in short intervals. Therefore, when defects are found on the pavement surface, we should investigate deck conditions simultaneously and identify the potential cause to select an effective repair method. For such deck surface defects which will remove the dense, impermeable surface layers of cement paste and reduce the cover depth to the steel, concrete patching is generally applied prior to repair to the pavement.

4-2-3 Procedures

- Remove standing water and temporary patching material from the defect or area to be levelled. The wet part should be heated to be dried with a burner.
- Shape defects so that; (a) depth provides for sufficient strength; (b) sides are vertical; (c) corners are square or slightly rounded; (d) sides have no abrupt changes in line; and (e) the hole is cut back into sound pavement.
- Clean and tack defects or areas to be levelled.
- Place premix in layers and compact each layer. When the depth of the pothole is more than 7cm, compact the mixture into two layers. The mixture should be placed only within the limits of the hole and area to be levelled.
- The surface layer should be flushed with the surrounding surface. Because it is apt to settle down, finish it higher (approx. 1cm), provided that it will not affect traffic.

・ Check cross-section, profile and drainage. Rework if needed.

Refer also to the Standard Specifications for Road and Bridge Works, Sep. 1998 SATCC, Series 4000: Asphalt Pavement and Seals, Section 4900: Treatment of Surface Defects, Patching, Repairing Edge-Breaks and Crack Sealing, 4905 Patching.

4-2-4 Required Materials and Tools/Equipment

(1) Required Materials

- Hot mix
- Emulsified Asphalt

(2) Required Tools/Equipment

- Service Vehicle or Dump Truck
- Vibratory Plate Compactor
- Road Roller (for levelling)
- Hand Tools
- Safety devices

4-3 CONCRETE DECK PATCHING

4-3-1 Description of Method

Patch repair is performed to restore small areas where sound concrete is damaged by spalling, scaling and impact. This method of repair is generally applied using a trowel and requires no or minimum formworks. The patch thickness is limited to a maximum of 100 mm depth of hollow surface.

Type A Patching is for defects without exposed rebars while Type B Patching is applied to surfaces with exposed rebars.

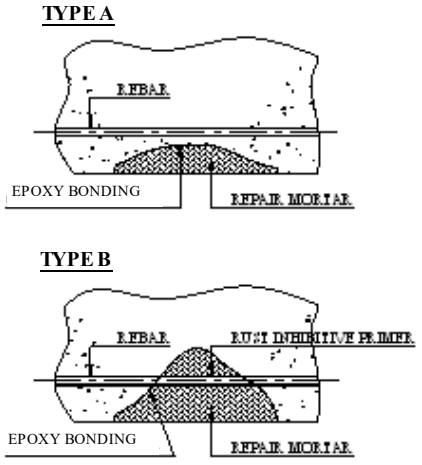


Figure 4-2 Types of Patching

4-3-2 Application Criteria

Patch repair is classified into two types as shown in Figure 4-2, considering defective area and surface. Type-A is applicable to surfaces without exposed rebars, having defective widths of up to 300 mm and depths of up to 50 mm. Type B is for surfaces with exposed rebars, with defective widths between 300 mm and 600 mm, and up to 100 mm depth. Polymer cement mortar is generally used for concrete deck patching.

4-3-3 Procedures

(1) Removal of Defective Concrete

Remove all defective, unsound and contaminated concrete and prepare the edges for the patch area. The perimeter of the area should be saw cut as shown in Figure 4-6, and the edges cut as neatly as possible keeping the sides square. If local corrosion in reinforcement with section loss is found in the Type-B case, which would require additional bars, remove the damaged area of concrete including the length needed to bond the new reinforcement as shown in Figure 4-3.

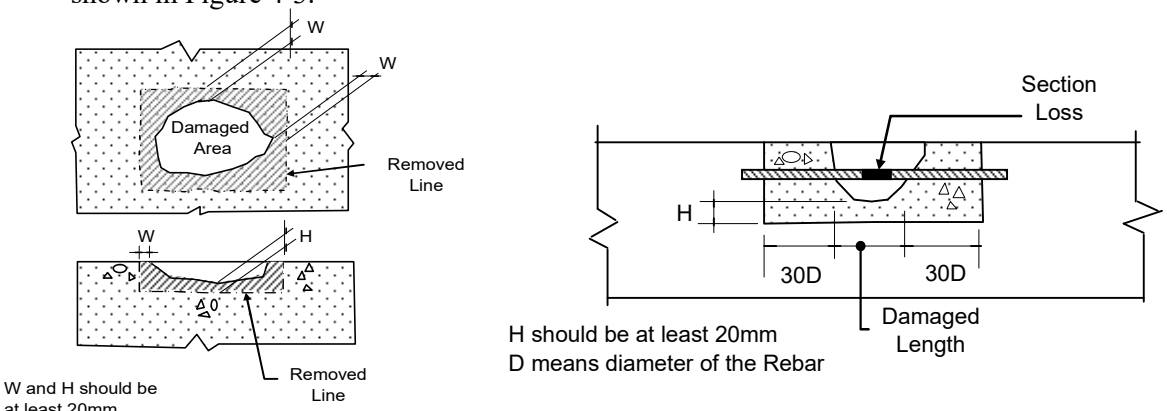


Figure 4-3 Limits of Removal of Damaged Concrete

(2) Cleaning of Surfaces of Concrete and Rebar

Remove loose particles and dust using high-pressure water or a vacuum cleaner. Concrete surfaces to be bonded have to be free from dirt, oil, grease, and asphalt. Corrosion has to be removed before placing the new concrete.

Cutting of spalled area using a grinder.

If the reinforcement is covered with loose corrosion elements and has developed pits, all the rust should be removed by power tools or wire brushing. Protection to the reinforcement can be provided by the use of zinc-rich epoxy primer.

(3) Priming Concrete

The bonding surface should be thoroughly saturated to provide a saturated surface dry condition prior to placing mortar. Epoxy bonding agents can be applied in order to bond firmly, as needed.

(4) Patching Mortar

The mortar should be placed in layers of about 20 mm thick. If the thickness exceeds 20 mm, it should be applied in two layers. Compact each layer thoroughly over the entire surface using a wooden trowel or hammer. Generally, there should be no time delays between the placing and compacting of layers.

The patching to the surrounding concrete is performed using a form material and then hammered using a mallet, wood floating or steel trowel.

Prior to patching, apply primer. Apply Poymer Cement Mortar within 30 minutes after Primer application. Mix Poymer Cement Mortar powder and emulsion.

The details are as follows;

- Hand-mix the emulsion and water for two (2) minutes.
- Put the mixed emulsion and water into the Pail and then add Poymer Cement Mortar. The mixture should be hand-mixed for two (2) minutes aswell.

(5) Curing

All types of cement repairs need thorough and continuous curing to develop strength and impermeability, and to minimize drying shrinkage while bond strength is developing. For initial curing, the surface should be covered with plastic against direct sun and wind and a waterproof coating can be applied for further protection.

Let the polymer cement mortar cure for 5 hours.

(6) Monitoring

Hammer tap inspection :

When struck with a hammer, the concrete in good condition will produce a ringing sound while the concrete that has voids, cavities etc will produce a flat or hollow sound. A good tapping waveform has a short decay time and a high-frequency distribution.

If cracks appear, it is due to the drying of the water that was mixed with Poymer Cement Mortar powder. And, if there is no delamination on the patched concrete, there is no urgent need for repair; however, if damage, such as widening of crack width, progresses in the future, repair will be required. To repair the cracked part, apply Epoxy Coating and/or Epoxy Injection to fill the grooves on the patching surface before patching with Poymer Cement Mortar.

4-3-4 Required Materials and Tools/Equipment

(1) Required Materials

- Polymer Cement Mortar Powder
- Water
- Emalusion
- Epoxy Bonding Agent to Concrete
- Zinc Rich Epoxy Primer

The polymer cement mortar shall conform to the following specification and shall meet the requirement of the SABS test method 862-2: 1994 or ASTM C1437-01. The material of polymer cement mortal powder should be permitted by the Engineer/RDA.

With the Engineer's approval, other materials are applicable. Requirements for such patching materials are similar strength, elasticity and thermal expansion coefficient to existing concrete. The manufacturer's instructions shall be strictly adhered to.

Table 4-1 Specification of Polymer Cement Mortar for Patching

Property	Test Method	Unit	Description
Compressive Strength	ASTM C39 equivalent	Mpa	More than the existing concrete design strength

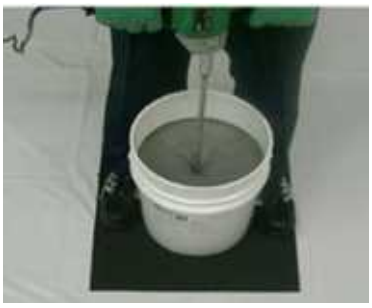
(2) Required Tools/Equipment

- Chisel
- Portable Generator
- Wire Brush
- Small Hammer
- Mortar Mix Bucket
- Safety Goggles
- Trowel
- Scaffolding or Inspection Vehicle

(3) Application of Primer

The table below shows the mixing ratios of the Poymer Cement Mortar. However, due to its fast setting property, it is advised to only prepare half a bag of Poymer Cement Mortar at a time to avoid wasting the material.

Poymer Cement Mortar		WATER	TOTAL YIELD		COVERAGE (@10mm Thickness)
POWDER	EMULSION		WEIGHT	VOLUME	
15Kg/Bag	1.65Kg	2.25～2.5Kg	18.9～19.15Kg	12Liter	1.2m^2



4-4 TOUCH-UP/REPAINTING

4-4-1 Description of Method

Work under this item shall consist of field touch-up painting on steel at localized areas. This work also includes containment, surface preparation, and collection and storage of all paint debris.

Touch-up painting is done to prevent corrosion. This work only covers painting in small areas where hand and power tool preparation is the only feasible method. Large areas, where sandblast cleaning can be justified, should be painted in individual painter's work.

4-4-2 Application Criteria

The most important function that can influence paint performance is the quality of surface preparation. For optimum service life, the surface has to be completely free of all contaminants that might impair performance and should be treated as such to assure good and permanent adhesion of the paint system. The quality of surface preparation has a direct relation with the lifetime of a system.

Even when using surface-tolerant paints it cannot be emphasized enough that better surface preparation always results in longer lifetimes.

(1) Hand tool cleaning

Loosely adhering mill scale, rust and old paint coatings may be removed from steel by hand wire brushing, scraping and chipping. However, these methods are incomplete, and always leave a layer of tightly adhering rust on the steel surface.

(2) Hand tool cleaning

Examples of mechanical tools are rotary wire brushes, sanding discs and needle guns. Power tool cleaning is in general more effective and less laborious than hand tool cleaning for the removal of loosely adhering mill scale, paint and rust. However, power tool cleaning will not remove tightly adhering rust and mill scale. Care should be taken, particularly with power wire brushes, not to polish the metal surface as this will reduce the key for the subsequent paint coating.

The table below gives the surface preparation standards used in ISO-8501-1.

Table 4-2 Surface Preparation Standards ISO-8501-1

Preparation Standards	International ISO-8501-1	Description
Power tool cleaning	St3	Similar to St2 but the surface has to appear very thoroughly treated to give a metallic sheen arising from the steel surface.
Hand tool cleaning	St2	When viewed without magnification, the surface has to be free from visible oil, grease and dirt and from poorly adhering mill scale, rust, varnish coating and foreign matter.

4-4-3 Procedures

(1) Scaffolding

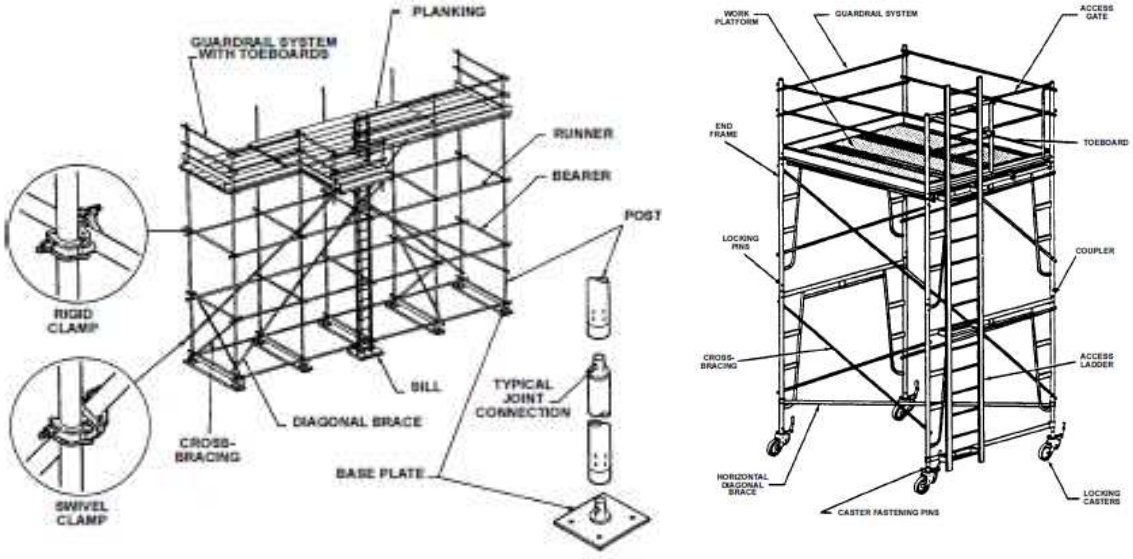
Prior to touch-up painting work, scaffolding should be installed at the side of the structure. Independent scaffolding is also appropriate for repair works. This consists of two standard types, connected longitudinally and transversely. These standard scaffoldings shown in Figure 4-5 are normally used in repair works.

Birdcage scaffolding is a stationary type built around an abutment and pier or, near a defective area. Movable scaffolding meanwhile allows movement in any direction, hence, is commonly used for repainting/touch-up painting for truss-type bridges. Inspection vehicles with scaffolding devices can also be utilized at locations where accessibility is

difficult, such as for bridges with high elevations at deep river crossings.

Figure 4-4 Touch-up Painting Utilizing Bridge Inspection Vehicle

Scaffolding can be installed at sites with topographic uneven terrain. Steel pipe scaffolding is popular. Its assembling sequences should comply with manufacturer's manual.



Birdcage Scaffolding Movable Scaffolding

Figure 4-5 Independent Scaffolding for Repair Work

(2) Surface Preparation

The steel surfaces for touch-up painting should be prepared in accordance with the recommendations from the manufacturer of the required paint system. Hand or power tool cleaning is the minimum requirement described in the 4-4-2 Application Criteria.

Sharp ridges and deep narrow grooves or pits shall be removed from the steel surface using a power grinder. Alternatively, for surfaces with site fillet welds, fill the surface to a smooth even finish using epoxy resin fillers. However, where the depth of roughness is less than 0.5mm, an adequate and durable paint system can be achieved without multiple coats of surface levelling paint. Each coat shall not be more than the maximum film thickness recommended by the manufacturer.

(3) Touch-up/Re- Painting

Paint shall be applied using a brush or roller. The paint shall be applied to produce a uniform smooth coat without runs, streaks, sags, wrinkles, or other defects. Surface-tolerant epoxy coating shall be used for the primer material and polyurethane coating shall be used for the topcoat material. The material of the painting should be permitted by the Engineer. The paint components shall be mixed properly and applied in accordance with the manufacturer's instructions. The paint shall be applied immediately after surface preparation, preferably within 4 hours on the same day. Top coating shall be started after a certain interval specified in the manufacturer's manuals.

The painting procedure shall comply with general conditions 5903 - 5097 of SATCC standard or equivalent.

4-4-4 Required Materials and Tools/Equipment

(1) Required Materials

- Surface Tolerant Epoxy Coating (Standard Dry-film Thickness (DFT): 120 μ m)
- Polyurethane Coating (Standard Dry-film Thickness (DFT): 50 μ m)
- Thinner

(2) Required Tools/Equipment

- Power Disk Grinder (Portable type)/Wire brush/Sand Paper
- High-Pressure Water Blaster (8.0Mpa, 10.0 litre/min.)
- Portable Generator (3.0 kVA)
- Paint Roller (Handy type) and Brush
- Scaffolding or Inspection Vehicle

4-5 CONCRETE PATCHING

4-5-1 Description of Method

Patch repair is performed to restore small areas where sound concrete is damaged by spalling, scaling and impact. This method of repair is generally applied using a trowel and requires no or minimum formworks. The patch thickness is limited to a maximum of 100 mm depth of hollow surface.

Type A Patching is for defects without exposed rebars while Type B Patching is applied to surfaces with exposed rebars.

For patch repairs, portland cement mortar, non-shrinkage cement mortar, fibre-reinforced mortar, etc. may be used, depending on the type of patching, location and extent of the damage.

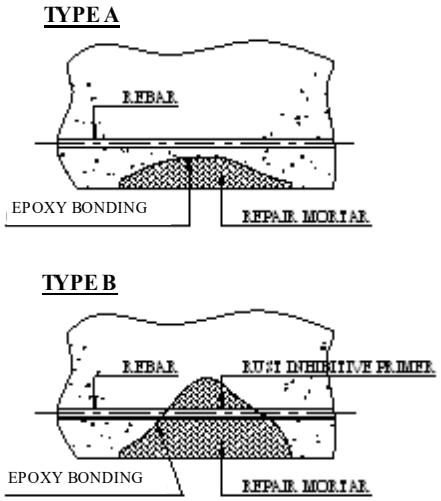


Figure 4-6 Types of Patching

4-5-2 Application Criteria

Patch repair is classified into two types as shown in Figure 4-6, considering defective area and surface. Type-A is applicable to surfaces without exposed rebars, having defective widths of up to 300 mm and depths of up to 50 mm. Type-B is for surfaces with exposed rebars, with defective widths between 300 mm and 600 mm, and up to 100 mm depth.

4-5-3 Procedures

(1) Removal of Defective Concrete

Remove all defective, unsound and contaminated concrete and prepare the edges for the patch area. The perimeter of the area should be saw cut as shown in Figure 4-10, and the edges cut as neatly as possible keeping the sides square. If local corrosion in reinforcement with section loss is found in the Type-B case, which would require additional bars, remove the damaged area of concrete including the length needed to bond the new reinforcement as shown in Figure 4-7.

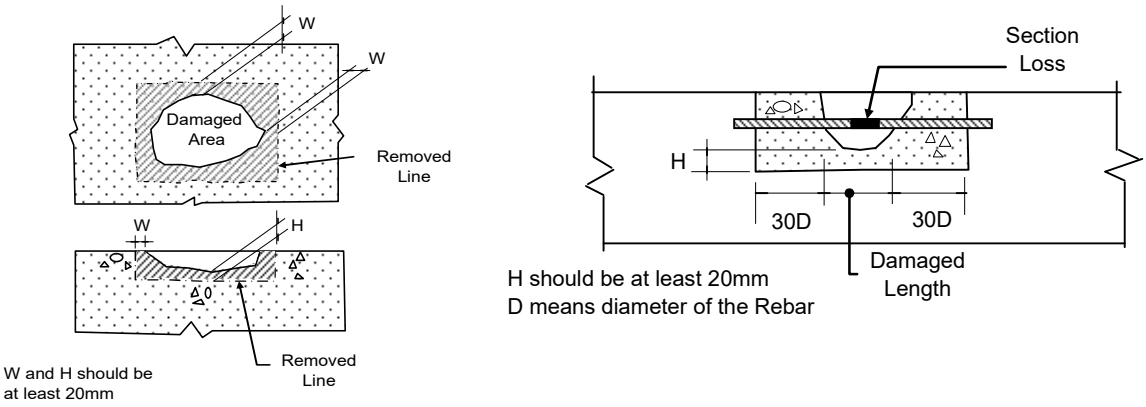


Figure 4-7 Limits of Removal of Damaged Concrete

(2) Cleaning of Surfaces of Concrete and Rebar

Remove loose particles and dust using high-pressure water or a vacuum cleaner. Concrete surfaces to be bonded have to be free from dirt, oil, grease, and asphalt. Corrosion has to be removed before placing the new concrete. If the reinforcement is covered with loose corrosion elements and has developed pits, all the rust should be removed by power tools or wire brushing. Protection to the reinforcement can be provided by the use of zinc-rich epoxy primer.

(3) Paching Mortar

The mortar should be placed in layers of about 20 mm thick. If the thickness exceeds 20 mm, it should be applied in two layers. Compact each layer thoroughly over the entire surface using a wooden trowel or hammer. Generally, there should be no time delays between the placing and compacting of layers.

The patching to the surrounding concrete is performed using a form material and then hammered using a mallet, wood floating or steel trowel.

Prior to patching, apply primer. Apply Poymer Cement Mortar within 30 minutes after Primer application. Mix Poymer Cement Mortar powder and emulsion.

The details are as follows;

- Hand-mix the emulsion and water for two (2) minutes.
- Put the mixed emulsion and water into the Pail and then add Poymer Cement Mortar. The mixture should be hand-mixed for two (2) minutes aswell.

(4) Curing

All types of cement repairs need thorough and continuous curing to develop strength and impermeability, and to minimize drying shrinkage while bond strength is developing. For initial curing, the surface should be covered with plastic against direct sun and wind and a waterproof coating can be applied for further protection.

Let the polymer cement mortar cure for 5 hours.

(5) Monitoring

Hammer tap inspection :

When struck with a hammer, the concrete in good condition will produce a ringing sound while the concrete that has voids, cavities etc will produce a flat or hollow sound. A good tapping waveform has a short decay time and a high-frequency distribution.

If cracks appear, it is due to the drying of the water that was mixed with Poymer Cement Mortar powder. And, if there is no delamination on the patched concrete, there is no urgent need for repair; however, if damage, such as widening of crack width, progresses in the future, repair will be required. To repair the cracked part, apply Epoxy Coating and/or Epoxy Injection to fill the grooves on the patching surface before patching with Poymer Cement Mortar.

4-5-4 Required Materials and Tools/Equipment

(1) Required Materials

- Polymer Cement Mortar Powder
- Water
- Emalusion
- Epoxy Bonding Agent to Concrete
- Zinc Rich Epoxy Primer

The polymer cement mortar shall conform to the following specification and shall meet the requirement of the SABS test method 862-2: 1994 or ASTM C1437-01. The material of polymer cement mortal powder should be permitted by the Engineer/RDA.

With the Engineer's approval, other materials are applicable. Requirements for such patching materials are similar strength, elasticity and thermal expansion coefficient to existing concrete.

The manufacturer's instructions shall be strictly adhered to.

Table 4-3 Specification of Polymer Cement Mortar for Patching

Property	Test Method	Unit	Description
Compressive Strength	ASTM C39 equivalent	Mpa	More than the existing concrete design strength

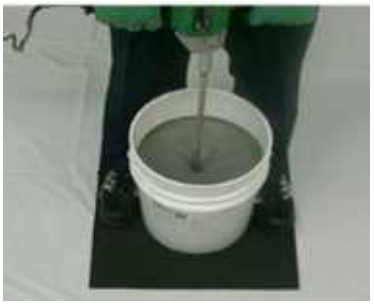
(2) Required Tools/Equipment

- Chisel
- Portable Generator
- Wire Brush
- Small Hammer
- Mortar Mix Bucket
- Safety Goggles
- Trowel
- Scaffolding or Inspection Vehicle

(3) Application of Primer

The table below shows the mixing ratios of the Poymer Cement Mortar. However, due to its fast setting property, it is advised to only prepare half a bag of Poymer Cement Mortar at a time to avoid wasting the material.

Poymer Cement Mortar		WATER	TOTAL YIELD		COVERAGE (@10mm Thickness)
POWDER	EMULSION		WEIGHT	VOLUME	
15Kg/Bag	1.65Kg	2.25～2.5Kg	18.9～19.15Kg	12Liter	1.2m^2



4-6 COATING

4-6-1 Description of Method

This work item is applicable to the repair of vertical or overhead cracks, with widths of less than 0.3mm.

The selection of a coating system should be according to the exposure conditions and the requirements in terms of aesthetics and durability, etc, which is generally divided into two types: cement-based coating and organic coating; elasticity and adhesiveness are important properties.

It should be noted that coating is not a repair method, but a protective or preventive application to prolong the bridge service life. The coating, applied using a roller brush, should be capable of penetrating overhead, downward and vertically. This measure is one of the most appropriate routine maintenance activities.

4-6-2 Application Criteria

Cracks with widths of less than 0.3mm, are acceptable if the cause is non-structural, and has no adverse effect on the structure. However, it is difficult during routine maintenance to evaluate whether the crack is stable or developing due to such factors as carbonation, chlorination, corrosion, overloading of structure, insufficient reinforcement or inadequate concrete cover.

As a protective or preventive measure, the coating should be applied on surfaces of concrete structures, with cracks of less than 0.3mm width, regardless if crack formation is structural or non-structural. Subsequently, the cracks should be regularly monitored for future repair, if necessary.

4-6-3 Procedures

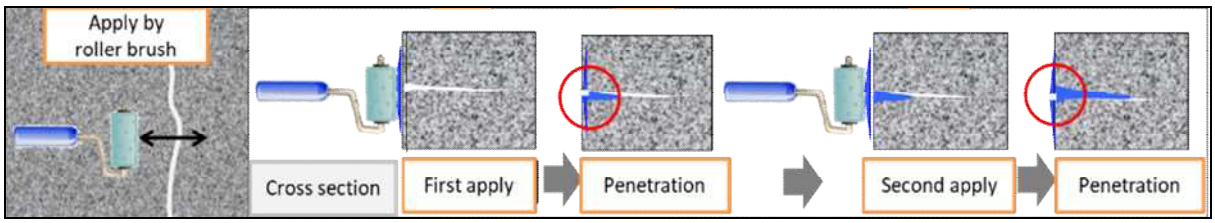
(1) Preparation of Concrete Surface

The concrete surface shall be cleared from dust, loose dirt and other foreign materials using a steel brush and vacuum/blower.

(2) Application of Epoxy Sealant

Using a 5 cm (2 inches) wide roller brush, apply the sealant to concrete cracks. If the cracks are straight, a wider roller may be used. The Epoxy Sealant starts to rise from the cracked surface right after application but eventually moves inside the crack. The speed of penetration varies depending on the crack situation.

Repeat this application about 10 times within 30 minutes. The pot life of the sealant is 30 minutes (if the temperature is at 30 °C).



(3) Curing

Let the Epoxy Sealant cure overnight (about 12 hours).

(4) Monitoring

The Crack shall be covered by Epoxy sealant completely or not.

Hammer tap inspection :

If the sealant has not penetrated the crack in the concrete, it is recommended that you apply it 7 to 10 times with a roller, and then fill the cracked groove with a spatula when it begins to harden in about 60 minutes. It appears to have penetrated immediately after about ten applications, but it requires several more applications to fill the crack groove.

4-6-4 Required Materials and Tools/Equipment

(1) Required Materials

- Epoxy Sealant
  The epoxy material shall conform to the requirements of the specifications in Table 4-4 and Table 4-5.

Table 4-4 Specification of Epoxy Sealant for Coating (1/2)

Property	Test Method	Unit	Specification
Viscosity	JIS K 6833/ASTMD2393	mPa-s*	500 below
Bond Strength to Concrete Dry / Wet	JIS K5400/ASTM D7234	N/mm^2	1.5
Slant Shear Bond Strength	JIS K6852/ASTM C882	N/mm^2	15

The material shall be approved by the Engineer through mill certificate of the supplier.;
*** milliPascal-second**

Table 4-5 Specification of Epoxy Sealant for Coating (2/2)

PROPERTY	Test Method	CURE CONDITION	UNIT	TYPICAL VALUE
Compressive Strength	JIS K 7208/ASTM D695M	23°C X 28 days	N/mm^2	30
Flexural Strength	JIS K 7203/ASTM D790M	23°C X 28 days	N/mm^2	25
Tensile Strength	JIS K 7113/ASTM D790M	23°C X 28 days	N/mm^2	25

Legend : COF – Cohesive Failure of Epoxy

(2) Required Tools/Equipment

- Brush or Paint Roller

(3) Mixing

- The Hardener and Base Resin should be mixed two (2) minutes by brush or spatula until a uniform mixture is obtained.
- The mixed resin system should be followed specification of pot life as Table 4-6.
- If the ambient temperature is increasing, the pot life becomes shorter.

Mixing

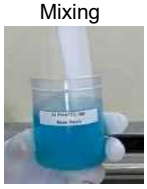


Table 4-6 Specification of pot life

Single Color		Base Resin (Light Yellow)	Hardener (Blue)
Mixture Color		Light Blue	
Mix Ratio	By Volume	2	1
	By Weight	100	43
Pot life	30 minutes (Temperature 30℃) 20 minutes (Temperature 40℃)		

4-7 EPOXY INJECTION

4-7-1 Description of Method

This method involves crack repairs to concrete structures, particularly to deck slabs as shown in Figure 4-8. The works include the preparation of the concrete surface, insertion of pipe fittings bonded with adhesive, injection of epoxy, curing and conducting performance tests. Epoxy injection for concrete cracks requires a highly skilled process and its effectiveness depends mostly on the proficiency of the certified applicator. The said person should be qualified based on his previous work records, and approved by the Engineer.

Materials and injection tools developed by the supplier or manufacturer shall be in conformity with ASTM standards or equivalent.

(After Injection)

Figure 4-8 Crack Injection Method

4-7-2 Application Criteria

Epoxy injection is used to restore the structural soundness of structures exhibiting inactive cracks. Cracks with more than 0.3 mm up to 3.0 mm widths can be bonded and sealed by injecting low-viscosity epoxy.

4-7-3 Procedures

(1) Cleaning of Cracks

All loose debris such as dirt, concrete fine particles and contaminants (oil, grease, etc.) should be removed from the cracks using high-pressure water, or a special and effective solvent. Remove the residual water or solvent in the crack with filtered (dust and oil-free) compressed air and allow adequate time for drying.

(2) Bonding of Injection entry ports

Apply a lot of putty to the inside of the entry port with a spatula. At this time, be careful not to put the putty in the hole in the centre of the entry port.

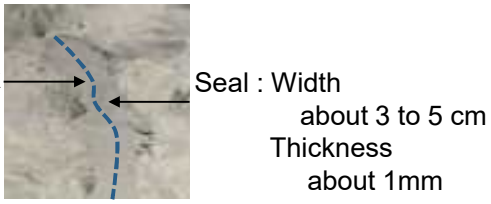
Installation of injection entry ports is at intervals of between 250mm – 300mm. Press entry ports until the putty sticks out.

Stick out putty from the entry port, and place it around the entry port using your finger.

Let the epoxy putty cure prior to injection work. It takes 4 hours to cure the seal and entry port.

(3) Sealing of Cracks at the Surface

Using about 3 to 5 cm width strap, epoxy sealant is applied to the area around the injection entry ports fitting and cracks, allowing it to harden.



(4) Injection of Epoxy

Epoxy shall be injected using Cylinders as shown below. Duration of the injection operation shall be in accordance with the supplier's instruction.

Prepare the Epoxy Resin and fill all cylinders that will be used within 15 minutes. Use the next 15 minutes to place all the cylinders on the entry ports to commence the

injection of epoxy. The total application time for epoxy injection at a temperature of 30°C is 30 minutes.

Figure 4-9 Crack Injection Method

(5) Curing

Set all of the cylinders to the entry ports after filling them with the Epoxy Resin, and then fasten rubbers to the cylinders to apply low pressure. If the crack is vertical, commence the setting of cylinders at the lowest entry port fitting to the topmost port. For a horizontal crack, the placing of cylinders onto the ports is done from one end of the crack to another. Continue the injection until there is no more epoxy discharged from the cylinders.

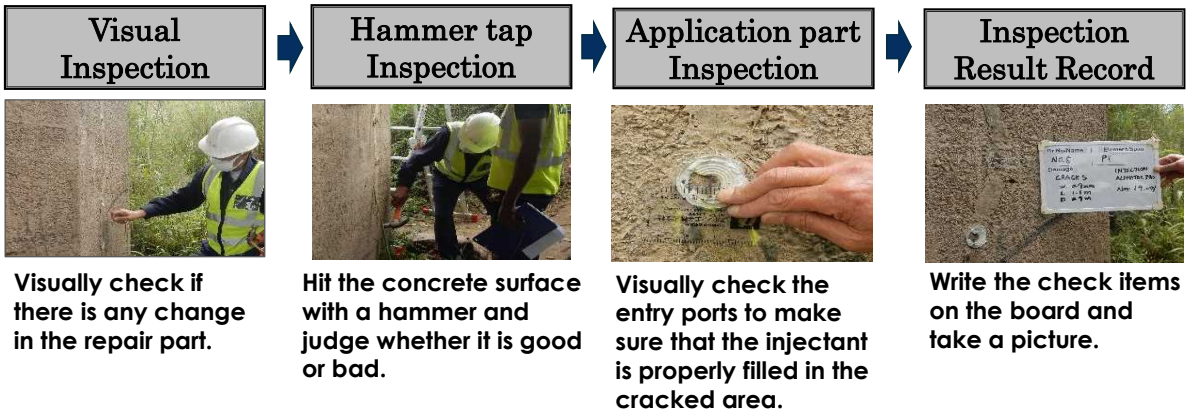
Let the Epoxy Resin cure overnight (about 12 hours), prior to the removal of the cylinders and entry ports. Any damaged areas shall be made good to the satisfaction of the Engineer.

If it leaks 1 to 2 minutes after injection, remove the cylinder and inject again.

(6) Monitor of leakage of Epoxy Resin

The cracks sealed by the epoxy resin shall be monitored to identify whether there is a leakage from sealing or not after 3month. The length, width, and depth of the cracks should be confirmed based on consumed volume of epoxy resin.

For instance, if the Epoxy injection volume is approximately 0.7 L, the size of crack is 0.7 mm wide, 110 cm long, and 90 cm deep (0.007x0.9x1.1=0.006390.7L).



4-7-4 Required Materials and Tools/Equipment

(1) Required Materials

- Epoxy Resin

The epoxy resin shall be compatible with the host concrete and shall have the properties shown in Table 4-7.

Testing of said properties shall be in accordance with the relevant standards shown in * milliPascal-second

Table 4-8, or equivalent ASTM Specifications.

Table 4-7 Specifications of Epoxy Resin for Injection to Deck Slab (1/2)

Property	Test Method	Unit	Specification
Viscosity	JIS K 6833/ASTM D2393	mPa-s*	≤ 1000
Pot life	-	minute	60
* milliPascal-second			

Table 4-8 Specifications of Epoxy Resin for Injection to Deck Slab (2/2)

Property	Test Method	Unit	Specification
Specific Gravity	JIS K 7112/ASTM D792	-	1.15 ± 0.10
Compressive Strength	JIS K 7208/ASTM D695	N/mm^2	≥ 50
Modulus of Elasticity	JIS K 7208/ASTM D695M	N/mm^2	≥ 1000
Flexural Strength	JIS K 7203/ASTM D790M	N/mm^2	≥ 40
Tensile Shear Bond Strength	JIS K 6850/ASTM D1002	N/mm^2	≥ 10
Bond Strength to Concrete Dry / Wet	JIS K5400/ASTM D7234	N/mm^2	≥ 1.5 CF

The material shall be approved by the Engineer through mill certificate of the supplier.
CF – Concrete Failure

- Sealant (Epoxy Putty)

The epoxy-based sealant material shall be compatible with the injection material and shall have the properties listed in Table 4-9 below. Testing of materials shall be in accordance with the listed standards or equivalent ASTM Specifications.

Table 4-9 Specifications of Sealant (Putty) for Epoxy Injection to Deck Slab

Property	Test Method	Unit	Specification
Specific Gravity	**JIS K 7112/ASTM D792**	**-**	**1.50±0.30**
Compressive Strength	**JIS K 7208/ASTM D695M**	**N/mm^2**	**≥ 50**
Flexural Strength	**JIS K 7203/ASTM D790M**	**N/mm^2**	**≥ 15**
Tensile Shear Bond Strength	**JIS K 6850/ASTM D1002**	**N/mm^2**	**≥ 10**
Bond Strength to Concrete (Dry/Wet)	**JIS K 5400/ASTM D 7234**	**N/mm^2**	**≥ 1.5 CF**

The material shall be approved by the Engineer through mill certificate of the supplier.
CF – Concrete Failure

(2) Required Tools/Equipment

- Cylinders and ports
- Rubber bands
- Brush etc.

(3) Mixing

(3)-1 Epoxy Putty

The Hardener and Base Resin should be mixed two (2) minutes by hand or spatula until a uniform mixture is obtained. The mix of putty material should be followed specification of pot life as Table 4-10

Table 4-10 Specification of pot life

Single Color		UNDERWATER EPOXY PUTTY	
		Base Resin (White)	Hardener (Black)
Mixture Color		Grey	
Mix Ratio	By Volume	1	1
	By Weight	1	1
Pot life	10 minutes (Temperature 30℃)		
	5 minutes (Temperature 40℃)		

(3)-2 Epoxy Resin

The Hardener and Base Resin should be mixed two (2) minutes by hand or spatula until a uniform mixture is obtained. The mix of putty material should be followed specification of pot life as Table 4-11

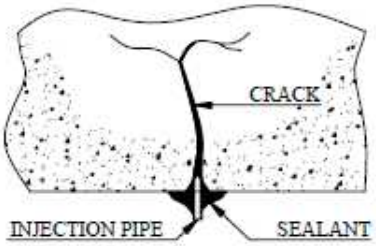
Table 4-11 Specification of pot life

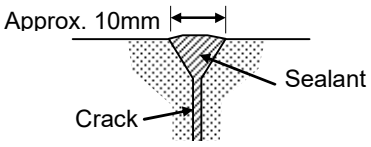
Single Color		Base Resin (transparent)	Hardener (Amber)
Mixture Color		Light Yellow	
Mix Ratio	By Volume	2	1
	By Weight	100	54
Pot life	30 minutes (Temperature 30℃) 20 minutes (Temperature 40℃)		

4-8 CAULKING

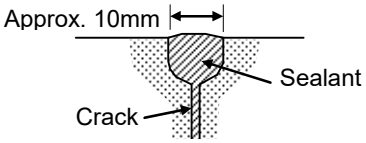
4-8-1 Description of Method

Active cracks are treated as moving joints and repaired with flexible sealants as shown in Figure 4-10. The sealant is generally installed in a wide recess cut along the crack. The dimensions of the recess (width and depth) depend on the total crack movement and the cyclic movement capability of the joint sealant used. For the selection of sealant material, crack movement should be calculated taking into account the applied loads, shrinkage and temperature variations.





(V-Type)



(U-Type)

Figure 4-10 Type of Caulking

4-8-2 Application Criteria

Crack widths should be more than 3.0 mm. The top surface edges should be chipped or sawn to form V-type or U-type groove to be filled with sealant using a caulking gun.

4-8-3 Procedures

(1) Cleaning of Cracks

Remove all loose debris such as dirt, concrete fine particles and contaminants (oil, grease, etc.) from the cracks using high-pressure water, or a special and effective solvent. Remove the residual water or solvent in the crack with filtered (dust and oil-free) compressed air and allow

adequate time for drying.

(2) Preparation of Caulking

Using a concrete saw, hand tools or pneumatic tools, a V-groove or U-groove of approximately 10 mm in width and depth is prepared at the surface along the crack.

(3) Application

Apply the sealant into the groove using a caulking gun to ensure a smooth continuous flow. The sealant should be tooled to a smooth finish using a spatula.

(4) Curing

After application, care until the sealant hardens. If surface coating will be applied, the extra portion should be ground to form a smooth surface.

4-8-4 Required Materials and Tools/Equipment

(1) Required Materials

- Epoxy Grout
- Sealant (or Flexible Epoxy Resin, Polymer Cement Mortar)

(2) Required Tools/Equipment

- Caulking Gun
- Power Disc Grinder/Cutter
- Portable Generator
- Brush

4-9 JOINT SEALING

4-9-1 Description of Method

The quality and maintenance of the expansion joints are vital to the behaviour of the bridges and their durability. Accordingly, it should be ensured that expansion joints are waterproofed as well as resistant to leakage. In the case of sealant asphalt, the sealant is easily damaged due to traffic load and ageing.

The need for repairs to this joint usually results from the sealant material coming loose and falling out of the joint or the joint becoming tight from filling with incompressible materials which enter through a broken seal at the top.

Before Repair

After Repair

4-9-2 Application Criteria

A loose or open joint may sometimes be left open without any harmful effects. However, this depends on the location of the joint in relation to the substructures and any crossing underneath.

4-9-3 Procedures

To repair a defective joint it should first be cleaned of all dirt, refuse, and existing sealant. Caulk joint gaps with backup material and seal joints using a sealant.

All work of joint sealing shall adhere to the Standard Specifications for Road and Bridge Works, Sep. 1998 SATCC, Series 6000: Structures, Section 6600: No-fines Concrete, Joints, Bearings, Parapets and Drainage for Structures, 6603 Joints in Structures.

4-9-4 Required Materials and Tools/Equipment

Required Materials

- Backup Material
- Sealant

4-10 REPAIR TO RAILING/PARAPET

4-10-1 Description of Method

Railings include any barrier or parapet that runs parallel with the traffic on either side of the bridge.

4-10-2 Application Criteria

Repair collision damage to the railing as soon as possible. In particular, avoid leaving the end of a bridge rail or a parapet wall exposed to the traffic flow. When damage is extensive, temporary installation of signs, lights, barricades or other safety/warning devices may be required.

(1) Concrete Railings/Parapet

Like concrete decks, concrete railings/parapets are susceptible to cracks and spalls from ageing and deterioration as well as collision damage. Sealing cracks and applying surface coating as is done to the deck is helpful in minimizing needed maintenance. While such a repair method as concrete patching is applicable to slight collision damage, major collision damage to a section of railing may make complete replacement of the entire run of railing more cost-effective than repair.

(2) Metal Railing

Metal railings are susceptible to collision damage, loose anchor bolts and connections, and corrosion damage. Repair typically consists of straightening any collision-damaged components for which replacement is not deemed necessary; tightening all loose anchor bolts and connections; painting any corrode areas with zinc-rich paint; replacing any railing components for which corrosion has significantly reduced the structural cross-section.

Refer also to the Standard Specifications for Road and Bridge Works, Sep. 1998 SATCC, Series 6000: Structures, Section 6600: No-fines Concrete, Joints, Bearings, Parapets and Drainage for Structures, 6605 Parapets, Railings and Sidewalks.

4-10-3 Procedures

(1) Concrete Railings/Parapet

- Verify all dimensions and elevations in the field prior to ordering or building forms.
- Retain existing reinforcement to be utilized in new construction to provide the maximum lap possible. Thoroughly clean existing reinforcement of concrete scale and rust before bonding into new construction.
- Apply epoxy resin adhesive to all hardened concrete surfaces just before pouring the concrete.

(2) Metal Railing

- Remove the existing rail system.
- Drill holes in concrete slab concrete anchors and bolts.
- Bolt posts to concrete with bolts.
- Bolt W-beam guardrails to pipe using bolts, nuts and washers.

Refer also to the Standard Specifications for Road and Bridge Works, Sep. 1998 SATCC, Series 6000: Structures, Section 6600: No-fines Concrete, Joints, Bearings, Parapets and Drainage for

Structures, 6605 Parapets, Railings and Sidewalks.

4-10-4 Required Materials and Tools/Equipment

(1) Required Materials

(Concrete Railings/Parapet)
- Concrete
- Reinforcing steel
- Epoxy Resin Adhesive

(Metal Railing)
- Replacement Rail Elements
- Concrete
- Anchor Bolts

(2) Required Tools/Equipment

- Hammer and Chisel
- Concrete Drill

4-11 REPAIR TO CURB/SIDEWALK

4-11-1 Description of Method

Problems with concrete curbs include spalling at expansion joints, cracking, and deterioration from corrosion of reinforcing steel or anchor bolts.

Since sidewalks facilitate the safe movement of pedestrians over a bridge, the surface needs to be maintained so that people do not encounter any surface hazards.

4-11-2 Application Criteria

(1) Curb

Spalling is often associated with expansion joint movement, so in the repair process, additional clearance for longitudinal movement should be provided. Where reinforcing steel and anchor bolts are encountered in curb repair, if the corrosion has caused the bar or bolt cross-section to be reduced, they should be replaced with new bars or bolts in the concrete repair process. The work area may also include the slab directly underneath and adjacent to the curbs when minor repairs have to be made to the slab to accomplish this activity.

(2) Sidewalk

In concrete sidewalks, cracks should be sealed and spalls or potholes need to be filled. To repair such defects, concrete patching and crack repairs as described in this chapter are also applicable with considering the extent and severity of the defects/damages. In precast slab sidewalks, dislocated or broken slab is frequently observed. When such defects are observed, the defective slab needs to be replaced as soon as practicable.

4-11-3 Procedures

The actual procedure should be changed depending on the structural type of each component. For concrete patching and crack repairs of the sidewalk, refer to the related items in this chapter.

- Remove existing deteriorated sections of the curb or sidewalk to sound concrete.
- Place replacement reinforcing bars of anchor bolts by tying them into reinforcing in sound concrete.
- Place forms for concrete. For precast curb stone, bed mortar is applied to the level deck in the installation location.
- Place and cure concrete.

Refer also to the Standard Specifications for Road and Bridge Works, Sep. 1998 SATCC, Series 6000: Structures, Section 6600: No-fines Concrete, Joints, Bearings, Parapets and Drainage for Structures, 6605 Parapets, Railings and Sidewalks.

4-11-4 Required Materials and Tools/Equipment

(1) Required Materials

- Concrete
- Reinforcing steel and Anchor bolt

(2) Required Tools/Equipment

- Air compressor with Hammer
- Welding Equipment

4-12 DRAIN EXTENSION

4-12-1 Description of Method

This operation is performed to carry water discharge of drains away from supporting structure members. Many bridges were built with short deck drains at the gutter line that barely go through the deck. Most of these drains are located close to the girders. Exposure to moisture causes a fast rate of girder deterioration at these locations for both steel and concrete bridges. If clearance to the roadway is not critical, the drain pipe should be extended at least 20cm from the bottom of the girder flange.

Photo 4-13 Deterioration at drain locations

Photo 4-14 Corrosion occurred under the outlet of a drain pipe

Photo 4-15 Deterioration at drain locations

4-12-2 Application Criteria

Bridge maintenance inspectors should become aware of such situations which could be improved by installing drain extensions and recommend these improvements with the appropriate installation procedures.

4-12-3 Procedures

Installation procedure for extending the bridge drain depends on girder type: steel or concrete, and whether or not the existing drain protrudes below the concrete deck. Welding, bolting and bracketing with anchorage are possible installation procedures.

Example of installation of Drain Pipe

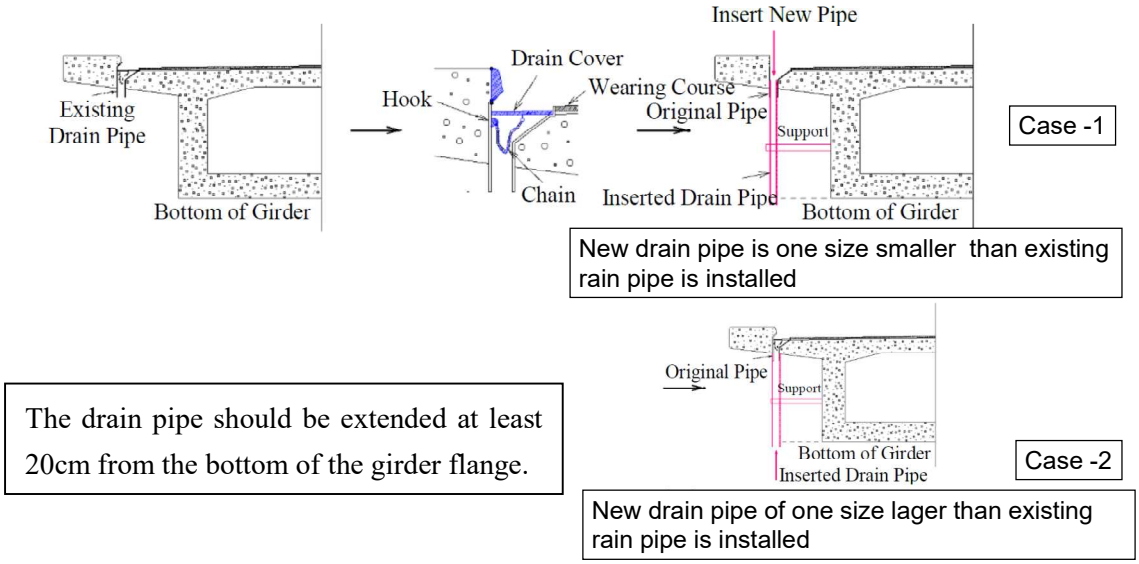


Figure 4-12 Example of installation of Drain Pipes

4-12-4 Required Materials and Tools/Equipment

(1) Required Materials

- Bolts, nuts and washers
- Bolt anchorages and angle brackets
- Paint

(2) Required Tools/Equipment

- Welding equipment
- Drill
- Paint brushes

4-13 VEGETATION CONTROL AND RUBBISH REMOVAL

4-13-1 Description of Method

This operation is performed to cut vegetation and remove rubbish from around substructures and approaches. The purpose of this activity is not only to improve the ambient environment for bridge structures but also to conduct inspection activities efficiently.

Photo 4-16 Tree Hanging Over the Girder

4-13-2 Application Criteria

Vegetation control and rubbish removal should be regularly at a fixed interval, not only from a structural preservation viewpoint but also from one of public perception. Vegetation and rubbish which is growing or has been collected shall be removed and disposed of as specified or as directed by the Engineer. Care should be also paid so as not to cause habitat loss, erosion, and sedimentation.

4-13-3 Procedures

The work includes, but is not limited to, cutting down and removing growing vegetation; removing debris collected around substructures manually and/or by machinery; loading material in a truck; and disposing of material at an approved dumping location.

Grass shall be cut 20 cm or less in height. Shrubs and trees shall be cut to ground level and where there is a need to uproot shrubs, done with the approval of the Engineer. The application of herbicide to kill the tree's root system should be approved by the Engineer.

Figure 4-12 Removal of Grass and Shrubs near the Bridge

4-13-4 Required Materials and Tools/Equipment

(1) Required Materials

None

(2) Required Tools/Equipment

- Electric Saw
- Bush Ax
- Dump Truck
- Back Hoe

4-14 REMOVAL OF DEBRIS AND DRIFTWOODS

4-14-1 Description of Method

The works involve the removal of debris and driftwoods from the river channel and overbank area and disposal to a designated area. This operation is performed to prevent scour and erosion of fills under abutments and piers. Excess deposited material reduces the hydraulic efficiency of the waterway and places an excessive lateral load on the whole structure.

Photo 4-17 Accumulated Drift Wood and Plants around Pier

4-14-2 Application Criteria

It is essential to remove the debris and driftwoods lodged on abutments and piers during the early stage of routine maintenance, otherwise, it will become more difficult to dislodge, increasing the risk of bridge or slope failure. Such material should be removed before periods of high water especially if the material is deposited in a manner that will change the direction or velocity of the flow increasing the possibility of scour. The removal and disposal of debris and driftwoods shall be carried out once a year, or especially after heavy rainfalls and runoffs when necessary.

4-14-3 Procedures

Driftwoods and debris shall be removed and properly disposed of to a designated disposal area. Large driftwoods are cut at the site and properly disposed of.

No burning of debris or driftwoods is permitted within the limits of the highway right of way. These are stockpiled for drying at the disposal area.

If there is difficulty to access the driftwoods piled around piers in the river channel, an access device is necessary for its removal. An inspection vehicle in place of scaffolding can be utilized.

Figure 4-13 Removal of Drift Wood around Piers

4-14-4 Required Materials and Tools/Equipment

(1) Required Materials

None

(2) Required Tools/Equipment

- Electric Saw
- Inspection Vehicle (for scaffolding)
- Dump Truck
- Back Hoe

4-15 REPAIR TO SLOPE PROTECTION

4-15-1 Description of Method

The works involve a restoration of the missing stones from masonry.

Photo 4-18 Missing Stone on Wet Masonry

4-15-2 Application Criteria

It is essential to replace the broken slope protection with stone during the early stage of routine maintenance; otherwise, it will become more difficult to repair the damages, increasing the risk of slope failure. The stone patching shall be carried out when necessary.

4-15-3 Procedures

The damaged stone masonry in limited areas shall be immediately repaired before the condition worsens. The damaged area is replaced by the installation of new stone masonry according to alignment and dimensions as shown in the drawings.

All unsound, imperfect or loose stones and mortar joints, panels, etc. shall be removed. The substrata shall then be compacted as preparation for the base. The slope line shall be carefully prepared at the same level as also shown in the drawings.

Stones shall be laid in a full bed of mortar, with joints completely filled with mortar and shoved into place. If necessary move or shift the unit already laid, remove the setting mortar, then clean and apply new fresh mortar for final placement. Coursing and mortar joints have to be done as directed by the Engineer. Stone has to be laid and anchors have to be installed in accordance with the drawings.

Where new stone masonry is placed on the existing masonry wall, joints shall be partially or completely set. The exposed surface of the existing stone masonry shall be cleaned with a wire brush and lightly moisten so as to attain the best possible bonding with the new work.

Except as specified herein, all works shall be performed in accordance with the Standard Specifications for Road and Bridge Works, Sep. 1998 SATCC, Series 2000: Drainage, Section 2500: Pitching, Stonework and Protection against Erosion.

4-15-4 Required Materials and Tools/Equipment

Materials and tools/equipment required for the works shall comply with the Standard Specifications for Road and Bridge Works, Sep. 1998 SATCC, Series 2000: Drainage, Section 2500: Pitching, Stonework and Protection against Erosion.

(1) Required Materials

- Stone and/or Concrete
- Joint sealing material

(2) Required Tools/Equipment

- Back Hoe
- Air compressor and Jack Hammer
- Concrete mixer

4-16 SCOUR PROTECTION

4-16-1 Description of Method

The Gabion Mattress is used for all areas at and adjacent to bridge substructure units that are subject to scour. When footing/pile-cap of abutment/pier is exposed, this protection prevents further inward erosion.

Photo 4-19 Exposed Pier Footing

4-16-2 Application Criteria

Inspection in addition to regularly scheduled inspection may be appropriate after unusually high water, particularly in areas where scourable material is present. This method is applicable in many locations, however, care should be taken not to reduce waterway section and/or change stream flow which may cause hydraulic problems.

4-16-3 Procedures

The work can include but is not limited to, installing siltation devices as needed; preparing the surface by excavating unsuitable material, backfilling, placing material, and grading surface; placing gabion baskets; placing rocks in gabion baskets; and wiring tops on gabion baskets.

All work of gabions shall adhere to the Standard Specifications for Road and Bridge Works, Sep. 1998 SATCC, Series 2000: Drainage, Section 2600: Gabions.

4-16-4 Required Materials and Tools/Equipment

Materials and tools/equipment required for the works shall comply with the Standard Specifications for Road and Bridge Works, Sep. 1998 SATCC, Series 2000: Drainage, Section 2600: Gabions.

(1) Required Materials

- Aggregates or rocks
- Gabion baskets

(2) Required Tools/Equipment

- Back Hoe

CHAPTER 5 ROUTINE MAINTENANCE FOR SPECIAL BRIDGES

5-1 PRESTRESSED CONCRETE BOX GIRDER BRIDGE (CHIRUNDU, TUTA, MONG KALABO, SIOMA BRIDGES)

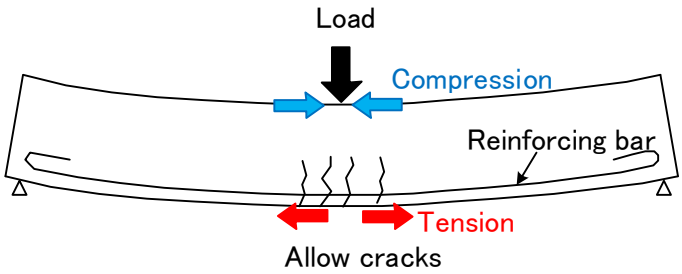
5-1-1 Structural Outline

Concrete is strong against compressive force but very weak against tensile force (tensile stress is about 1/10 of compressive strength), so cracking occurs in the part where tensile stress occurs.

Reinforced concrete structure (hereinafter referred to as RC structure) is one which is reinforced by rebars inserted into the concrete so as to resist tensile strength. However, some cracks will be occurred in concrete and the cracks generated by excessive load will remain after the load is disappeared.

Prestressed concrete structure (hereinafter referred to as PC structure) is one in which a compressive force is introduced to concrete using the prestressing steel in advance not so as to be generated tensile stress. Even if cracks occur due to excessive load, the cracks will close after removing the load.

(RC Structure)



(PC Structure)

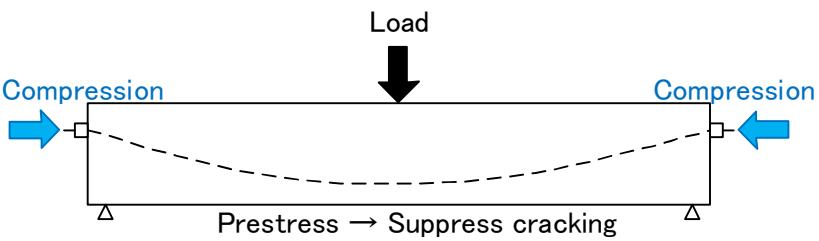


Figure 5-1-1 Structural System of Prestressed Concrete Box Girder Bridge

Advantages of PC structures:

(1) Cracking is less likely to occur, (2) High strength concrete and high tensile steel can be used effectively, (3) Since the cross section of the member can be made smaller than that of RC structure, it is advantageous for long span bridges and large span frames whose self-weights occupy most of the load, (4) Division, addition and assembly are possible by the precast segment method* (prefabrication is easy), (5) Even if a crack or deformation occurs due to a temporary overload, it almost recovers after unloading, etc.

Disadvantages of PC structures:

(1) Design and construction of prestressing requires PC-specific advanced technologies such as introduction of tensioning force, anchorage and grout injection, (2) At the stage of manufacture and initial use, since the elastic deformation due to pre-stress and the creep deformation are large, technical consideration in design and construction is necessary, (3) If the members were heavily damaged, repair of members is more difficult than the case of RC structure, etc.

*The precast segment method is a construction method in which precast members (segments) are fabricated divisionally in a factory or a site yard in advance and are joined at a bridge site, prestressed and integrated.

5-1-2 Routine Inspection

(1) Bridge Components and Defects

The PC girder has a structure in which PC steel materials are added to RC materials, and is made by applying compressive stress to the girder through anchor devices for PC steel materials. In addition to the defects that occur in the RC girder, in the PC girder the PC steel materials and those anchor devices may have the following defects:

1) PC Steels

When the residual prestress of PC steels decreases, cracks occur and the main girder stiffness decreases. With decrease of the main girder stiffness, abnormal deflection and/or abnormal vibration of the girder tend to occur. If the abnormal vibration continues, the fatigue of PC steels will progress and cracks of the concrete structures will occur. The PC steels will corrode due to the occurrence of cracks. The progress of fatigue and corrosion of PC steels will lead to fracture of PC steels.

2) Anchor Devices for PC Steels

The defects of the anchoring portion of the PC steels include cracks near the anchoring protrusions in the box girder, cracking and peeling of the finished concrete, water/rust juice leakage from the cracks and free lime. Further, corrosion of the anchor devices due to penetration of water also occurs.

However, since the routine inspection is not performed inside the girder, the inspection of the cable and anchor device is carried out on the Condition inspection.

Table 5-1-1a shows possible defects in the bridge components of Chirundu Bridge. And, Table 5-1-1b shows defects in the bridge components of Chirundu Bridge which shall be inspected on the routine inspection.

Table 5-1-1a Bridge Components and Possible Defects (Chirundu Bridge)

Bridge Component	Sub-Component	Possible Defects
Superstructure	Concrete members	1) Crack, 2) Spalling, 3) Scaling, 4) Delamination, 5) Honeycomb/Loose concrete, 6) Cold joint, 7) Rebar exposure/Rebar corrosion, 8) Water leakage/Free lime, 9) Abnormal deflection, 10) Abnormal vibration
	Prestressed concrete members	1) Cracks, 2) Abnormal deflection, 3) Abnormal vibration, 4) Water leakage/Free lime, 5) Loss of prestress (presumed), 6) Decrese of girder stiffness (presumed), 7) Corrosion of prestressing steels (presumed), 8) Fatigue of prestressing steels (presumed), 9) Fracture of prestressing steels (presumed), 10) Grout filling failure (presumed)
	Anchorage of prestressing steel	1) Cracks near protrusion of anchorage, 2) Cracks/Delamination in finish concrete at anchorage, 3) Corrosion of anchor devices, 4) Water leakage/Free lime, 5) Rust seepage, 6) Exposure of anchor devices
Deck	Concrete deck	1) Crack, 2) Spalling, 3) Scaling, 4) Honeycomb/Loose concrete, 5) Rebar exposure/Rebar corrosion, 6) Water leakage/Free lime
Substructure	Concrete members (Abutment, Pier)	1) Crack, 2) Spalling, 3) Delamination, 4) Honeycomb/Loose concrete, 5) Cold joint, 6) Rebar exposure/Rebar corrosion, 7) Water leakage/Free lime
	Foundation	1) Tilt, 2) Settlement, 3) Scouring/Lowering of river bed
	Protection work	1) Slope/Bank erosion, 2) Loss/Disintegration of protection materials, 3) Defects due to displacement of foundation
Expansion Joint	Hybrid joint with metal and rubber (Load-bearing type)	1) Breakage of rubber material, 2) Damage to adjacent pavement, 3) Water leakage, 4) Damage to post-cast concrete, 5) Difference in level, 6) Abnormal sound, 7) Abnormal spacing
Wearing Course	Asphalt pavement	1) Potholes, 2) Rutting, 3) Bump, 4) Corrugation, 5) Crack, 6) Raveling, 7) Ponding
Sidewalk		1) Crack, 2) Potholes/Spalling, 3) Bump, 4) Ponding, 5) Accumulation of garbage and debris
Bearing	Rubber bearing	1)Deformation/Displacement of bearing, 2) Deterioration of bearing, 3) Breakage of mortar/concrete seat, 4) Accumulation of garbage and debris
Railing	Metal railing	1) Deformation, 2) Corrosion, 3) Disappearance, 4) Loose connection
Drainage	Scupper	1) Damage to scupper, 2) Damage to cover, 3) Accumulation of garbage and debris
	Drain pipe	1) Damage to pipe, 2) Defect in connection, 3) Accumulation of garbage and debris, 4) Insufficient length, 5) No drain pipe
Site/Others	Waterway	1) Accumulation of driftwoods/debris, 2) Changes in river direction/lowering river bed (within a range of 20m from the bridge to the upstream and downstream sides)
	Approach	1) Accumulation of vegetation/debris/garbage, 2) Damage to rip-rap/retaining wall, 3) Settlement of approach section/incorrect vertical alignment, 4) Damage to approach pavement (crack, pothole, etc.)

Table 5-1-1b Bridge Components and Defects on the Routine Inspection (Chirundu Bridge)

Bridge Component	Sub-Component	Defects to be inspected
Superstructure	Concrete members	1) Crack, 2) Spalling/Loose concrete, 3) Rebar exposure/Rebar corrosion, 4) Water leakage/Free lime
	Prestressed concrete members	1) Cracks, 2) Abnormal deflection, 3) Abnormal vibration, 4) Water leakage/Free lime
	Anchorage of prestressing steel	
Deck	Concrete deck	1) Crack, 2) Spalling/Loose concrete, 3) Rebar exposure/Rebar corrosion, 4) Water leakage/Free lime
Substructure	Concrete members (Abutment, Pier)	1) Crack, 2) Spalling/Loose concrete, 3) Cold joint, 4) Rebar exposure/Rebar corrosion, 5) Water leakage/Free lime
	Foundation	1) Tilt, 2) Settlement, 3) Scouring
	Protection work	1) Slope/Bank erosion, 2) Loss/Disintegration of protection materials
Expansion Joint	Hybrid joint with metal and rubber (Load-bearing type)	1) Breakage of rubber material, 2) Damage to post-cast concrete, 3) Difference in level, 4) Abnormal spacing
Wearing Course	Asphalt pavement	1) Potholes, 2) Rutting, 3) Crack, 4) Raveling, 5) Ponding
Sidewalk		1) Crack, 2) Potholes, 3) Ponding, 4) Accumulation of garbage and debris
Bearing	Rubber bearing	1)Deformation/Displacement of bearing, 2) Deterioration of bearing, 3) Breakage of mortar/concrete seat, 4) Accumulation of garbage and debris
Railing	Metal railing	1) Deformation, 2) Corrosion, 3) Disappearance, 4) Loose connection
Drainage	Scupper	1) Damage to scupper, 2) Damage to cover, 3) Accumulation of garbage and debris
	Drain pipe	1) Damage to pipe, 2) Insufficient length, 3) No drain pipe
Site/Others	Waterway	1) Accumulation of driftwoods/debris
	Approach	1) Accumulation of vegetation/debris/garbage, 2) Damage to rip-rap/retaining wall, 3) Settlement of approach section/incorrect vertical alignment, 4) Damage to approach pavement (crack, pothole, etc.)

(2) Sheets for Routine Inspection (Chirundu Bridge)

The Routine Inspection Report consists of following 4 kinds of sheet:

a. Bridge Routine Inspection Form;

b. Defect Drawing Sheet;

c. Photo Record Sheet; and

d. Routine maintenance Record Schedule and Record Form.

Bridge Routine Inspection Form

Date:		Contractor Name:				Contract Ref. No. :			Province:	
Bridge No.:		Bridge Name:			Road No.:		Road Name:		Location:	
No.	(1) Bridge Component	(2) Sub-Component	(3) Defect Type	(4) Condition Rating	(5) Quantity (Unit)	(6) Proposed Action	(7) New/ Existing	(8) Date of Detection	(9) Remarks	

Note: - To categorize (1) Bridge Component, (2) Sub-component and (3) Defect type, refer to Table 5-1-1b.

To determine (4) Condition rating and (6) Proposed action, refer to the Table 2-1 and Table 2-2 with Figure 2-2, respectively.

(7) New/Existing means damage newly identified in this inspection/already identified in previous inspection.

Note: How to fill out the Bridge Routine Inspection Form

If you find a defect, enter the location in the columns of "(1) Bridge Component & (2) Sub-Component" and enter the type of defect in column of "(3) Defect Type", in the Bridge Routine Inspection Form, and fill the location and type of defect on the Defect Drawing Sheet. And, in the column "(4) Condition Rating", select Good, Fair, Poor or Bad according to Table 1 Routine Inspection Condition Rating Criteria. In the column "(6) Proposed Action", suitable actions should be entered refer to the Figure 1 Determination flow of Maintenance Action. Table 1 shows the criteria for judgment of Condition Rating. Table 2 shows the types of required actions and their contents of actions. Figure1 is a flowchart for determining a maintenance action based on the identified damage situation.

Table1 Routine Inspection Condition Rating Criteria

Condition Rating	Description
Good	No damage
Fair	With minor damage(s) not affecting the stability of the structure
Poor	With deteriorating damage(s) which should be monitored or could be repaired as a preventive action
Bad	With severe damage(s) that affects stability of bridge or that has possibility to harm a third party

Table 2 Required Maintenance Action

Required Action	Description
MO: Monitoring	No repair work and keeping monitoring (Damage not progressing or very slow)
RM: Routine Maintenance	Should be maintained by Routine Maintenance
MM: Major Maintenance	Should be maintained by Major Maintenance
EA: Emergency Action	Need to take actions immediately to avoid bridge collapse or harm to a third party
In-Depth Inspection	Condition Inspection or Detailed Inspection - Selection of appropriate repair method - Monitoring of progress of any damages

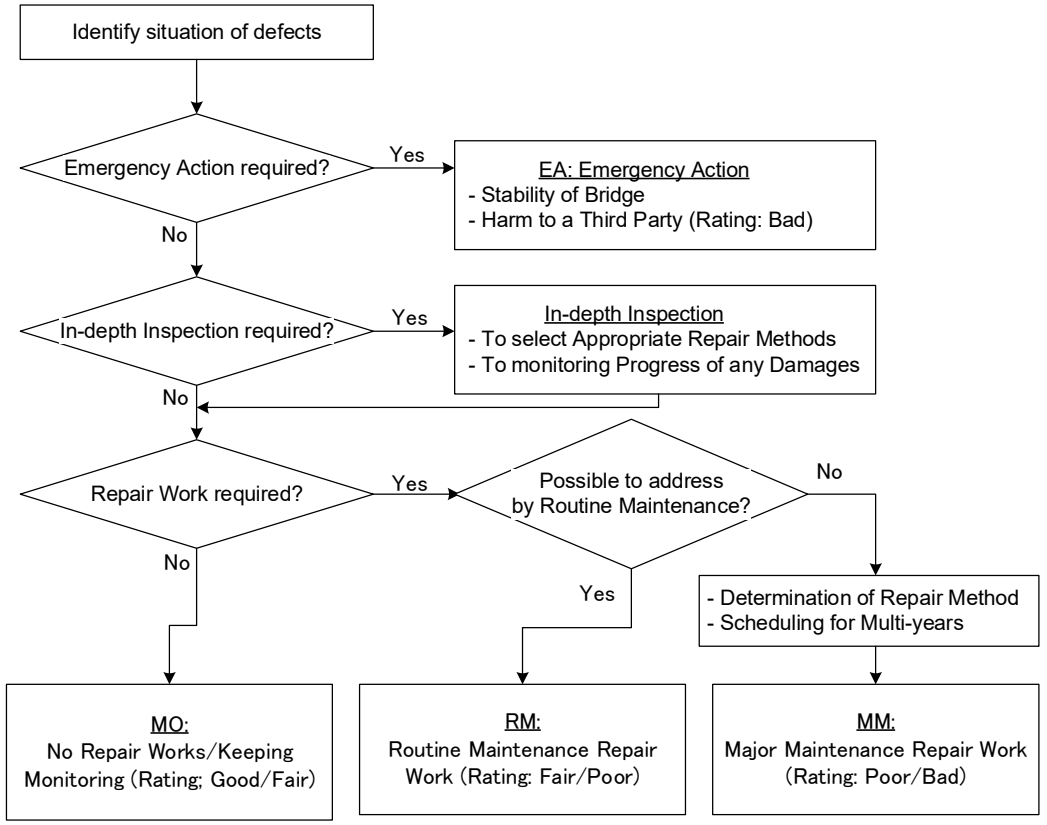
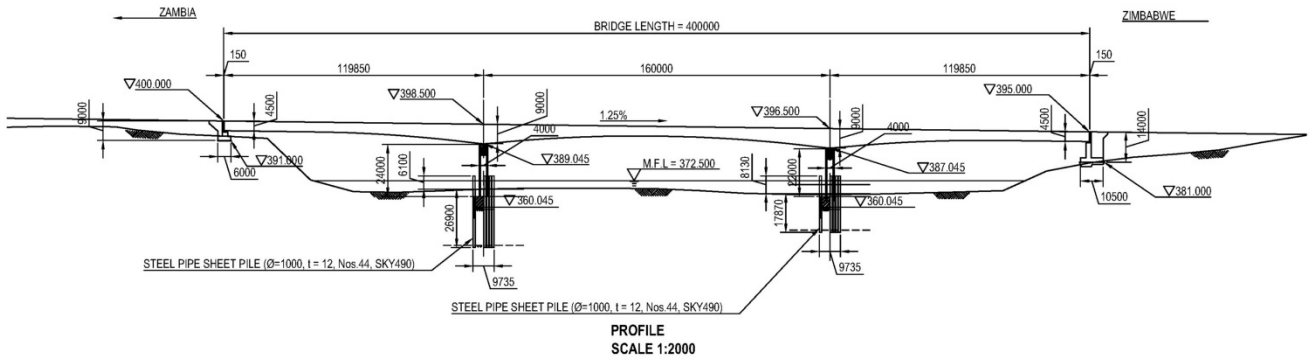


Figure 1 Determination Flow of Maintenance Action

Defect Drawing Sheet



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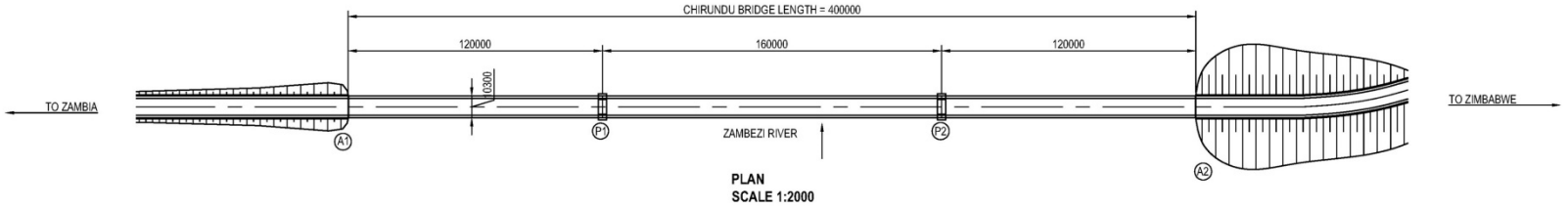

PLAN
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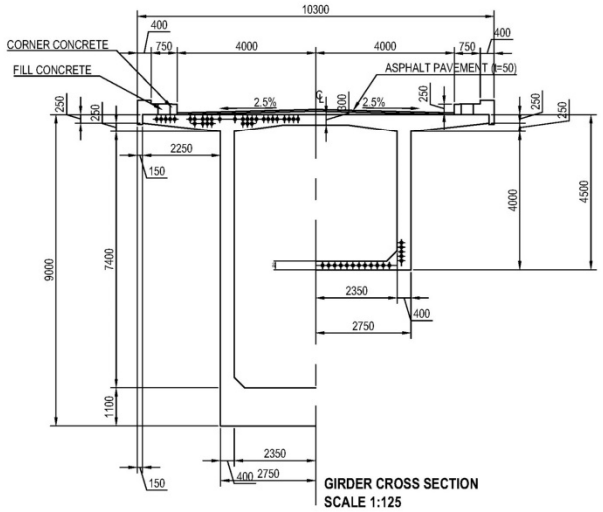
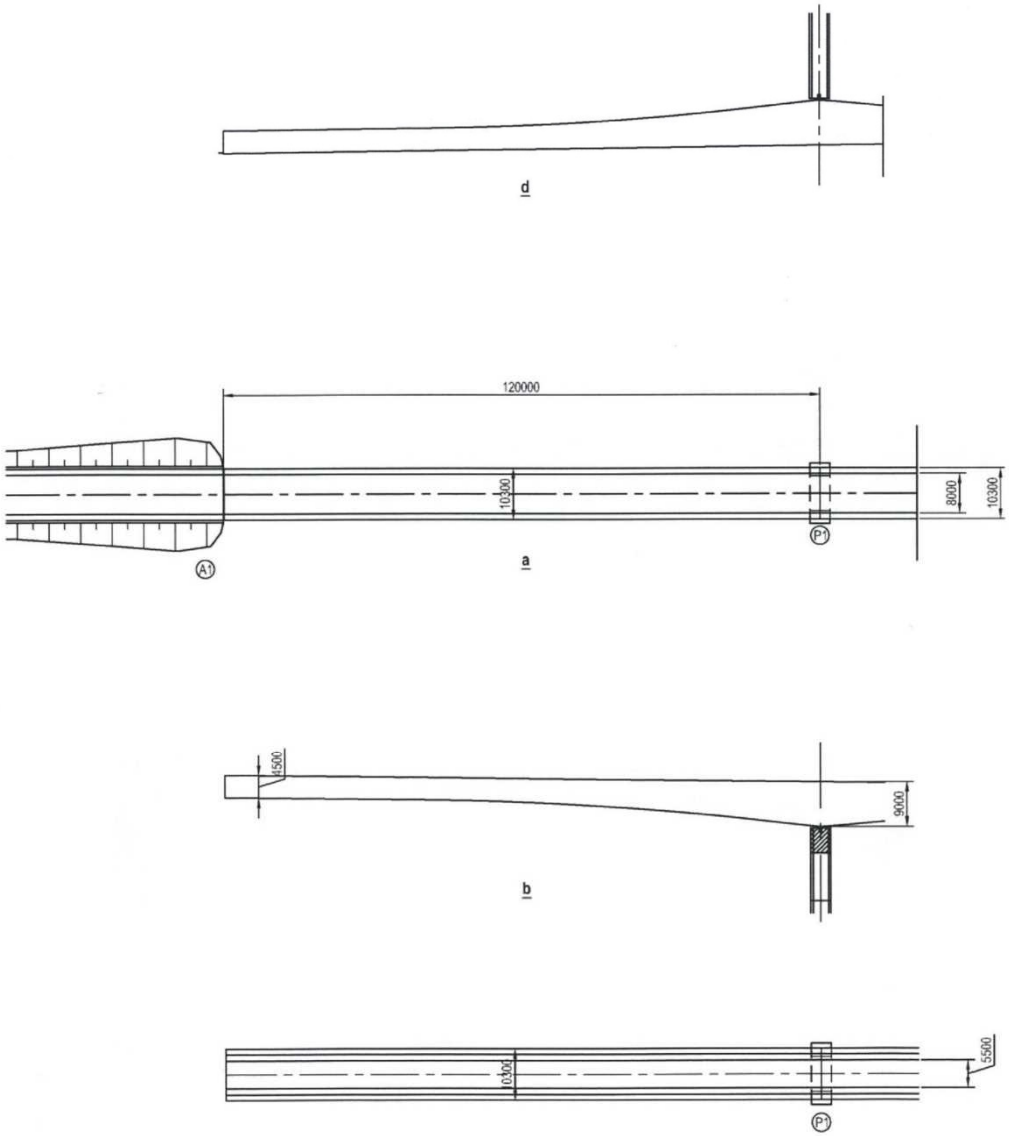
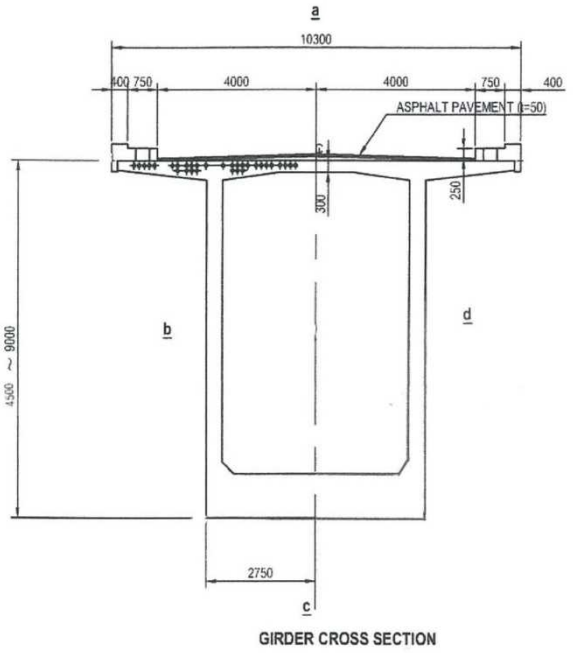


GIRDER CROSS SECTION
SCALE 1:125

General Drawing (1/8)
Plan, Profile and Cross Section

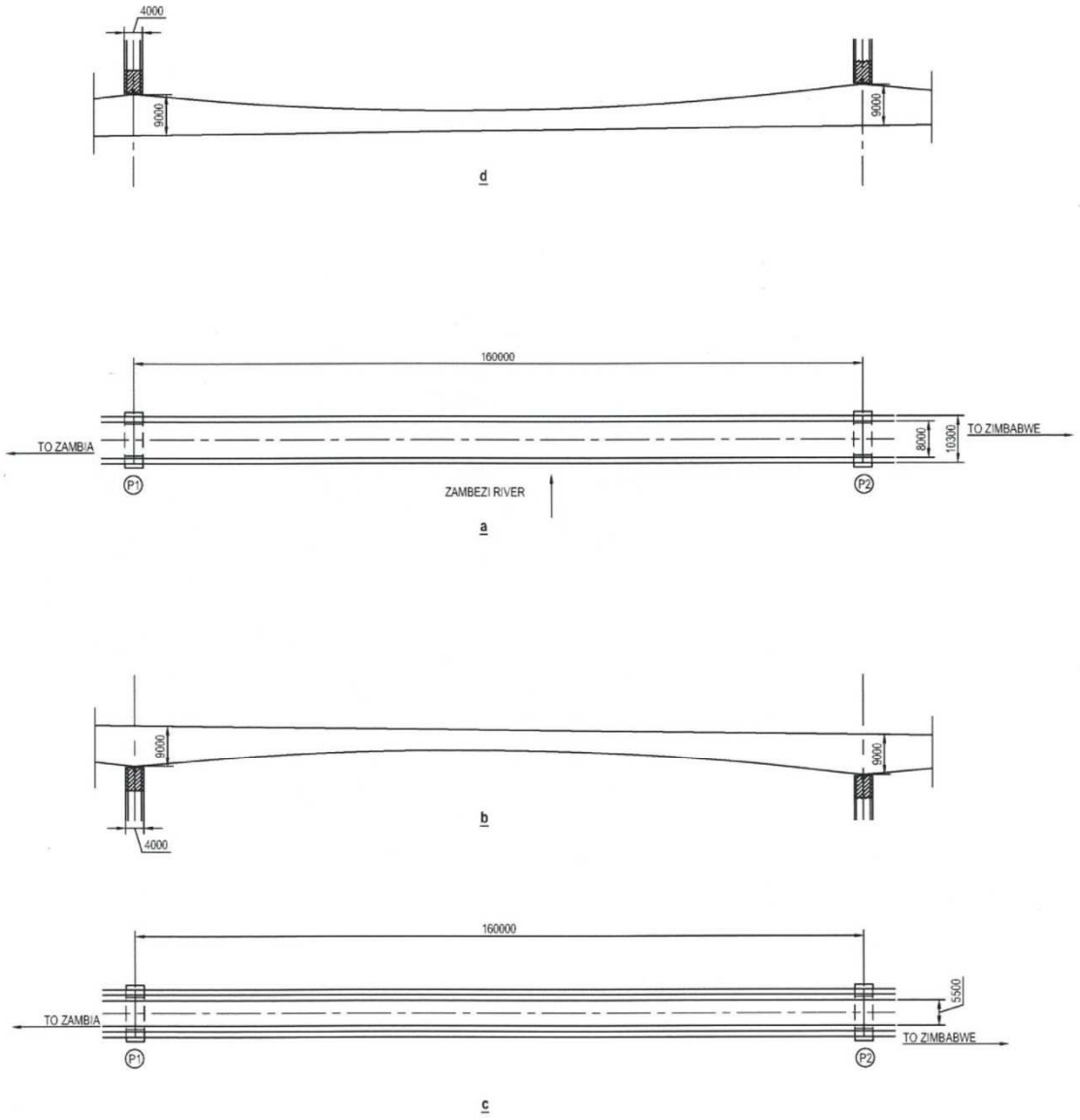
Bri

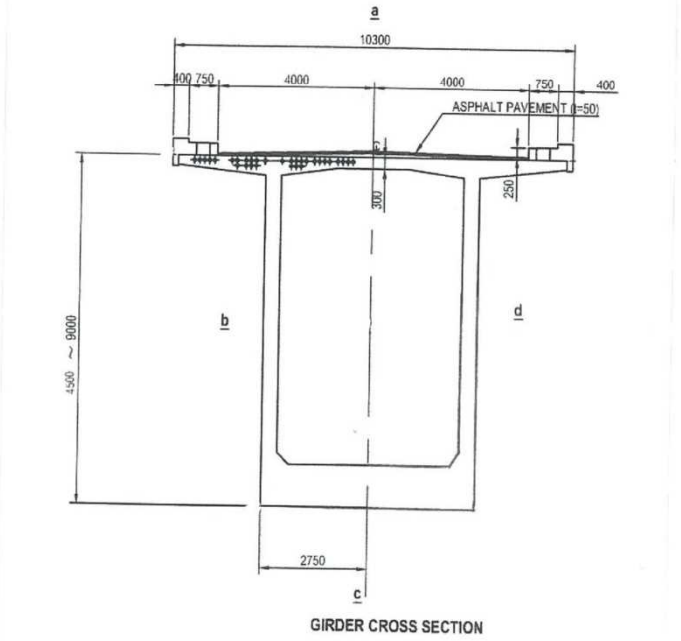




GIRDER CROSS SECTION

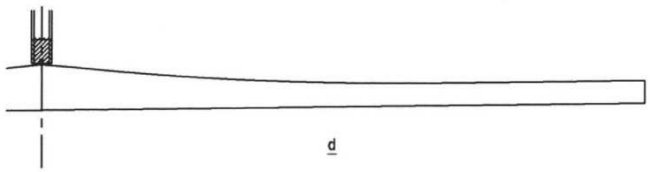
Damage Drawing Sheet (2/8)
Girder: Span 1

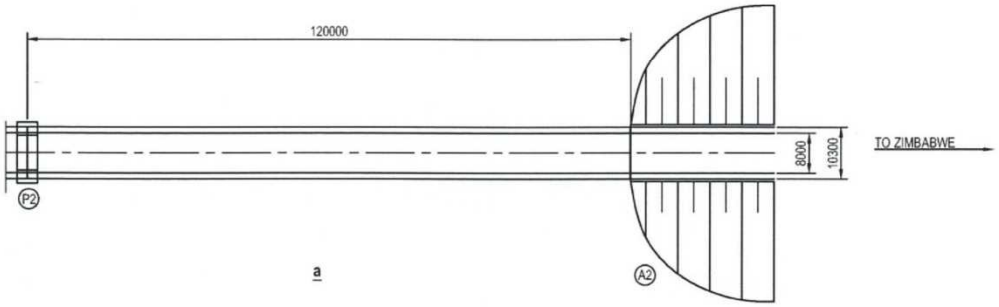


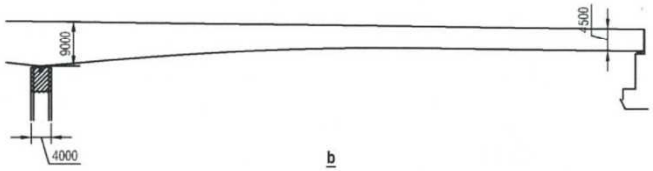


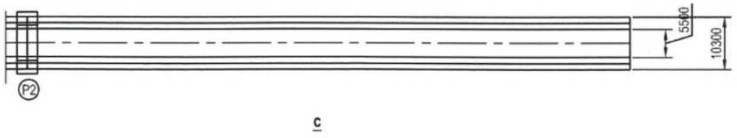
GIRDER CROSS SECTION

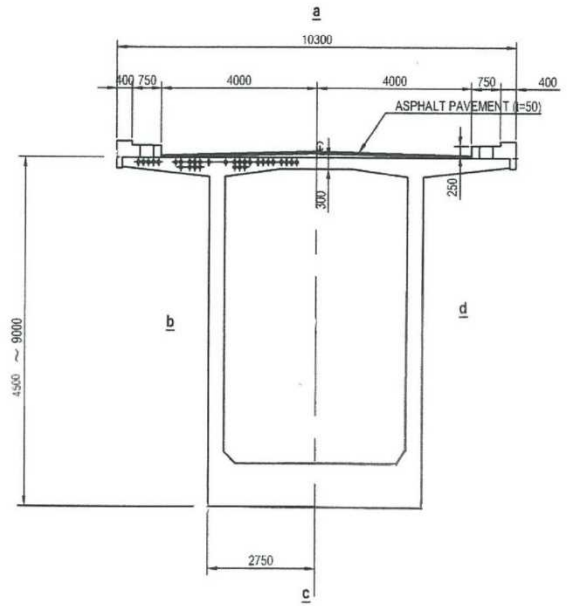
Damage Drawing Sheet (3/8)
Girder: Span 2





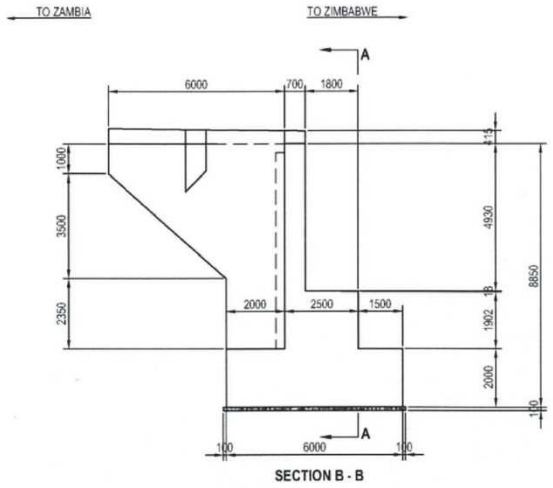




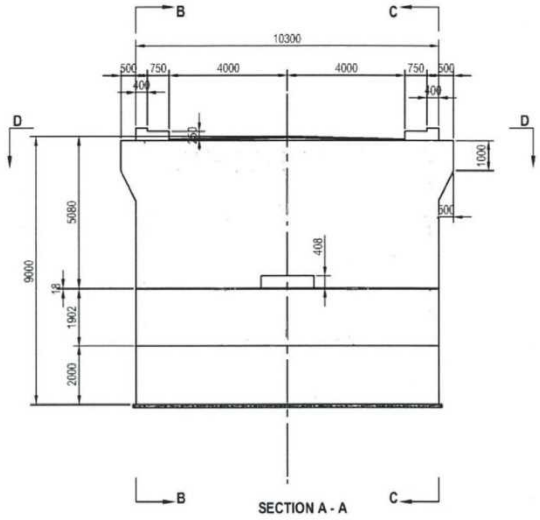


GIRDER CROSS SECTION

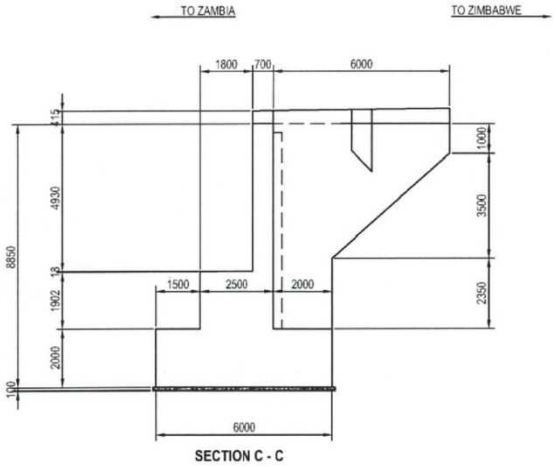
Damage Drawing Sheet (4/8)
Girder: Span 3



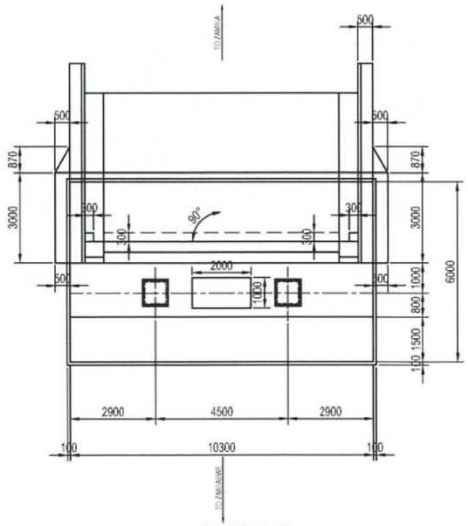
SECTION B - B



SECTION A - A

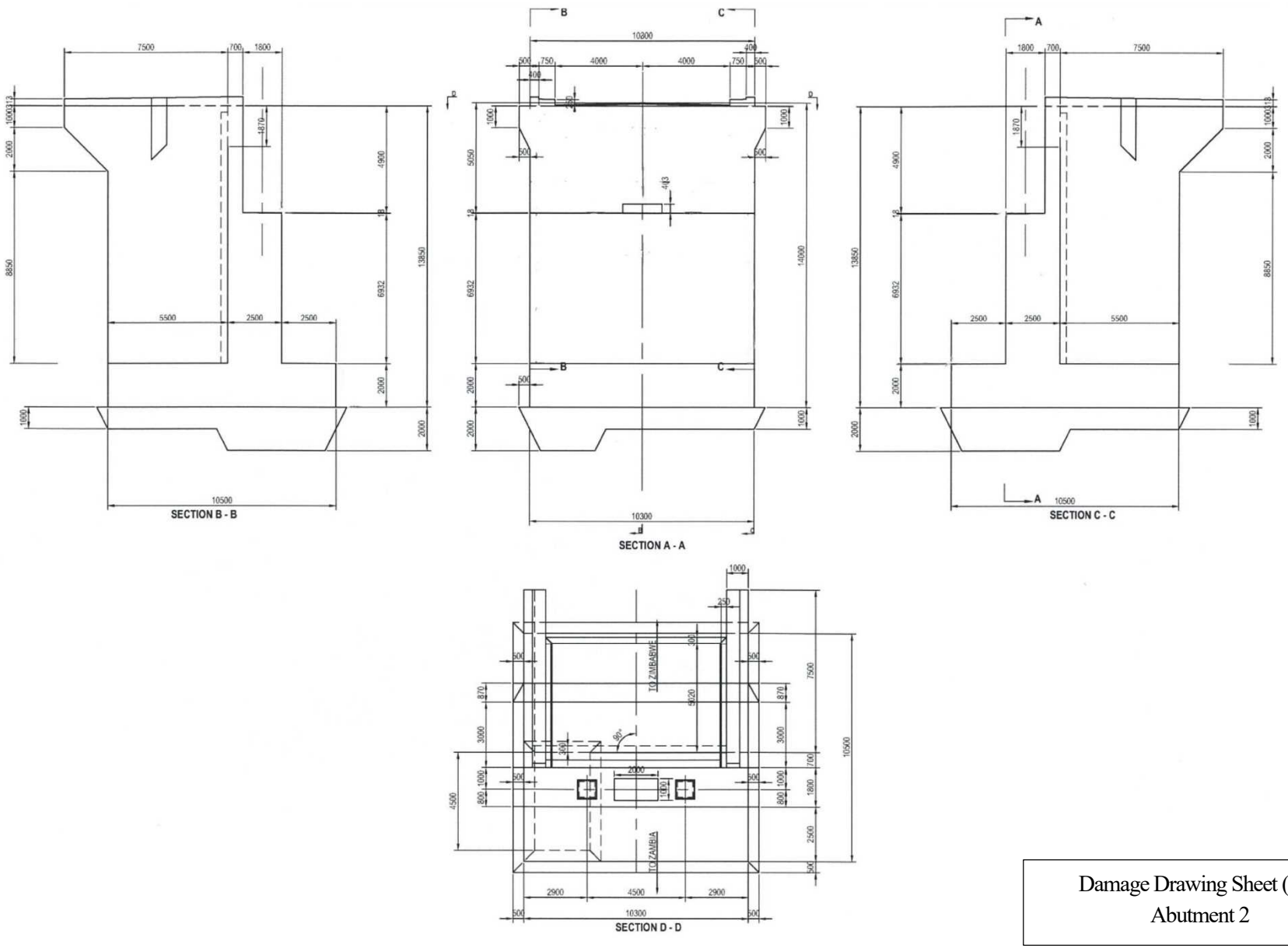


SECTION C - C

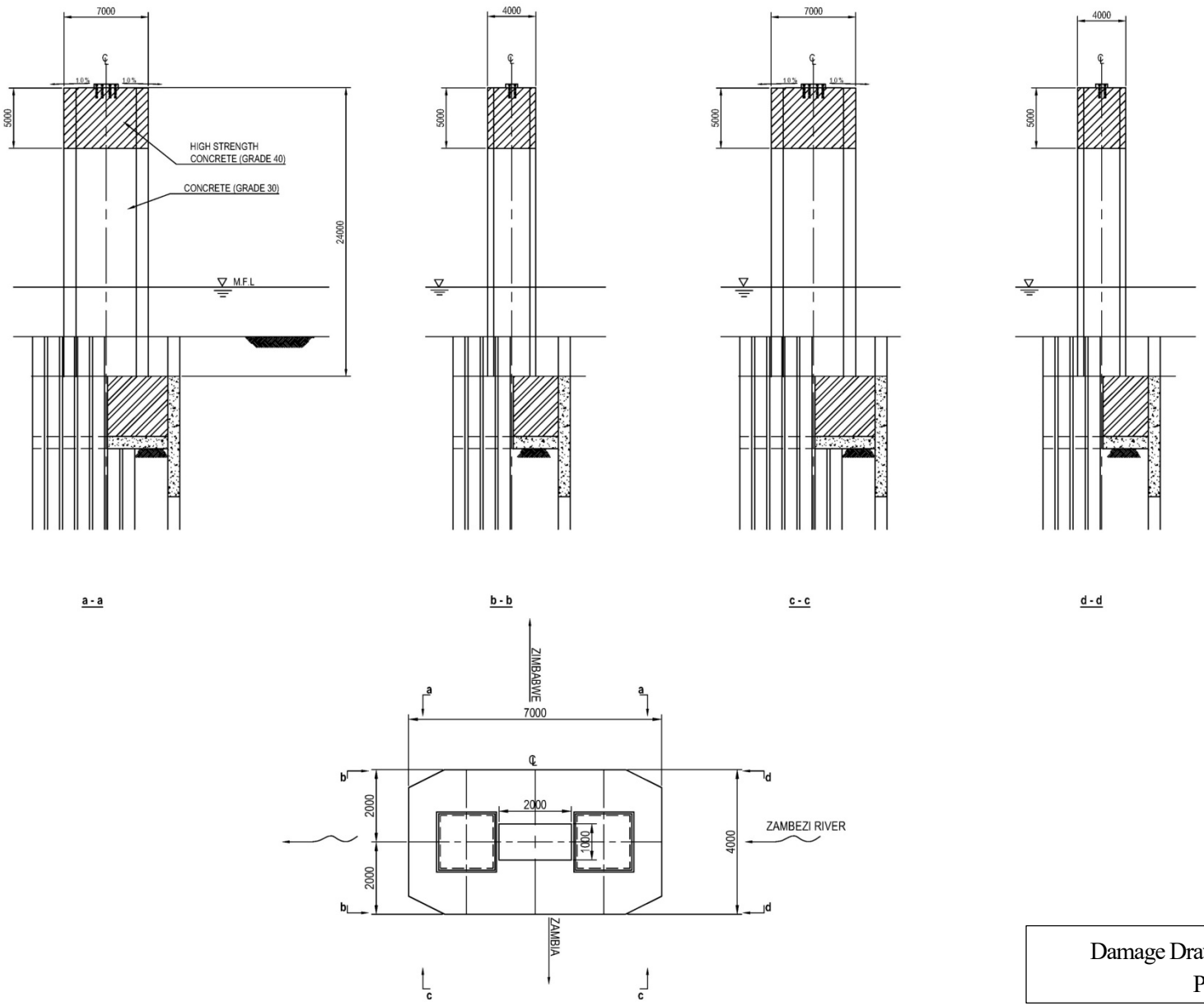


SECTION D - D

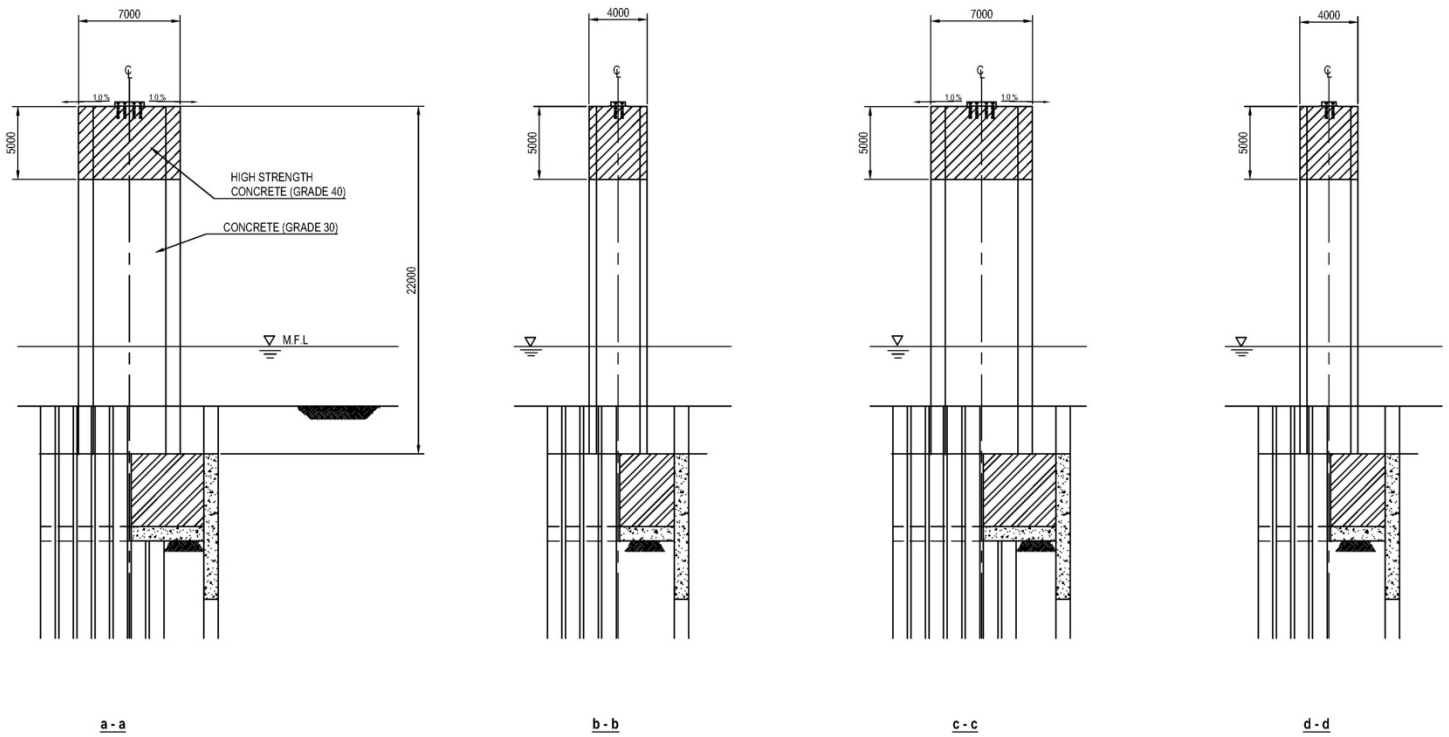
Damage Drawing Sheet (5/8)
Abutment 1

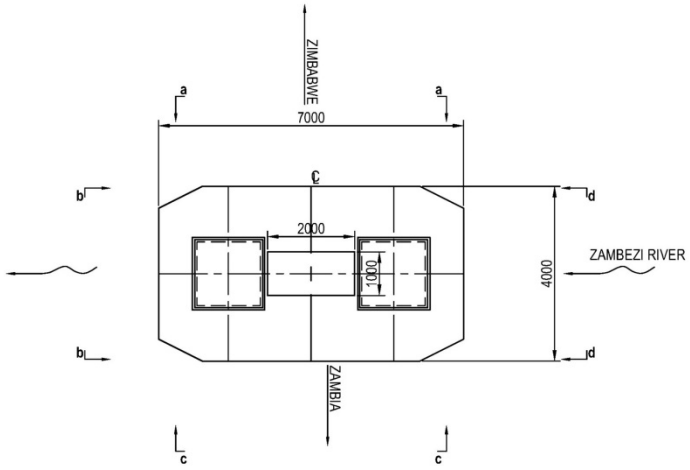


Damage Drawing Sheet (6/8)
Abutment 2



Damage Drawing Sheet (7/8)
Pier 1





Damage Drawing Sheet (8/8)
Pier 2

Photo Record Sheet (Bridge Name: Chirundu Bridge)

Contractor Name:		Contract Ref. No.:		Province:	
Date:		Date:		Date:	
No.:		No.:		No.:	
Defect Type:		Defect Type:		Defect Type:	
Description:		Description:		Description:	
Date:		Date:		Date:	
No.:		No.:		No.:	
Defect Type:		Defect Type:		Defect Type:	
Description:		Description:		Description:	

Bridge Routine Maintenance Schedule and Record Form

Bridge No.:	Bridge Name:	Contractor Name:	Contract Ref. No.:	Province:
	Chirundu Bridge			

No.	(1) Contract Item No.:	(2) Activities	(3) Description: Condition before Maintenance	(4) Ref. No. of Defect	(5) Estimated Cost	(6) Date: Instruction to Contractor	(7) Date: Work Completed	(8) Additional Work Required	(9) Remarks

Note: -Ref. No. of defect corresponds to No. with the inspection date in the Bridge Routine Inspection Form-e.g. No.01-26.11.2015

(3) Routine Inspection Results (August 28, 2019)

Bridge Routine Inspection Form

Date:	2019/8/28	Contractor Name:				Contract Ref. No. :			Province: Lusaka
Bridge No.:		Bridge Name:			Road No.:		Road Name:		Location:
		Chirundu bridge			T2				Zambezi Riber
No.	(1) Bridge Component	(2) Sub-Component	(3) Defect Type	(4) Condition Rating	(5) Quantity (Unit)	(6) Proposed Action	(7) New/ Existing	(8) Date of Detection	(9) Remarks
1	Drainage	Scupper	Accumulation of debris	Poor	21 scuppers	RM repair	New	2019/8/28	all downstream side scuppers
2	Drainage	Drain pipe	Insufficient length	Poor	42 pipes	RM repair	Existing	2019/8/28	all pipes
3	Expansion Joint	Hybrid Joint	Brakage of rubber material	Poor	2 joints	MM repair	New	2019/8/28	Both expansion joints, Replacement is needed.
4	Superstructure	PC members	Abnormal deflection	Poor	160 m	In-depth Inspection	New	2019/8/28	Center span, Follow-up observation is required.
5	Superstructure	Concrete member	Cracks	Poor	2 points	RM repair	New	2019/8/28	Transverse cracks on Pier 1 &2 (sidewalk and kerb)
6	Substructure	Concrete member (Abutment)	Cracks	Poor	18 m	MM repair (or RM repair)	New	2019/8/28	Vertical cracks (A1 & A2)
7	Site/Others	Approach	Cracks on pavement	Bad	200 m^2	MM repair	New	2019/8/28	Zimbabwe approach, Removal and reconstruction of the pavement is required.
8	Site/Others	Around Zambian side abutment	Accumulation of garbage	Poor	300 m^2	RM repair	New	2019/8/28	

Note: - To categorize (1) Bridge Component, (2) Sub-component and (3) Defect type, refer to Table 5-1-1b

To determine (4) Condition rating and (6) Proposed action, refer to the Table 2-1 and Table 2-2 with Figure 2-2, respectively.

(7) New/Existing means damage newly identified in this inspection/already identified in previous inspection.

Photo Record Sheet (Bridge Name: Chirundu Bridge)

Contractor Name:		Contract Ref. No.:		Province:	Lusaka

Date:	2019/8/28
No.:	1
Defect Type:	Accumulation of debris
Description:	The drain outlets of the carriageway on the downstream side (Otto Beit Bridge side) is buried with earth and sand throughout the bridge.

Date:	2019/8/28
No.:	2
Defect Type:	Insufficient length
Description:	The drain pipes under the girder are extremely short.

Date:	2019/8/28
No.:	3
Defect Type:	Brakage of rubber material
Description:	Both expansion joints (Hybrid Joint) are damaged.

Date:	2019/8/28
No.:	4
Defect Type:	Abnormal deflection
Description:	The bridge surface in the central span looks like to have sunk.

Date:	2019/8/28
No.:	5
Defect Type:	Cracks
Description:	Cracks in the transverse direction to the bridge axis, which seems to be due to bending moment, are seen on the kerb and sidewalk surface on the intermediate support points (pier).

Date:	2019/8/28
No.:	5
Defect Type:	Cracks
Description:	Same as the left

Date:	2019/8/28
No.:	6
Defect Type:	Cracks
Description:	There are many vertical cracks in the front surface of the Zambian side abutment.

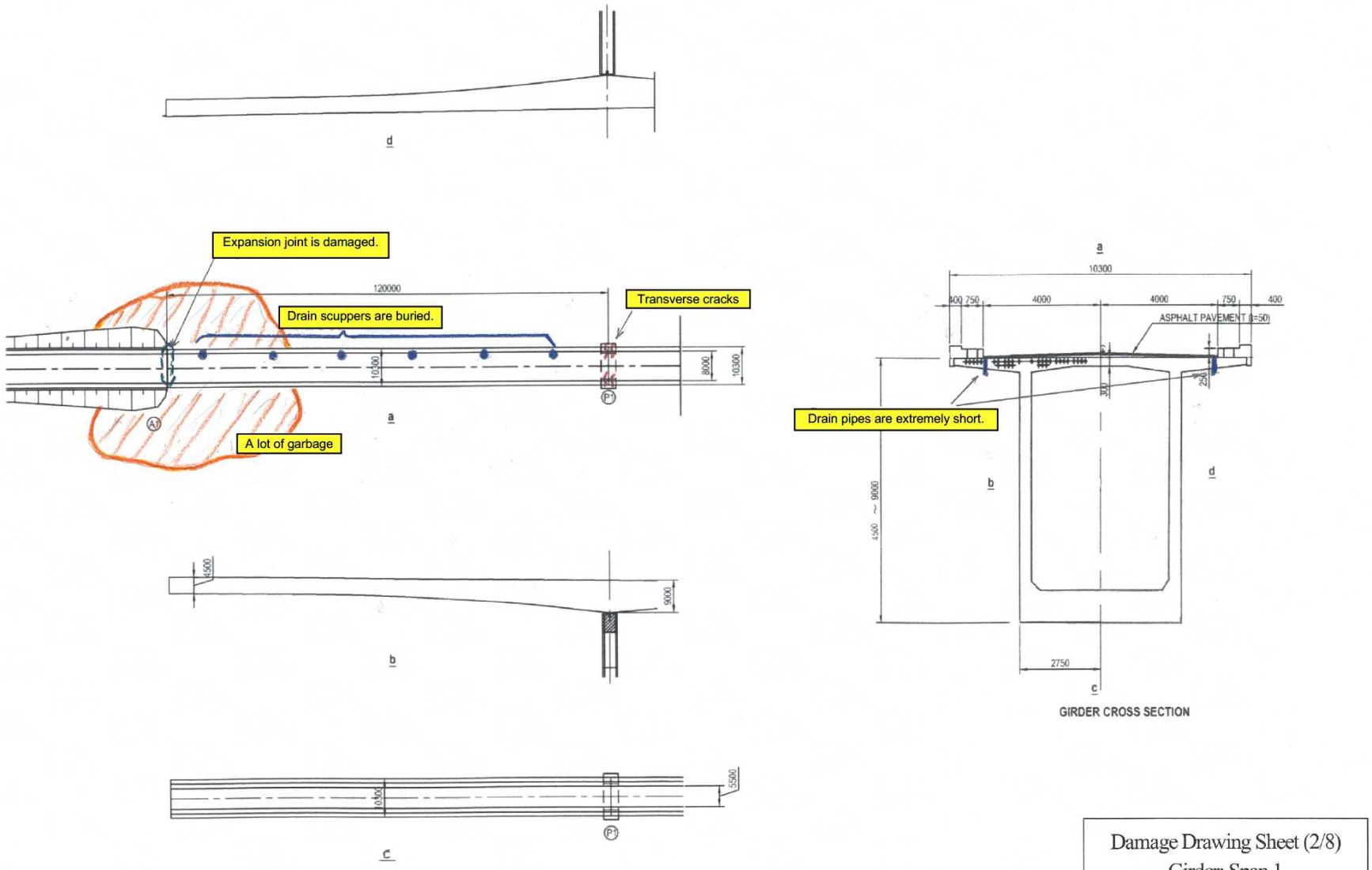
Date:	2019/8/28
No.:	6
Defect Type:	Cracks
Description:	There are many vertical cracks in the front surface of the Zimbabwe side abutment.

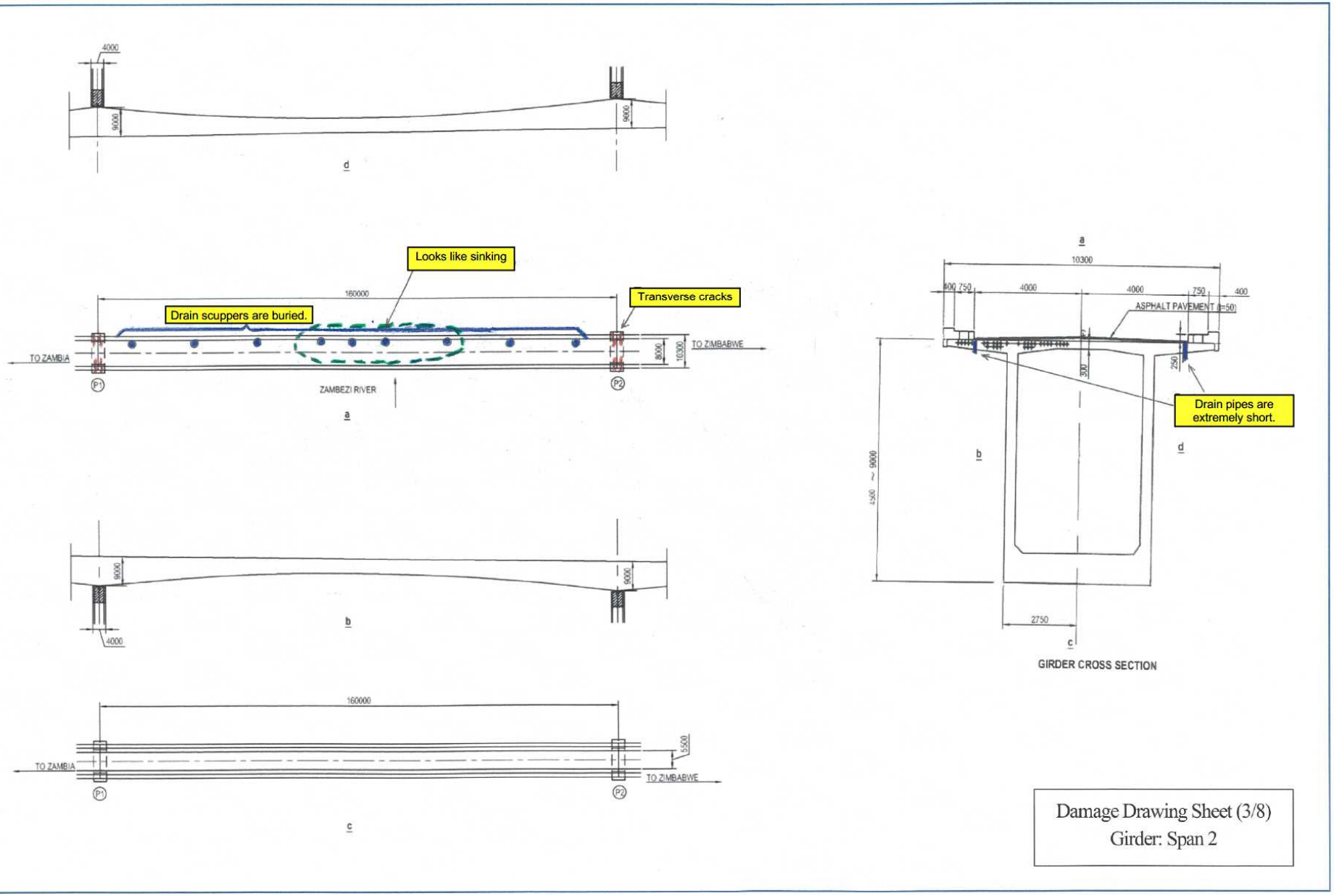
Date:	2019/8/28
No.:	7
Defect Type:	Cracks on pavement
Description:	Many alligator cracks are seen on the pavement of the Zimbabwe approach.

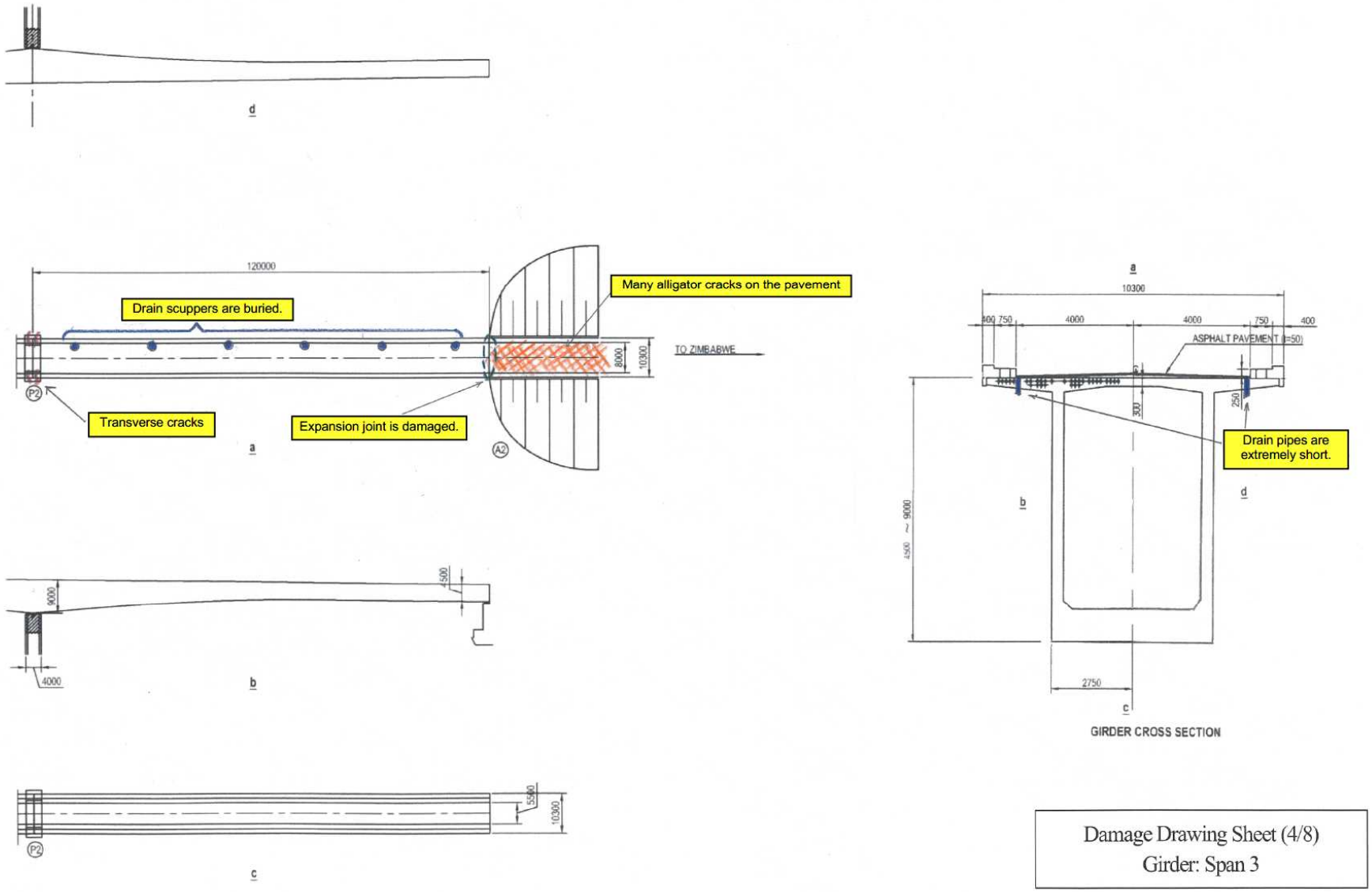
Date:	2019/8/28
No.:	8
Defect Type:	Acumulation of garbage
Description:	A lot of garbage such as plastic bottles is scattered around the Zambian side abutment.

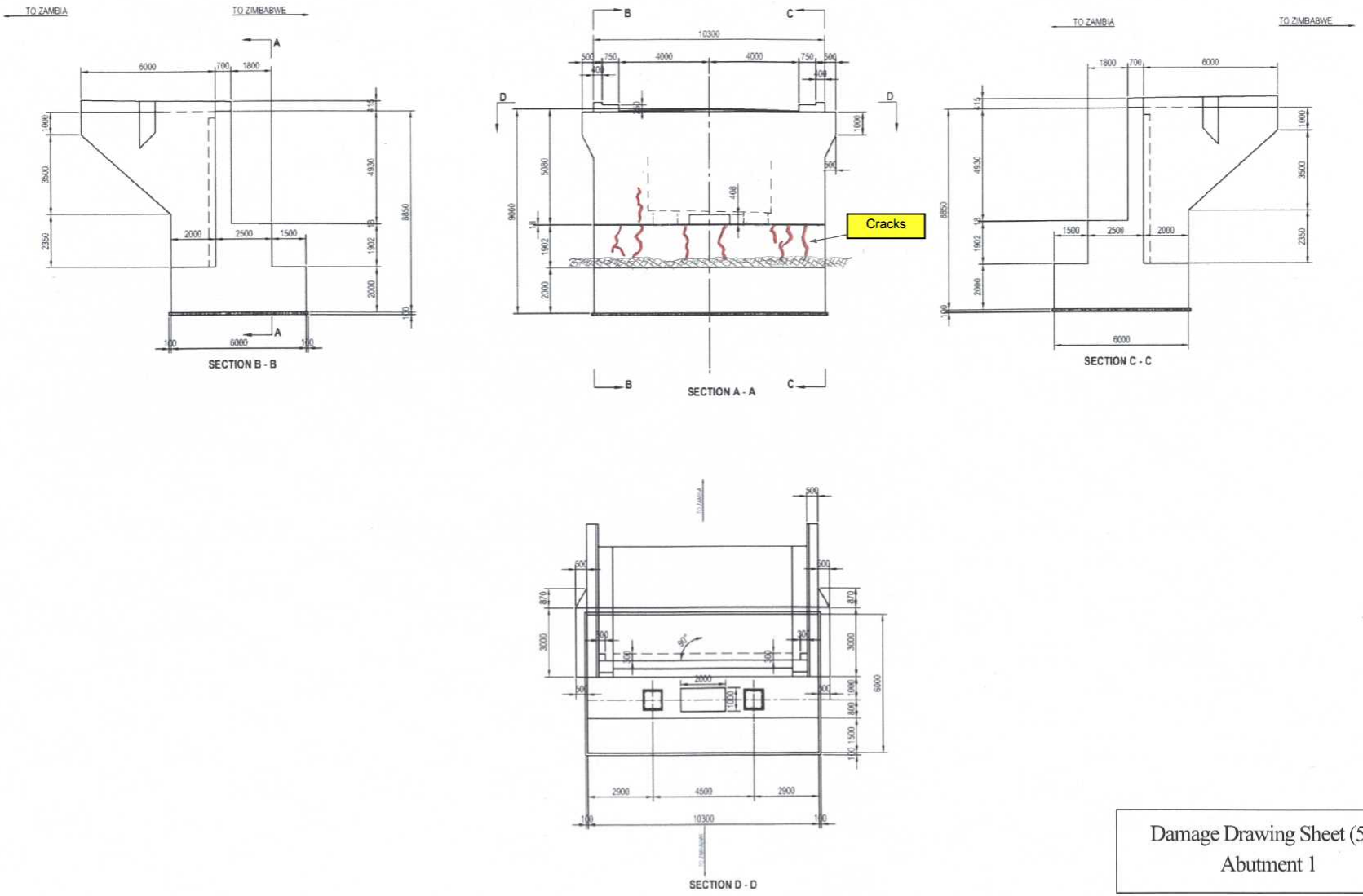
Date:	
No.:	
Defect Type:	
Description:	

Date:	
No.:	
Defect Type:	
Description:	

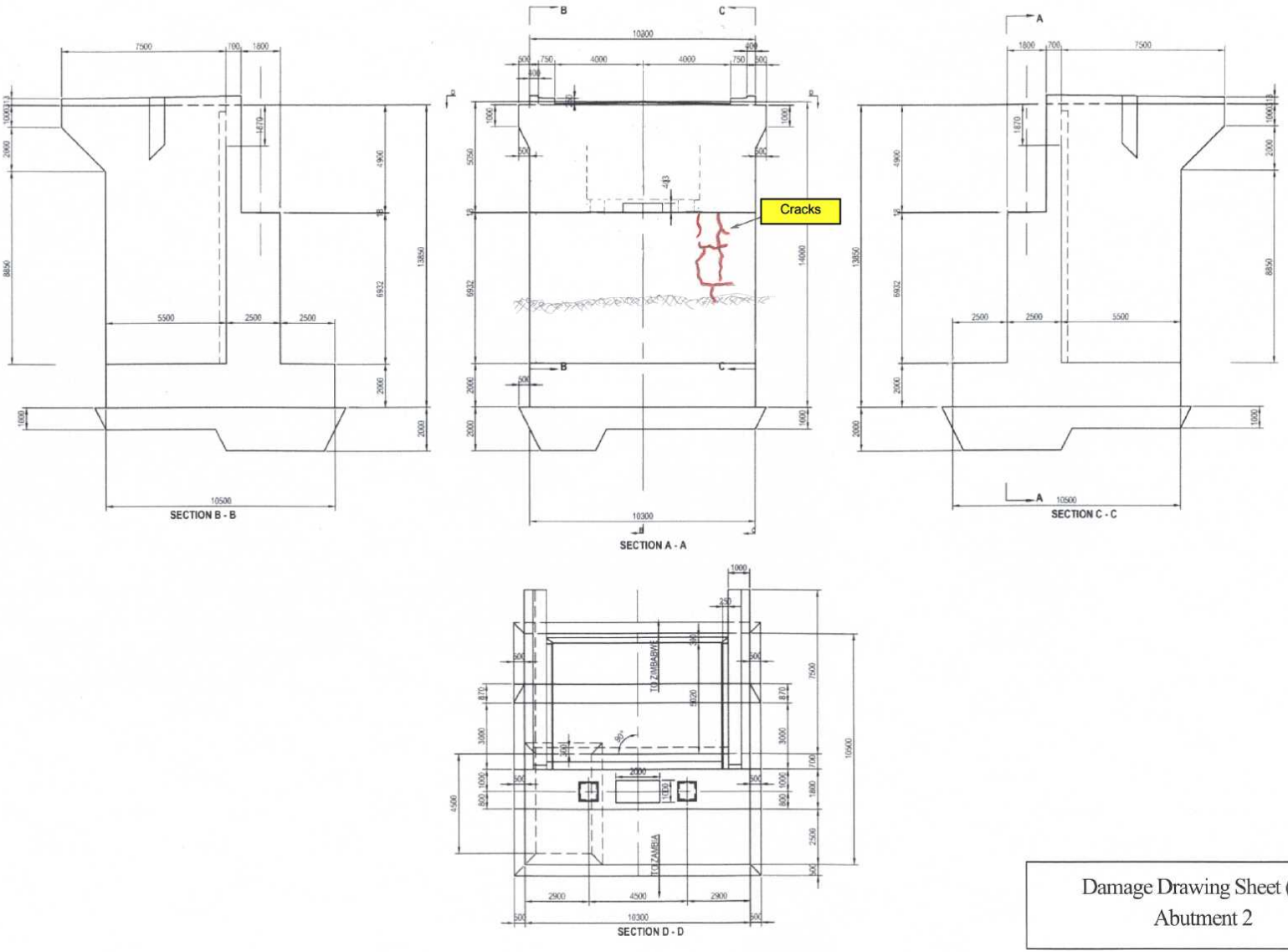

d
Expansion joint is damaged.
120000
Transverse cracks
Drain scuppers are buried.
10300
8000
10300
a
A lot of garbage
4500
9000
b
0300
5500
c
a
10300
400 750
4000
4000
750
400
ASPHALT PAVEMENT t=50
Drain pipes are extremely short.
300
250
4500 ~ 9000
b
d
2750
c
GIRDER CROSS SECTION
Damage Drawing Sheet (2/8)
Girder: Span 1


4000
9000
d
Looks like sinking
Transverse cracks
Drain scuppers are buried.
160000
TO ZAMBIA
TO ZIMBABWE
8000
10300
P1
P2
ZAMBEZI RIVER
a
9000
4000
b
160000
5500
TO ZAMBIA
TO ZIMBABWE
P1
P2
c
a
10300
400
750
4000
4000
750
400
ASPHALT PAVEMENT (t=50)
300
250
Drain pipes are extremely short.
b
d
9000
4500
2750
c
GIRDER CROSS SECTION
Damage Drawing Sheet (3/8)
Girder: Span 2


d
120000
Drain scuppers are buried.
Many alligator cracks on the pavement
TO ZIMBABWE
8000
10300
P2
Transverse cracks
Expansion joint is damaged.
a
A2
9000
500
4000
b
5590
10300
P2
c
a
10300
400 750
4000
4000
750
400
ASPHALT PAVEMENT (t=50)
300
250
Drain pipes are extremely short.
b
d
1500 ~ 9000
2750
c
GIRDER CROSS SECTION
Damage Drawing Sheet (4/8)
Girder: Span 3



Damage Drawing Sheet (5/8)
Abutment 1



Damage Drawing Sheet (6/8)
Abutment 2

(4) Routine Inspection Results (November 23, 2021)

- Many of the defects observed during the 2019 inspection are about the same condition in this inspection.
- These are the damage of the rubber materials of the expansion joints, transverse cracks on the sidewalk and deck surface beside the sidewalk near the intermediate support points, vertical cracks on the front surfaces of the abutments, cracks on the Zimbabwe side approach pavement.
- What is different from the observation result in 2019 is that the previous inspection result in 2019 reported that the bridge surface of the central span seemed to subside, but this time, the RDA survey team measured the vertical profile of the bridge.
- As a result, it is clear that all three spans subsided. From the survey results, the vertical profile of the bridge becomes the vertical curve in the figure below when the vertical gradient -1.25% is subtracted.

- Even when observed with the naked eye in the field, all three spans appear to be lowered. The amount of subsidence is 16 cm in the Zambia side span, 12 to 15 cm in the central span, and 18 to 19 cm in the Zimbabwe side span.

Bridge Routine Inspection Form

Date:		Contractor Name:				Contract Ref. No. :			Province:
Bridge No.:		Bridge Name:			Road No.:		Road Name:		Location:
		Chirundu Bridge			T2				
No.	(1) Bridge Component	(2) Sub-Component	(3) Defect Type	(4) Condition Rating	(5) Quantity (Unit)	(6) Proposed Action	(7) New/ Existing	(8) Date of Detection	(9) Remarks
1	Deck	Pavement	Scaling	Fair	All spans	MO	New	2021/11/23	Down stream side pavement (Photo: 1-1) Monitoring needed.
2	Deck	Pavement	Pothole	Fair	5 m^2	RM repair	New	2021/11/23	Upstream side pavement (Photo: 1-2) Patching is needed.
3	Expansion Joint	Hybrid Joint (Maurer Joint)	Brakage of rubber members	Bad	2 joints	MM repair	Existing	2021/11/23	Replacement of 2 joints is necessary. (Photo: 2-1, 2-2)
4	Superstructure	PC Girder	Abnormal deflection	Bad	All spans	In-depth Inspection	Existing	2021/11/23	Follow-up observation is necessary. (Photo: 3)
5	Superstructure	Sidewalk & Deck surface	Cracks	Poor	2 locations	RM repair	Existing	2021/11/23	Epoxy coating or Epoxy injection is necessary. (Photo: 4-1, 4-2)
6	Drainage	Scupper	Clogged	Poor	Several portions	RM repair	Existing	2021/11/23	Cleaning is necessary. (Photo: 5-1)
7	Drainage	Drain Pipes	Very short	Poor	All pipes	RM repair	Existing	2021/11/23	Replace if possible (Photo: 5-2)
8	Substructure	Abutment	Cracks	Poor	18m (Crack length)	RM or MM repair	Existing	2021/11/23	Epoxy injection is necessary (A1 & A2, Photo: 6-1, 6-2)
9	Site/Others	Approach	Crack on pavement	Bad	200m^2	MM repair	Existing	2021/11/23	Zimbabwe approach. (Photo: 7-1, 7-2) Removal & reconstruction of the pavement is required.
10	Site/Others	Around Zambia side abutment	Accumulation of garbage	Poor	300m^2	RM repair	Existing	2021/11/23	Cleaning is necessary. (Photo: 8)

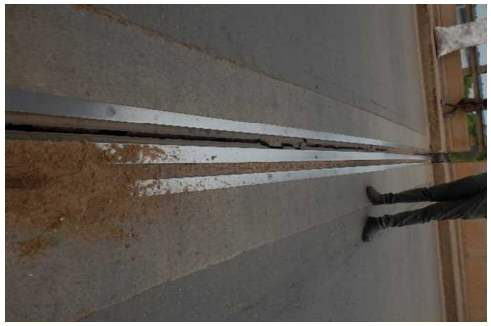
Photo Record Sheet (Bridge Name: Chirundu Bridge)

Contractor Name:		Contract Ref. No.:		Province:	

No. :	1-1
Date:	November 23, 2021
Location:	Pavement (Downstream side)
Defect Type	Scaling
Description:	Scaling has occurred over the entire length of the bridge.

No.:	1-2
Date:	November 23, 2021
Location:	Pavement (Upstream side)
Defect Type	Pothole
Description:	No scaling has occurred, but a large pothole can be seen.

No.:	2-1
Date:	November 23, 2021
Location:	Expansion Joint (Zambia side)
Defect Type	Rubber material broken
Description:	The rubber member on the approach side is broken.



No.:	2-2
Date:	November 23, 2021
Location:	Expansion Joint
Defect Type	Rubber material broken
Description:	The rubber member on the river side is broken.

No.:	3
Date:	November 23, 2021
Location:	Bridge Surface
Defect Type	Abnormal deflection
Description:	The surface of the bridge is subsided in all three spans.

No.:	4-1
Date:	November 23, 2021
Location:	Sidewalk
Defect Type	Transverse crack
Description:	Transverse cracks on the sidewalk surface near the intermediate support points

No.:	4-2
Date:	November 23, 2021
Location:	Deck Surface near Sidewalk
Defect Type	Cracks
Description:	Transverse cracks on the deck surface beside the sidewalk near the intermediate support points

No.:	5-1
Date:	November 23, 2021
Location:	Scupper
Defect Type	Clogged
Description:	Several scuppers are filled with earth and sand.

No.:	5-2
Date:	November 23, 2021
Location:	Drain Pipe
Defect Type	Very Short
Description:	Length of the drain pipes are short.

No.:	6-1
Date:	November 23, 2021
Location:	Zambia side Abutment (A1)
Defect Type	Cracks
Description:	There are many vertical cracks in the front surface of the Zambian side abutment.

No.:	6-2
Date:	November 23, 2021
Location:	Zimbabwe side Abutment (A2)
Defect Type	Cracks
Description:	There are many vertical cracks in the front surface of the Zimbabwe side abutment.

No.:	7-1
Date:	November 23, 2021
Location:	Zimbabwe side Approach
Defect Type	Cracks
Description:	Many alligator cracks are seen on the Zimbabwe approach.

					
No.:	7-2	No.:	8	No.:	
Date:	November 23, 2021	Date:	November 23, 2021	Date:	
Location:	Zimbabwe side Approach	Location:	Around Abutment (A1)	Location:	
Defect Type	Crack	Defect Type	Accumulation of garbage	Defect Type:	
Description:	Enlarged photo of cracks	Description:	A lot of garbage such as plastic bottles is scattered around the Zambia side abutment.	Description:	

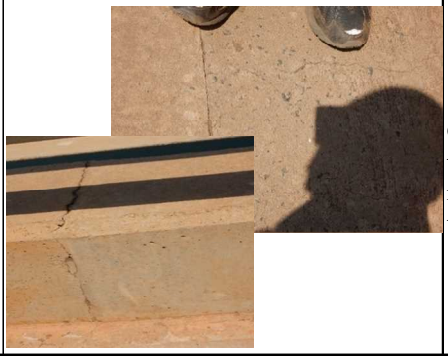
5-1-3 Routine Maintenance

(1) Defects and Causes

The defects observed during the inspection of the Chirundu Bridge on November 23, 2021 and their presumed causes are described below.

For the defects common to general bridges, please see "Bridge Routine maintenance Guideline, 3-6 Types of Defects and Causes".

Table 5-1-2 Defects and Presumed Causes of Chirundu Bridge

Location+A2:D7	Defects	Photography	Presumed Causes
Drainage (Scupper)	Accumulation of debris		Soil that adhered to the vehicle or was carried by the vehicle fell on the road surface and was carried to the drain scupper by rainwater/wind and accumulated.
Drainage (Drain pipe)	Insufficient length		If the drain pipe is short, when it rains with wind, the water flowing down from the pipe is blown by the wind and hits the girder. The water seeps into the girder and may eventually lead to corrosion of the steel. When rainwater contains chloride ions, the progress of corrosion is especially fast.
PC Girder	Abnormal deflection		After the bridge was completed, the shrinkage strain due to the drying of the concrete and the creep strain due to the action of the sustained stress due to the dead load progressed more than expected, and as a result, the deflection of the girder increased.Therefore, it is presumed that the rubber bearing was deformed and destroyed diagonally downward toward the river, the expansion joint was pulled in the direction of the bridge axis, and the rubber part could not withstand and was damaged.
Expansion Joint	Brakage of rubber material		
Sidewalk, Kerb	Transverse cracks on pier (P1, P2)		Cracks are seen on the sidewalk surface on the piers due to the negative bending moment. The state of the upper surface of the main girder should be inspected.

Abutment	Vertical cracks		The following cause is considered: Cracking occurred because the temperature deformation due to the heat of hydration was constrained by the temperature difference between the post-cast and the first cast and/or the temperature difference in the cross section.
Approach Pavement	Cracks		It would be considered a cause of damage that heavy vehicles repeatedly passed the pavement over a long period of time.
Around Zambian side abutment	Accumulation of garbage		Driver's manner

Abnormal Phenomena and Presumed Causes

What's happening on the Chirundu Bridge now?

The Chirundu Bridge, completed in 2002, the rubber bearings were replaced in May 2015. During the 13 years since completion, the rubber bearings were sheared and the upper half of the bearings was greatly displaced toward the river side. This time, as a result of surveying the vertical profile of the bridge, it was found that all the spans were subsided. If the bridge surface did not sink at the time of completion and had an almost straight vertical profile, the following process can be inferred:

- The sinking of the girder gradually progressed after completion.
- Due to the sinking of the girder, the lower surface of the girder on the bearing was pulled toward the span (river) side, the rubber bearing was sheared and broken, and the expansion joint on the upper surface of the girder was pulled in the direction of the bridge axis.
- The beam inside the Maurer joint did not move with respect to the extension width larger than expected, and one of the two rubber parts could not withstand the extension and was damaged.

Further guessing, it is presumed that:

- After the bridge was completed, the shrinkage strain due to the drying of the concrete and the creep strain due to the action of the sustained stress due to the dead load progressed more than expected, and as a result, the introduction prestress of the girder decreased and the deflection of the girder increased.

(2) Routine Maintenance Activities

The standard routine maintenance activities of the prestressed concrete box girder bridge are shown in Table 5-1-3.

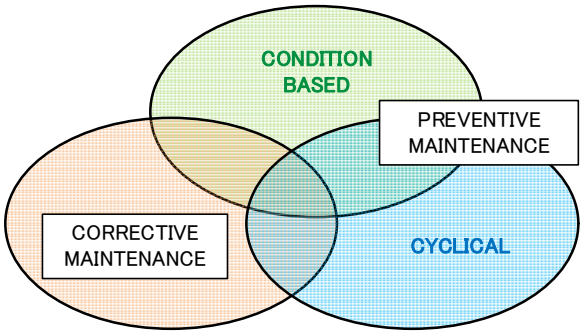


Figure 5-1-2 Treatment Categories

Table 5-1-3 Routine Maintenance Activity List (Chirundu Bridge)

Activity No.	Activity Item	Frequency	Classification	Applied Item	
				Chapter 4	Chapter 5
	(Deck)				
1-1	Clean deck and gutters	Yearly	Preventive(Cycl.)	4-1	
1-2	Clean deck drains/scuppers	Yearly	Preventive(Cycl.)	4-1	
1-3	Clean joint	Yearly	Preventive(Cycl.)	4-1	
1-4	Joint sealing	As needed	Corrective	4-9	
1-5	Deck repair – Coating on /injection/caulking into cracks	As needed	Preventive(CB.)	4-6/4-7/4-8	
1-6	Deck repair – Pavement Patching	As needed	Corrective	4-11	
1-7	Deck repair – Concrete Deck Patching	As needed	Corrective	4-3	
1-8	Collision damage repair to railing/parapet	As needed	Corrective	4-10	
1-9	Repair to damaged curb/sidewalk	As needed	Corrective	4-11	
1-10	Drain extensions	As needed	Preventive(CB.)	4-12	
	(Superstructure)				
2-1	Clean girders	2 years	Preventive(Cycl.)	4-1	
2-3	Coating on/injection/caulking into cracks	As needed	Preventive(CB.)	4-6/4-7/4-8	
2-4	Patching on concrete members	As needed	Corrective	4-5	
	(Substructure)				
3-1	Clean abutments/caps/bearings	2 years	Preventive(Cycl.)	4-1	
3-2	Coating on/injection/caulking into cracks	As needed	Preventive(CB.)	4-6/4-7/4-8	
3-3	Repairs to slope protection	As needed	Preventive(CB.)	4-15	
3-4	Repair to scour protections around foundations	As needed	Preventive(CB.)	4-16	
	(Site)				
4-1	Vegetation control and rubbish removal around substructures	Quarterly	Preventive(Cycl.)	4-13	
4-2	Removal of debris/driftwoods from waterway	As needed	Preventive(CB.)	4-14	

Table 5-1-4 shows the recommended maintenance activities for the defects observed during the inspection of Chirundu Bridge.

Table 5-1-4 Recommended Maintenance Activities for Chirundu Bridge

No.	Bridge Component/ Sub-Component	Defect Type	Routine Maintenance Activity	Applied Item in Chapter 4 and 5	Other Activities
1	Dainage/Scupper	Accumulation of debris	1-2 Clean deck drains/scuppers	4-1 Cleaning/Desilting	-
2	Drainage/Drain pipe	Insufficient length	1-10 Drain extension	4-12 Drain Extension	Monitoring: Though no major damage has not occurred so far, it is recommended to repair it when the budget allows. Until the budget is available, it is also recommended to check the girder condition near the drain pipes at the time of routine inspection
3	Expansion Joint/ Hybrid Joint	Brakage of rubber material	-	-	MM Repair: Replacement
4	Superstructure/ PC member	Abnormal deflection	-	-	Monitoring: Perform a vertical profile survey of the bridge once every six months In-depth Inspection: a. Detailed visual inspection of the bottom and side surfaces of the box girder. b. Static loading and running tests of vehicles on the bridge. (The actual stiffness of the girder from the obtained deflection and vibration characteristics of the bridge.)
5	Superstructure/ Concrete member	Cracks	2-3 Injection into cracks	4-7 Epoxy Injection	-
6	Substructure/ Concrete member(Abutment)	Cracks	3-2 Injection into cracks (Repair scale of cracks is small)	4-7 Epoxy Injection	Injection by MM Repair: Repair scale of cracks is large
7	Site/Others/ Approach	Cracks on pavement	-	-	MM Repair: Removal and replacement of pavement
8	Site/Others/ Around Zambian side abutment	Accumulation of garbage	4-1 vegitation control and rubbish removal around substructures	4-13 Vegetation Control and Rubbish Removal	-

For reference

Non-destructive and small destructive tests are introduced as methods of investigating settlement phenomena in PC box girder bridges.

Type of Survey	Survey Method	Effectiveness	Remarks
1. Residual prestress	Stress Release Method (Incision Core Method)	Possible	Micro-destructive testing: Survey equipment & Scaffolding are required
2. Grout Filling Degree	a. Elastic Wave Method	Possible	Nondestructive testing: Survey equipment & Scaffolding are required
	b.Drilling Survey (small hole)	Valid	Small destructive testing: Survey equipment & Scaffolding are required
3. Damage of PC Steel	a.Magnetic Stream Method	Possible	Nondestructive testing: Survey equipment & Scaffolding are required
	b.Drilling Survey (small hole)	Valid	Small destructive testing: Survey equipment & Scaffolding are required
4. Concrete Sterength	Core sampling and compression testing	Valid	Small destructive testing: Survey equipment & Scaffolding are required

5-1-4 Routine Maintenance and Repair Method

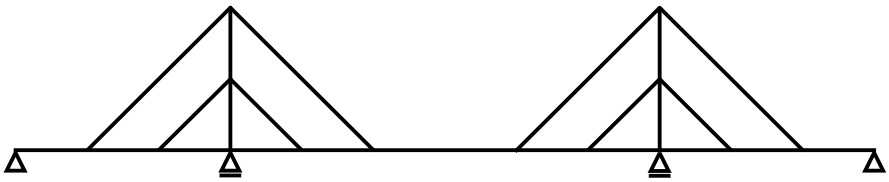
If there are any items that should be added as routine maintenance activities of the Chirundu Bridge in the future, add them to Table 5-1-3 and describe the contents, methods, materials used, and equipment in "5-1-4 Routine Maintenance and Repair method".

5-2 CABLE-STAYED BRIDGE (LUANGWA BRIDGE)

5-2-1 Structural Outline

When the span of the continuous girder bridge becomes long, the dead load increases rapidly and reaches the application limit at a certain span length. The cable-stayed bridge is a structure in which the main girder is hung (supported) by a cable stretched diagonally from a tower erected on the intermediate pier of the continuous girder bridge. Therefore, since the main girder behaves as an elastically supported structure at the cable attachment point, the girder height can be kept low.

On the other hand, in a cable structure such as a cable-stayed bridge, since the damping property of the entire girder is reduced, vibrations due to wind are likely to occur, therefore, a girder structure considering wind resistance is desirable.



(Cable-stayed bridge)

(Continuous Beam on Elastic Supports)

Figure 5-2-1 Structural System of Cable-stayed Bridge

5-2-2 Routine Inspection

(1) Bridge Components and Defects

Table 5-2-1a shows possible defects in the bridge components of Luangwa Bridge. And, Table 5-2-1b shows defects in the bridge components of Luangwa Bridge which shall be inspected on the routine inspection.

Table 5-2-1a Bridge Components and Possible Defects (Luangwa Bridge)

Bridge Component	Sub-Component	Possible Defects
Supersructure	Steel members (Main girder, Cross beam)	1) Deterioration of painting, 2) Corrosion, 3) Fatigue crack/Fracture, 4) Loose connection/Missing rivet or HTB, 5) Deformation/Buckling, 6) Abnormal deflection, 7) Abnormal vibration, 8) Abnormal sound
Deck	Concrete deck	1) Crack, 2) Spalling, 3) Scaling, 4) Honeycomb/Loose concrete, 5) Rebar exposure/Rebar corrosion, 6) Water leakage/Free lime
Substructure	Concrete members (Abutment, Pier)	1) Crack, 2) Spalling, 3) Delamination, 4) Honeycomb/Loose concrete, 5) Cold joint, 6) Rebar exposure/Rebar corrosion, 7) Water leakage/Free lime
	Foundation	1) Tilt, 2) Settlement, 3) Scouring/Lowering of river bed
	Protection work	1) Slope/Bank erosion, 2) Loss/Disintegration of protection materials, 3) Defects due to displacement of foundation
Expansion Joint	Metal joint (Load-bearing type)	1) Crack/Fracture, 2) Damage to post-cast concrete, 3) Deterioration of waterproof system, 4) Crrosion, 5) Difference in level, 6) Abnormal sound, 7) Abnormal spacing, 8)Bump
Wearing Course	Asphalt pavement	1) Potholes, 2) Rutting, 3) Bump, 4) Corrugation, 5) Crack, 6) Raveling, 7) Ponding
Sidewalk		1) Crack, 2) Potholes/Spalling, 3) Bump, 4) Ponding, 5) Accumulation of garbage and debris
Bearing	Metal bearing	1)Deformation/Breakage of bearing, 2) Corrosion of bearing, 3) Loose connection/Missing bolts, 4) Corrosion of bolts, 5) Breakage of mortar/concrete seat, 6) Abnormal sound, 7) Accumulation of garbage and debris
Railing	Metal railing	1) Deformation, 2) Corrosion, 3) Disappearance, 4) Loose connection
Drainage	Scupper	1) Damage to scupper, 2) Damage to cover, 3) Accumulation of garbage and debris
	Drain pipe	1) Damage to pipe, 2) Defect in connection, 3) Accumulation of garbage and debris, 4) Insufficient length, 5) No drain pipe
Site/Others	Waterway	1) Accumulation of driftwoods/debris, 2) Changes in river direction/lowering river bed (within a range of 20m from the bridge to the upstream and downstream sides)
	Approach	1) Accumulation of vegetation/debris/garbage, 2) Damage to rip-rap/retaining wall, 3) Settlement of approach section/incorrect vertical alignment, 4) Damage to approach pavement (crack, pothole, etc.)
Cable System	Cable	1) Failure, 2) Deformation, 3) Abnormal sag, 4) Corrosion, 5) Abnormal vibration, 6) Damage of protection cover/coating, 7) Water leakage
	Tower (Steel)	1) Corrosion, 2) Fatigue crack, 3) Deformation/Buckling, 4) Loose/Missing HTB, 5) Deterioration of painting, 6) Abnormal sound, 7) Abnormal vibration, 8) Water leakage
	Anchorage	1) Crack, 2) Corrosion, 3) Loose/Missing HTB, 4) Deterioration of painting, 5) Deformation, 6) Water leakage

able 5-2-1b Bridge Components and Defects on Routine Inspection (Luangwa Bridge)

Bridge Component	Sub-Component	Defects to be inspected
Supersructure	Steel members (Main girder, Cross beam)	1) Deterioration of painting, 2) Corrosion, 3) Fatigue crack/Fracture, 4) Loose connection/Missing rivet or HTB, 5) Deformation/Buckling, 6) Abnormal deflection
Deck	Concrete deck	1) Crack, 2) Spalling/Loose concrete, 3) Rebar exposure/Rebar corrosion, 4) Water leakage/Free lime
Substructure	Concrete members (Abutment, Pier)	1) Crack, 2) Spalling/Loose concrete, 3) Cold joint, 4) Rebar exposure/Rebar corrosion, 5) Water leakage/Free lime
	Foundation	1) Tilt, 2) Settlement, 3) Scouring
	Protection work	1) Slope/Bank erosion, 2) Loss/Disintegration of protection materials
Expansion Joint	Metal joint (Load-bearing type)	1) Crack/Fracture, 2) Damage to post-cast concrete, 3) Crrosion, 4) Abnormal sound, 5) Abnormal spacing
Wearing Course	Asphalt pavement	1) Potholes, 2) Rutting, 3) Crack, 4) Raveling, 5) Ponding
Sidewalk		1) Crack, 2) Potholes, 3) Ponding, 4) Accumulation of garbage and debris
Bearing	Metal bearing	1)Deformation/Breakage of bearing, 2) Corrosion of bearing, 3) Loose connection/Missing bolts, 4) Breakage of mortar/concrete seat, 5) Accumulation of garbage and debris
Railing	Metal railing	1) Deformation, 2) Corrosion, 3) Disappearance, 4) Loose connection
Drainage	Scupper	1) Damage to scupper, 2) Damage to cover, 3) Accumulation of garbage and debris
	Drain pipe	1) Damage to pipe, 2) Insufficient length, 3) No drain pipe
Site/Others	Waterway	1) Accumulation of driftwoods/debris
	Approach	1) Accumulation of vegetation/debris/garbage, 2) Damage to rip-rap/retaining wall, 3) Settlement of approach section/incorrect vertical alignment, 4) Damage to approach pavement (crack, pothole, etc.)
Cable System	Cable	1) Failure, 2) Deformation, 3) Abnormal sag, 4) Corrosion, 5) Abnormal vibration, 6) Damage of protection cover/coating, 7) Water leakage
	Tower (Steel)	1) Corrosion, 2) Fatigue crack, 3) Deformation/Buckling, 4) Loose/Missing HTB, 5) Deterioration of painting, 6) Abnormal sound, 7) Abnormal vibration, 8) Water leakage
	Anchorage	1) Crack, 2) Corrosion, 3) Loose/Missing HTB, 4) Deterioration of painting, 5) Deformation, 6) Water leakage

(2) Sheets for Routine Inspection (Luangwa Bridge)

The Routine Inspection Report consists of following 4 kinds of sheet:

a. Bridge Routine Inspection Form;

b. Defect Drawing Sheet;

c. Photo Record Sheet; and

d. Routine maintenance Record Schedule and Record Form.

Bridge Routine Inspection Form

Date:		Contractor Name:				Contract Ref. No. :			Province:	
Bridge No.:		Bridge Name:			Road No.:		Road Name:		Location:	
No.	(1) Bridge Component	(2) Sub-Component	(3) Defect Type	(4) Condition Rating	(5) Quantity (Unit)	(6) Proposed Action	(7) New/ Existing	(8) Date of Detection	(9) Remarks	

Note: - To categorize (1) Bridge Component, (2) Sub-component and (3) Defect type, refer to Table 5-2-1b.

To determine (4) Condition rating and (6) Proposed action, refer to the Table 1 and Table 2 with Figure 1, respectively.

(7) New/Existing means damage newly identified in this inspection/already identified in previous inspection.

Note: How to fill out the Bridge Routine Inspection Form

If you find a defect, enter the location in the columns of "(1) Bridge Component & (2) Sub-Component" and enter the type of defect in column of "(3) Defect Type", in the Bridge Routine Inspection Form, and fill the location and type of defect on the Defect Drawing Sheet. And, in the column "(4) Condition Rating", select Good, Fair, Poor or Bad according to Table 1 Routine Inspection Condition Rating Criteria. In the column "(6) Proposed Action", suitable actions should be entered refer to the Figure 1 Determination flow of Maintenance Action. Table 1 shows the criteria for judgment of Condition Rating. Table 2 shows the types of required actions and their contents of actions. Figure1 is a flowchart for determining a maintenance action based on the identified damage situation.

Table1 Routine Inspection Condition Rating Criteria

Condition Rating	Description
Good	No damage
Fair	With minor damage(s) not affecting the stability of the structure
Poor	With deteriorating damage(s) which should be monitored or could be repaired as a preventive action
Bad	With severe damage(s) that affects stability of bridge or that has possibility to harm a third party

Table 2 Required Maintenance Action

Required Action	Description
MO: Monitoring	No repair work and keeping monitoring (Damage not progressing or very slow)
RM: Routine Maintenance	Should be maintained by Routine Maintenance
MM: Major Maintenance	Should be maintained by Major Maintenance
EA: Emergency Action	Need to take actions immediately to avoid bridge collapse or harm to a third party
In-Depth Inspection	Condition Inspection or Detailed Inspection - Selection of appropriate repair method - Monitoring of progress of any damages

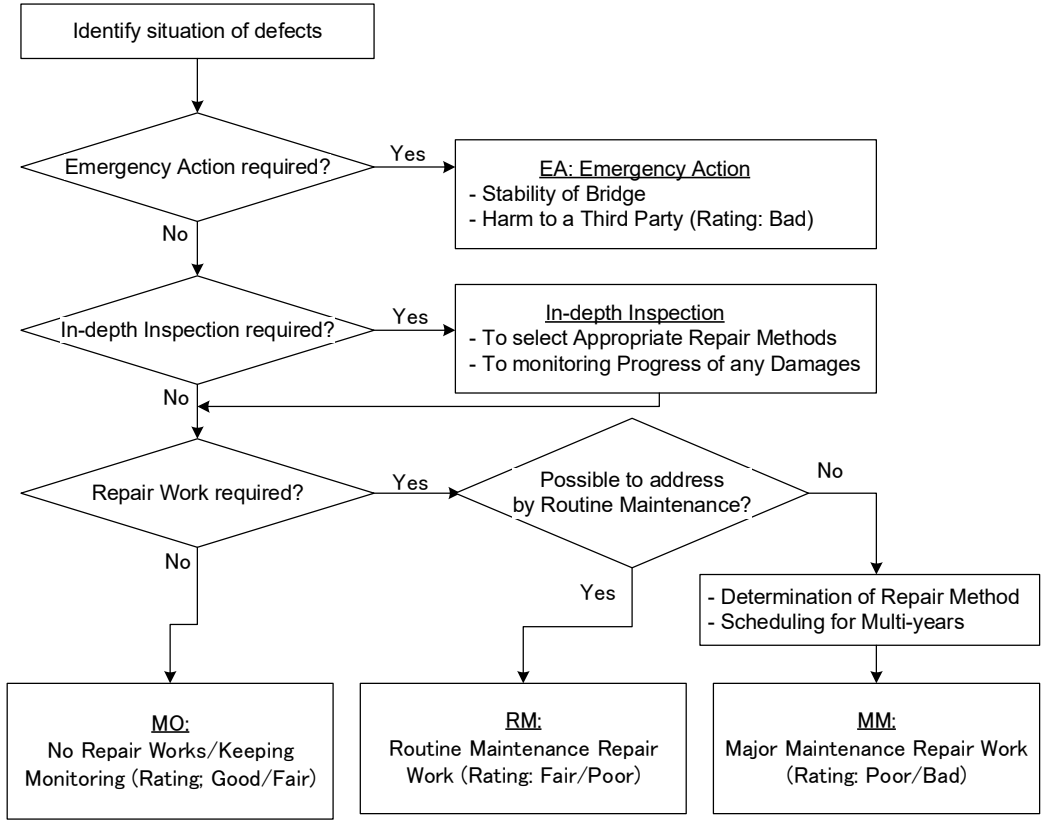
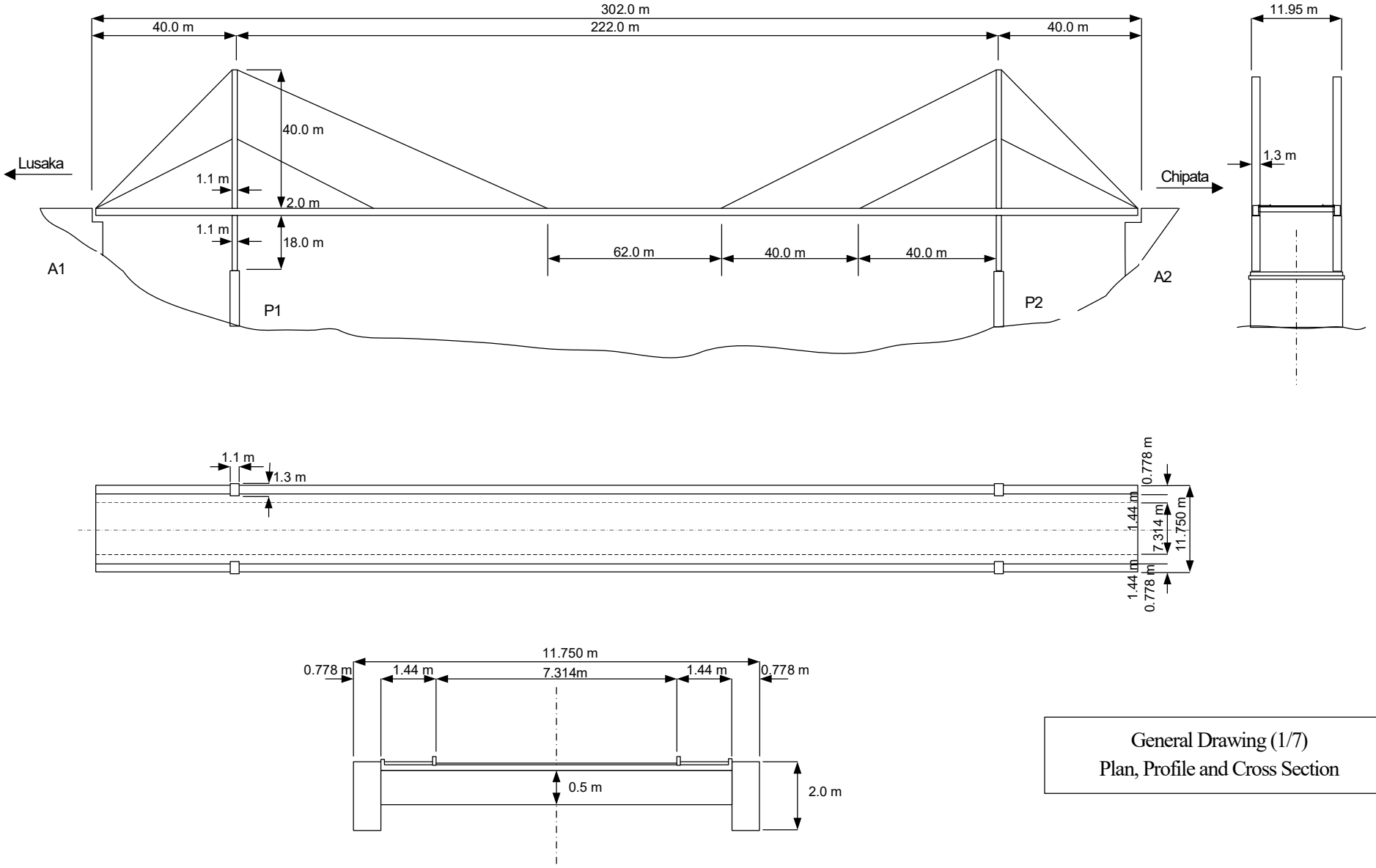
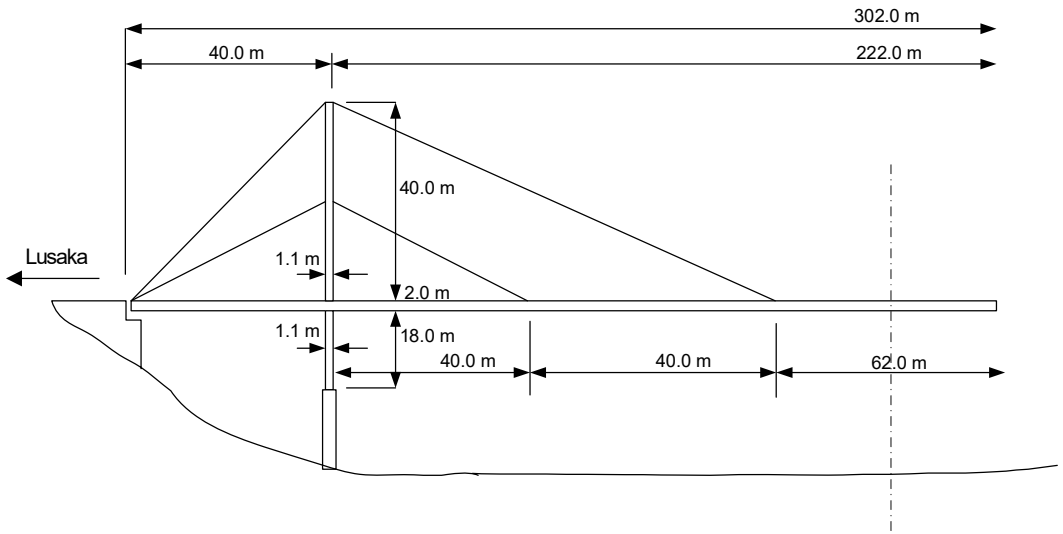
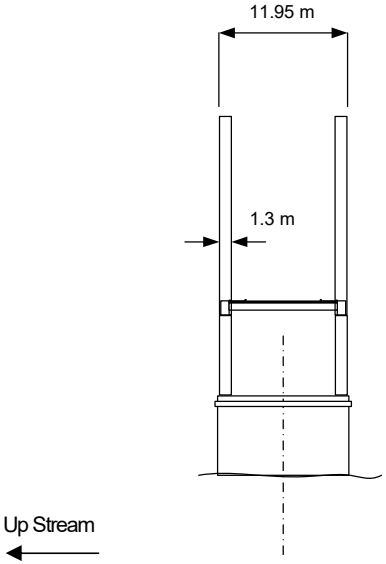


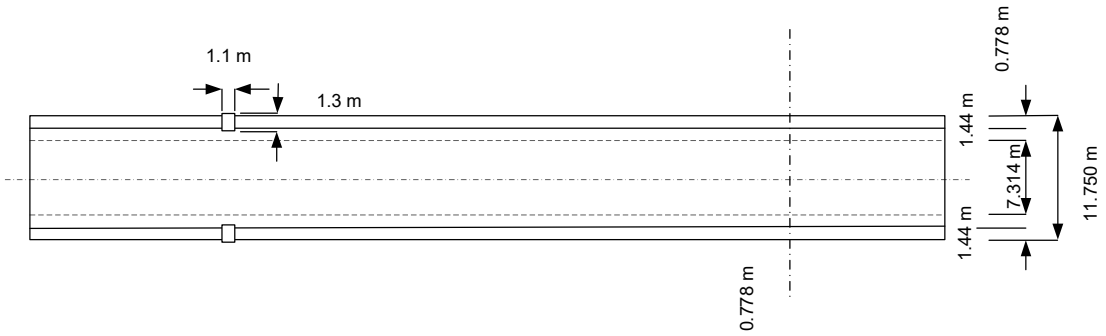
Figure 1 Determination Flow of Maintenance Action

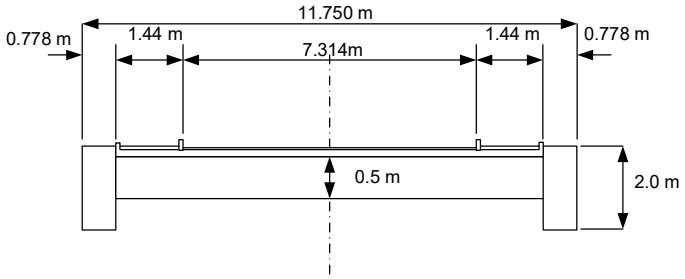


General Drawing (1/7)
Plan, Profile and Cross Section

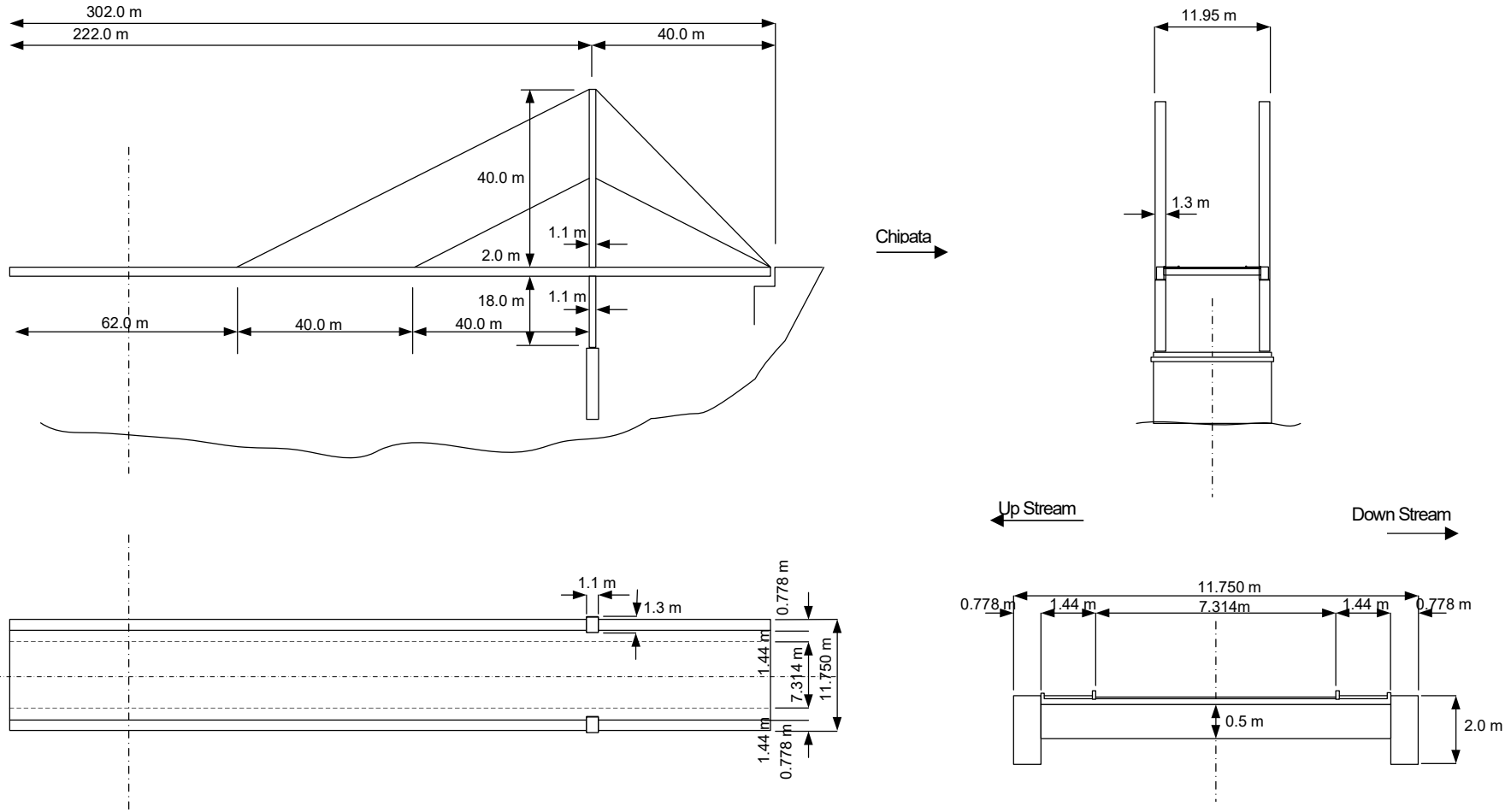




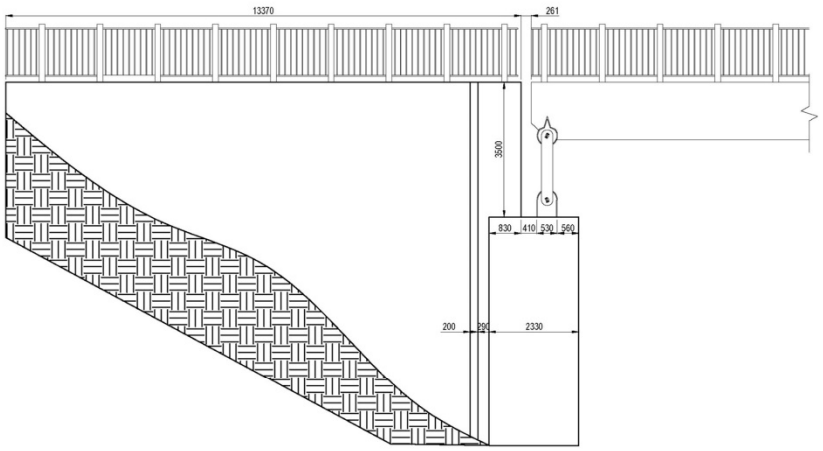




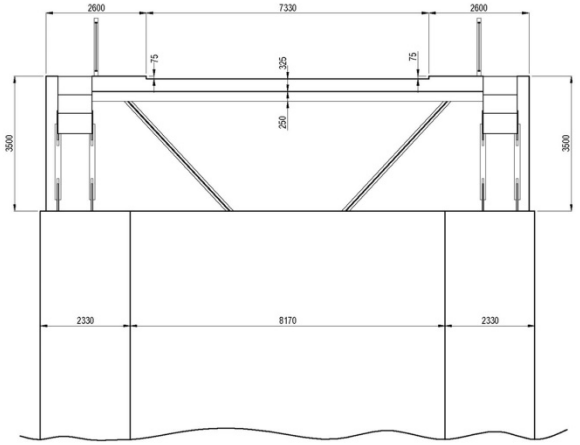
Damage Drawing Sheet (2/7)
Girder, Slab, Tower, Cable (Western Part)



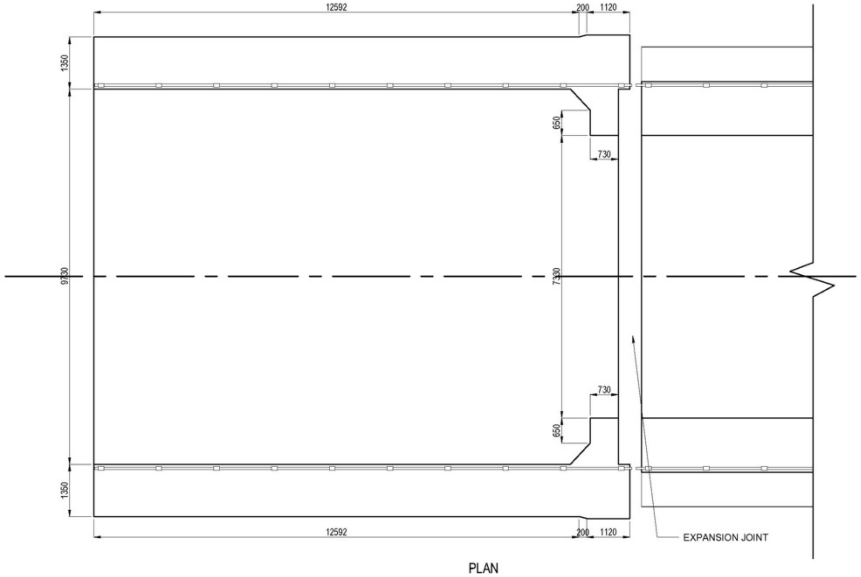
Damage Drawing Sheet (3/7)
Girder, Slab, Tower, Cable (Eastern Part)



TYPICAL ELEVATION

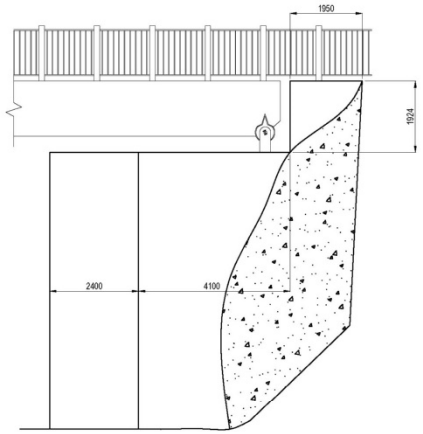


TYPICAL CROSS SECTION

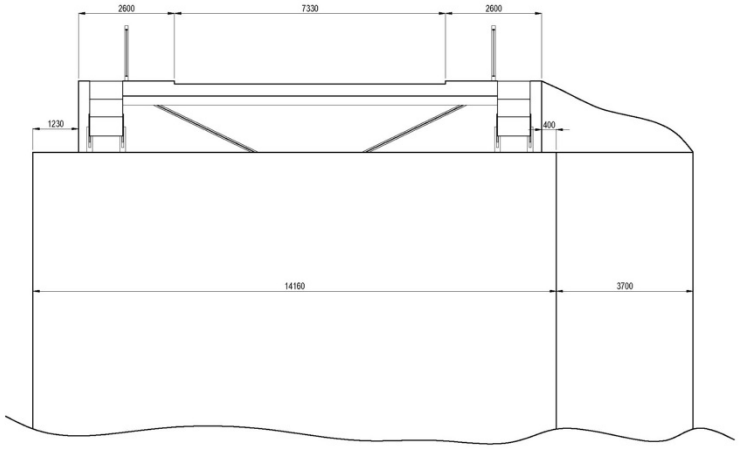


PLAN

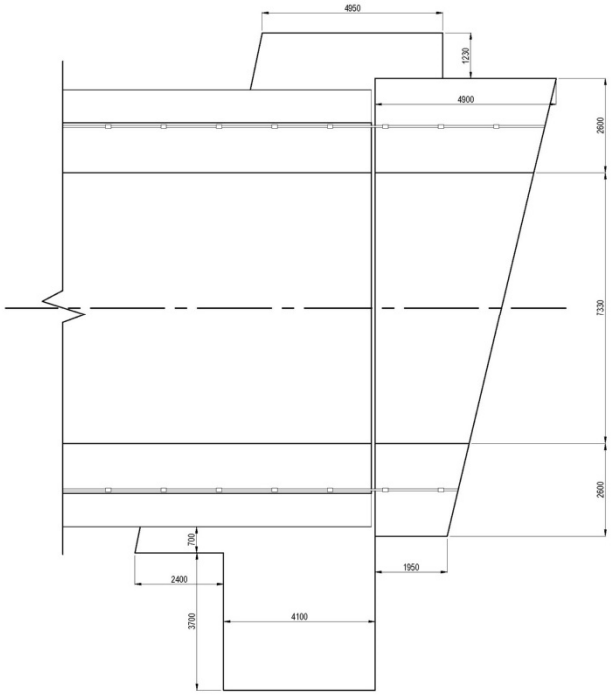
Damage Drawing Sheet (4/7)
Abutment: Western Side



TYPICAL ELEVATION

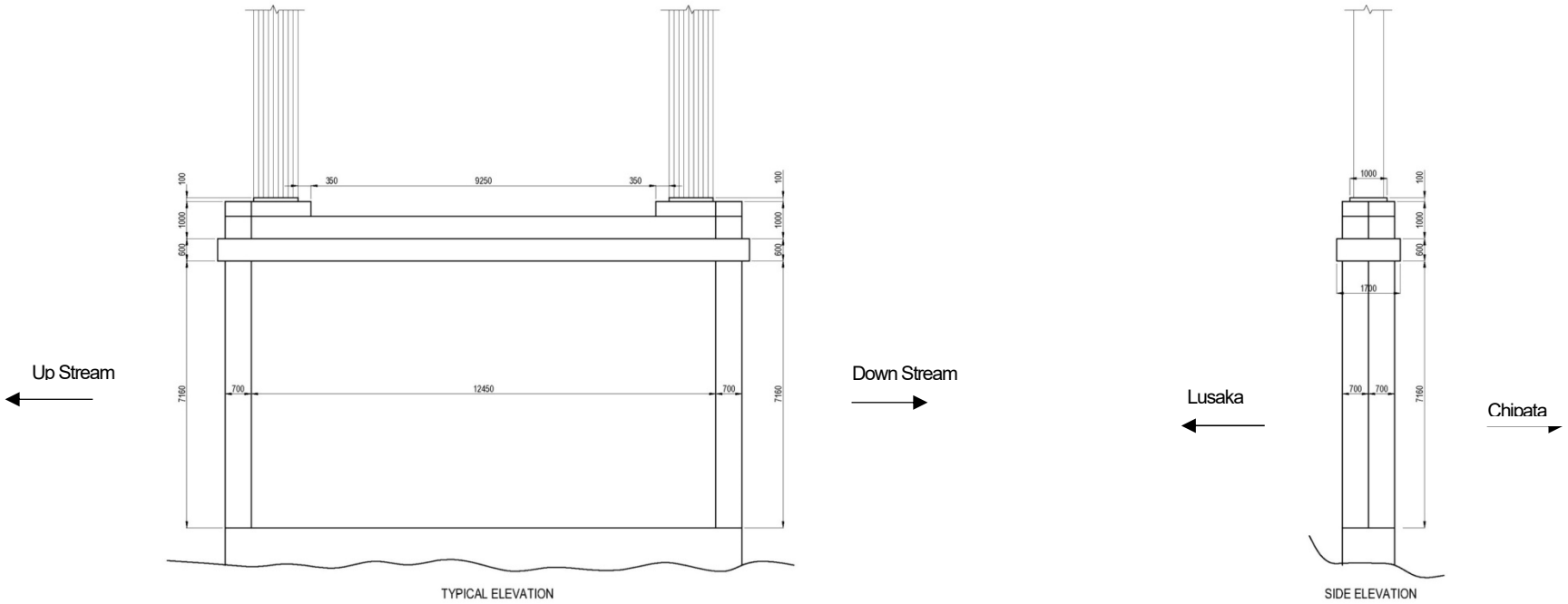


TYPICAL CROSS SECTION

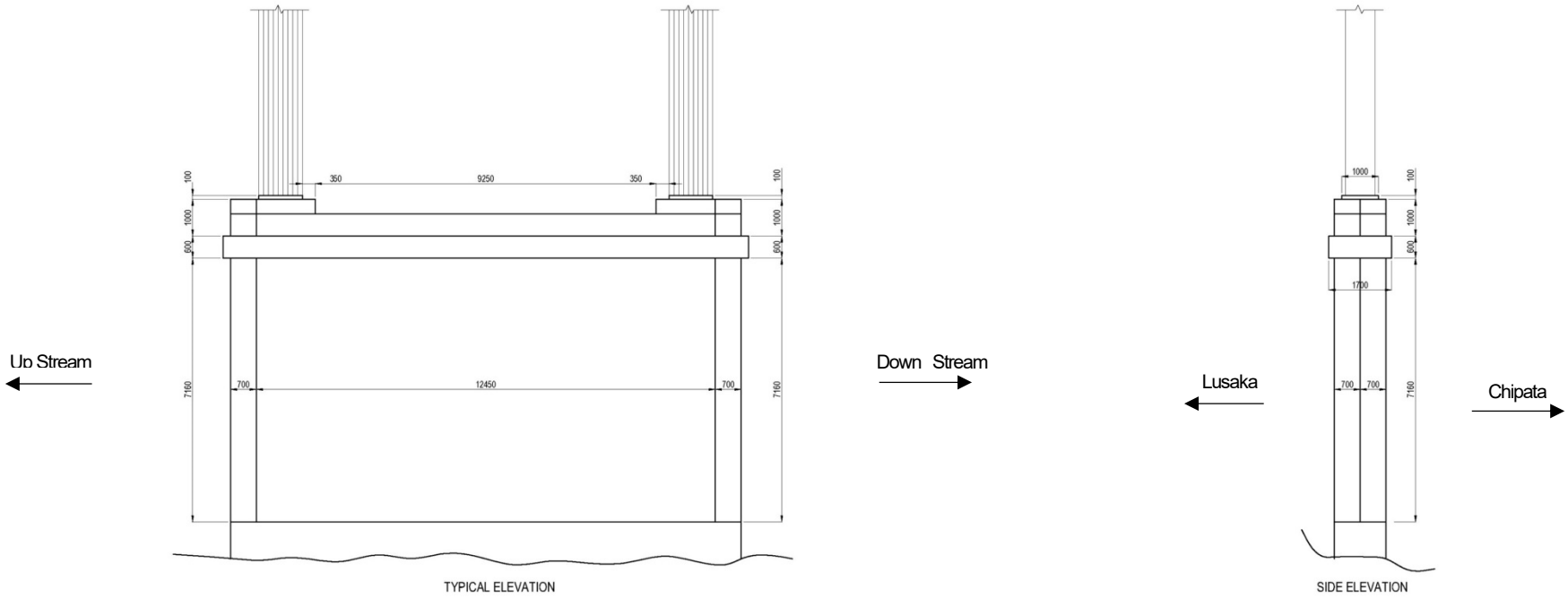


PLAN

Damage Drawing Sheet (5/7)
Abutment: Eastern Side



Damage Drawing Sheet (6/7)
Pier: 1



Damage Drawing Sheet (7/7)
Pier: 2

Photo Record Sheet (Bridge Name: Luangwa Bridge)

Contractor Name:		Contract Ref. No.:		Province:	
Date:		Date:		Date:	
No.:		No.:		No.:	
Defect Type:		Defect Type:		Defect Type:	
Description:		Description:		Description:	
Date:		Date:		Date:	
No.:		No.:		No.:	
Defect Type:		Defect Type:		Defect Type:	
Description:		Description:		Description:	

Bridge Routine Maintenance Schedule and Record Form

Bridge No.:	Bridge Name:	Contractor Name:	Contract Ref. No.:	Province:
	Luangwa Bridge			

No.	(1) Contract Item No.:	(2) Activities	(3) Description: Condition before Maintenance	(4) Ref. No. of Defect	(5) Estimated Cost	(6) Date: Instruction to Contractor	(7) Date: Work Completed	(8) Additional Work Required	(9) Remarks

Note: -Ref. No. of defect corresponds to No. with the inspection date in the Bridge Routine Inspection Form-e.g. No.01-26.11.2015

(3) Routine Inspection Results (October 27 and December 10, 2020)

Bridge Routine Inspection Form

Date: 27/10/2020		Contractor Name:	Dorman Long Limited			Contract Ref. No. :			Province: Eastern
Bridge No.:		Bridge Name:			Road No.:		Road Name:		Location:
B-T004-005		Luangwa bridge			T004		Great East		Luangwa River - 14.975682° S/ 30.212473° E
No.	(1) Bridge Component	(2) Sub-Component	(3) Defect Type	(4) Condition Rating	(5) Quantity (Unit)	(6) Proposed Action	(7) New/ Existing	(8) Date of Detection	(9) Remarks
1	Superstructure	Steel member (Main girder and Cross beam)	Paint deterioration, Corrosion	Fair	Touch-up painting: A=250m^2	RM Repair	Existing	27/10/2020	Corrosion observed on the joints and lower flange of girders and cross beams. Paint deterioration observed on entire girder surface. See sketches and photos 1.1 – 1.4.
2	Superstructure	Main girder, Deck	Sagging	Fair	-	Monitoring	Existing	27/10/2020	Superstructure is sagging between stays. See sketches and photo 1.9.
3	Railing	Metal railing	Paint deterioration	Fair	Repainting All	MM Repair	Existing	27/10/2020	Paint deterioration observed on entire railing. See sketches and photo 1.16.
4	Railing	Guardrail	Missing bolts	Fair	Installation 2 bolts	RM Repair	New	27/10/2020	Missing bolts observed. See sketch and photo 1.15.
5	Cable system	Tower	Paint deterioration	Fair	Repainting All	MM Repair	Existing	27/10/2020	Paint deterioration observed on tower surface. See sketch and photo 1.20.
6	Cable system	Anchorage	Corrosion	Fair	Repainting All	MM Repair	Existing	27/10/2020	Corrosion observed. See sketch and photo 1.21.
7	Deck	Concrete deck (Upper surface)	Cracks, Spalling	Poor	Epoxy injection: V=250cm^3 Patching: V=400cm3	RM Repair	Existing	27/10/2020	Many cracks and spalled sections observed on deck surface. See sketches and photos 1.6 & 1.8.

8	Deck	Concrete deck (Lower surface)	Cracks, Spalling	Poor	Epoxy injection: V=2,800cm^3 Patching: V=75,000cm3	RM Repair	Existing	27/10/2020	A big crack is observed on bottom of slab on P1. A big spalling is observed near P2. See sketches and photos 1.5 & 17.
9	Drainage	Drain pipe	Insufficient length	Poor	Extension: L=80 m	RM Repair	Existing	27/10/2020	Short drain pipes observed. Suspected to cause corrosion on the cross beams. See sketches and photos 1.1 & 1.17.
10	Substructure	Abutment A1 (Western side)	Cracks	Poor	Epoxy injection: V=300cm^3 Patching: V=18,000cm3	RM Repair	Existing	27/10/2020	Big cracks observed on the upper surface of the abutment. See sketche and photos 1.10.
11	Substructure	Abutment A2 (Eastern side)	Cracks	Poor	Epoxy injection: V=409cm^3	RM Repair	Existing	27/10/2020	Big cracks observed on the upper surface and front surface of the abutment. See sketches and photos 1.11 & 1.12.
12	Substructure	Pier P1 (Western side)	Cracks	Poor	Epoxy injection: V=150cm^3	RM Repair	Existing	27/10/2020	Cracks observed on the wall. See sketches and photos 1.13 & 1.14.
13	Substructure	Pier P2 (Eastern side)	water leakage, Corrosin	Poor	Touch-up painting: A=1.2m^2	RM Repair	Existing	27/10/2020	Water leakage and corrosion observed at the part that support the girder and tower. See sketches and photo 1.19.
14	Site/Others	Approach (Eastern side)	Cracks	Poor	Epoxy injection: V=11,100cm^3	MM Repair	Existing	27/10/2020	Many cracks observed. See sketch and photo 1.18.
15	Lightening system	All	Unfunctioned	Poor	4 units	RM Repair	New	27/10/2020	Four (4) lights were said not be working.

Photo Record Sheet (Bridge Name: Luangwa Bridge)

Contractor Name:	Dorman Long Limited	Contract Ref. No.:		Province:	Eastern

Date:	27/10/2020
No.:	1.1
Defect Type:	Short drain pipe & corrosion on cross beam
Description:	Insufficient length of drain pipes (all pipes), cross beam near the drain pipe is corroded.

Date:	27/10/2020
No.:	1.2
Defect Type:	Corrosion on girder joint
Description:	Many joint plates and bolts are corroded.

Date:	27/10/2020
No.:	1.3
Defect Type:	Paint deterioration on upper flange of main girder
Description:	Paint deterioration is observed on upper flange of main girder.

Date:	27/10/2020
No.:	1.4
Defect Type:	Corrosion on girder lower flange
Description:	Corrosion is observed at the edge of lower flange on the main girder.

Date:	27/10/2020
No.:	1.5
Defect Type:	Spalling on bottom surface of deck slab
Description:	A big spalling is observed on bottom surface of deck slab.

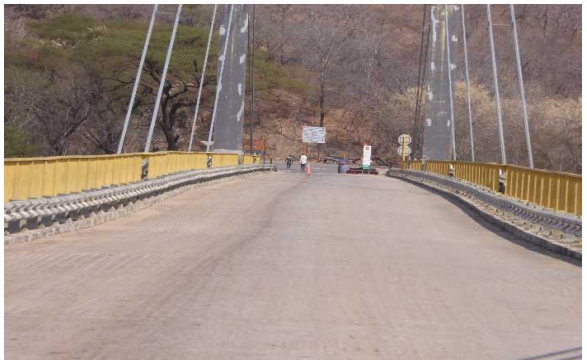
Date:	27/10/2020
No.:	1.6
Defect Type:	Spalling & disintegration on top surface of deck slab
Description:	Spalling & disintegration are observed on the top surface of deck slab.

Photo Record Sheet (Bridge Name: Luangwa Bridge)

Contractor Name:	Dorman Long Limited	Contract Ref. No.:		Province:	Eastern

Date:	27/10/2020
No.:	1.7
Defect Type:	Big cracks on deck bottom surface
Description:	Big cracks are observed on the bottom surface of deck slab.

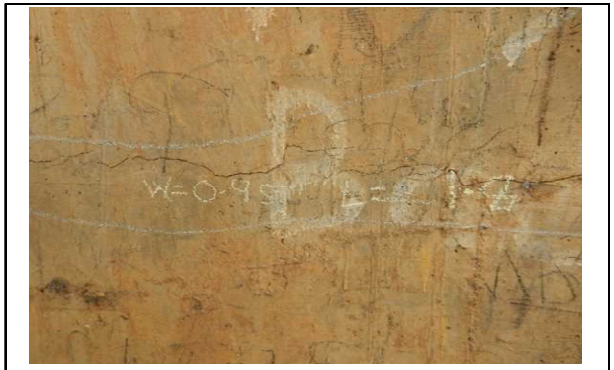
Date:	27/10/2020
No.:	1.8
Defect Type:	Cracks on deck top surface
Description:	Many cracks are observed on the top surface of deck slab.



Date:	27/10/2020
No.:	1.9
Defect Type:	Sagging of superstructure
Description:	Sagging of superstructure is observed between the cable stays in the main span.

Date:	27/10/2020
No.:	1.10
Defect Type:	Cracks on western side abutment A1
Description:	Cracks are observed on the top surface of western side abutment A1.

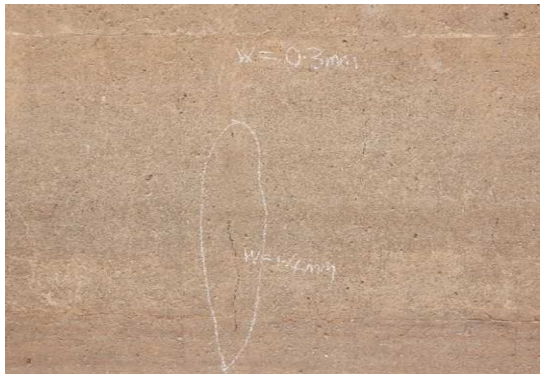
Date:	27/10/2020
No.:	1.11
Defect Type:	Cracks on eastern side abutment A2
Description:	Cracks are observed on the front wall of eastern side abutment A2.



Date:	27/10/2020
No.:	1.12
Defect Type:	Cracks on eastern side abutment A2
Description:	Cracks are observed on the front wall of eastern side abutment A2.

Photo Record Sheet (Bridge Name: Luangwa Bridge)

Contractor Name:	Dorman Long Limited	Contract Ref. No.:		Province:	Eastern



Date:	27/10/2020
No.:	1.13
Defect Type:	Cracks on western side pier (P1)
Description:	Cracks are observed on the eastern side wall of western side pier P1.

Date:	27/10/2020
No.:	1.14
Defect Type:	Cracks on western side pier (P1)
Description:	Cracks are observed on the eastern side wall of western side pier P1.

Date:	27/10/2020
No.:	1.15
Defect Type:	Missing bolts on guardrail
Description:	

Date:	27/10/2020
No.:	1.16
Defect Type:	Paint deterioration on handrail
Description:	Paint deterioration is observed on handrail entirely.

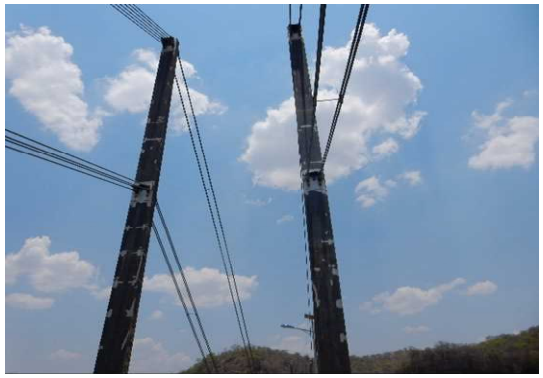
Date:	27/10/2020
No.:	1.17
Defect Type:	Drain scupper
Description:	

Date:	27/10/2020
No.:	1.18
Defect Type:	Cracks on approach slab
Description:	Many longitudinal & transverse cracks are observed on the approach slab

Photo Record Sheet (Bridge Name: Luangwa Bridge)

Contractor Name:	Dorman Long Limited	Contract Ref. No.:		Province:	Eastern

Date:	27/10/2020
No.:	1.19
Defect Type:	Water leakage & corrosion on eastern pier (P2)
Description:	Water leakage & corrosion are observed at the girder supporting portion of eastern pier P2.



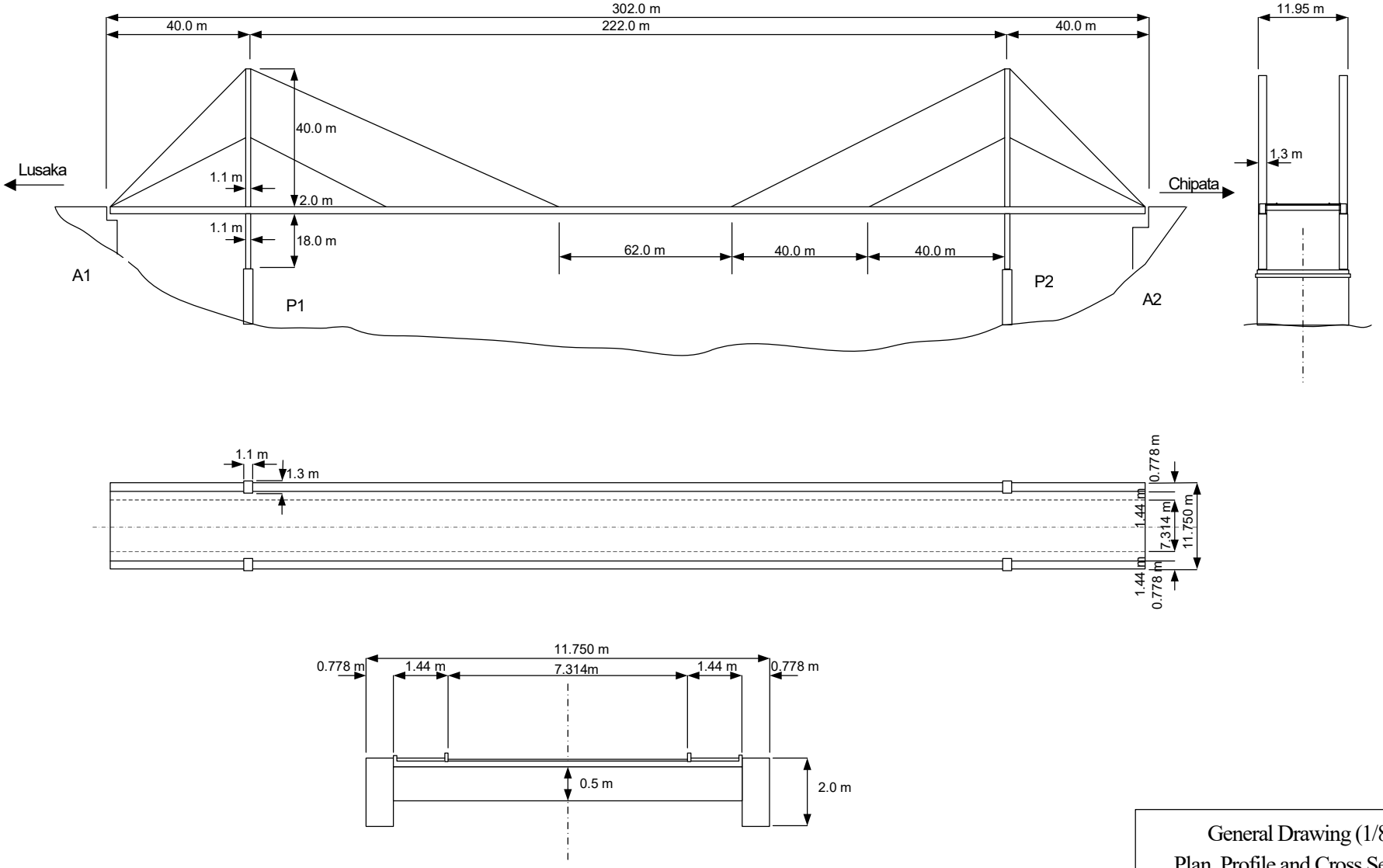
Date:	27/10/2020
No.:	1.2
Defect Type:	Paint deterioration on tower
Description:	Paint deterioration is observed on all tower members.

Date:	27/10/2020
No.:	1.21
Defect Type:	Corrosion & paint deterioration on anchorage
Description:	Corrosion & paint deterioration are observed on most anchorages.

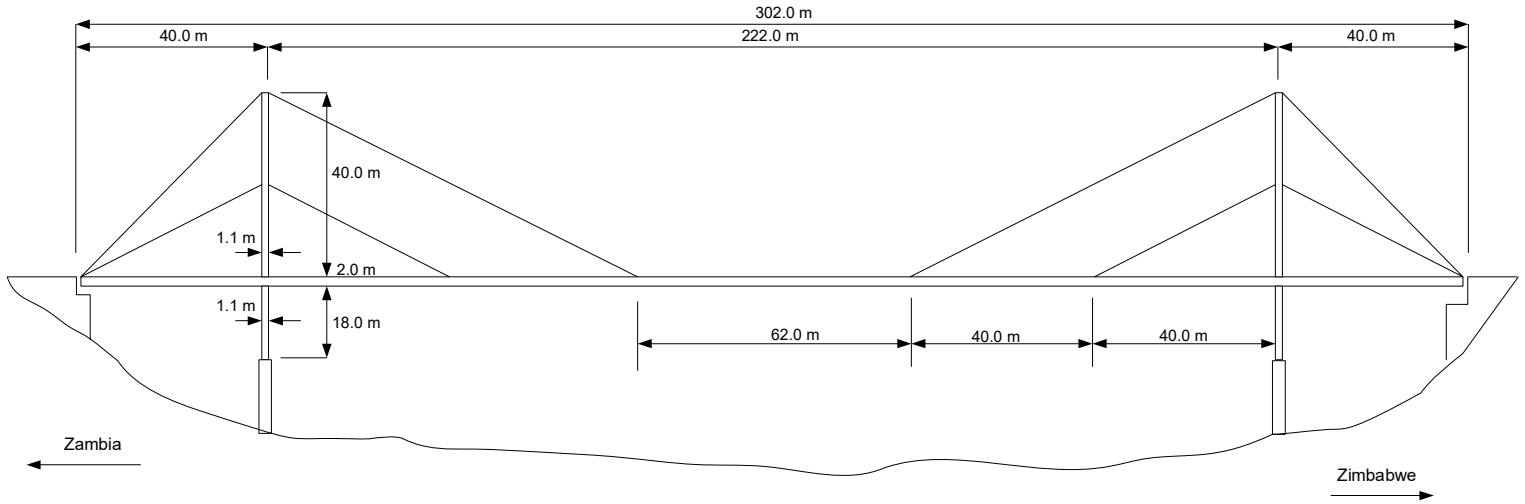
Date:	
No.:	
Defect Type:	
Description:	

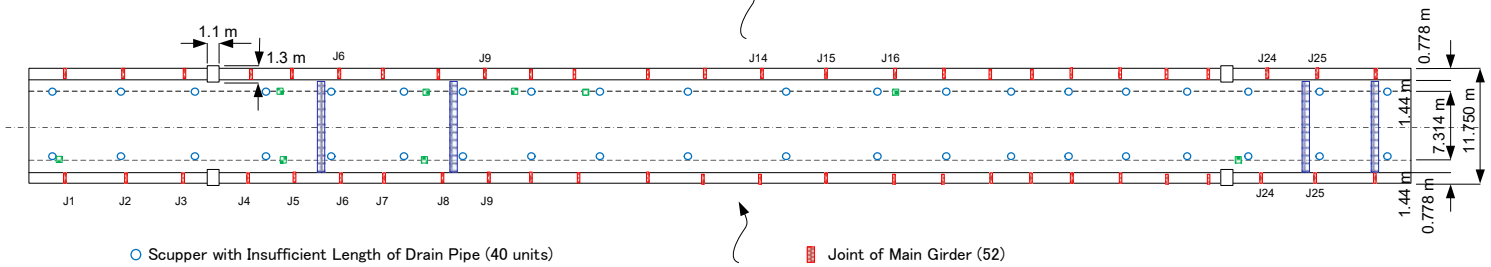
Date:	
No.:	
Defect Type:	
Description:	

Date:	
No.:	
Defect Type:	
Description:	



General Drawing (1/8)
Plan, Profile and Cross Section





○ Scupper with Insufficient Length of Drain Pipe (40 units)

Missing Bolt of Gurdrail (9 points)

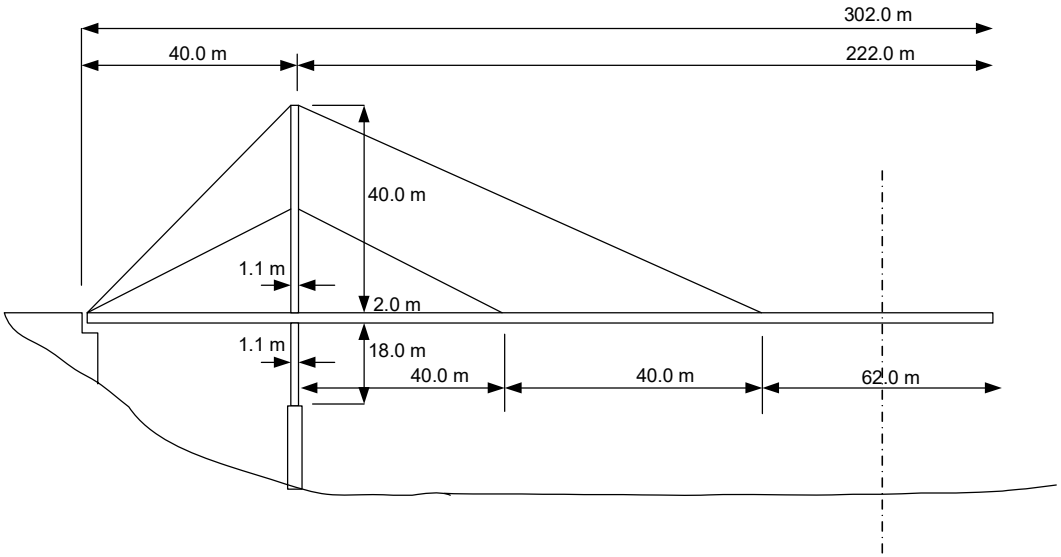
Corroded Cross Beam (4 beams)

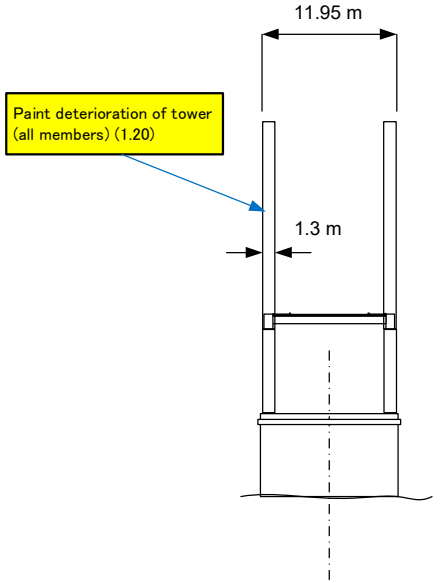
Joint of Main Girder (52)

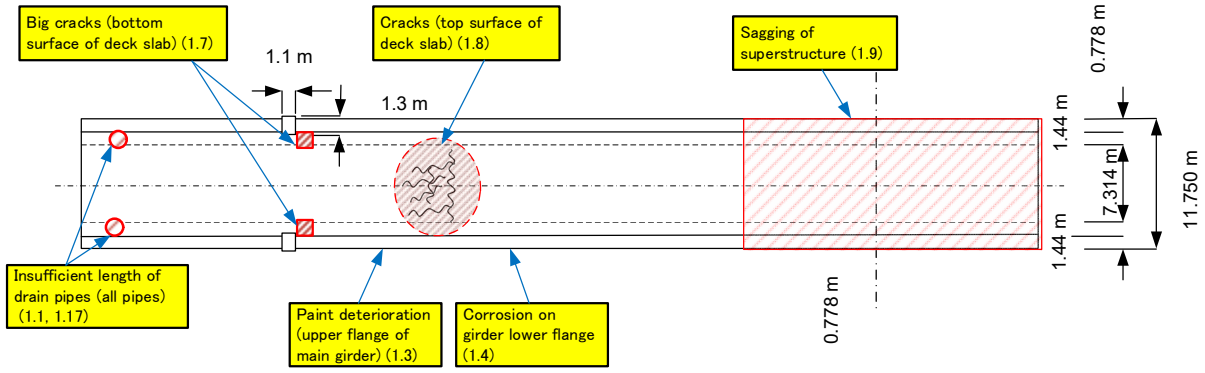
Condition of Joint

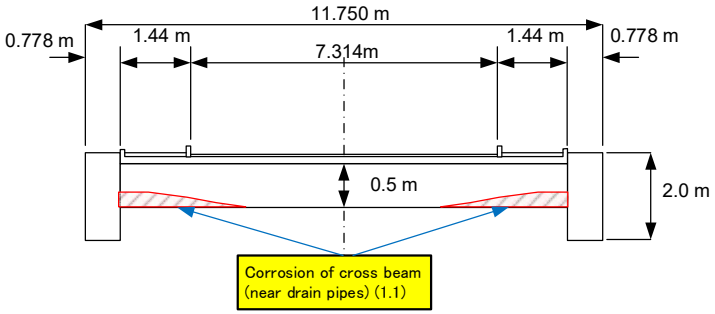
	No.	Condition
Downstream side	J6, J9, J14-J16, J24-J25	Corroded
	Others	Fair
Upstream side	J1, J5-J9, J24-J25	Corroded
	J2-J4	Slightly corroded
		Fair

Damage Drawing Sheet (2/8)
Girder joint, Cross Beam, Guardrail & Scupper

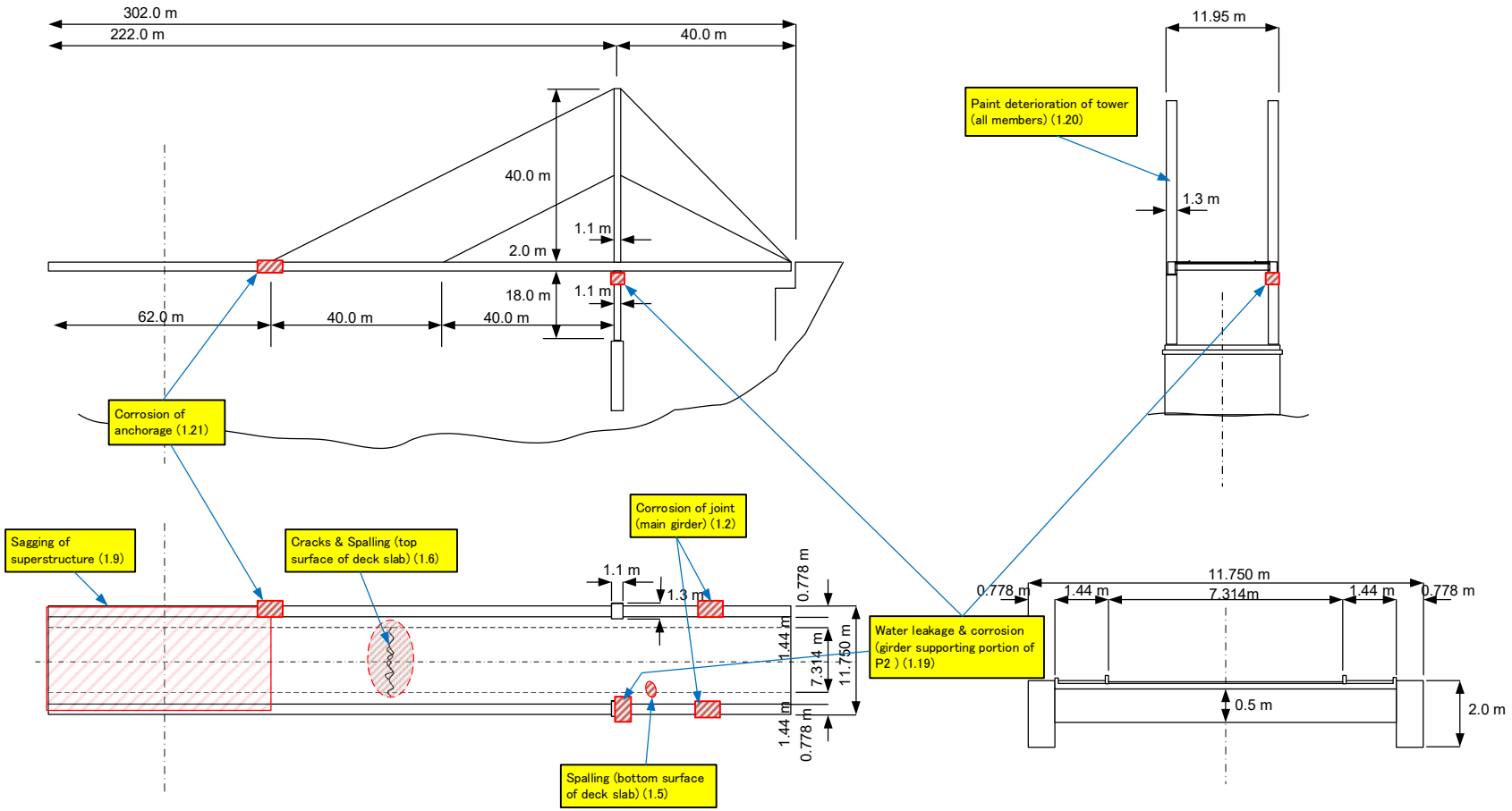




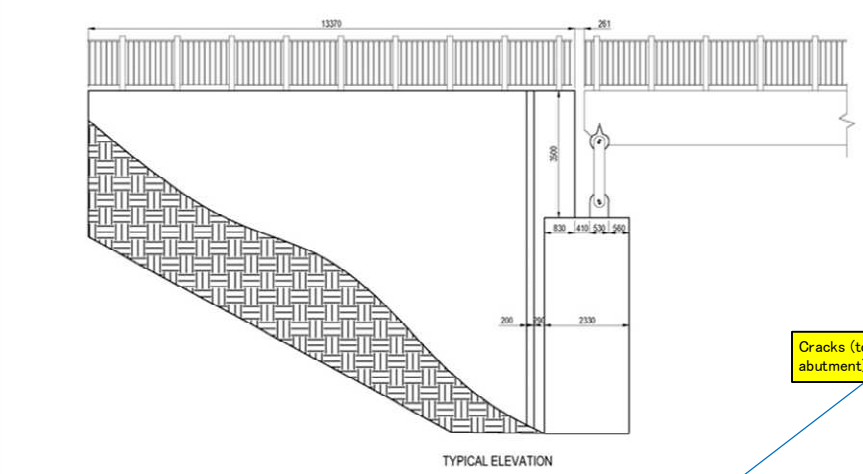


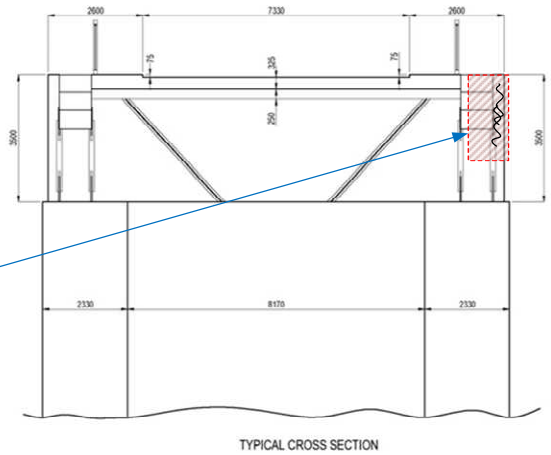


Damage Drawing Sheet (3/8)
Girder, Slab, Tower, Cable (Western Part)

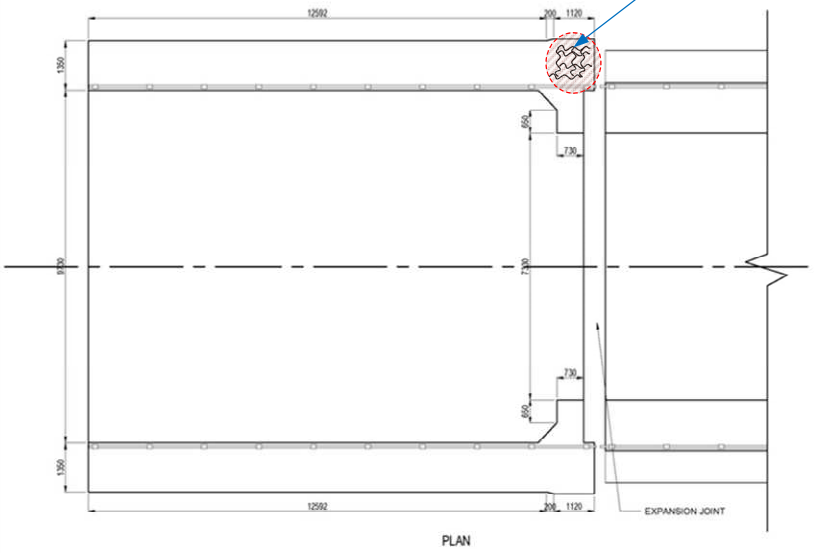


Damage Drawing Sheet (4/8)
Girder, Slab, Tower, Cable (Eastern Part)

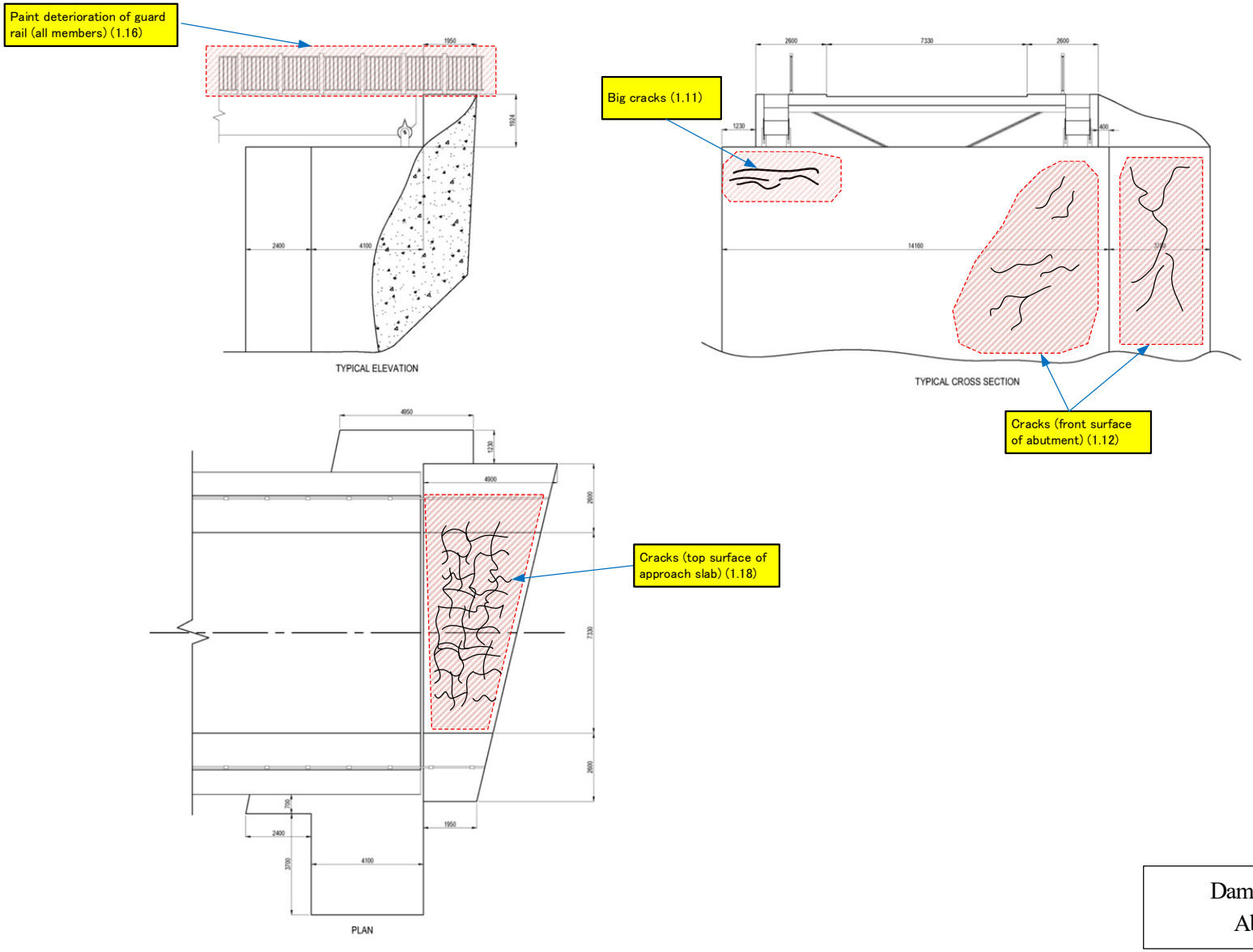




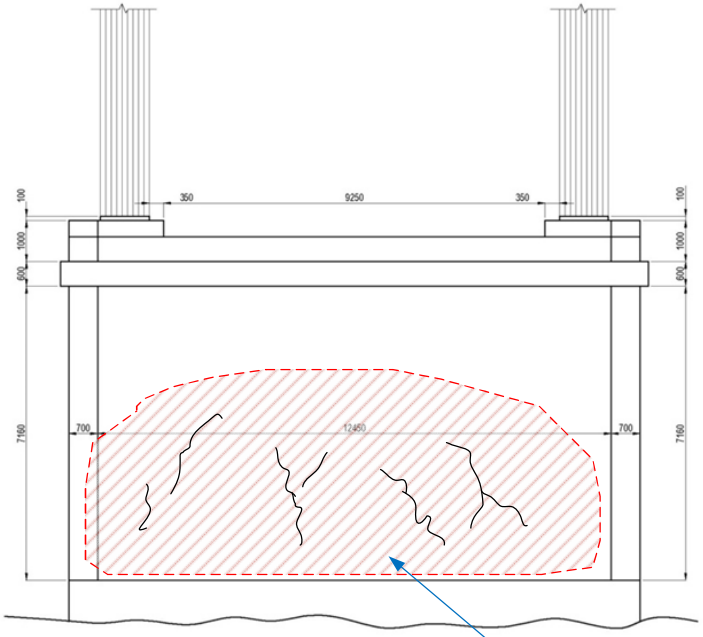
Cracks (top surface of abutment) (1.10)

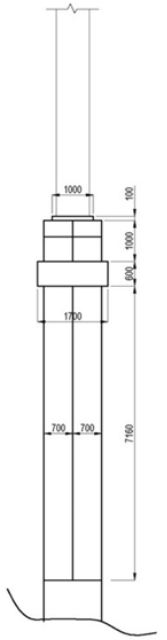


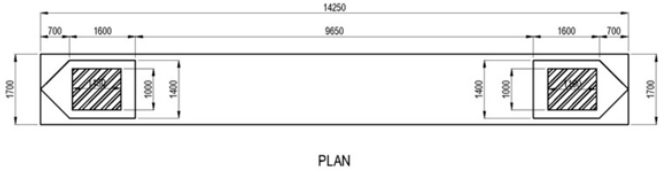
Damage Drawing Sheet (5/8)
Abutment: Western Side



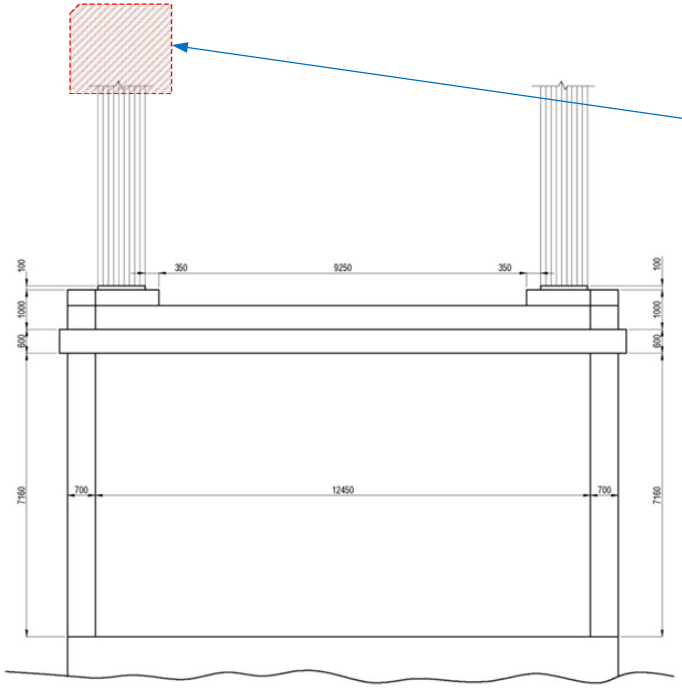
Damage Drawing Sheet (6/8)
Abutment: Eastern Side

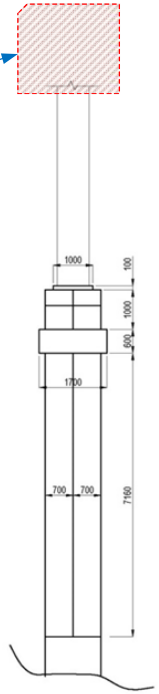


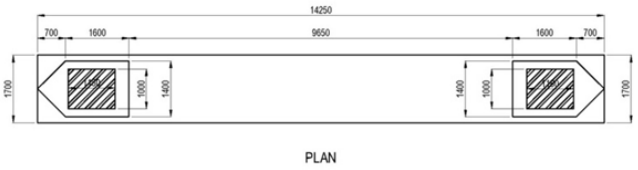




Damage Drawing Sheet (7/8)
Pier: 1







Damage Drawing Sheet (8/8)
Pier: 2

(4) Routine Inspection Results (November 3, 2021)

This section describes the newly observed conspicuous damage in the Special Bridge Routine Maintenance OJT of Luangwa Bridge conducted on November 3, 2021.

In addition, we will consider the measurement results of the vertical profile of the bridge by the RDA survey team conducted in October of the same year.

(4-1) Cracks on the top surface of the concrete deck slab

On the top surface of the concrete deck slab, the pavement layer is worn and the concrete surface is exposed. Moreover, many cracks are seen over the entire bridge length. Cracks in the bridge axis direction and in the bridge transverse direction were observed, especially more cracks in the bridge axis direction.

In addition, grid-shape cracks are seen throughout the concrete slab on the Chipata side approach. The left side is the concrete slab of the approach, and the right side is the concrete deck slab of the bridge.

(4-2) Squeak of Expansion Joint

In the Lusaka side expansion joint (steel lap joint), the steel plate on the bridge side moves back and forth when a heavy-loaded vehicle passes by, and a squeak noise is generated. It was observed that there was a large movement when the vehicle was traveling from the center of the bridge to the tower on the Lusaka side, not when the vehicle was passing over the expansion joint.

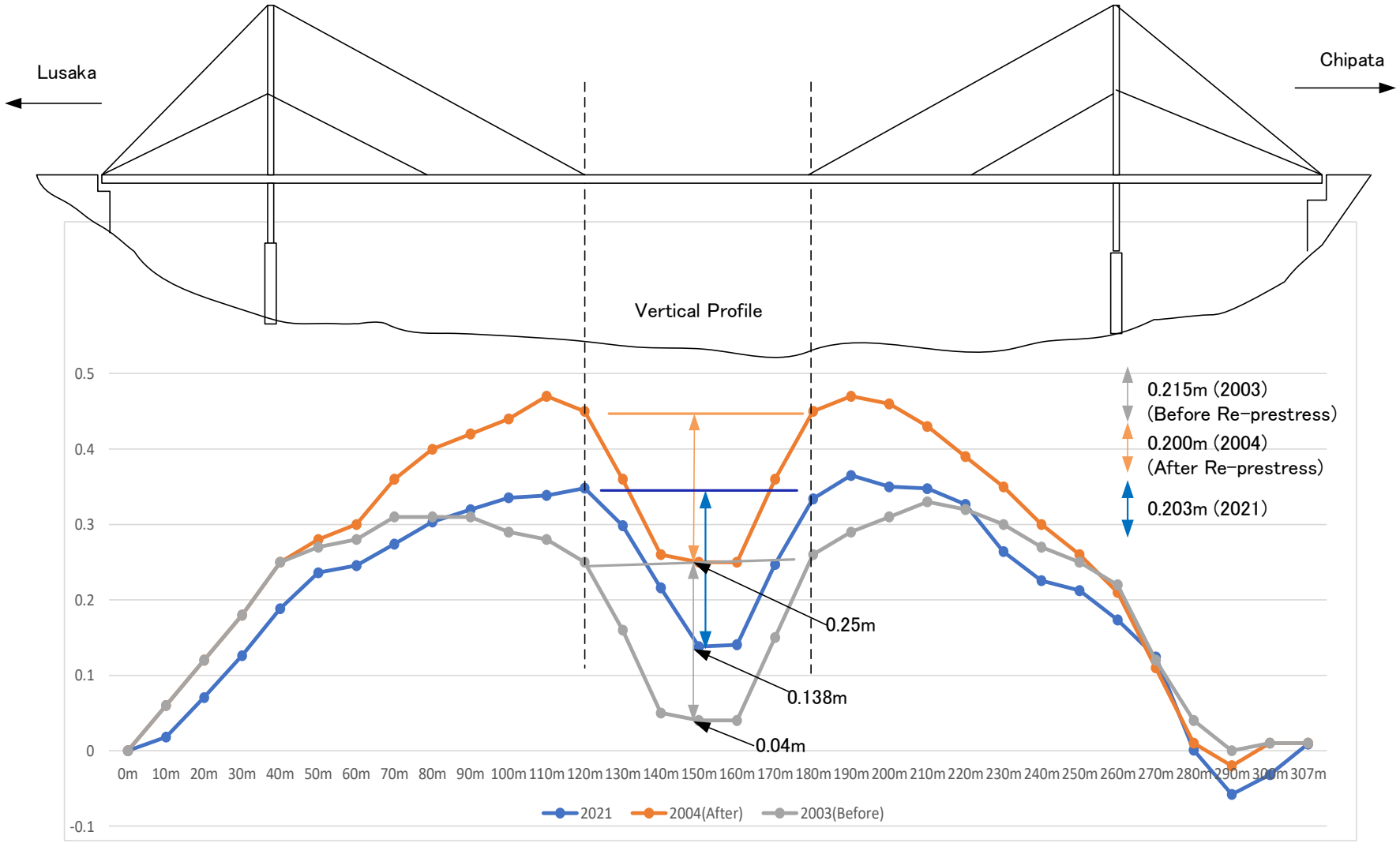
(4-3) Survey Results of Bridge Vertical Profile

The Luangwa Bridge was re-prestressed from 2003 to 2004. The survey results for October 2021 are shown in the graph along with the values before and after Re-prestressing.

In the case that the height of the abutment on the Lusaka side was to be 0.0 m, the height of the center of the girder increased by 0.21 m from 0.04 m to 0.25 m due to Re-prestressing. Then, 17 years later, in October 2021, it sank 0.112m from that height to a height of 0.138m, which means that about half of the rise due to Re-prestressing sank.

However, the amount of depression between the center stays was 0.215m in 2003, 0.200m in 2004 (after raising), and 0.203m in 2021 (current), showing no change. What does this mean? It could mean that the decrease in cable tension is not the cause of the settlement between the center stays.

From the above, it seems that the consideration of the FS report* is the most promising cause of the depression at present. In other words, the girder between the center stays was erected upside down. (* Feasibility Studies and Assessment of the Luangwa Bridge across the Luangwa River on the Great East Road (T4) in Eastern Province, Zambia Final Feasibility Report, 16 February, 2016)

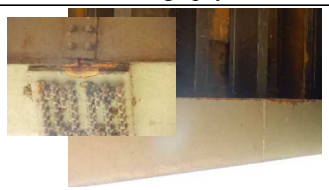

Lusaka
Chipata
Vertical Profile
0.5
0.4
0.3
0.2
0.1
0
-0.1
0.215m (2003)
(Before Re-prestress)
0.200m (2004)
(After Re-prestress)
0.203m (2021)
0.25m
0.138m
0.04m
0m 10m 20m 30m 40m 50m 60m 70m 80m 90m 100m 110m 120m 130m 140m 150m 160m 170m 180m 190m 200m 210m 220m 230m 240m 250m 260m 270m 280m 290m 300m 307m
2021
2004(After)
2003(Before)

5-2-3 Routine Maintenance

(1) Defects and Causes

The defects observed in cable-stayed bridge (Luangwa bridge) and their causes are described below. For the defects common to general bridges, please see "Bridge Routine maintenance Guideline, 3-6 Types of Defects and Causes".

Table 5-2-2 Defects and Causes of Luangwa Bridge

Location	Defects	Photography	Presumed Causes
Main Girder, Cross Beam	Paint deterioration, Corrosion		Rainwater tends to stay around the edges of the joint splicing plate and around the bolts, and also tend to stay on the edges of the lower flange, so paint deterioration and corrosion are likely to occur in those areas.
Cable System (Tower, Anchorage)	Paint deterioration, Corrosion		It is considered that the paint has deteriorated due to repeated dry and wet for many year. Deterioration of the upper surface of the anchor portion was accelerated by the retention of rainwater.
Cable System (Cable)	Vibration (observed when heavy vehicles loading the bridge)		In a cable structure such as a cable-stayed bridge, the damping characteristics of the entire bridge are low, so vibration due to wind is likely to occur. Further, it is conceivable that the girder and the cable vibrate due to the impact when the heavy vehicle passes through the uneven surface of the deck slab, and the vibration of the cable becomes particularly large.
Railing	Paint deterioration, Corrosion		It is considered that the paint has deteriorated due to repetition of dry and wet for many years.
Superstructure between cable-stays	Sagging	 	Probable cause 1: The main towers tilted toward the center during construction due to the short side span. Therefore the main girder hung down. Probable cause 2: The tension of the hanging cables decreased and the girder hung down. Probable cause 3: The main girder segment between the hanging cables was installed upside down causing the excessive sag as a sum of initial camber and dead-load deflection. According to the 2016 FS report, the response of the bridge girder due to heavy vehicle loading is normal throughout, including the sagging section, and there are no structural defects in the main structure of the bridge. As a result of considering the Vertical Profile measured in October 2021, Probable cause 2 is not considered to be the cause of sagging. (See 5-2-2 (4-3))
Deck Top Surface	Crack, Spalling, Bumpy Surface		Possible causes of damage include poor quality of concrete deck slab materials, poor construction performance during concrete placement, drying shrinkage of concrete, and repeated passing of heavy vehicles.

Deck Bottom Surface	Crack, Spalling		Possible causes of damage include poor formwork installation, poor quality of concrete materials, discontinuous and/or uneven placement in concrete slab construction.
Drain Pipe	Insufficient length (Cause of cross beam corrosion)		During design and construction, insufficient consideration is given to corrosion of steel materials due to drainage water.
Guardrail	Missing bolts		Probably due to a vehicle collision.
Abutment A1, A2	Crack		In addition to the possibility that cracking occurred early stage after the construction because the temperature deformation due to the heat of hydration (similar to Pier P1), there is a possibility of cracks due to the alkali-aggregate reaction because the hexagonal cracks and large crack widths.
Pier P1	Crack		Cracking occurred early stage after the construction because the temperature deformation due to the heat of hydration was constrained by the temperature difference between the concrete placed first and the concrete placed later and/or the temperature difference in the cross section.
Pier P2	Water leakage, Corrosion		Corrosion due to water leakage from drainage pipes and boundary between girder and slab, etc.
Bearing (P1, P2)	Clacking noise by diurnal and seasonal bridge thermal movement		It is considered to be a frictional sound when the girder expands and contracts due to temperature changes.
Expansion Joint (A1)	Squeak of Expansion Joint		The girder may be moving abnormally large as a heavy-duty vehicle passes over the bridge.
Approach Road	Crack		It is considered to be due to the poor quality of the concrete pavement material and the repeated loading of heavy vehicles.

(2) Routine Maintenance Activities

The standard routine maintenance activities of the cable-stayed bridge are shown in Table 5-2-3.

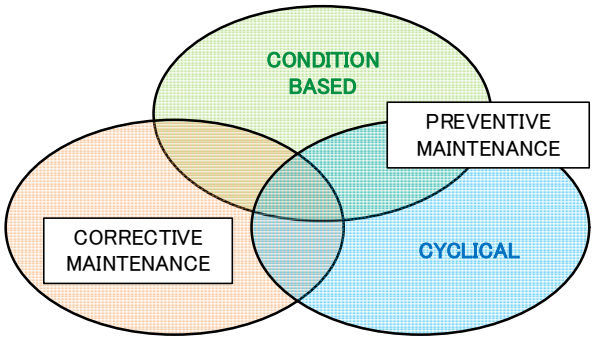


Figure 5- 2-2 Treatment Categories

Table 5-2-3 Routine Maintenance Activity List (Luangwa Bridge)

Activity No.	Activity Item	Frequency	Classification	Applied Item	
				Chapter 4	Chapter 5
	(Deck)				
1-1	Clean deck and gutters	Yearly	Preventive(Cycl.)	4-1	
1-2	Clean deck drains/scuppers	Yearly	Preventive(Cycl.)	4-1	
1-3	Clean joint	Yearly	Preventive(Cycl.)	4-1	
1-4	Joint sealing	As needed	Corrective	4-9	
1-5	Deck repair – Coating on /injection/caulking into cracks	As needed	Preventive(CB.)	4-6/4-7/4-8	
1-6	Deck repair – Pavement patching	As needed	Corrective	4-11	
1-7	Deck repair – Concrete deck patching	As needed	Corrective	4-3	
1-8	Collision damage repair to railing/parapet	As needed	Corrective	4-10	
1-9	Repair to damaged curb/sidewalk	As needed	Corrective	4-11	
1-10	Drain extensions	As needed	Preventive(CB.)	4-12	
	(Superstructure)				
2-1	Clean girders	2 years	Preventive(Cycl.)	4-1	
2-2	Touch-up/re- painting on steel members	As needed	Preventive(CB.)	4-4	
	(Substructure)				
3-1	Clean abutments/caps/bearings	2 years	Preventive(Cycl.)	4-1	
3-2	Repairs to slope protection	As needed	Preventive(CB.)	4-15	
3-3	Repair to scour protections around foundations	As needed	Preventive(CB.)	4-16	
	(Site)				
4-1	Vegetation control and rubbish removal around substructures	Quarterly	Preventive(Cycl.)	4-13	
4-2	Removal of debris/driftwoods from waterway	As needed	Preventive(CB.)	4-14	
	(Cable System)				
5-1	Clean cables/towera/anchor devices	2 years	Preventive(Cycl.)	4-1	
5-2	Touch-up/re- painting on steel members of cable system	As needed	Preventive(CB.)	4-4	

Table 5-2-4 shows the recommended maintenance activities for the defects observed during the inspection of Luangwa Bridge.

Table 5-2-4a Recommended Maintenance Activities for Luangwa Bridge (1/2)

No.	Bridge Component/ Sub-Component	Defect Type	Routine Maintenance Activity	Applied Item in Chapter 4 and 5	Other Activities
1	Superstructure/Steel member (Main girder and Cross beam)	Paint deterioration, Corrosion	2-2 Touch-up/re- painting on steel members	4-4 Touch-up/Re-painting	
2	Superstructure/ Main girder, Deck	Sagging	-	-	Monitoring of the vertical profile of the bridge by surveying is necessary once a year.
3	Railing/Metal railing	Paint deterioration	1-11 Touch-up/re- painting on railing	4-4 Touch-up/Re-painting	
4	Railing/Guardrail	Missing bolts	1-8 Collision damage repair to railing/parapet tightening	4-10 Repair to Railing/Parapet	
5	Cable system/Tower	Paint deterioration	5-2 Touch-up/re- painting on steel members of cable system	4-4 Touch-up/Re-painting	
6	Cable system/Anchorage	Corrosion	5-2 Touch-up/re- painting on steel members of cable system	4-4 Touch-up/Re-painting	
7	Deck/Concrete deck (Upper surface)	Cracks, Spalling	-	-	MM Repair (Reconstruction of deck slab)
8	Deck/Concrete deck (Lower surface)	Cracks, Spalling	-	-	

Table 5-2-4b Recommended Maintenance Activities for Luangwa Bridge (2/2)

No.	Bridge Component/ Sub-Component	Defect Type	Routine Maintenance Activity	Applied Item in Chapter 4 and 5	Other Activities
9	Drainage/Drain pipe	Insufficient length	1-10 Drain extension	4-12 Drain extension	
10	Substructure/Abutment A1 (Western side)	Cracks	3-2 Injection into cracks 3-3 Concrete patching	4-7 Epoxy injection 4-5 Concrete patching	
11	Substructure/Abutment A2 (Eastern side)	Cracks	3-2 Injection into crack	4-7 Epoxy injection	
12	Substructure/Pier P1 (Western side)	Cracks	3-2 Injection into crack	4-7 Epoxy injection	
13	Substructure/Pier P2 (Eastern side)	water leakage, Corrosin	3-4 Touch-up/re- painting on steel member of substructure	4-4 Touch-up/Re-painting	
14	Bearing (P1, P2)	Clacking noise	-	-	In-depth Inspection (Investigation of the source and cause of sound)
15	Expansion Joint (A1)	Squeak	-	-	In-depth Inspection (Carry out a vehicle running test and investigate the behavior of the girder at the expansion joint.)
16	Site/Others/ Approach(Eastern side)	Cracks	-	-	MM Repair (Replacement of pavement in the approach section.)
17	Lightening system/All	Unfunctioned	4-3 Repair of lightening system	-	If a malfunction was found, repair it as soon as possible.

5-2-4 Routine Maintenance and Repair Method

If there are any items that should be added as routine maintenance activities of the Luangwa Bridge, add them to Table 5-2-3 and describe the contents, methods, materials used, and equipment in "5-2-4 Routine Maintenance and Repair method".

5-3 SUSPENSION BRIDGE (OTTO BEIT BRIDGE)

5-3-1 Structural Outline

The suspension bridge has main cables which are stretched between the main towers and fixed to anchor blocks at both ends of the bridge, and has a structure in which the transportation route is suspended by hanger ropes hanging from the main cables. The leading role of the suspension bridge is a cable, but a stiffening girder is used in combination to give the suspension bridge appropriate rigidity, load distribution action to the cable, wind resistance, etc. The stiffening girder supports the upper traffic route (floor structure of road and/or railway). The cable and the stiffening girder are connected by hangers, and the load is transmitted to the cable through the hangers. Because of this, all the load becomes high tension of the high strength cable and transmits to the ground through the cable anchorage. Moreover, this cable tension has a restoring force on deformation, which increases the apparent stiffness, so the suspension bridge is a very suitable type of long span bridge.

On the other hand, since the stiffening girder of the suspension bridge is liable to be vibrated by wind, a structure considering wind resistance is desirable.

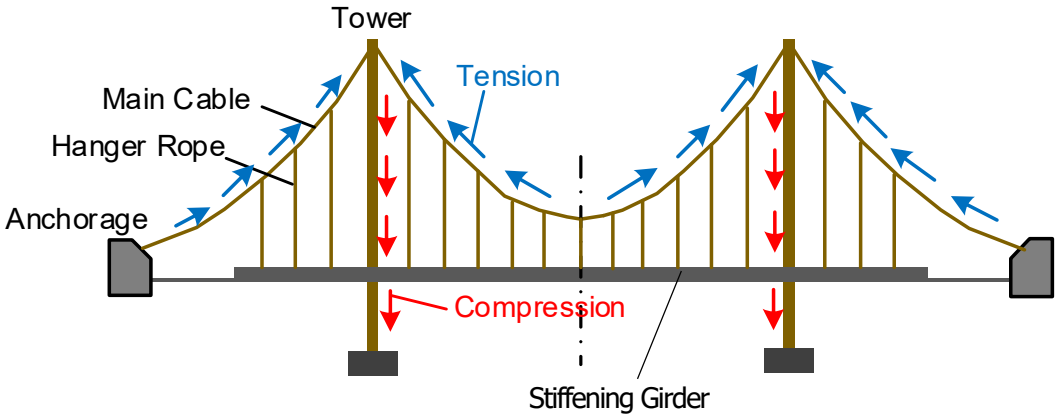


Figure 5-3-1 Structural System of Suspension Bridge

5-3-2 Routine Inspection

(1) Bridge Components and Defects

Table 5-3-1a shows possible defects in the bridge components of Otto Beit Bridge. And, Table 5-3-1b shows defects in the bridge components of Otto Beit bridge which shall be inspected on the routine inspection.

Table 5-3-1a Bridge Components and Possible Defects (Otto Beit Bridge)

Bridge Component	Sub-Component	Possible Defects
Superstructure (Steel member)	Stiffening girder, Cross beam, Lateral bracing	1) Deterioration of painting, 2) Corrosion, 3) Fatigue crack/Fracture, 4) Loose connection/Missing rivet or HTB, 5) Deformation/Buckling, 6) Abnormal deflection, 7) Abnormal vibration, 8) Abnormal sound
Deck	Concrete slab	1) Crack, 2) Spalling, 3) Scaling, 4) Honeycomb/Loose concrete, 5) Rebar exposure/Rebar corrosion, 6) Water leakage/Free lime
Substructure	Abutment, Pier (Concrete member)	1) Crack, 2) Spalling, 3) Delamination, 4) Honeycomb/Loose concrete, 5) Cold joint, 6) Rebar exposure/Rebar corrosion, 7) Water leakage/Free lime
	Foundation	1) Tilt, 2) Settlement, 3) Scouring/Lowering of river bed
	Protection work	1) Slope/Bank erosion, 2) Loss/Disintegration of protection materials, 3) Defects due to displacement of foundation
Expansion Joint	Metal joint (Load-bearing type)	1) Crack/Fracture, 2) Damage to post-cast concrete, 3) Deterioration of waterproof system, 4) Crrosion, 5) Difference in level, 6) Abnormal sound, 7) Abnormal spacing, 8)Bump
Wearing Course	Asphalt pavement	1) Potholes, 2) Rutting, 3) Bump, 4) Corrugation, 5) Crack, 6) Raveling, 7) Ponding
Sidewalk	Grating panel	1) Corrosion, 2) Deformation, 3) Fracture
Bearing	Metal bearing	1)Deformation/Breakage of bearing, 2) Corrosion of bearing, 3) Loose connection/Missing bolts, 4) Corrosion of bolts, 5) Breakage of mortar/concrete seat, 6) Abnormal sound, 7) Accumulation of garbage and debris
Railing	Metal railing	1) Deformation, 2) Corrosion, 3) Disappearance, 4) Loose connection
Drainage	Scupper	1) Damage to scupper, 2) Damage to cover, 3) Accumulation of garbage and debris
	Drain pipe	1) Damage to pipe, 2) Defect in connection, 3) Accumulation of garbage and debris, 4) Insufficient length, 5) No drain pipe
Site/Others	Waterway	1) Accumulation of driftwoods/debris, 2) Changes in river direction/lowering river bed (within a range of 20m from the bridge to the upstream and downstream sides)
	Approach	1) Accumulation of vegetation/debris/garbage, 2) Damage to rip-rap/retaining wall, 3) Settlement of approach section/incorrect vertical alignment, 4) Damage to approach pavement (crack, pothole, etc.)
Cable System	Main cable	1) Failure, 2) Deformation, 3) Abnormal sag, 4) Corrosion, 5) Abnormal vibration, 6) Damage of protection cover/coating
	Hanger rope	1) Failure, 2) Deformation, 3) Corrosion, 4) Abnormal vibration, 5) Loose/Missing HTB of cable band, 6) Damage of socket, 7) Damage of protection cover/coating
	Tower (Steel member)	1) Corrosion, 2) Fatigue crack, 3) Deformation/Buckling, 4) Loose/Missing HTB of saddle, 5) Deterioration of painting, 6) Abnormal sound, 7) Abnormal vibration
	Anchorage	1) Cracks, 2) Spalling/loose concrete, 3) Exposed/corroded rebars, 4) Water leakage, 5) Corrosion of anchor devices, 6) Fracture/slipping out of anchor devices, 7) Separation/swelling of repaired/strengthened part

Table 5-3-1b Bridge Components and Defects on Routine Inspection (Otto Beit Bridge)

Bridge Component	Sub-Component	Defects to be inspected
Superstructure (Steel member)	Stiffening girder, Cross beam, Lateral bracing (Main bridge) Main girder, Cross beam (Access bridge)	1) Deterioration of painting, 2) Corrosion, 3) Fatigue crack/Fracture, 4) Loose connection/Missing rivet or HTB, 5) Deformation/Buckling, 6) Abnormal deflection
Deck	Concrete slab	1) Crack, 2) Spalling/Loose concrete, 3) Rebar exposure/Rebar corrosion, 4) Water leakage/Free lime
Substructure	Abutment, Pier (Concrete member)	1) Crack, 2) Spalling/Loose concrete, 3) Cold joint, 4) Rebar exposure/Rebar corrosion, 5) Water leakage/Free lime
	Foundation	1) Tilt, 2) Settlement, 3) Scouring
	Protection work	1) Slope/Bank erosion, 2) Loss/Disintegration of protection materials
Expansion Joint	Metal joint (Load-bearing type)	1) Crack/Fracture, 2) Damage to post-cast concrete, 3) Crrosion, 4) Abnormal sound, 5) Abnormal spacing
Wearing Course	Asphalt pavement	1) Potholes, 2) Rutting, 3) Crack, 4) Raveling, 5) Ponding
Sidewalk	Grating panel	1) Corrosion, 2) Deformation, 3) Fracture
Bearing	Metal bearing	1)Deformation/Breakage of bearing, 2) Corrosion of bearing, 3) Loose connection/Missing bolts, 4) Breakage of mortar/concrete seat, 5) Accumulation of garbage and debris
Railing	Metal railing	1) Deformation, 2) Corrosion, 3) Disappearance, 4) Loose connection
Drainage	Scupper	1) Damage to scupper, 2) Damage to cover, 3) Accumulation of garbage and debris
	Drain pipe	1) Damage to pipe, 2) Insufficient length, 3) No drain pipe
Site/Others	Waterway	1) Accumulation of driftwoods/debris
	Approach	1) Accumulation of vegetation/debris/garbage, 2) Damage to rip-rap/retaining wall, 3) Settlement of approach section/incorrect vertical alignment, 4) Damage to approach pavement (crack, pothole, etc.)
Cable System	Main cable	1) Failure, 2) Deformation, 3) Abnormal sag, 4) Corrosion, 5) Abnormal vibration, 6) Damage of protection cover/coating
	Hanger rope	1) Failure, 2) Deformation, 3) Corrosion, 4) Abnormal vibration, 5) Loose/Missing HTB of cable band, 6) Damage of socket, 7) Damage of protection cover/coating
	Tower (Steel member)	1) Corrosion, 2) Fatigue crack, 3) Deformation/Buckling, 4) Loose/Missing HTB of saddle, 5) Deterioration of painting, 6) Abnormal sound, 7) Abnormal vibration
	Anchorage	1) Cracks, 2) Spalling/loose concrete, 3) Exposed/corroded rebars, 4) Water leakage, 5) Corrosion of anchor devices, 6) Fracture/slipping out of anchor devices

(2) Sheets for Routine Inspection (Otto Beit Bridge)

The Routine Inspection Report consists of following 4 kinds of sheet:

a. Bridge Routine Inspection Form;

b. Defect Drawing Sheet;

c. Photo Record Sheet; and

d. Routine maintenance Record Schedule and Record Form.

Bridge Routine Inspection Form

Date:		Contractor Name:				Contract Ref. No. :			Province:
Bridge No.:		Bridge Name:			Road No.:		Road Name:		Location:
		Otto Beit Bridge							
No.	(1) Bridge Component	(2) Sub-Component	(3) Defect Type	(4) Condition Rating	(5) Quantity (Unit)	(6) Proposed Action	(7) New/ Existing	(8) Date of Detection	(9) Remarks

Note: - To categorize (1) Bridge Component, (2) Sub-component and (3) Defect type, refer to Table 5-3-1b.

To determine (4) Condition rating and (6) Proposed action, refer to the Table 1 and Table 2 with Figure 1, respectively.

(7) New/Existing means damage newly identified in this inspection/already identified in previous inspection.

Note: How to fill out the Bridge Routine Inspection Form

If you find a defect, enter the location in the columns of "(1) Bridge Component & (2) Sub-Component" and enter the type of defect in column of "(3) Defect Type", in the Bridge Routine Inspection Form, and fill the location and type of defect on the Defect Drawing Sheet. And, in the column "(4) Condition Rating", select Good, Fair, Poor or Bad according to Table 1 Routine Inspection Condition Rating Criteria. In the column "(6) Proposed Action", suitable actions should be entered refer to the Figure 1 Determination flow of Maintenance Action. Table 1 shows the criteria for judgment of Condition Rating. Table 2 shows the types of required actions and their contents of actions. Figure1 is a flowchart for determining a maintenance action based on the identified damage situation.

Table1 Routine Inspection Condition Rating Criteria

Condition Rating	Description
Good	No damage
Fair	With minor damage(s) not affecting the stability of the structure
Poor	With deteriorating damage(s) which should be monitored or could be repaired as a preventive action
Bad	With severe damage(s) that affects stability of bridge or that has possibility to harm a third party

Table 2 Required Maintenance Action

Required Action	Description
MO: Monitoring	No repair work and keeping monitoring (Damage not progressing or very slow)
RM: Routine Maintenance	Should be maintained by Routine Maintenance
MM: Major Maintenance	Should be maintained by Major Maintenance
EA: Emergency Action	Need to take actions immediately to avoid bridge collapse or harm to a third party
In-Depth Inspection	Condition Inspection or Detailed Inspection - Selection of appropriate repair method - Monitoring of progress of any damages

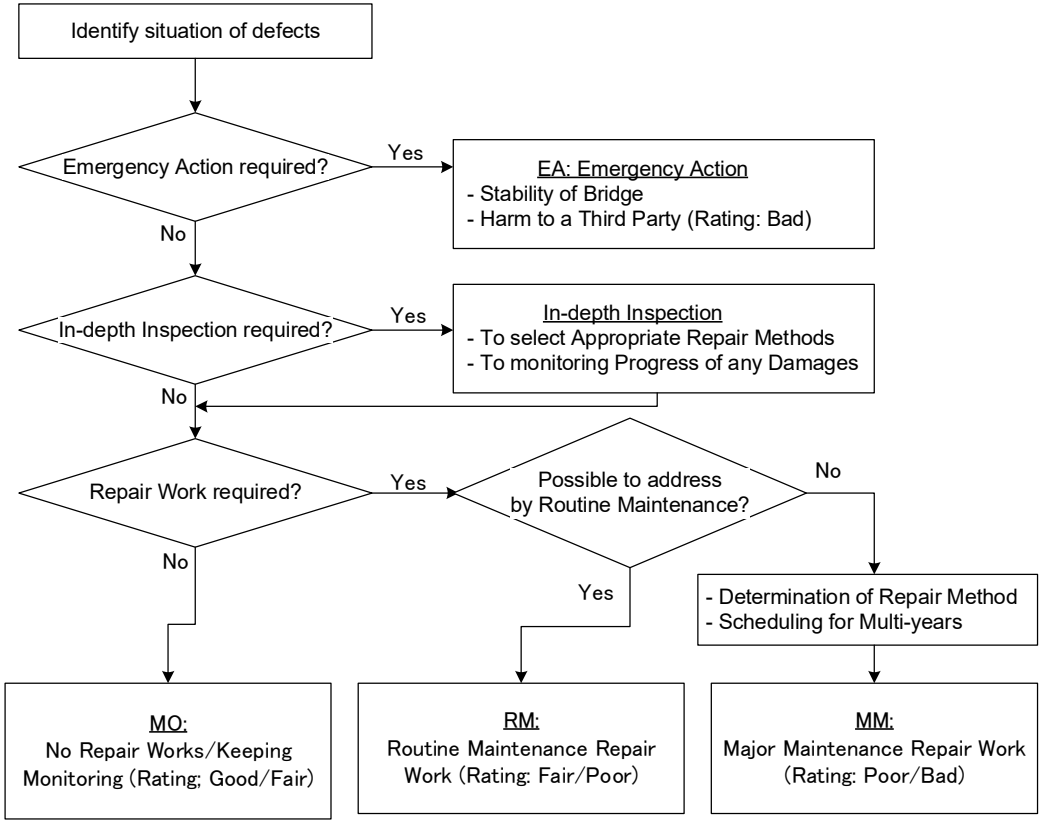
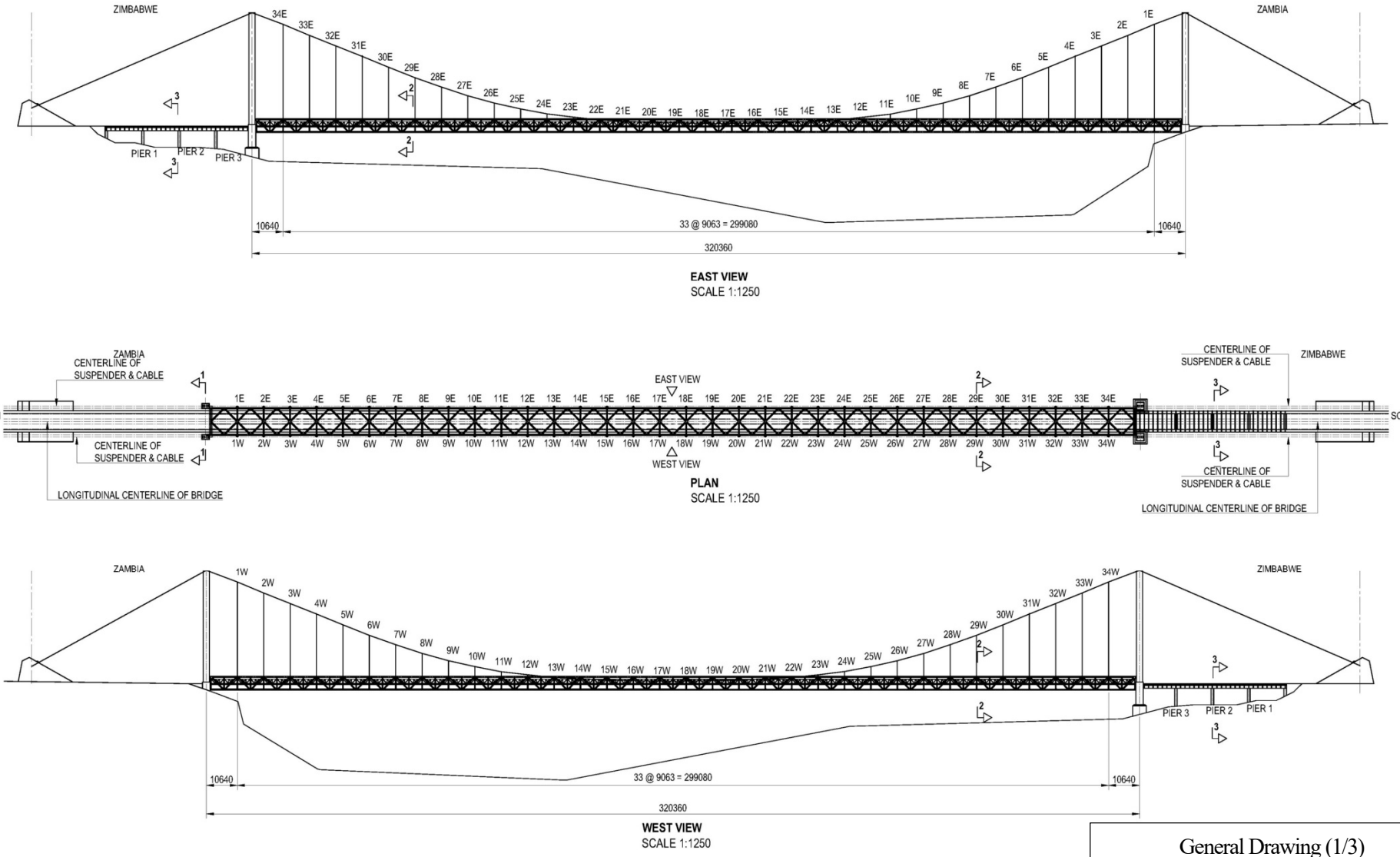
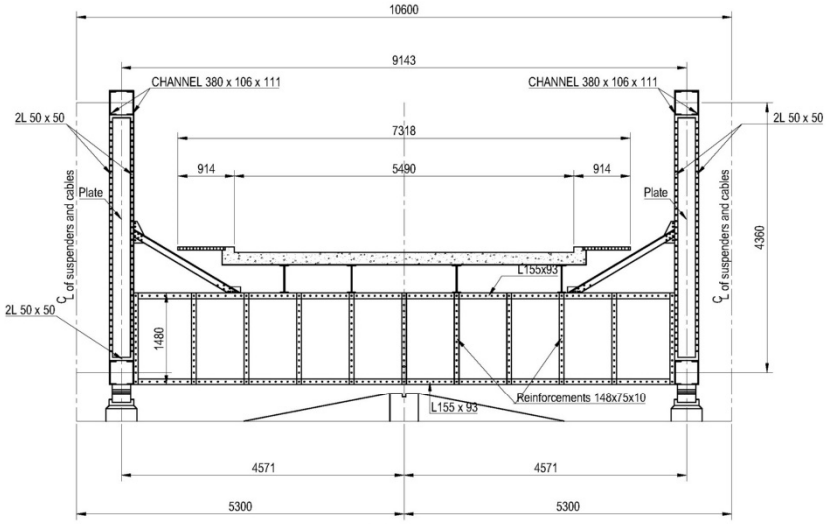


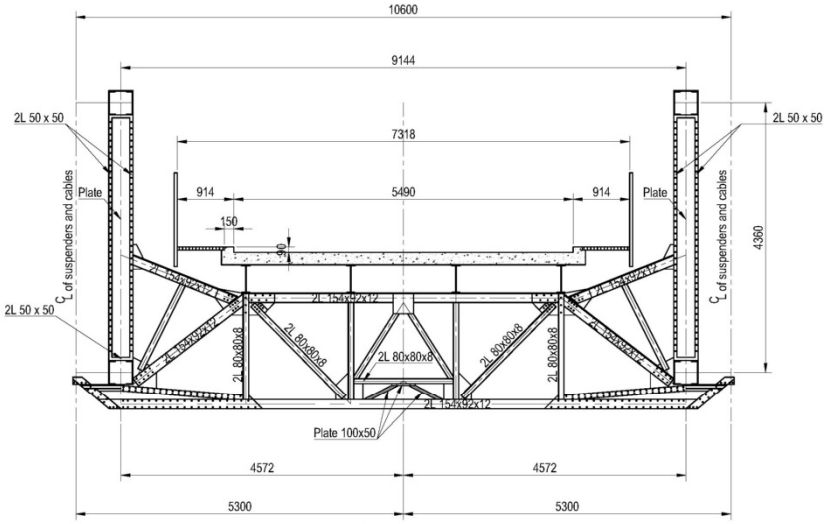
Figure 1 Determination Flow of Maintenance Action



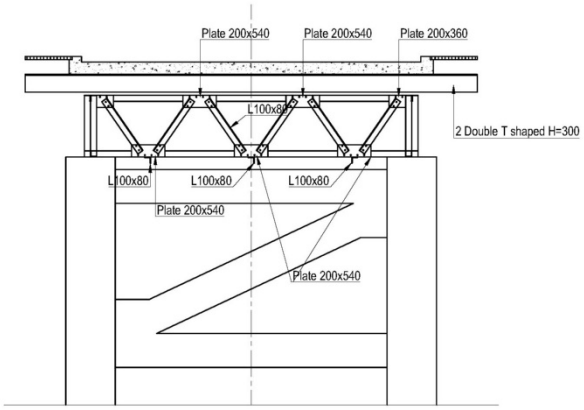
General Drawing (1/3)
Plan & Profile



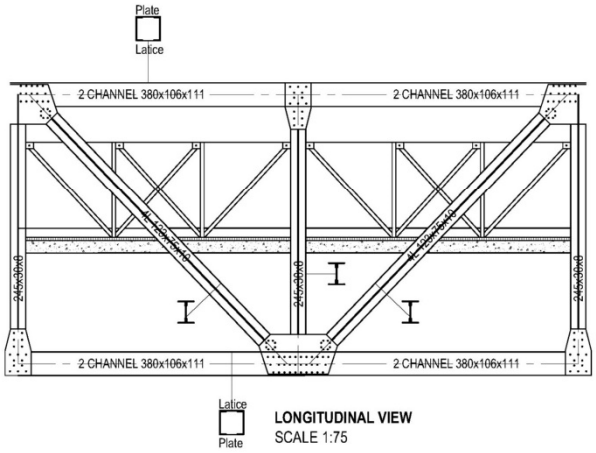
SECTION 1 - 1
SCALE 1:75



SECTION 2 - 2
SCALE 1:75

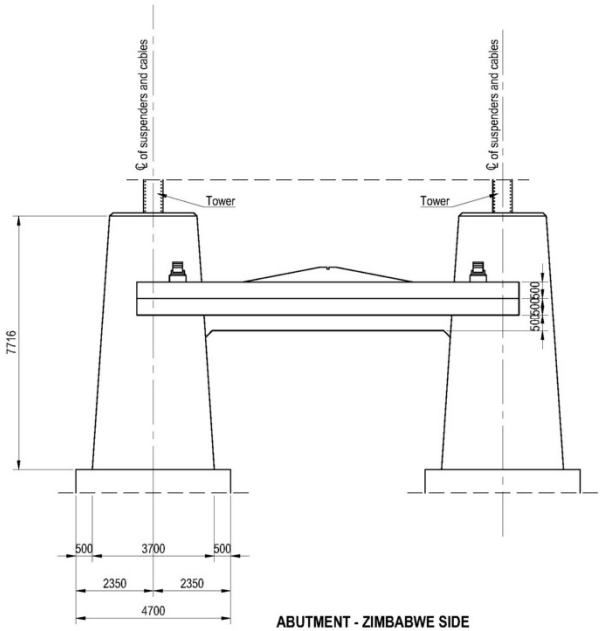


SECTION 3 - 3
SCALE 1:75

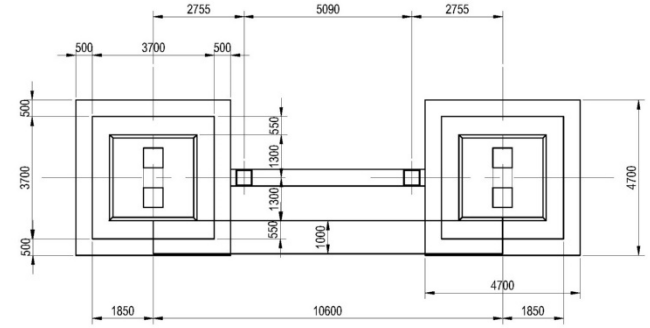


LONGITUDINAL VIEW
SCALE 1:75

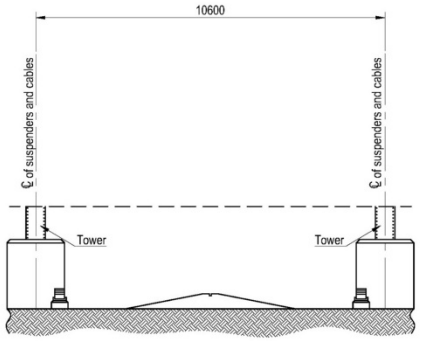
General Drawing (2/3)
Girder Cross Section & Longitudinal View



ABUTMENT - ZIMBABWE SIDE
SCALE 1:140

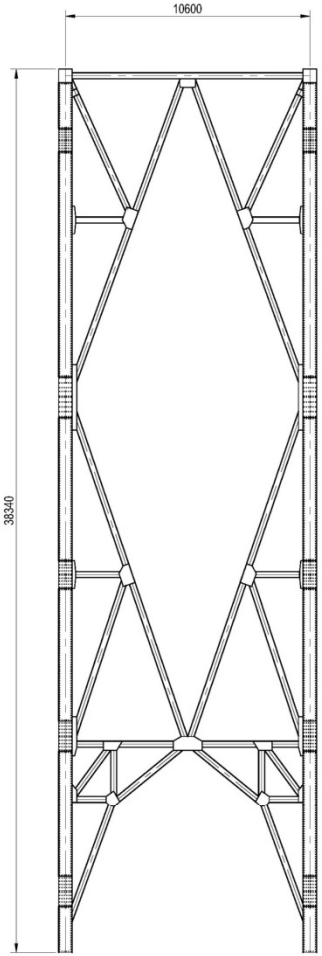


PLAN OF ABUTMENT - ZIMBABWE SIDE
SCALE 1:140



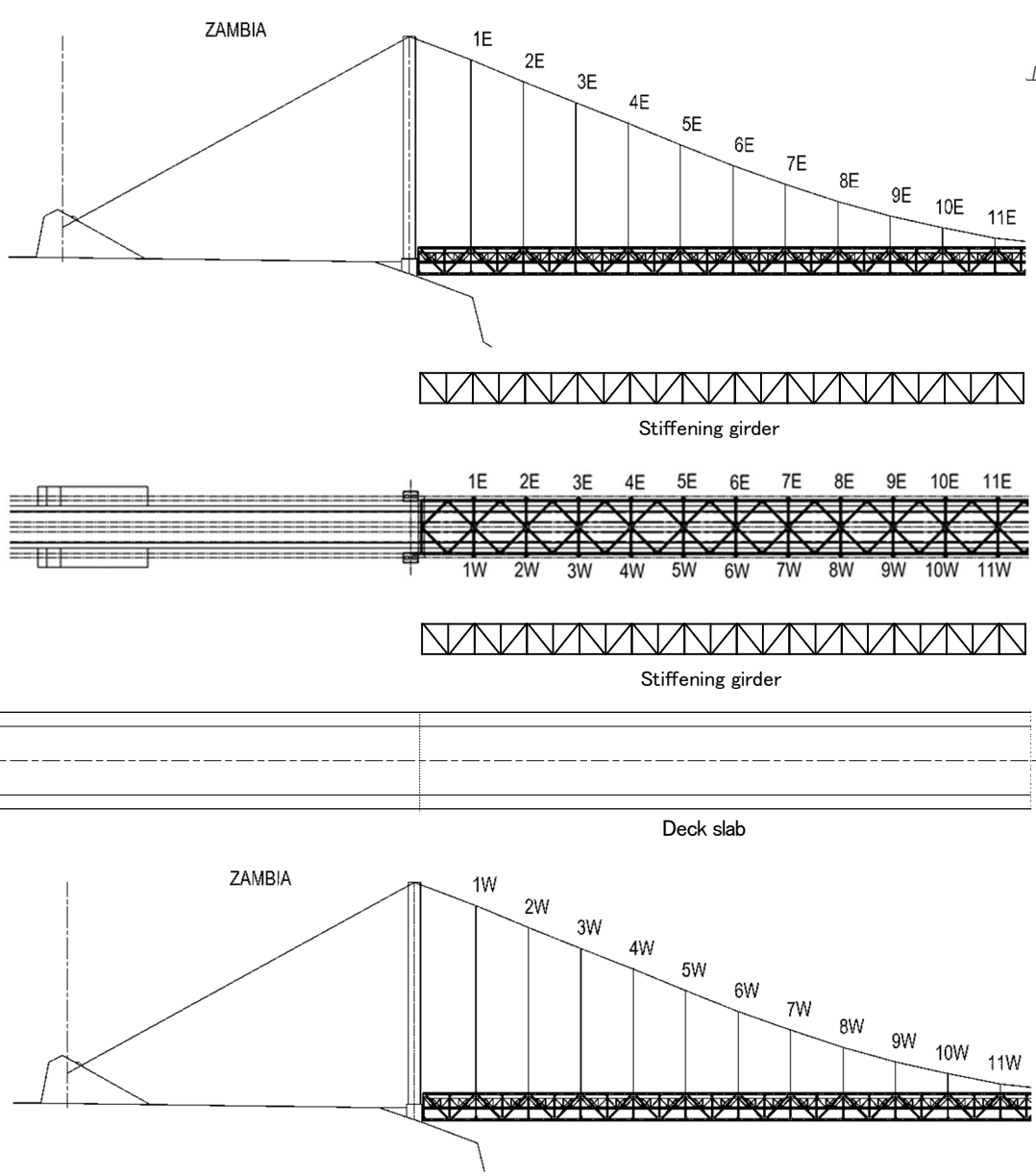
ABUTMENT - ZAMBIA SIDE
SCALE 1:140

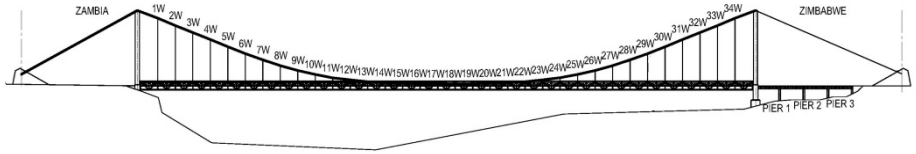
PLAN OF ABUTMENT - ZAMBIA SIDE
SCALE 1:140

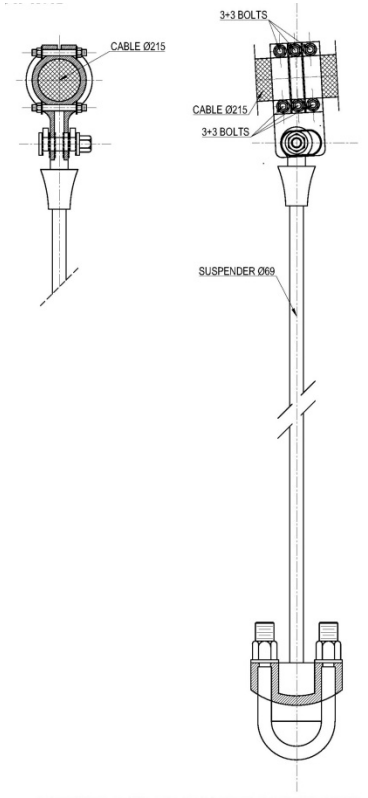


TOWER
SCALE 1:200

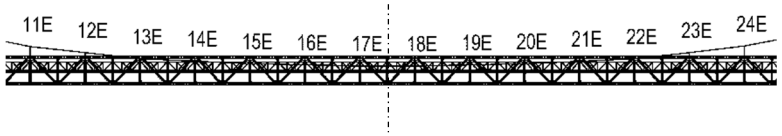
General Drawing (3/3)
Tower & Abutment

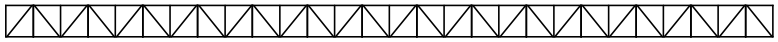




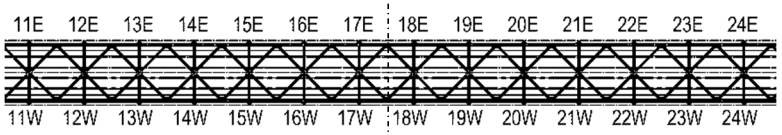


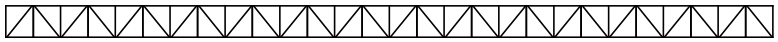
Defect Drawing Sheet (1/5)
Cable, Hanger, Girder, Floor structure,
Deck slab (Block 1)



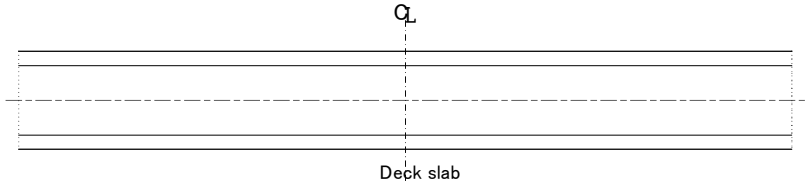


Stiffening girder

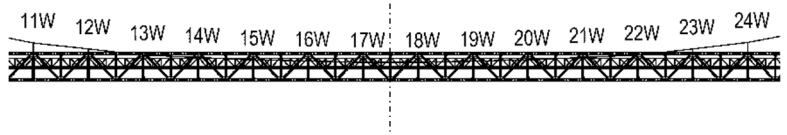


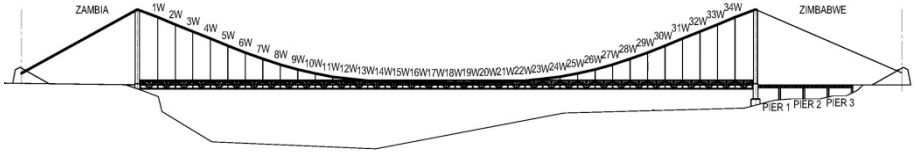


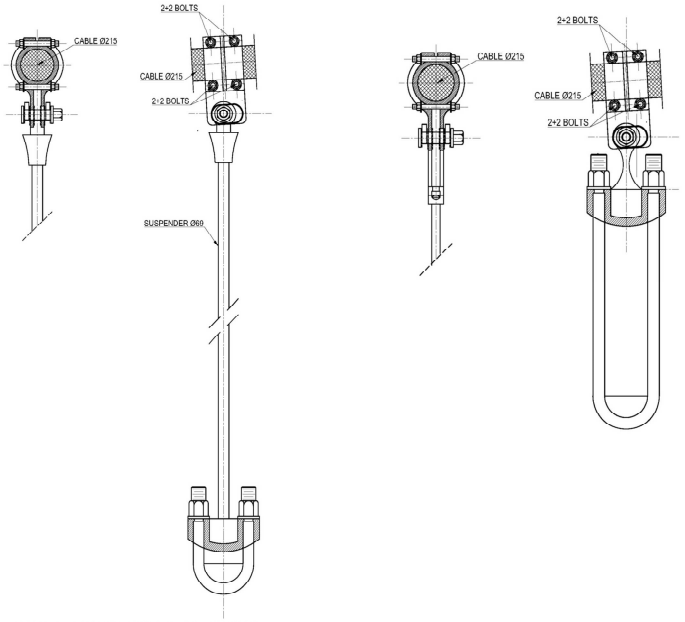
Stiffening girder



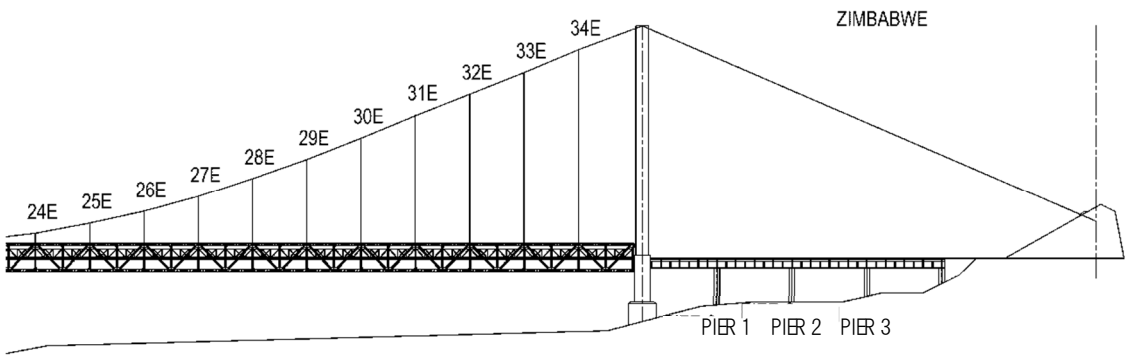
Deck slab

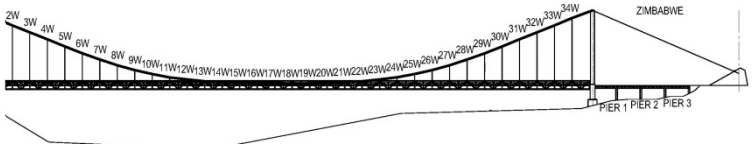


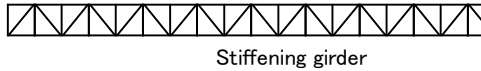


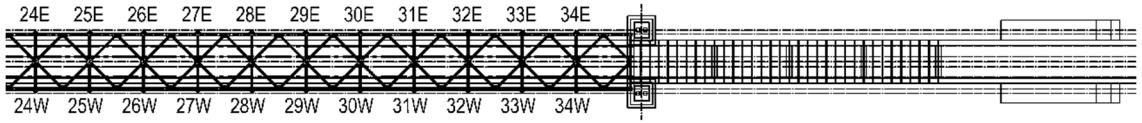


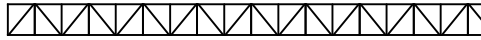
Defect Drawing Sheet (2/5)
Cable, Hanger, Girder, Floor structure,
Deck slab (Block 2)

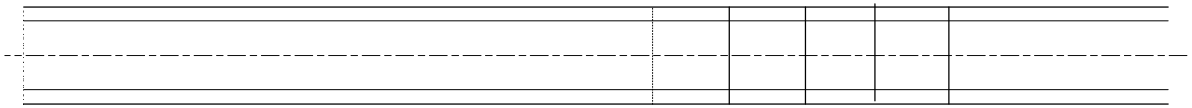


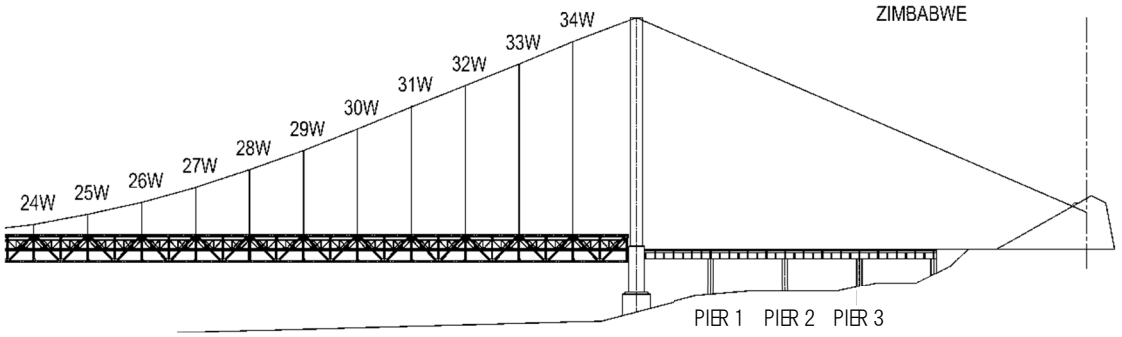


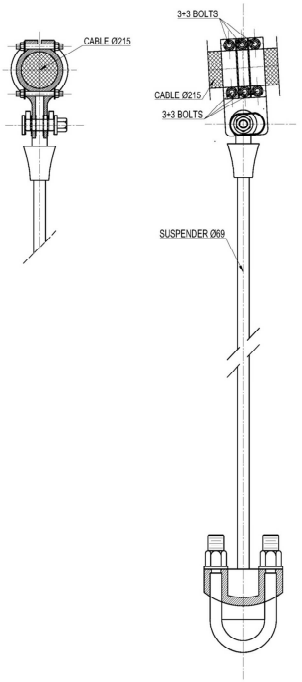

Stiffening girder



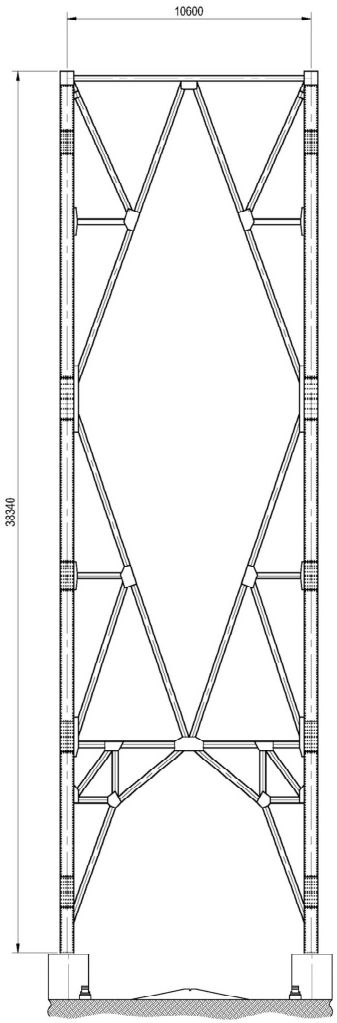

Stiffening girder


Deck slab

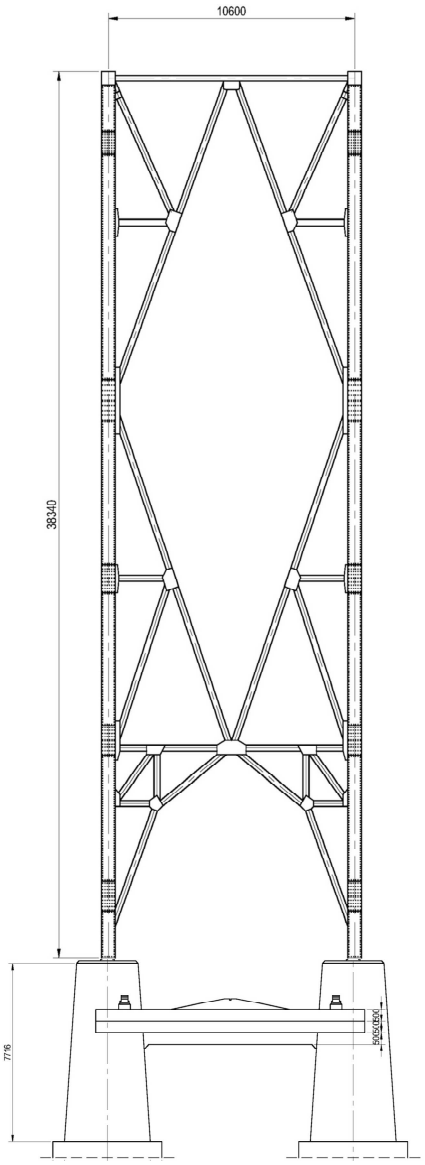




Defect Drawing Sheet (3/5)
Cable, Hanger, Girder, Floor structure,
Deck slab (Block 3)

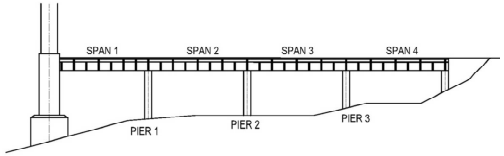


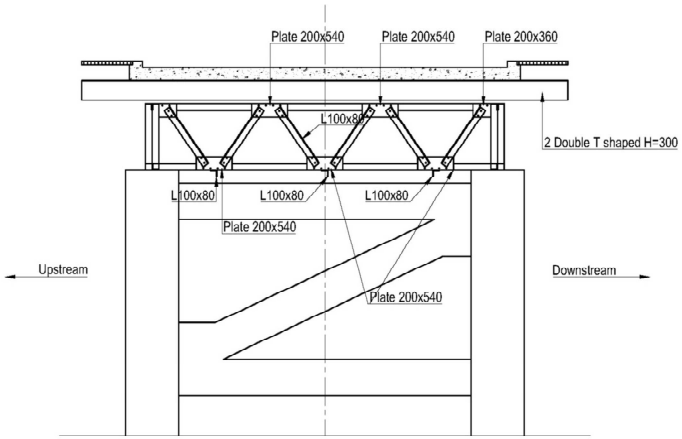
Zambian side



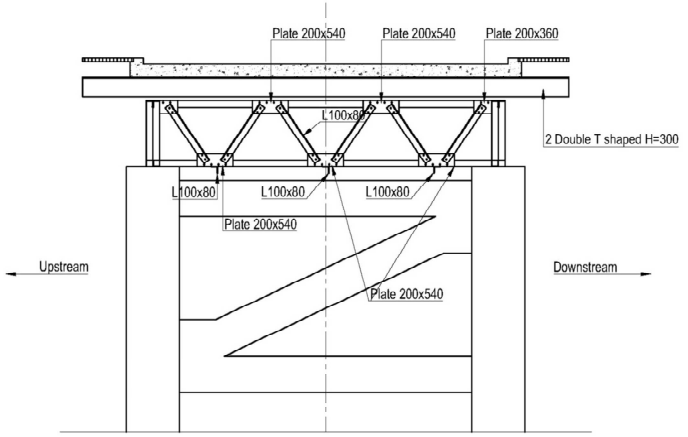
Zimbabwe side

Defect Drawing Sheet (4/5)
Tower

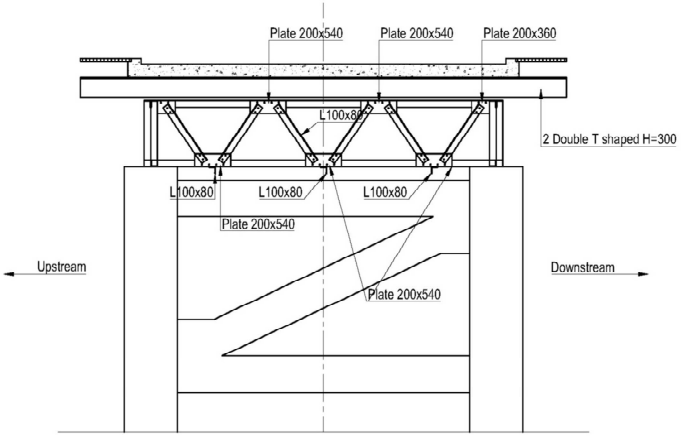




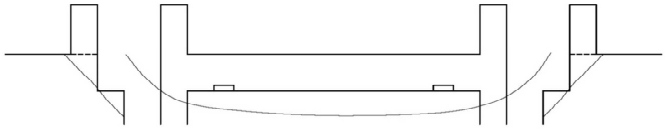
PIER 1



PIER 2



PIER 3



ABUTMENT

Defect Drawing Sheet (5/5)
Zimbabwe Side Approach Bridge

Photo Record Sheet (Bridge Name: Otto Beit Bridge)

Contractor Name:		Contract Ref. No.:		Province:	
Date:		Date:		Date:	
No.:		No.:		No.:	
Defect Type:		Defect Type:		Defect Type:	
Description:		Description:		Description:	
Date:		Date:		Date:	
No.:		No.:		No.:	
Defect Type:		Defect Type:		Defect Type:	
Description:		Description:		Description:	

Bridge Routine Maintenance Schedule and Record Form

Bridge No.:	Bridge Name:	Contractor Name:	Contract Ref. No.:	Province:
	Otto Beit Bridge			

No.	(1) Contract Item No.:	(2) Activities	(3) Description: Condition before Maintenance	(4) Ref. No. of Defect	(5) Estimated Cost	(6) Date: Instruction to Contractor	(7) Date: Work Completed	(8) Additional Work Required	(9) Remarks

Note: -Ref. No. of defect corresponds to No. with the inspection date in the Bridge Routine Inspection Form-e.g. No.01-26.11.2015

(3) Inspection Results (Arranged the results of October 2016 and August 2019)

Bridge Routine Inspection Form

Date:		Contractor Name:				Contract Ref. No. :			Province:	
Bridge No.:		Bridge Name:			Road No.:		Road Name:		Location:	
No.	(1) Bridge Component	(2) Sub-Component	(3) Defect Type	(4) Condition Rating	(5) Quantity (Unit)	(6) Proposed Action	(7) New/ Existing	(8) Date of Detection	(9) Remarks	
1	Cable System	Anchorage	Cracks	Fair	Epoxy injection V=300cm^3	RM Repair	Existing	Aug. 2019	Cracks are observed near the anchor device of the concrete anchorage. See sketch and photo 1.	
2	Cable System	Main Cable	Wrapping wire broken	Bad	Partial replacement of wrapping wire (L=15m)	EA	Existing	Oct. 2016	Broken wrapping wire (West side main cable). See sketch and photos 2 & 3.	
3	Cable System	Main Cable	Wrapping wire chipped	Bad			Existing	Oct. 2016	Chipped wrapping wire between hangers 21E and 22E. See sketch and photo 4.	
4	Cable System	Main Cable	Rust on repaired wire	Bad			Existing	Oct. 2016	Rusted repaired area between hangers 20E and 21E. See sketch and photo 5.	
5	Cable System	Hanger Rope	Fractured wire	Bad	Partial repair (Wrapping wire+Bituminous paint) (L=10m)	EA	Existing	Oct. 2016	Fractured wire on hanger 2W. See sketch and photo 6.	
6	Cable System	Hanger Rope	Rusted	Bad			Existing	Oct. 2016	Rust caused by local loss of bituminous paint. See sketch snd photos 7 & 8.	
7	Cable System	Shackle & Clamp of Hanger Rope	Rusted	Fair	Repainting (All members)	MM Repair	Existing	Aug. 2019	Many shackles and some clamps of hanger ropes are rusted. See sketch and photos 9 & 10.	
8	Superstructure	Stiffening Girder	Corrosion	Fair	Repainting (All members)	MM Repair	Existing	Oct. 2016	Corrosion, mostly lower cords and their surrounding members. See sketch and photos 11 to 14.	
9	Sidewalk	Grating panel	Rusted and/or Buckled	Bad	Replacement (All)	EA	Existing	Oct. 2016	Most of sidewalk panels are rusted and/or buckled. See sketch and photos 15 & 16.	

10	Wearing Cource	Asphalt Pavement	Potholes & Cracks	Poor	Replacement (All)	MM Repair	New	Aug. 2019	Potholes and cracks in the asphalt pavement on the deck slab. See sketch and photos 17 & 18.
11	Superstructure	Access bridge	Corrosion	Bad	Repainting (All members)	MM Repair	New	Aug. 2019	Steel girder of span 4 is corroded near the abutmemt. See sketch and photo 19.
12	Expansion Joint	Metal Joint (Zambian side)	Covered with sandy materials	Fair	Cleaning	RM Repair	New	Aug. 2019	Expansion device is covered with accumulated sandy materials. See sketch and photo 20.
13	Expansion Joint	Metal Joint (Zimbabwe side)	Damage to adjacent pavement	Fair	Replacement	MM Repair	New	Aug. 2019	Adjacent pavement is damaged. See sketch and photo 21.
14	Expansion Joint	Metal Joint (Zimbabwe side)	Corrosion	Poor			Existing	Oct. 2016	The lower part of the expansion joint is corroded. See sketch and photo 22.
15	Deck	Concrete slab	Spalling, Rebar exposure & Corrosion	Poor	Patching (A=20 m^2)	RM Repair	Existing	Oct. 2016	Spalling, rebar exposure and corrosion. See sketch and photos 23 & 24.
16	Bearing	Metal Bearing	Rusted	Poor	Repainting	MM Repair	Existing	Oct. 2016	Rust on the steel surface. See sketch and photo 25.
17	Bearing	Metal Bearing	Sliding plates moving	Bad	Repair	EA	Existing	Oct. 2016	Sliding plates moving outwards. See sketch and photo 26.

Note: - To categorize (1) Bridge Component, (2) Sub-component and (3) Defect type, refer to Table 5-3-1b.

To determine (4) Condition rating and (6) Proposed action, refer to the Table 1 and Table 2 with Figure 1, respectively.

(7) New/Existing means damage newly identified in this inspection/already identified in previous inspection.

Note: How to fill out the Bridge Routine Inspection Form

If you find a defect, enter the location in the columns of "(1) Bridge Component & (2) Sub-Component" and enter the type of defect in column of "(3) Defect Type", in the Bridge Routine Inspection Form, and fill the location and type of defect on the Defect Drawing Sheet. And, in the column "(4) Condition Rating", select Good, Fair, Poor or Bad according to Table 1 Routine Inspection Condition Rating Criteria. In the column "(6) Proposed Action", suitable actions should be entered refer to the Figure 1 Determination flow of Maintenance Action. Table 1 shows the criteria for judgment of Condition Rating. Table 2 shows the types of required actions and their contents of actions. Figure1 is a flowchart for determining a maintenance action based on the identified damage situation.

Table1 Routine Inspection Condition Rating Criteria

Condition Rating	Description
Good	No damage
Fair	With minor damage(s) not affecting the stability of the structure
Poor	With deteriorating damage(s) which should be monitored or could be repaired as a preventive action
Bad	With severe damage(s) that affects stability of bridge or that has possibility to harm a third party

Table 2 Required Maintenance Action

Required Action	Description
MO: Monitoring	No repair work and keeping monitoring (Damage not progressing or very slow)
RM: Routine Maintenance	Should be maintained by Routine Maintenance
MM: Major Maintenance	Should be maintained by Major Maintenance
EA: Emergency Action	Need to take actions immediately to avoid bridge collapse or harm to a third party
In-Depth Inspection	Condition Inspection or Detailed Inspection - Selection of appropriate repair method - Monitoring of progress of any damages

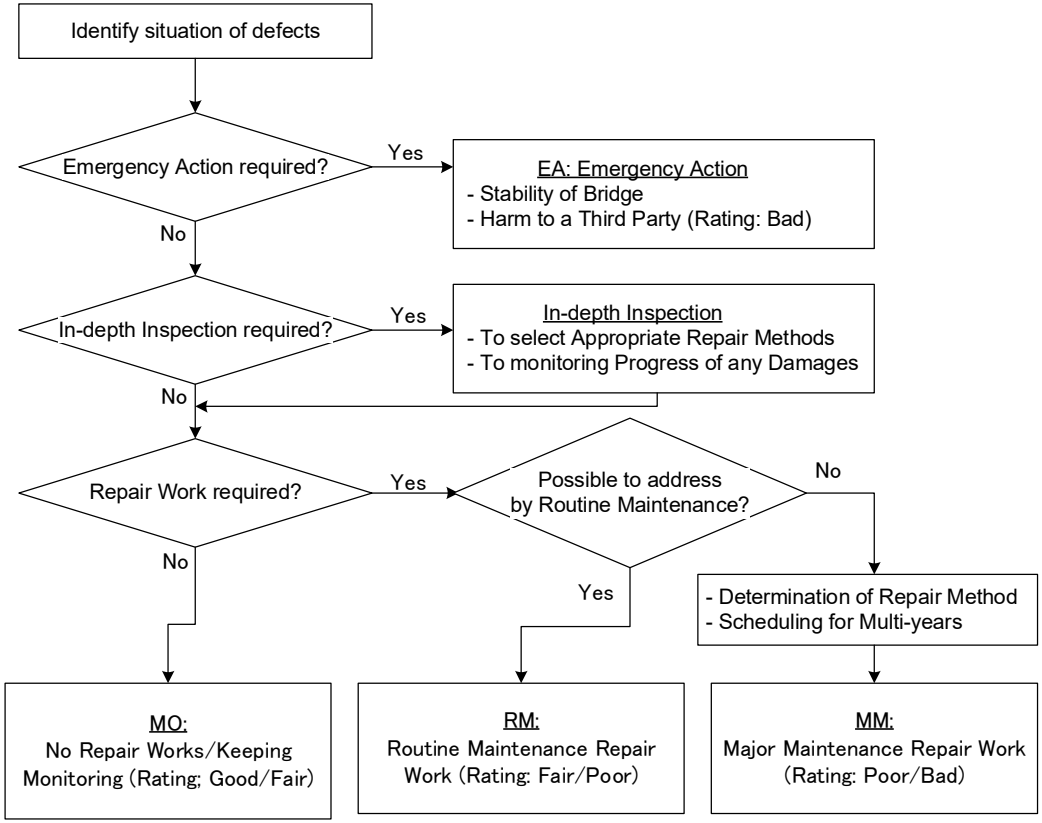
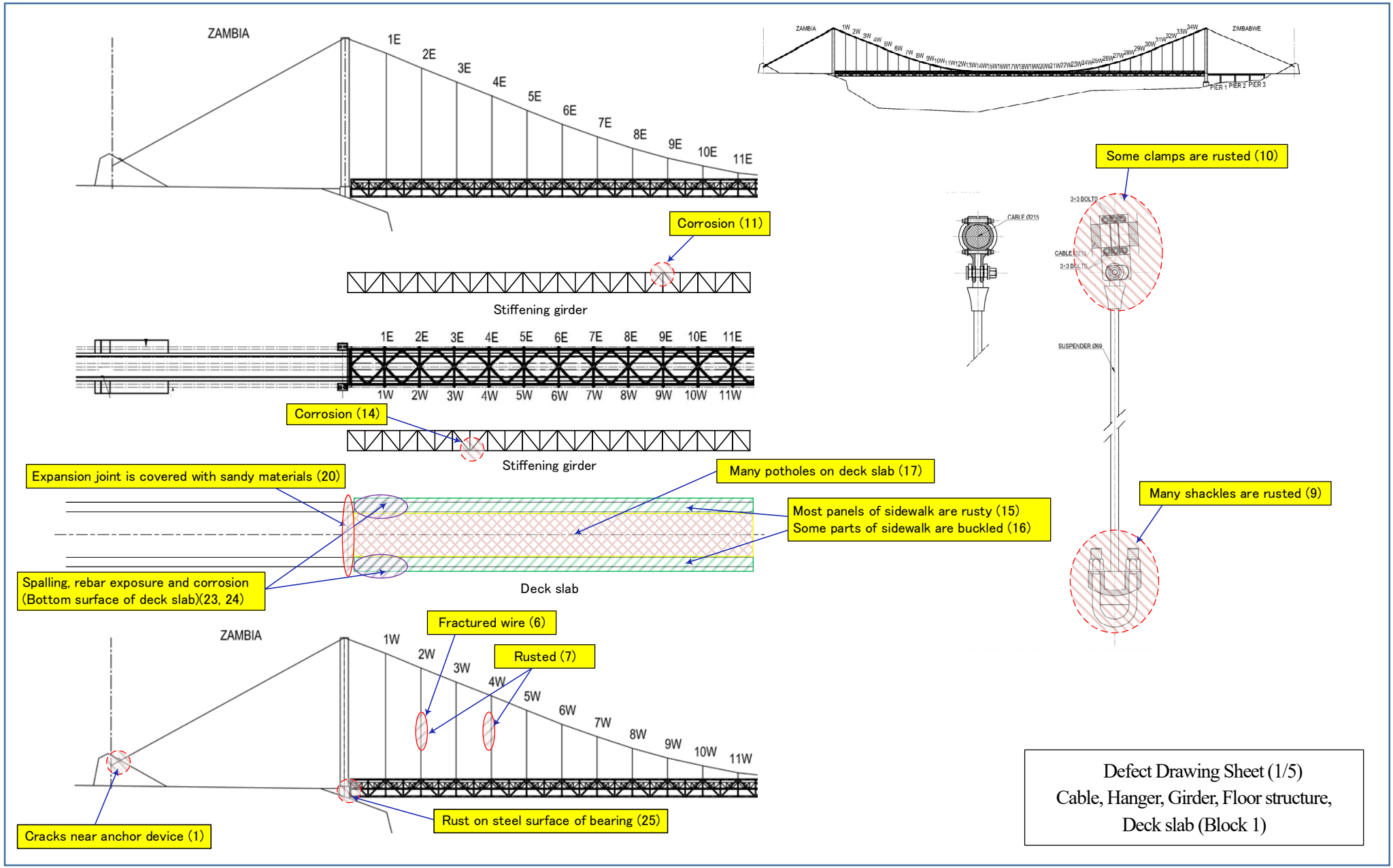
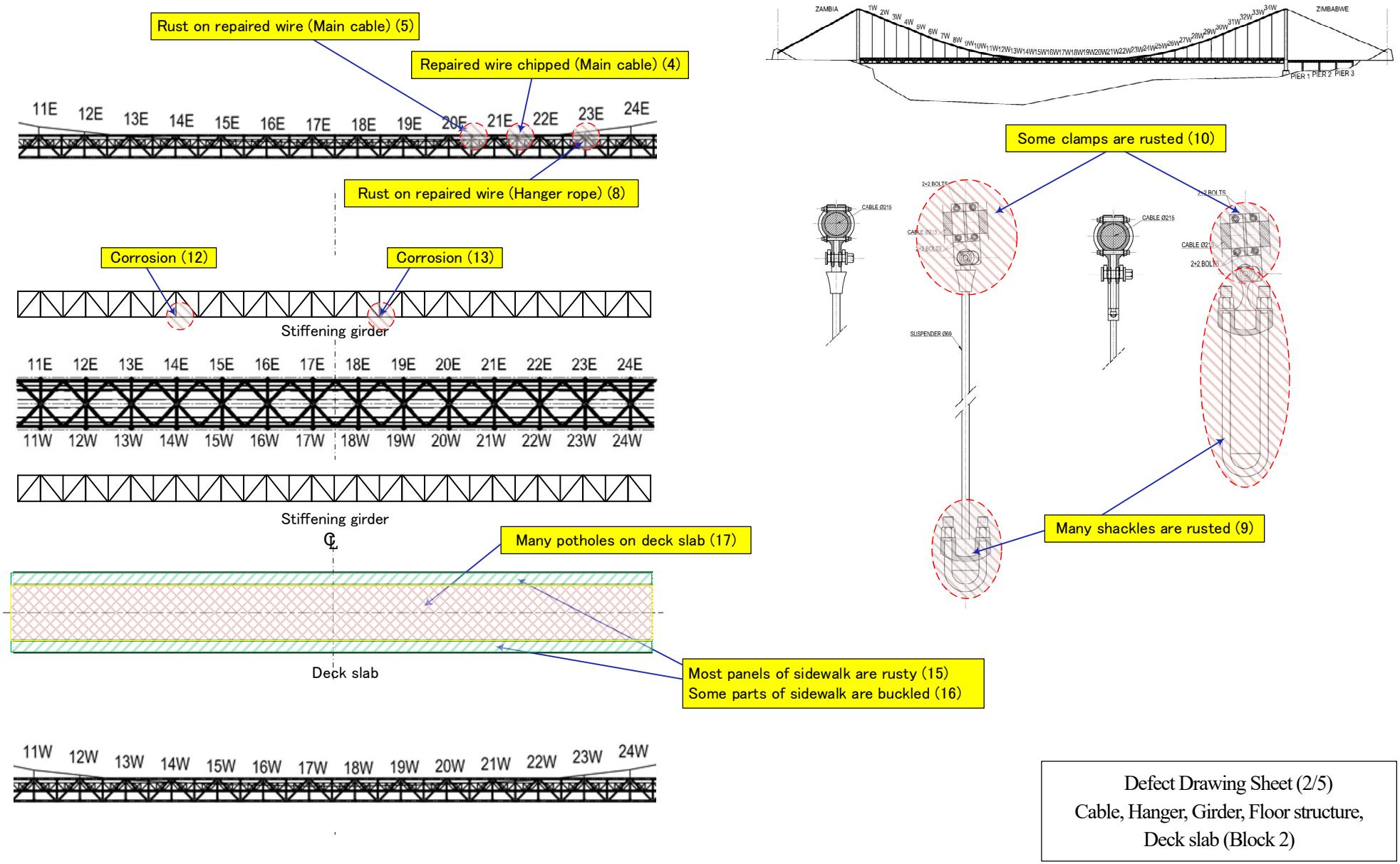
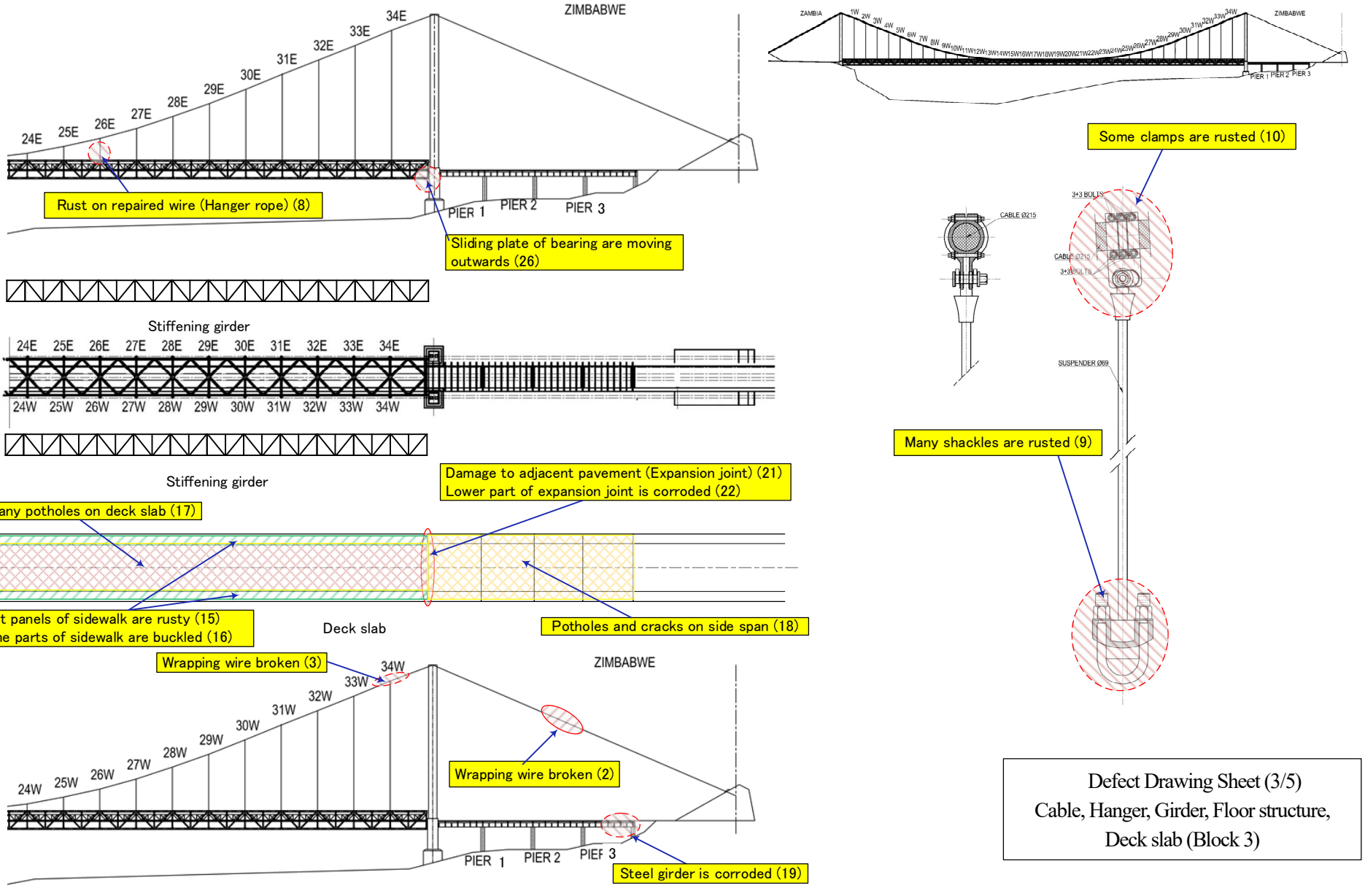


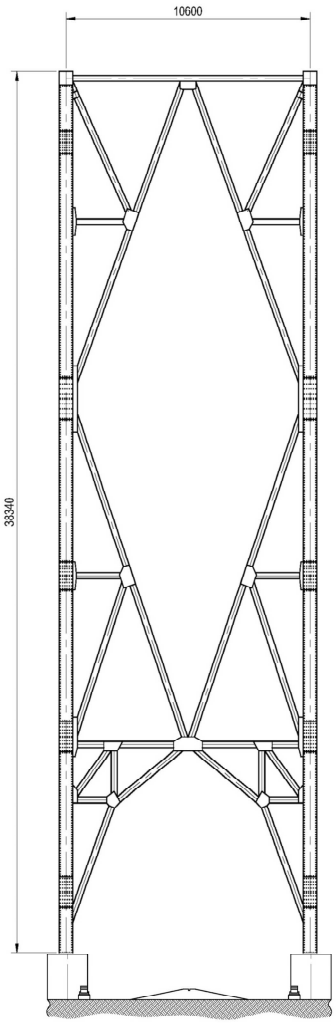
Figure 1 Determination Flow of Maintenance Action


ZAMBIA
1E
2E
3E
4E
5E
6E
7E
8E
9E
10E
11E
ZIMBABWE
PIER 1 PIER 2 PIER 3
Some clamps are rusted (10)
Corrosion (11)
Stiffening girder
1W
2W
3W
4W
5W
6W
7W
8W
9W
10W
11W
Corrosion (14)
Stiffening girder
Expansion joint is covered with sandy materials (20)
Many potholes on deck slab (17)
Most panels of sidewalk are rusty (15)
Some parts of sidewalk are buckled (16)
Many shackles are rusted (9)
Spalling, rebar exposure and corrosion
(Bottom surface of deck slab)(23, 24)
Deck slab
Fractured wire (6)
Rusted (7)
Cracks near anchor device (1)
Rust on steel surface of bearing (25)
Defect Drawing Sheet (1/5)
Cable, Hanger, Girder, Floor structure,
Deck slab (Block 1)

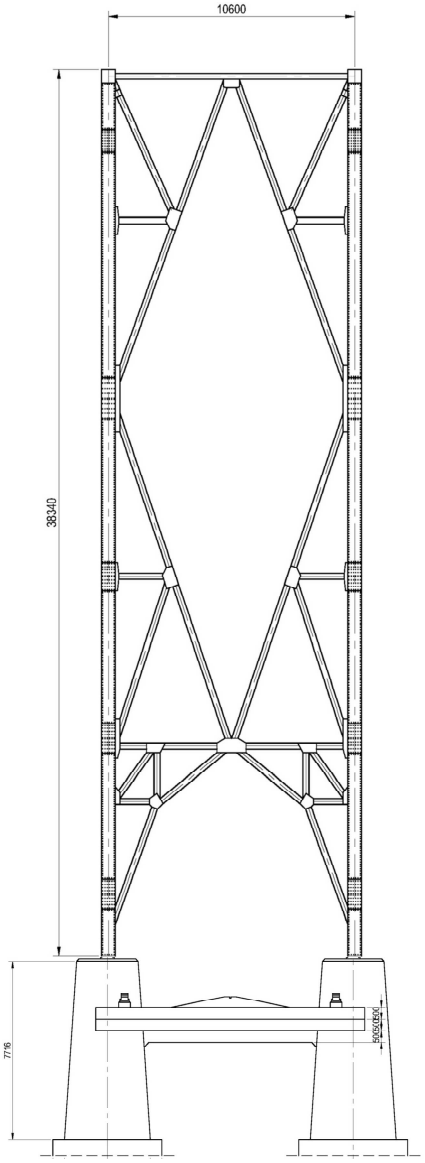


Defect Drawing Sheet (2/5)
Cable, Hanger, Girder, Floor structure,
Deck slab (Block 2)


ZIMBABWE
24E 25E 26E 27E 28E 29E 30E 31E 32E 33E 34E
Rust on repaired wire (Hanger rope) (8)
PIER 1 PIER 2 PIER 3
Sliding plate of bearing are moving outwards (26)
Stiffening girder
24E 25E 26E 27E 28E 29E 30E 31E 32E 33E 34E
24W 25W 26W 27W 28W 29W 30W 31W 32W 33W 34W
Stiffening girder
Damage to adjacent pavement (Expansion joint) (21)
Lower part of expansion joint is corroded (22)
Many potholes on deck slab (17)
Most panels of sidewalk are rusty (15)
Some parts of sidewalk are buckled (16)
Deck slab
Potholes and cracks on side span (18)
Wrapping wire broken (3)
ZIMBABWE
24W 25W 26W 27W 28W 29W 30W 31W 32W 33W 34W
Wrapping wire broken (2)
PIER 1 PIER 2 PIER 3
Steel girder is corroded (19)
ZAMBIA
ZIMBABWE
PIER 1 PIER 2 PIER 3
Some clamps are rusted (10)
CABLE Ø215
3+3 BOLTS
SUSPENDER Ø69
Many shackles are rusted (9)
Defect Drawing Sheet (3/5)
Cable, Hanger, Girder, Floor structure,
Deck slab (Block 3)

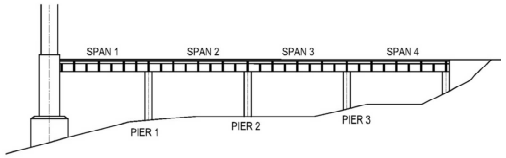


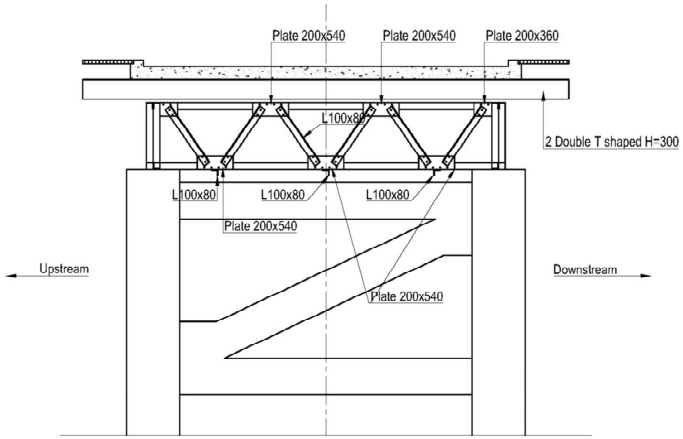
Zambian side



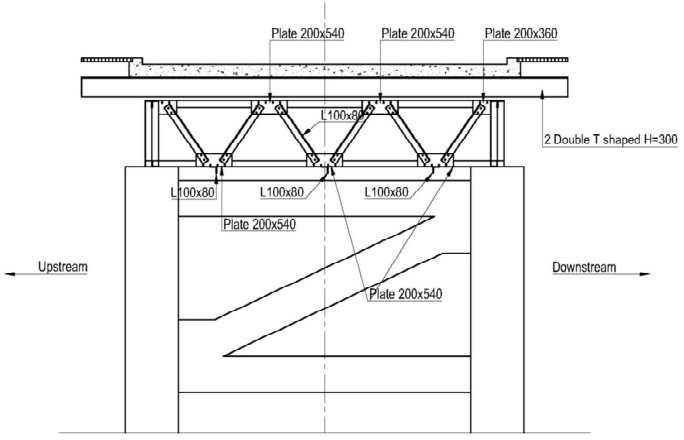
Zimbabwe side

Defect Drawing Sheet (4/5)
Tower

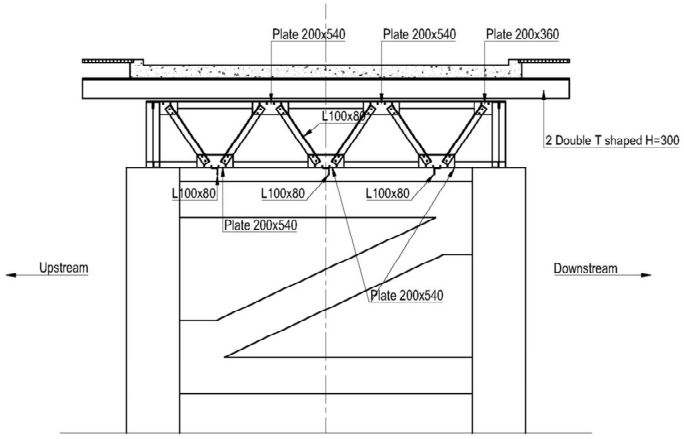




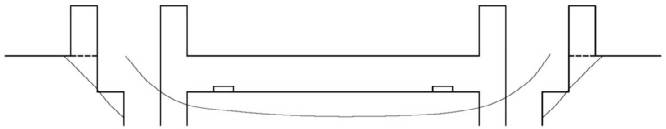
PIER 1



PIER 2



PIER 3



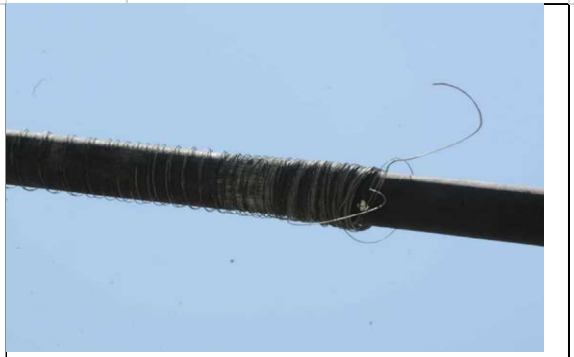
ABUTMENT

Defect Drawing Sheet (5/5)
Zimbabwe Side Approach Bridge

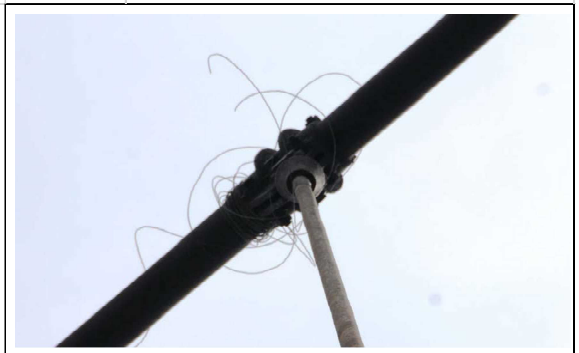
Photo Record Sheet (Bridge Name: Otto Beit Bridge)

Contractor Name:		Contract Ref. No.:		Province:	

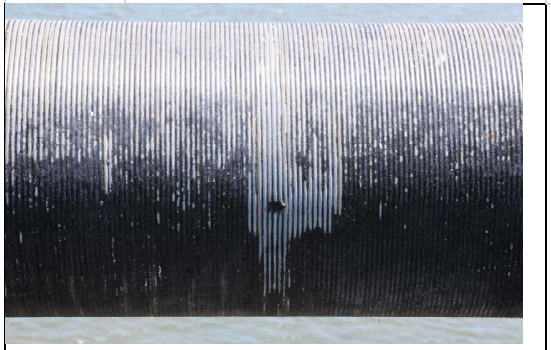
No. :	1
Date:	August 28, 2019
Location:	Zambian side anchorage
Defect Type	Cracks concrete part
Description:	Cracks are observed near the anchor device of the concrete anchorage



No.:	2
Date:	Octber 2016
Location:	Main cable (West side)
Defect Type	Wrapping wire broken
Description:	Broken wrapping wire between Zimbabwe west side tower and anchorage



No.:	3
Date:	Octber 2016
Location:	Main cable (West side)
Defect Type	Wrapping wire broken
Description:	Broken wrapping wire between west side hanger 34 and tower



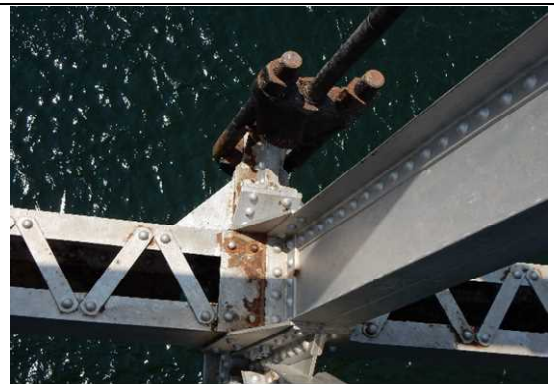
No.:	4
Date:	October 2016
Location:	Main cable (East side)
Defect Type	Wrapping wire chipped
Description:	Chipped wrapping wire between hangers 21E and 22E

No.:	5
Date:	October 2016
Location:	Main cable (East side)
Defect Type	Rust on repaired wire
Description:	Rusted repaired area between hangers 20E and 21E

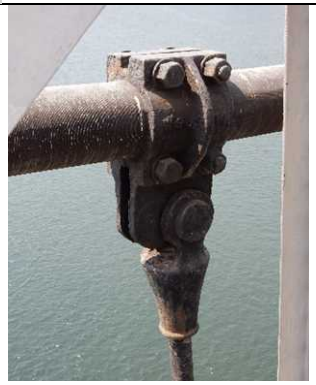
No.:	6
Date:	October 2016
Location:	Hanger 2W
Defect Type	Fractured wire
Description:	Fractured wire on hanger 2W

No.:	7
Date:	October 2016
Location:	Hanger 2W & 4W
Defect Type	Rusted
Description:	Rust caused by local loss of bituminous paint

No.:	8
Date:	October 2016
Location:	Hanger 23E & 26E
Defect Type	Rust on some repaired area
Description:	Rust on some repaired area (Recent repairing)



No.:	9
Date:	August 28, 2019
Location:	Shackle of hanger rope
Defect Type	Rusted
Description:	Many hanger rope shackles are rusted



No.:	10
Date:	August 28, 2019
Location:	Clamp of hanger rope
Defect Type	Rusted
Description:	Some hanger rope clamps are rusted

No.:	11
Date:	October 2016
Location:	Stiffening girder (9E)
Defect Type	Corrosion
Description:	Corrosion spot

No.:	12
Date:	October 2016
Location:	Stiffening girder (14E)
Defect Type	Corrosion
Description:	Corrosion spot (Lower cords and their surrounding members)

No.:	13
Date:	October 2016
Location:	Stiffening girder (18E-19E)
Defect Type	Corrosion
Description:	Corrosion spot (Lower cords and their surrounding members)

No.:	14
Date:	October 2016
Location:	Stiffening girder (3W-4W)
Defect Type	Corrosion
Description:	Corrosion spot (Lower cords and their surrounding members)

No.:	15
Date:	August 28, 2019
Location:	Sidewalk
Defect Type	Corrosion
Description:	Most of sidewalk are rusty

No.:	16
Date:	August 28, 2019
Location:	Sidewalk
Defect Type	Buckling
Description:	Some parts of sidewalk are buckled.

No.:	17
Date:	August 28, 2019
Location:	Pavement on deck slab (Main span)
Defect Type	Pothole
Description:	Many potholes in the asphalt pavement on the deck slab

No.:	18
Date:	August 28, 2019
Location:	Pavement on deck slab (Side span)
Defect Type	Potholes and Cracks
Description:	Potholes and cracks in the asphalt pavement on the deck slab

No.:	19
Date:	August 28, 2019
Location:	Span 4 (abutment side)
Defect Type	Corrosion
Description:	Steel girder of span 4 is corroded near the abutmemt

No.:	20
Date:	August 28, 2019
Location:	Zambian side expansion joint
Defect Type	Covered with sandy materials
Description:	Expansion device is covered with accumulated sandy materials

No.:	21
Date:	August 28, 2019
Location:	Zimbabwe side expansion joint
Defect Type	Damage to adjacent pavement
Description:	Adjacent pavement is damaged

No.:	22
Date:	October 2016
Location:	Zimbabwe side expansion joint
Defect Type	Corrosion
Description:	The lower part of the expansion joint is corroded.

No.:	23
Date:	October 2016
Location:	Deck slab (Near Zambian tower)
Defect Type	Spalling, Rebar exposure
Description:	Spalling, rebar exposure and corrosion

No.:	24
Date:	October 2016
Location:	Deck slab (Near Zambian tower)
Defect Type	Spalling, Rebar exposure
Description:	Spalling, rebar exposure and corrosion (distant view)

No.:	25
Date:	October 2016
Location:	Zambia side upstream bearing
Defect Type	Rusted
Description:	Rust on the steel surface

No.:	26
Date:	October 2016
Location:	Zimbabwe side downstream bearing
Defect Type	Sliding plates moving
Description:	Sliding plates moving outwards

No.:	
Date:	
Location:	
Defect Type:	
Description:	

(4) Inspection Results (Date of Inspection: October 22, 2021)

In this inspection, we investigated newly generated defects and worsened defects after the 2019 inspection, and filled them out on the inspection sheet.

Currently, the Chirundu Bridge is being used as usual, but the Otto Beit Bridge has been closed due to the effects of COVID-19.

Partly because of this, the road surface is covered with a thin layer of earth and sand, and the cable wrapping wires have been frayed or damaged, the hanger's bitumen coating has deteriorated, and the stiffening girder paint has deteriorated /corroded. The defect condition of the Otto Beit Bridge is worse further than it at the time of inspection in 2019.

The deck slab and the pavement above it are also heavily damaged, such as potholes in the pavement and cracks in the deck slab.

There is concern that the condition of the Otto Beit Bridge will further worsen in the future due to the fact that it has not been properly repaired and maintained for a long period of time and is currently closed to traffic and not cleaned.

Bridge Routine Inspection Form

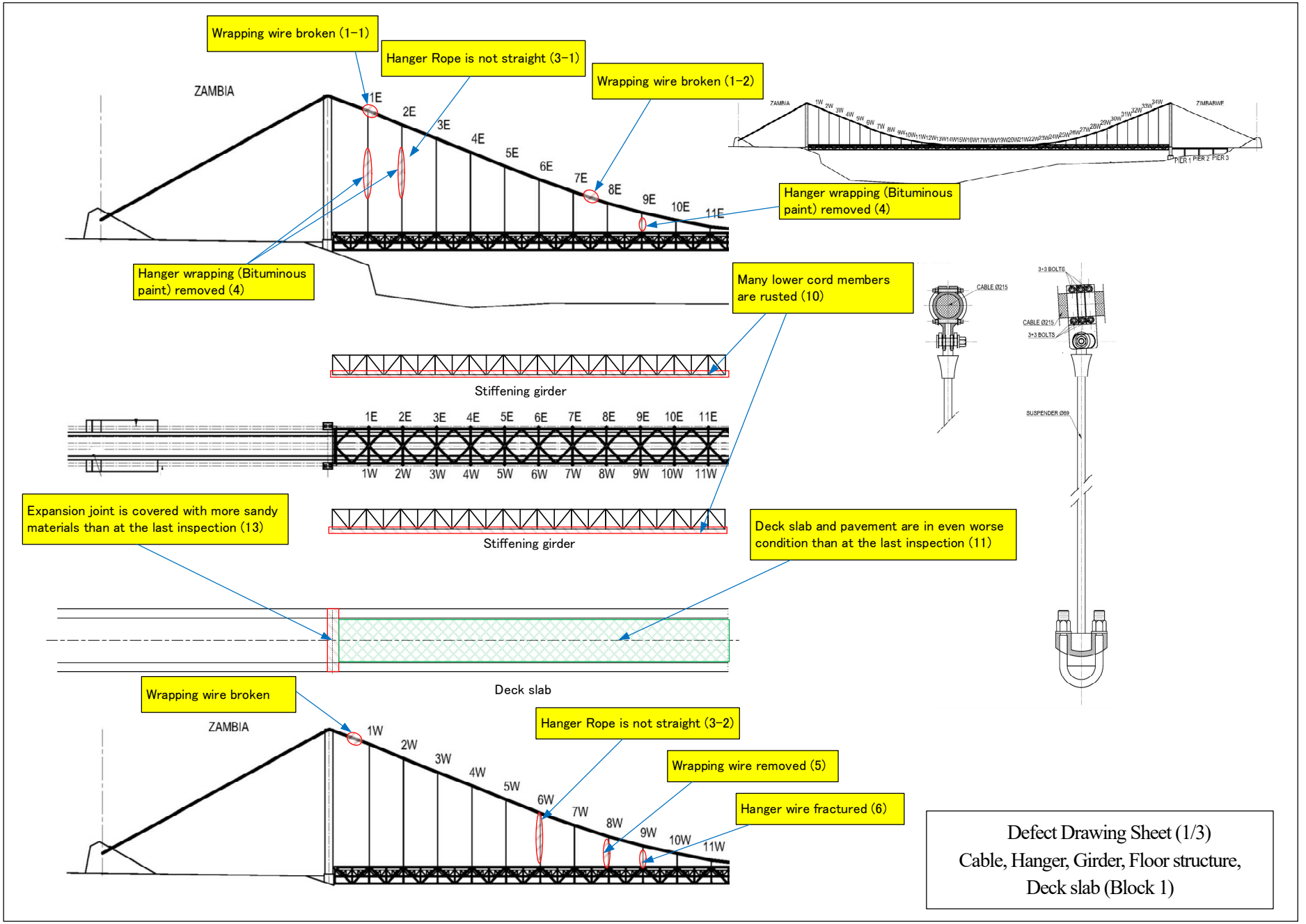
Date:		Contractor Name:				Contract Ref. No. :		Province:	
Bridge No.:		Bridge Name:			Road No.:		Road Name:		Location:
No.	(1) Bridge Component	(2) Sub-Component	(3) Defect Type	(4) Condition Rating	(5) Quantity (Unit)	(6) Proposed Action	(7) New/ Existing	(8) Date of Detection	(9) Remarks
1	Cable System	Main Cable	Wrapping wire broken	Bad	Replacement of wrapping wire	EA	New	Oct. 2021	Wrapping wires are newly broken at several portions of the main cables. (1E, 7E-8E, 28E, & Tow-Ank E), (Photo: 1-1, 1-2, 1-3 & 1-4)
2	Cable System	Anchorage	Dirty anchorage houses	Bad	Cleaning	RM Repair	New	Oct. 2021	Zimbabwe anchorage houses are full of garbages. (Photo: 2)
3	Cable System	Hanger Rope	Not straight	Bad	Detailed Inspection (2 ropes)	In-depth Inspection	New	Oct. 2021	Hanger Rope is not straight. (2E, 6W), (Photo: 3-1, 3-2)
4	Cable System	Hanger Rope	Bituminous paint removed	Bad	Replacement of coating materials (All Hanger Ropes)	EA	New	Oct. 2021	Hanger wrapping(Bituminous paint) removed (1E, 2E & 9E), (Photo: 4)
5	Cable System	Hanger Rope	Wrapping wire removed				New	Oct. 2021	Wrapping wire is removed. (8W), (Photo: 5)
6	Cable System	Hanger Rope	Fractured wire				New	Oct. 2021	Hanger wire is fractured. (9W), (Photo: 6)
7	Cable System	Hanger Rope	Rusted hanger				New	Oct. 2021	Hanger Rope is rusted. (14E), (Photo: 7)

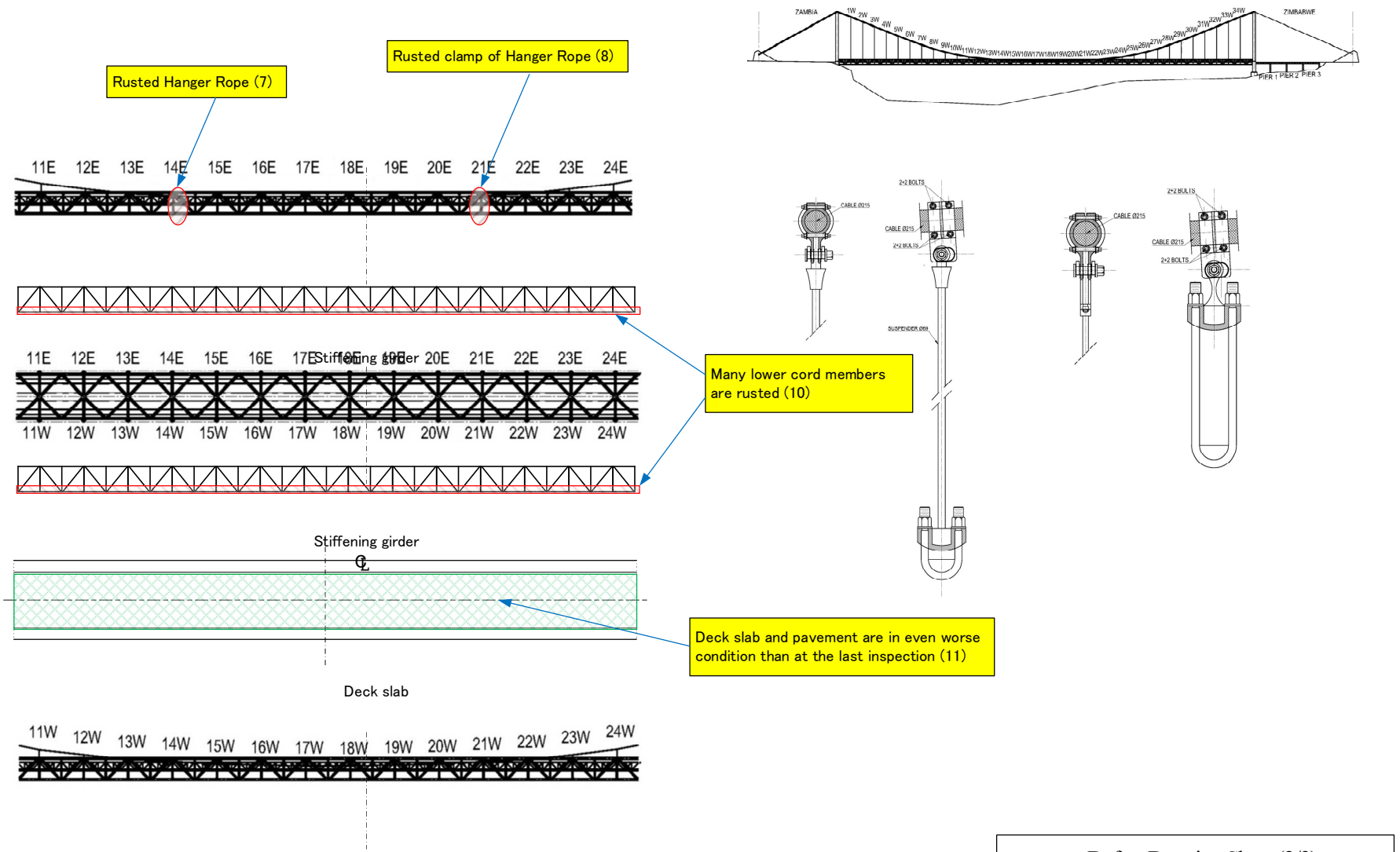
8	Cable System	Hanger Rope	Clamp rusted	Poor	Repainting (Clamps and Shackles of All Hangers)	MM Repair	Existing	Oct. 2021	Hanger clamp is rusted. (21E), (Photo: 8)
9	Cable System	Hanger Rope	Rotated shackle	Poor	Correcting position	MM Repair	New	Oct. 2021	Shackles have been rotated. (32E, 26W, 27W 31W), (Photo: 9-1, 9-2)
10	Superstructure	Stiffening girder	Rusted	Fair	Repainting (All members)	MM Repair	Existing	Oct. 2021	Many lower cord members are rusted. (Photo: 10)
11	Deck slab	Main bridge	Pothole, crack	Bad	Replace with precast slab	MM Repair	Existing	Oct. 2021	Deck slab and pavement are in even worse condition than the last inspection (potholes, cracks, etc.) (Photo: 11)
12	Deck slab	Access bridge	Pothole, crack	Bad	Reconstruction	MM Repair	Exsisting	Oct. 2021	Dameges (potholes & cracks) are worse than at the last inspection. (Photo: 12)
13	Expansion joint	Zambia side	Buried with sandy marterials	Poor	Cleaning	RM Repair	Exsisting	Oct. 2021	Expansion joint is covered with more sandy materials than at the last inspection. (Photo: 13)
14	Expansion joint	Zimbabwe side	Damage of adjacent pavement	Poor	Replacement	MM Repair	Exsisting	Oct. 2021	Damage of adjacent pavement to expansion joint become worse yhan at the last inspection. (Photo 14)
15	Guard fence	Access bridge	Wire mesh deformed	Poor	Partial replacement	RM Repair	New	Oct. 2021	Wire mesh of the guard fence is deformed in several places. (Photo: 15)

Note: - To categorize (1) Bridge Component, (2) Sub-component and (3) Defect type, refer to Table 5-3-1b.

To determine (4) Condition rating and (6) Proposed action, refer to the Table 1 and Table 2 with Figure 1, respectively.

(7) New/Existing means damage newly identified in this inspection/already identified in previous inspection.


Wrapping wire broken (1-1)
Hanger Rope is not straight (3-1)
Wrapping wire broken (1-2)
ZAMBIA
1E
2E
3E
4E
5E
6E
7E
8E
9E
10E
11E
Hanger wrapping (Bituminous paint) removed (4)
Hanger wrapping (Bituminous paint) removed (4)
Many lower cord members are rusted (10)
Stiffening girder
1E 2E 3E 4E 5E 6E 7E 8E 9E 10E 11E
1W 2W 3W 4W 5W 6W 7W 8W 9W 10W 11W
Expansion joint is covered with more sandy materials than at the last inspection (13)
Stiffening girder
Deck slab and pavement are in even worse condition than at the last inspection (11)
Deck slab
Wrapping wire broken
ZAMBIA
1W
2W
3W
4W
5W
6W
7W
8W
9W
10W
11W
Hanger Rope is not straight (3-2)
Wrapping wire removed (5)
Hanger wire fractured (6)
CABLE Ø215
3+3 BOLTS
SUSPENDER Ø69
Defect Drawing Sheet (1/3)
Cable, Hanger, Girder, Floor structure,
Deck slab (Block 1)



Defect Drawing Sheet (2/3)
Cable, Hanger, Girder, Floor structure,
Deck slab (Block 2)

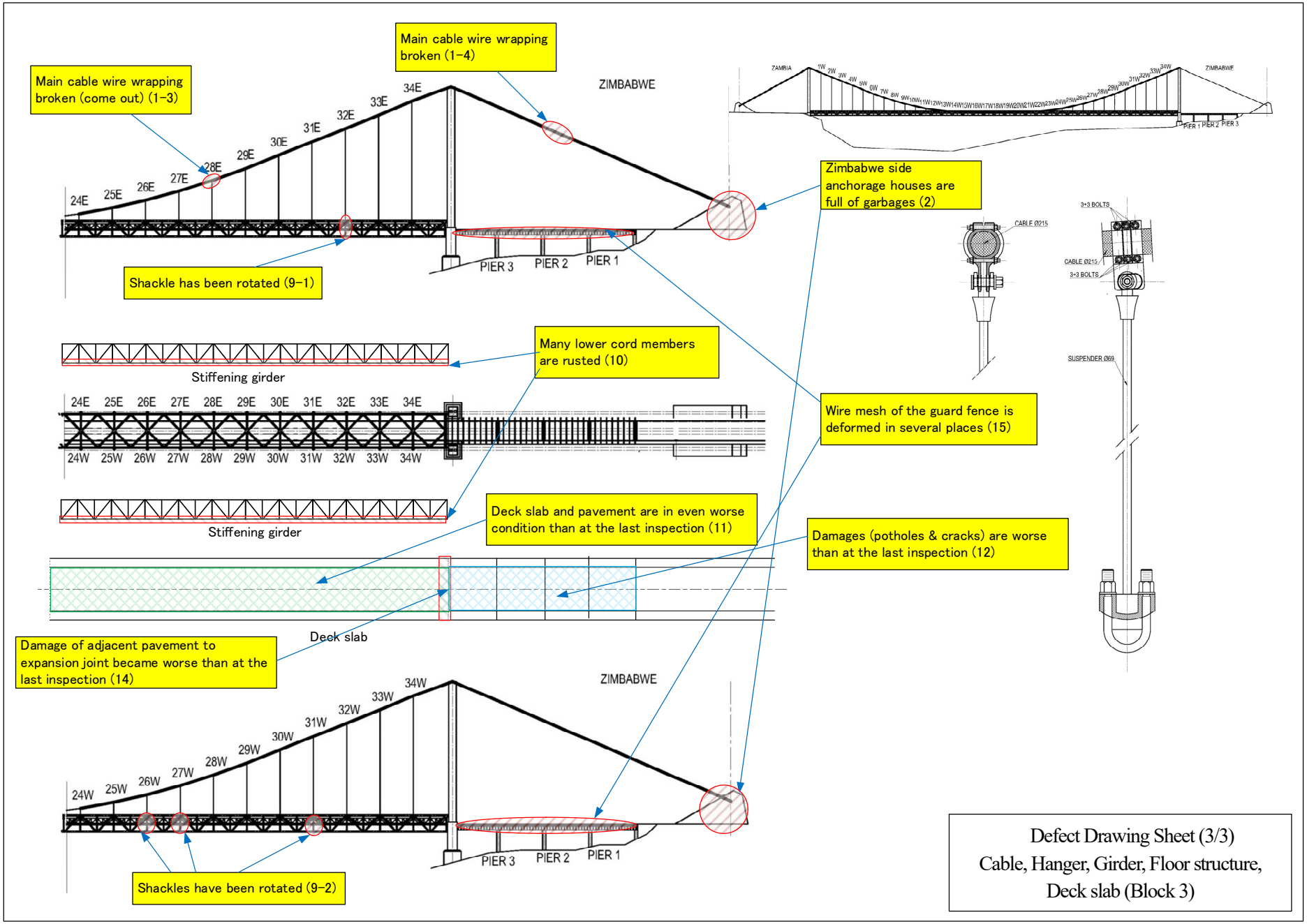
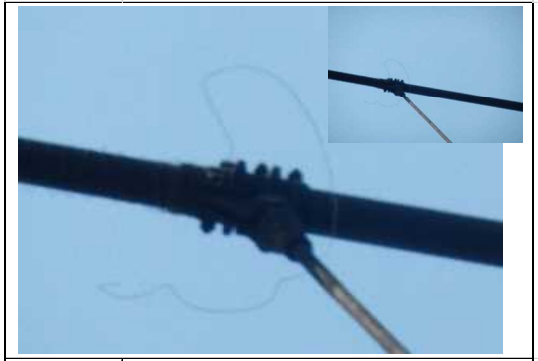

Main cable wire wrapping broken (1-4)
Main cable wire wrapping broken (come out) (1-3)
ZIMBABWE
Zimbabwe side anchorage houses are full of garbages (2)
Shackle has been rotated (9-1)
PIER 3
PIER 2
PIER 1
Many lower cord members are rusted (10)
Stiffening girder
Wire mesh of the guard fence is deformed in several places (15)
Deck slab and pavement are in even worse condition than at the last inspection (11)
Damages (potholes & cracks) are worse than at the last inspection (12)
Deck slab
Damage of adjacent pavement to expansion joint became worse than at the last inspection (14)
Shackles have been rotated (9-2)
CABLE Ø215
3+3 BOLTS
SUSPENDER Ø69
Defect Drawing Sheet (3/3)
Cable, Hanger, Girder, Floor structure,
Deck slab (Block 3)

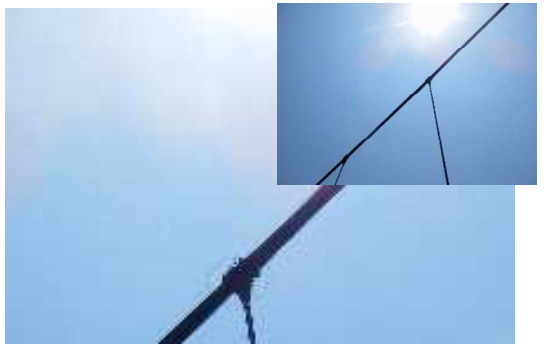
Photo Record Sheet (Bridge Name: Otto Beit Bridge)

Contractor Name:		Contract Ref. No.:		Province:	



No. :	1-1
Date:	October 22, 2021
Location:	Main Cable (East side)
Defect Type:	
Description:	Wrapping wire is broken (near 1E)

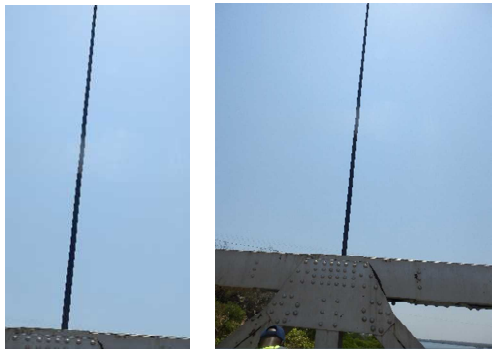
No.:	1-2
Date:	October 22, 2021
Location:	Main Cable (East side)
Defect Type:	
Description:	Wrapping wire is broken (between 7E & 8E))



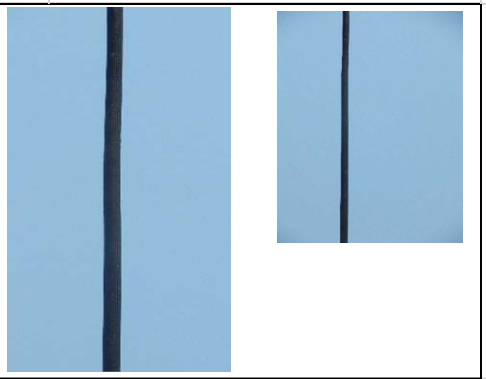
No.:	1-3
Date:	October 22, 2021
Location:	Main Cable (East side)
Defect Type:	
Description:	Wrapping wire is coming out. (near 28E)

No.:	1-4
Date:	October 22, 2021
Location:	Main Cable (East side)
Defect Type:	
Description:	Wrapping wire is broken (between Zimbabwe east side tower & anchorage)

No.:	2
Date:	October 22, 2021
Location:	Anchorage (Zimbabwe side)
Defect Type:	
Description:	Zimbabwe side anchorage houses are full of garbages



No.:	3-1
Date:	October 22, 2021
Location:	Hanger Rope (East side)
Defect Type:	
Description:	Hanger Rope is not straight (2E)

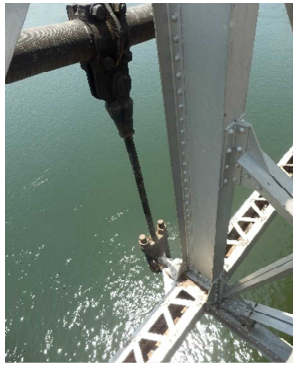


No.:	3-2
Date:	October 22, 2021
Location:	Hanger Rope (West side)
Defect Type:	
Description:	Hanger Rope is not straight (6W)

No.:	4
Date:	October 22, 2021
Location:	Hanger Rope (East side)
Defect Type:	
Description:	Hanger wrapping (Bituminous paint) is removed (1E, 2E & 9E)

No.:	5
Date:	October 22, 2021
Location:	Hanger Rope (West side)
Defect Type:	
Description:	Wrapping wire is removed (8W)

No.:	6
Date:	October 22, 2021
Location:	Hanger Rope(West side)
Defect Type:	
Description:	Hanger wire is fractured (9W)



No.:	7
Date:	October 22, 2021
Location:	Hanger Rope (East side)
Defect Type:	
Description:	Hanger Rope is rusted (14E)

No.:	8
Date:	October 22, 2021
Location:	Hanger Rope (East side)
Defect Type:	
Description:	Hanger clamp is rusted (21E)

No.:	9-1
Date:	October 22, 2021
Location:	Hanger Rope (East side)
Defect Type:	
Description:	Hanger shackle has been rotated (32E)

No.:	9-2
Date:	October 22, 2021
Location:	Hanger Rope (West side)
Defect Type:	
Description:	Hanger shackle has been rotated (26W, 27W and 31W)

No.:	10
Date:	
Location:	Stiffening Girder (Whole girder)
Defect Type:	
Description:	Many lower cord members are rusted

No.:	11
Date:	October 22, 2021
Location:	Deck slab and Pavement
Defect Type:	
Description:	Deck slab and pavement are in even worse condition than at the last inspection (Potholes & Cracks)

No.:	12
Date:	October 22, 2021
Location:	Access Bridge surface
Defect Type:	
Description:	Damages (Potholes & Cracks) are worse than at the last inspection

No.:	13
Date:	October 22, 2021
Location:	Expansion Joint (Zambia side)
Defect Type:	
Description:	Expansion joint is coverd with more sandy materials than at the last inspection

No.:	14
Date:	October 22, 2021
Location:	Expansion joint (Zimbabwe side)
Defect Type:	
Description:	Damage of adjacent pavement to the expansion joint bacame worse than at the last inspection

No.:	15
Date:	October 22, 2021
Location:	Guard fence (Access Bridge)
Defect Type:	
Description:	Wire mesh of the guard fence is deformed in several places

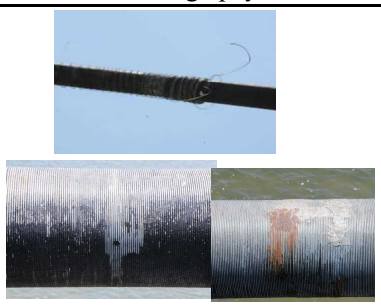
No.:	
Date:	
Location:	
Defect Type:	
Description:	

5-3-3 Routine Maintenance

(1) Defects and Causes

The defects observed in suspension bridge (The Otto Beit Bridge) and their causes are described below. For the defects common to general bridges, please see “Bridge Routine maintenance Guideline, 3-6 Types of Defects and Causes”.

Table 5-3-2 Defects and Causes of Otto Beit Bridge

Location	Defects	Photography	Presumed Causes
Cable System - Main Cable -	Wrapping wire broken, Chipped & rusted		It seems that the main cable has never been repaired or otherwise maintained after the bridge was completed in 1939. It is presumed that the wrapping wire has deteriorated and damaged due to the effects of long-term wind and rain and vibration when the vehicle passes through.
Cable System - Anchorage -	Cracks		It is thought that cracks have occured in the surface layer of concrete. It is presumed that the drying shrinkage that occurred in the surface concrete during the construction of the surface concrete was restrained by the concrete inside and cracks occurred.
	Anchorage houses are full of garbages (Zimbabwe side)		It seems that it was used as a garbage dump for some reason.
Cable System - Hanger Rope -	Bituminous paint deteriorated, Hanger rope rusted, Repaired wrapping wire broken		The hanger ropes are covered with Bituminous Paint, but those paints have deteriorated over time, and at some portions, those coatings have peeled off and wires have been damaged. Those dameged portions have been partially repaired with wrapping wire, but the repaired portions are also deteriorating.
	Shackles & Clamps are rusted		The shackles and clamps that secure the hanger ropes are also all rusted due to the effects of many years of wind and rain.

Location	Defects	Photography	Presumed Causes
Cable System - Hanger Rope -	Rope is not straight, Some Shackles are rotated	 	If it is not straight, it is possible that the tension is reduced. It seems that the shackles are rotating because of vibrations by passing vehicles/strong winds which have affected the bridge for many years.
Superstructure - Stiffening Girder -	Many lower cord members are rusted		When it rains, water from the upper structures such as the road surface and the upper chord members falls on the lower chord members, so it is presumed that the rust has progressed due to the repetition of those phenomenon.
Sidewalk - Grating Panels -	Most panels are rusted and some parts of sidewalk are buckled		Rust and corrosion appear to be the effects of long-standing rainwater. The buckling may be caused by the event that the vehicle's tires rode on the sidewalk.
Superstructure - Access Bridge -	Steel girder is corroded (span 4)		The positions of the girders are low, therefore it is thought that the girders were submerged in water when the water increased due to heavy rain.
Deck - Main Bridge -	Many potholes (pavement) & many cracks (concrete slab)		Due to the effects of heavy vehicles passing for many years, pavement and concrete deck are being damaged. In addition, maintenance has not been done so far, and the bridge is currently closed due to the influence of COVID-19, then it is in a more rough state than the last inspection time.
	Spalling, rebar exposure and corrosion (Bottom surface of deck slab)		It is presumed that due to the use of low-quality concrete and insufficient compaction of concrete during construction, moist air penetrated into the inside of concrete, causing corrosion of the reinforcing bars. After that, it is also presumed that the corrosion of the reinforcing bars progressed and expanded, and the cover concrete fell off.
Deck - Access Bridge -	Many potholes (pavement) & many cracks (concrete slab)		Due to the effects of heavy vehicles passing for many years, pavement and concrete deck are being damaged. In addition, maintenance has not been done so far, and the bridge is currently closed due to the influence of COVID-19, then it is in a more rough state than the last inspection time.

Location	Defects	Photography	Presumed Causes
Expansion Joint - Zambia side -	Covered with sandy materials		It is presumed that the bridge had not been maintained for many years and the bridge is closing due to the influence of COVID-19, therefore, the surrounding earth and sand flowed to and covered over the joint.
Expansion Joint - Zimbabwe side -	Damage to adjacent pavement & lower part of expansion joint is corroded		The adjacent pavement was damaged due to the passage of heavy vehicles for many years.In addition, it is presumed that rainwater on the road surface flowed into the lower side of the joint and the back side of the joint was corroded.
Bearing - Zambia side -	Steel surface of bearing is rusted		It is probable that rainwater flowed down from the expansion joint, causing corrosion of the bearings.
Bearing - Zimbabwe side -	Sliding plates of bearing are moving outwards		It is presumed that the sliding plate did not function normally and followed the movement of the stiffening girder and moved out to the river side.
Guard Fence - Access Road -	Wire mesh of guard rail is deformed in several places		It seems to be due to artificial behavior for some reason.

(2) Routine Maintenance Activities

The standard routine maintenance activities of the suspension bridge are shown in Table 5-3-3.

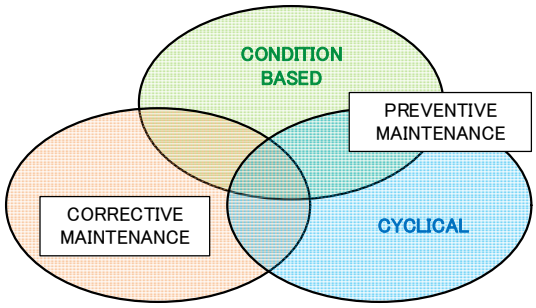


Figure 5-3-2 Treatment Categories

Table 5-3-3 Routine Maintenance Activity List (Otto Beit Bridge)

Activity No.	Activity Item	Frequency	Classification	Applied Item	
				Chapter 4	Chapter 5
	(Deck)				
1-1	Clean deck and gutters	Yearly	Preventive(Cycl.)	4-1	
1-2	Clean deck drains/scuppers	Yearly	Preventive(Cycl.)	4-1	
1-3	Clean joint	Yearly	Preventive(Cycl.)	4-1	
1-4	Joint sealing	As needed	Corrective	4-9	
1-5	Deck repair – Coating on /injection/caulking into cracks	As needed	Preventive(CB.)	4-6/4-7/4-8	
1-6	Deck repair – Pavement Patching	As needed	Corrective	4-11	
1-7	Deck repair – Concrete Deck Patching	As needed	Corrective	4-3	
1-8	Collision damage repair to railing/parapet	As needed	Corrective	4-10	
1-9	Repair to damaged curb/sidewalk	As needed	Corrective	4-11	
1-10	Drain extensions	As needed	Preventive(CB.)	4-12	
	(Superstructure)				
2-1	Clean girders	2 years	Preventive(Cycl.)	4-1	
2-2	Touch-up/re- painting on steel members	As needed	Preventive(CB.)	4-4	
	(Substructure)				
3-1	Clean abutments/caps/bearings	2 years	Preventive(Cycl.)	4-1	
3-2	Repairs to slope protection	As needed	Preventive(CB.)	4-15	
3-3	Repair to scour protections around foundations	As needed	Preventive(CB.)	4-16	
	(Site)				
4-1	Vegetation control and rubbish removal around substructures	Quarterly	Preventive(Cycl.)	4-13	
4-2	Removal of debris/driftwoods from waterway	As needed	Preventive(CB.)	4-14	
	(Cable System)				
5-1	Clean main cables/hunger ropes/Towers/anchorages	2 years	Preventive(Cycl.)	4-1	
5-2	Touch-up/re- painting on steel members of cable system	As needed	Preventive(CB.)	4-4	
5-3	Coating on/injection/caulking into cracks of anchorages	As needed	Preventive(CB.)	4-6/4-7/4-8	
5-4	Patching on anchorages	As needed	Corrective	4-5	

5-2-4 Routine Maintenance and Repair Method

Table 5-3-4 shows the recommended maintenance activities for the defects observed during the inspection of the Otto Beit Bridge.

Table 5-3-4a Recommended Maintenance Activities for Otto Beit Bridge (1/2)

No.	Bridge Component/ Sub-Component	Defect Type	Routine Maintenance Activity	Applied Item in Chapter 4 and 5	Other Activities
1	Cable System/Main Cable	Wrapping wire broken, chipped & rusted	-	-	Replacing the wrapping wire for the damaged sections of the main cables (MM Repair)
2	Cable System/Anchorage	Cracks	5-3 Epoxy injection	4-7 Epoxy injection	
3	Cable System/Anchorage	Full of Garbage	5-1 Cleaning	4-1 Cleaning	
4	Cable System/Hanger Rope	Deformed (not straight)	-	-	Measuring the tension of 2 ropes (In-depth inspection)
5	Cable System/Hanger Rope	Bituminous paint deteriorated, Hanger rope rusted, Repaired wrapping wire broken	-	-	Replacement of coating materials for all ropes (MM Repair)
6	Cable System/Hanger Rope	Shackles & Clamps are rusted	-	-	Repainting of clamps & shackles for all hanger ropes (MM Repair)
7	Cable System/Hanger Rope	Shackles are rotated	-	-	Correcting the positions (MM Repair)

Table 5-3-4b Recommended Maintenance Activities for Otto Beit Bridge (2/2)

No.	Bridge Component/ Sub-Component	Defect Type	Routine Maintenance Activity	Applied Item in Chapter 4 and 5	Other Activities
8	Superstructure/Stiffening Girder	Rusted	-	-	Repainting for all members (MM Repair)
9	Deck Slab/Main Bridge	Pothole, crack (Top surface) Spalling, Rebar exposed and Corrosion (Bottom surface)	-	-	Replace the existing deck slab with a precast slab (MM Repair)
10	Sidewalk/Main Bridge	Rusted and/or Buckled	-	-	Replacement for all panels (MM Repair)
11	Deck Slab/Access Bridge	Pothole, crack	-	-	Reconstruction (MM Repair)
12	Expansion Joint/Zambia side	Buried with sandy materials	5-1 Cleaning	4-1 Cleaning	
13	Expansion Joint/Zimbabwe side	Damage to adjacent pavement & lower part of expansion joint is corroded	-	-	Replacement (MM Repair)
14	Bearing/Zambia side	Rusted	-	-	Repainting (MM Repair)
15	Bearing/Zimbabwe side	Sliding plate moving	-	-	Repair (MM Repair)
16	Guard Fence/Access Bridge	Wire mesh deformed	1-8 Collision damage repair to railing/parapet	4-10 Repair to railing/ parapet	

5-3-4 Routine Maintenance and Repair Method

If there are any items that should be added as routine maintenance activities of Otto Beit Bridge, add them to Table 5-3-3 and describe the contents, methods, materials used, and equipment in "5-3-4 Routine Maintenance and Repair method".

5-4 STEEL ARCH BRIDGE (VICTORIA FALLS BRIDGE)

5-4-1 Structural Outline

Arch bridge is a structure that transmits loads using a bow-shaped arch members (arch rib). As shown in the figure below, when an external load is applied, a compressive force (axial force) acts on the arch rib, and ground reaction forces (horizontal and vertical reaction forces) corresponding to the compressive force are generated on the support points at the both ends of the arch rib. The basis of arch design is to determine the axial shape so as to be resisted dead load by only axial force. Axial force increases in accordance with going to the springing from the crown portion, the dead load also increases in accordance with the going to the end. Therefore, the arch axis shape is a curve having a steep slope toward the end.

The Victoria Falls Bridge uses the spandrel braced arch structure, which consists of a truss between the arch rib and the girder, to increase the arch stiffness.

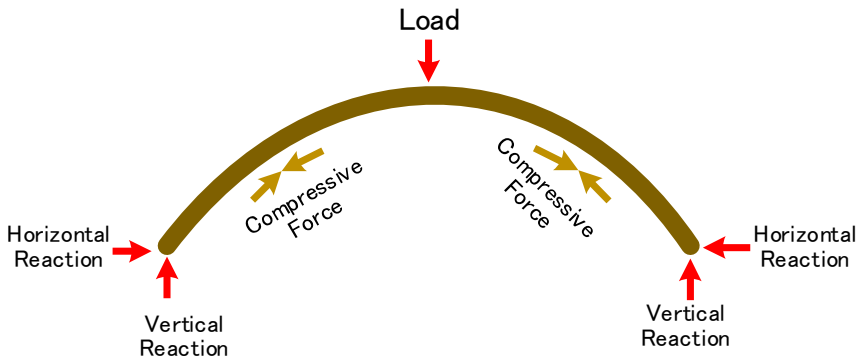


Figure 5-4-1 Structural System of Steel Arch Bridge

5-4-2 Routine Inspection

(1) Bridge Components and Defects

Table 5-4-1a shows possible defects in the bridge components of Victoria Falls Bridge. And, Table 5-4-1b shows defects in the bridge components of Victoria Falls bridge which shall be inspected on the routine inspection.

Table 5-4-1a Bridge Components and Possible Defects (Victoria Falls Bridge)

Bridge Component	Sub-Component	Possible Defects
Supersructure (Steel)	Members on Arch Main Structure (Cross girder, Longitudinal girder, Lateral truss)	1) Deterioration of painting, 2) Corrosion, 3) Fatigue crack/Fracture, 4) Loose connection/Missing rivet or HTB, 5) Deformation/Buckling, 6) Abnormal deflection, 7) Abnormal vibration, 8) Abnormal sound, 9) Displacement
	Arch Main Structure (Upper chord, Arch lib, Vertical member, Diagonal member, Upper lateral bracing, Lower lateral bracing, Horizontal member, Cross frame)	
	Side Span Truss Girder	
Deck	Steel Troughing	1) Deterioration of painting, 2) Corrosion, 3) Deformation, 4) Abnormal deflection, 5) Water leakage/Free lime
Substructure	Concrete members (Abutment, Springing)	1) Crack, 2) Spalling, 3) Delamination, 4) Honeycomb/Loose concrete, 5) Cold joint, 6) Rebar exposure/Rebar corrosion, 7) Water leakage/Free lime
	Foundation	1) Tilt, 2) Settlement
	Protection work	1) Slope/Bank erosion, 2) Loss/Disintegration of protection materials, 3) Defects due to displacement of foundation
Expansion Joint	Asphalt sealant	1) Water leakage, 2) Abnormal space, 3) Abnormal sound, 4) Difference in level, 5) Deterioration of sealant, 6) Damage to adjacent pavement/slab concrete
Wearing Course	Asphalt pavement	1) Potholes, 2) Rutting, 3) Bump, 4) Corrugation, 5) Crack, 6) Raveling, 7) Ponding
Footway		1) Crack, 2) Potholes/Spalling, 3) Bump, 4) Ponding, 5) Accumulation of garbage and debris
Bearing (Metal)	Abutment, Springing	1)Deformation/Breakage of bearing, 2) Corrosion of bearing, 3) Loose connection/Missing bolts, 4) Corrosion of bolts, 5) Breakage of mortar/concrete seat, 6) Abnormal sound, 7) Accumulation of garbage and debris
Railing	Metal railing	1) Deformation, 2) Corrosion, 3) Disappearance, 4) Loose connection
Drainage	Scupper	1) Damage to scupper, 2) Damage to cover, 3) Accumulation of garbage and debris
	Drain pipe	1) Damage to pipe, 2) Defect in connection, 3) Accumulation of garbage and debris, 4) Insufficient length, 5) No drain pipe
Site/Others	Waterway	1) Accumulation of driftwoods/debris, 2) Changes in river direction/lowering river bed (within a range of 20m from the bridge to the upstream and downstream sides)
	Approach	1) Accumulation of vegetation/debris/garbage, 2) Damage to rip-rap/retaining wall, 3) Settlement of approach section/incorrect vertical alignment, 4) Damage to approach pavement (crack, pothole, etc.)

Table 5-4-1b Bridge Components and Defects on Routine Inspection (Victoria Falls Bridge)

Bridge Component	Sub-Component	Defects to be inspected
Supersructure (Steel)	Members on Arch Main Structure (Cross girder, Longitudinal girder, Lateral truss)	1) Deterioration of painting, 2) Corrosion, 3) Fatigue crack/Fracture, 4) Loose connection/Missing rivet or HTB, 5) Deformation/Buckling, 6) Abnormal deflection
	Arch Main Structure (Upper chord, Arch lib, Vertical member, Diagonal member, Upper lateral bracing, Lower lateral bracing, Horizontal member, Cross frame)	
	Side Span Truss Girder	
Deck	Steel Troughing	1) Deterioration of painting, 2) Corrosion, 3) Deformation, 4) Abnormal deflection, 5) Water leakage/Free lime
Substructure	Concrete members (Abutment, Springing)	1) Crack, 2) Spalling/Loose concrete, 5) Cold joint, 6) Rebar exposure/Rebar corrosion, 7) Water leakage/Free lime
	Foundation	1) Tilt, 2) Settlement
	Protection work	1) Slope/Bank erosion, 2) Loss/Disintegration of protection materials
Expansion Joint	Asphalt sealant	1) Abnormal space, 2) Difference in level, 3) Deterioration of sealant, 4) Damage to adjacent pavement/slab concrete
Wearing Course	Asphalt pavement	1) Potholes, 2) Rutting, 3) Crack, 4) Raveling, 5) Ponding
Footway		1) Crack, 2) Potholes, 3) Ponding, 4) Accumulation of garbage and debris
Bearing (Metal)	Abutment, Springing	1)Deformation/Breakage of bearing, 2) Corrosion of bearing, 3) Loose connection/Missing bolts, 4) Breakage of mortar/concrete seat, 5) Accumulation of garbage and debris
Railing	Metal railing	1) Deformation, 2) Corrosion, 3) Disappearance, 4) Loose connection
Drainage	Scupper	1) Damage to scupper, 2) Damage to cover, 3) Accumulation of garbage and debris
	Drain pipe	1) Damage to pipe, 2) Insufficient length, 3) No drain pipe
Site/Others	Waterway	1) Accumulation of driftwoods/debris,
	Approach	1) Accumulation of vegetation/debris/garbage, 2) Damage to rip-rap/retaining wall, 3) Settlement of approach section/incorrect vertical alignment, 4) Damage to approach pavement (crack, pothole, etc.)

(2) Sheets for Routine Inspection

The Routine Inspection Report consists of following 4 kinds of sheet:

a. Bridge Routine Inspection Form;

b. Defect Drawing Sheet;

c. Photo Record Sheet; and

d. Routine maintenance Schedule and Record Form.

Bridge Routine Inspection Form

Date:		Contractor Name:				Contract Ref. No. :			Province:	
Bridge No.:		Bridge Name:			Road No.:		Road Name:		Location:	
		Victoria Falls Bridge								
No.	(1) Bridge Component	(2) Sub-Component	(3) Defect Type	(4) Condition Rating	(5) Quantity (Unit)	(6) Proposed Action	(7) New/ Existing	(8) Date of Detection	(9) Remarks	

Note: - To categorize (1) Bridge Component, (2) Sub-component and (3) Defect type, refer to Table

To determine (4) Condition rating and (6) Proposed action, refer to the Table and Table with Figure , respectively.

(7) New/Existing means damage newly identified in this inspection/already identified in previous inspection.

Note: How to fill out the Bridge Routine Inspection Form

If you find a defect, enter the location in the columns of "(1) Bridge Component & (2) Sub-Component" and enter the type of defect in column of "(3) Defect Type", in the Bridge Routine Inspection Form, and fill the location and type of defect on the Defect Drawing Sheet. And, in the column "(4) Condition Rating", select Good, Fair, Poor or Bad according to Table 1 Routine Inspection Condition Rating Criteria. In the column "(6) Proposed Action", suitable actions should be entered refer to the Figure 1 Determination flow of Maintenance Action. Table 1 shows the criteria for judgment of Condition Rating. Table 2 shows the types of required actions and their contents of actions. Figure1 is a flowchart for determining a maintenance action based on the identified damage situation.

Table1 Routine Inspection Condition Rating Criteria

Condition Rating	Description
Good	No damage
Fair	With minor damage(s) not affecting the stability of the structure
Poor	With deteriorating damage(s) which should be monitored or could be repaired as a preventive action
Bad	With severe damage(s) that affects stability of bridge or that has possibility to harm a third party

Table 2 Required Maintenance Action

Required Action	Description
MO: Monitoring	No repair work and keeping monitoring (Damage not progressing or very slow)
RM: Routine Maintenance	Should be maintained by Routine Maintenance
MM: Major Maintenance	Should be maintained by Major Maintenance
EA: Emergency Action	Need to take actions immediately to avoid bridge collapse or harm to a third party
In-Depth Inspection	Condition Inspection or Detailed Inspection - Selection of appropriate repair method - Monitoring of progress of any damages

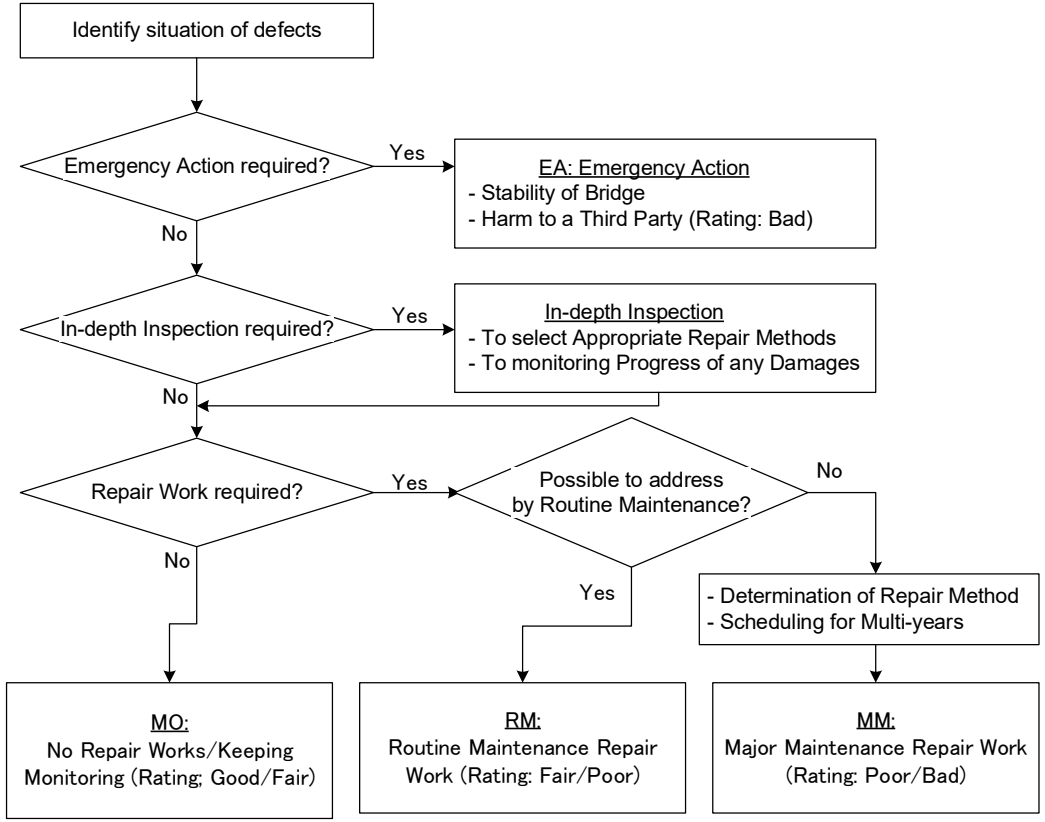
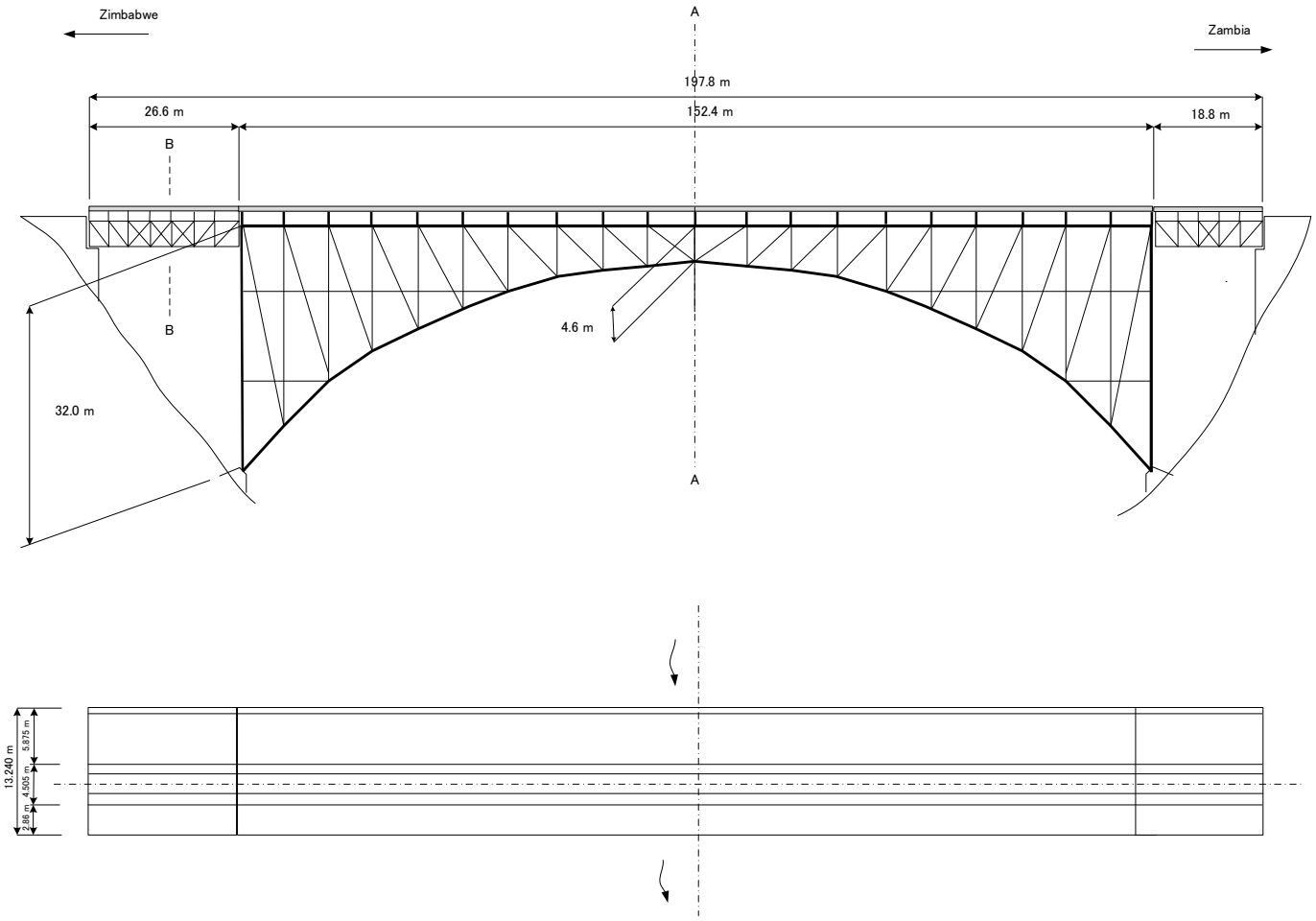
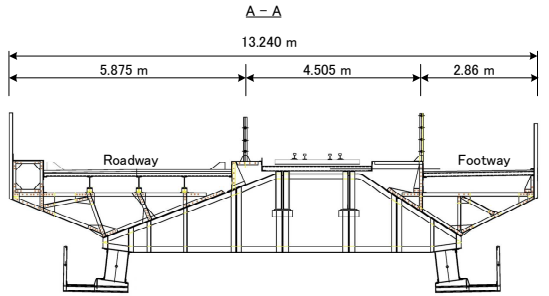
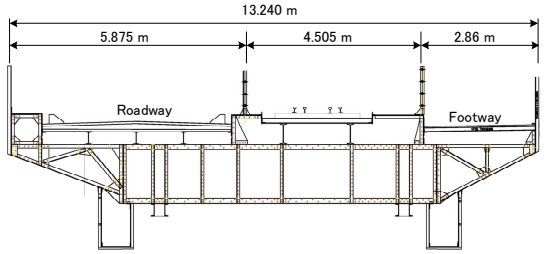


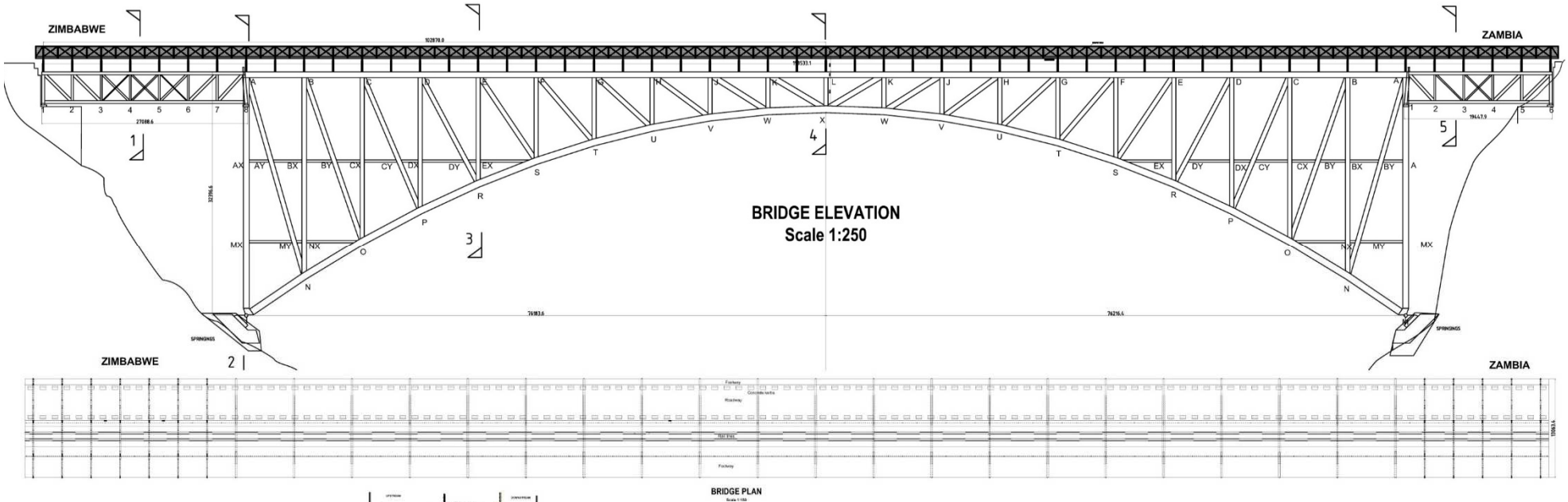
Figure 1 Determination Flow of Maintenance Action

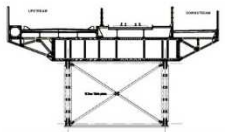




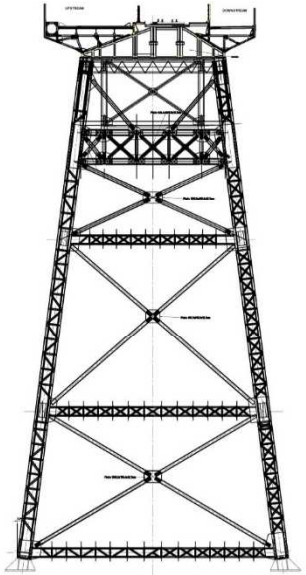


General Drawing - 1
Plan, Profile & Cross Sections

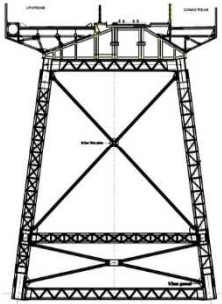




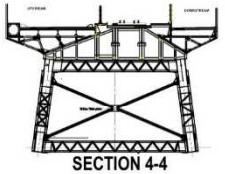
SECTION 1-1 SHOWING SIDE SPA
AND DECK CROSS GIRDER
ON ZIMBABWE SIDE SPAN
Scale 1:150



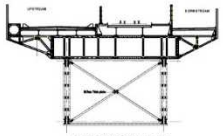
SECTION 2-2 SHOWING END POST,
SWAY BRACING,BEARING GIRDER
AND DECK CROSS GIRDER
Scale 1:150



SECTION 3-3
THROUGH POST ER
SHOWING SWAY BRACING
AND DECK CROSS GIRDER
Scale 1:150

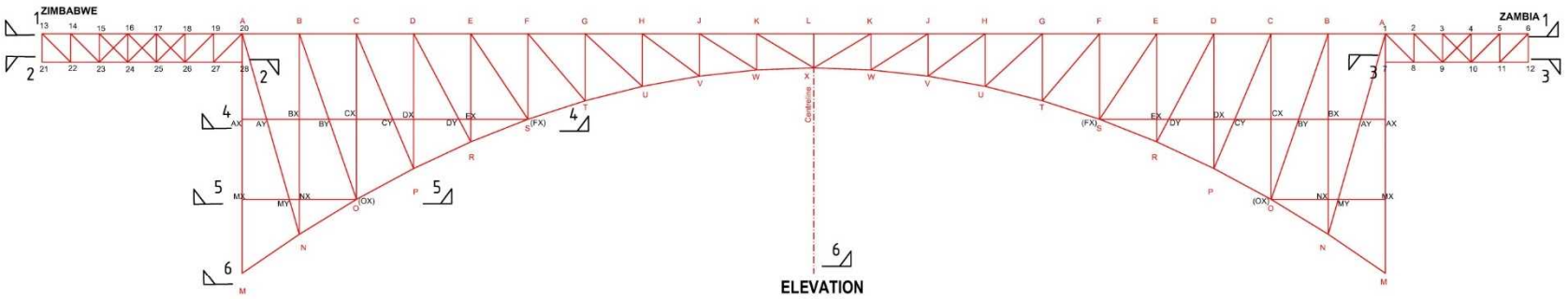


SECTION 4-4
Scale 1:150



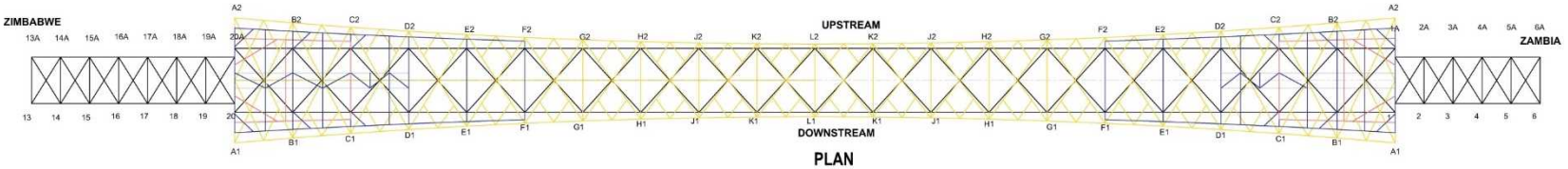
SECTION 5-5
Scale 1:150

General Drawing -2
Plan, Profile & Cross Sections



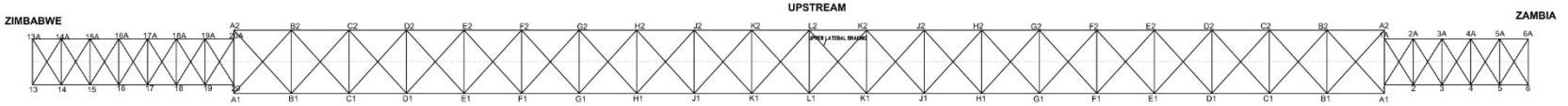
ELEVATION

Scale 1:300



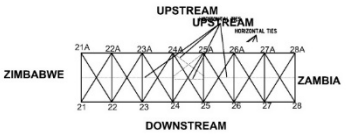
PLAN

Scale 1:300



DOWNSTREAM
SECTION 1-1

Scale 1:300



SECTION 2-2
SIDE SPAN-ZIMBABWE LOWER CHORD LEVEL

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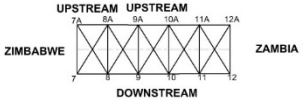
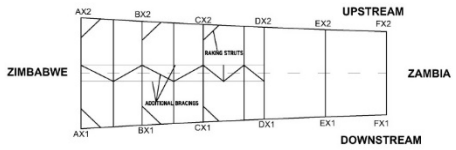
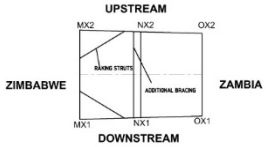


SECTION 3-3
SIDE SPAN-ZAMBIA LOWER CHORD LEVEI

Scale 1:300

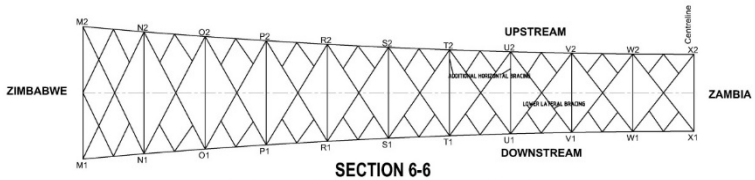


VIEW OF UPPER HORIZONTAL BEAM LEVEL
SECTION 4-4



VIEW OF LOWER HORIZONTAL BEAM LEVEL
SECTION 5-5

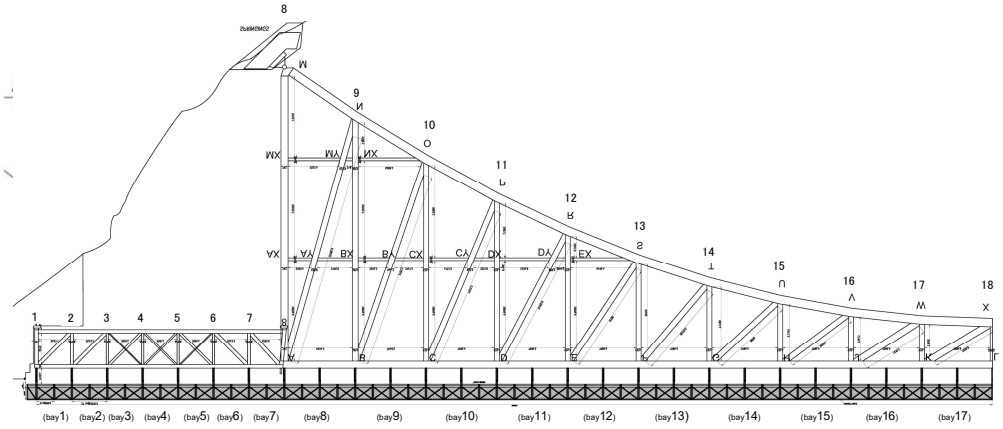
Scale 1:300



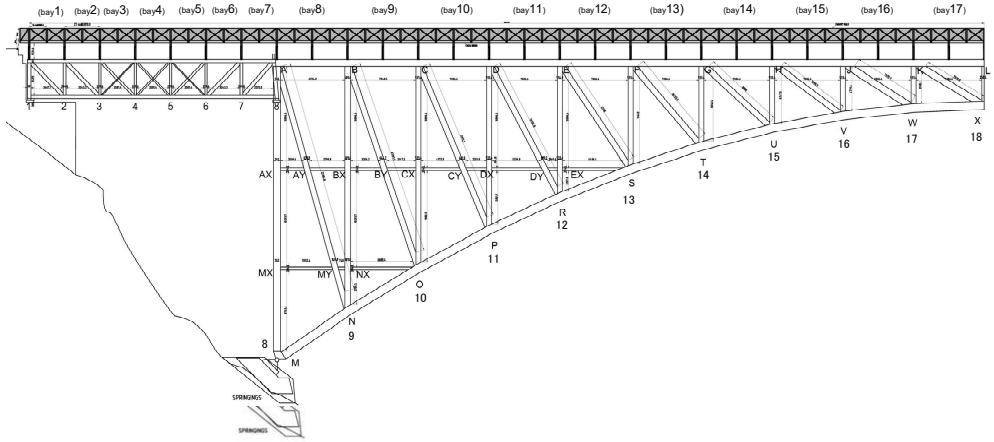
SECTION 6-6
VIEW OF UPPER HORIZONTAL BEAM LEVEL

Scale 1:300

Node Symbol Diagram

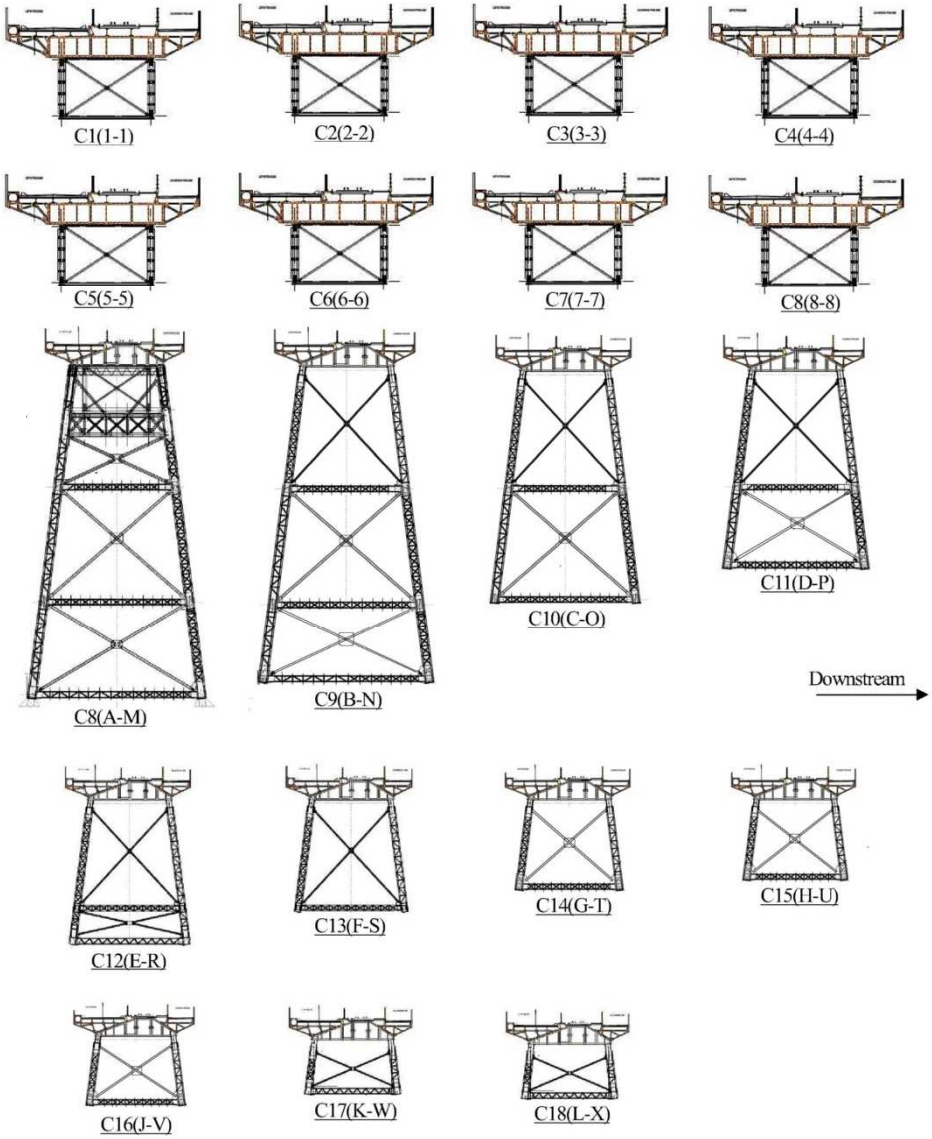


Upstream Side Structural Profile



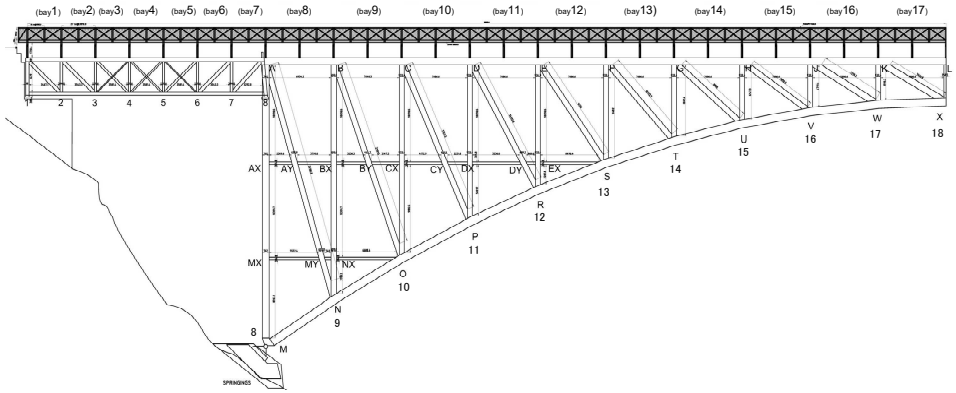
Downstream Side Structural Profile

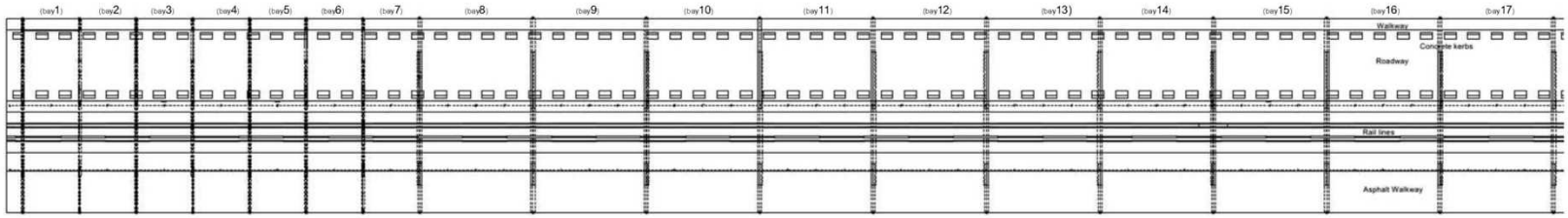
Upstream



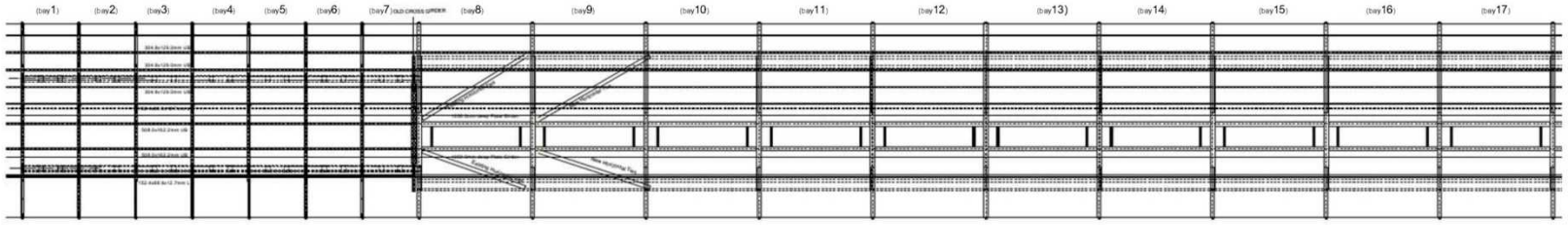
Downstream

Defect Drawing Sheet
Side Span and Main Arch
(Zimbabwe Side Half)



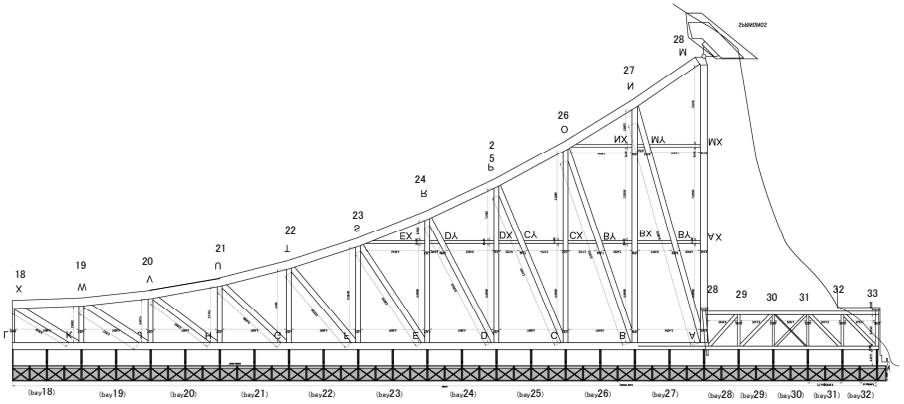


Top Surface of Deck

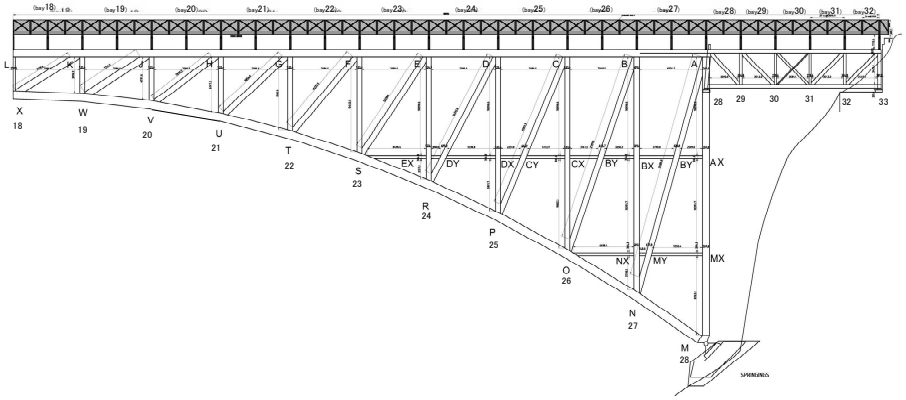


Under Surface of Deck

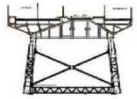
Defect Drawing Sheet
Top Surface and Under Surface of Deck
(Zimbabwe Side Half)



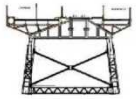
Upstream Side Structural Profile



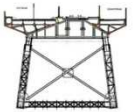
Downstream Side Structural Profile



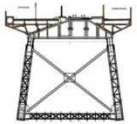
C18(L-X)



C19(K-W)

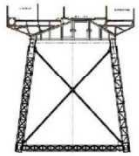


C20(J-V)

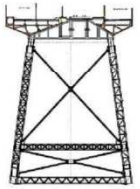


C21(H-U)

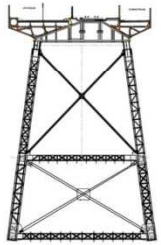
C22(G-T)



C23(F-S)



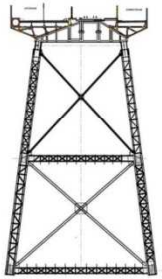
C24(E-R)



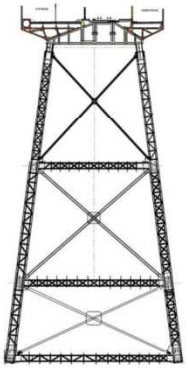
C25(D-P)

Upstream

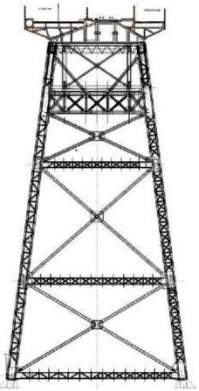
Downstream



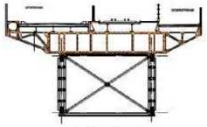
C26(C-O)



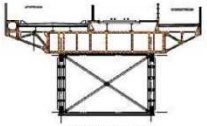
C27(B-N)



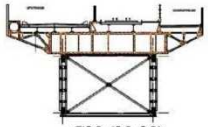
C28(A-M)



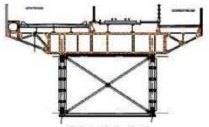
C28(28-28)



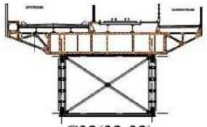
C29 (29-29)



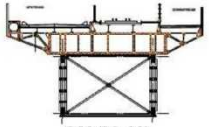
C30 (30-30)



C31(31-31)

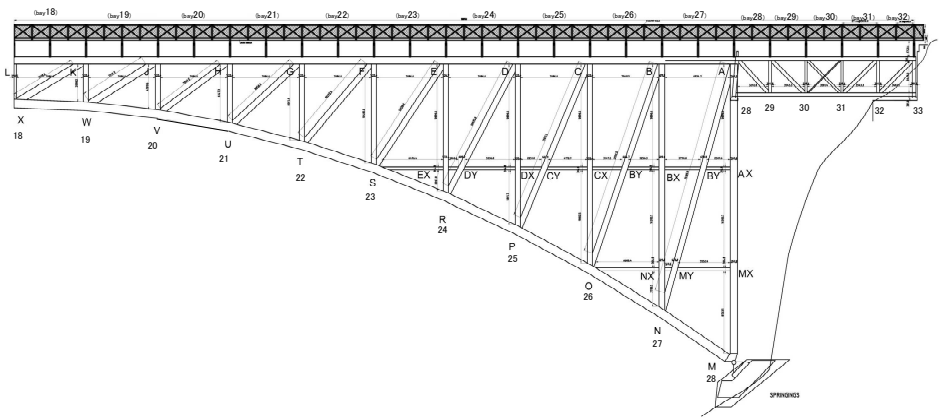


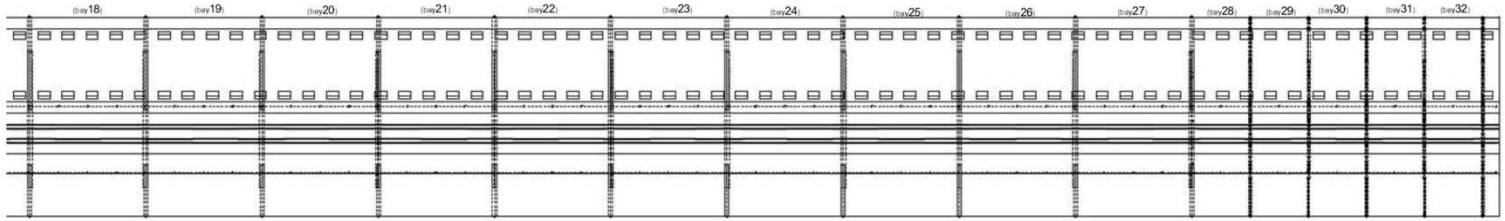
C32(32-32)



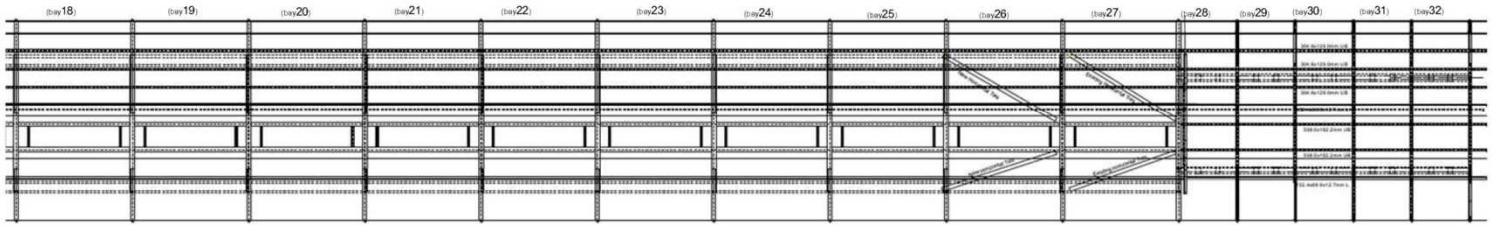
C33(33-33)

Defect Drawing Sheet
Side Span and Main Arch
(Zambia Side Half)





Top Surface of Deck



Under Surface of Deck

Defect Drawing Sheet
Top Surface and Under Surface of Deck
(Zambia Side Half)

Photo Record Sheet				(Bridge Name: Victoria Falls Bridge)	
Contractor Name:		Contract Ref. No.:		Province:	
Date:		Date:		Date:	
No.:		No.:		No.:	
Defect Type:		Defect Type:		Defect Type:	
Description:		Description:		Description:	
Date:		Date:		Date:	
No.:		No.:		No.:	
Defect Type:		Defect Type:		Defect Type:	
Description:		Description:		Description:	

Bridge Routine Maintenance Schedule and Record Form

Bridge No.:	Bridge Name:	Contractor Name:	Contract Ref. No.:	Province:
	Victoria Falls Bridge			

No.	(1) Contract Item No.:	(2) Activities	(3) Description: Condition before Maintenance	(4) Ref. No. of Defect	(5) Estimated Cost	(6) Date: Instruction to Contractor	(7) Date: Work Completed	(8) Additional Work Required	(9) Remarks

Note: -Ref. No. of defect corresponds to No. with the inspection date in the Bridge Routine Inspection Form-e.g. No.01-26.11.2015

(3) Inspection Results (April 21, 2022)

Bridge Routine Inspection Form

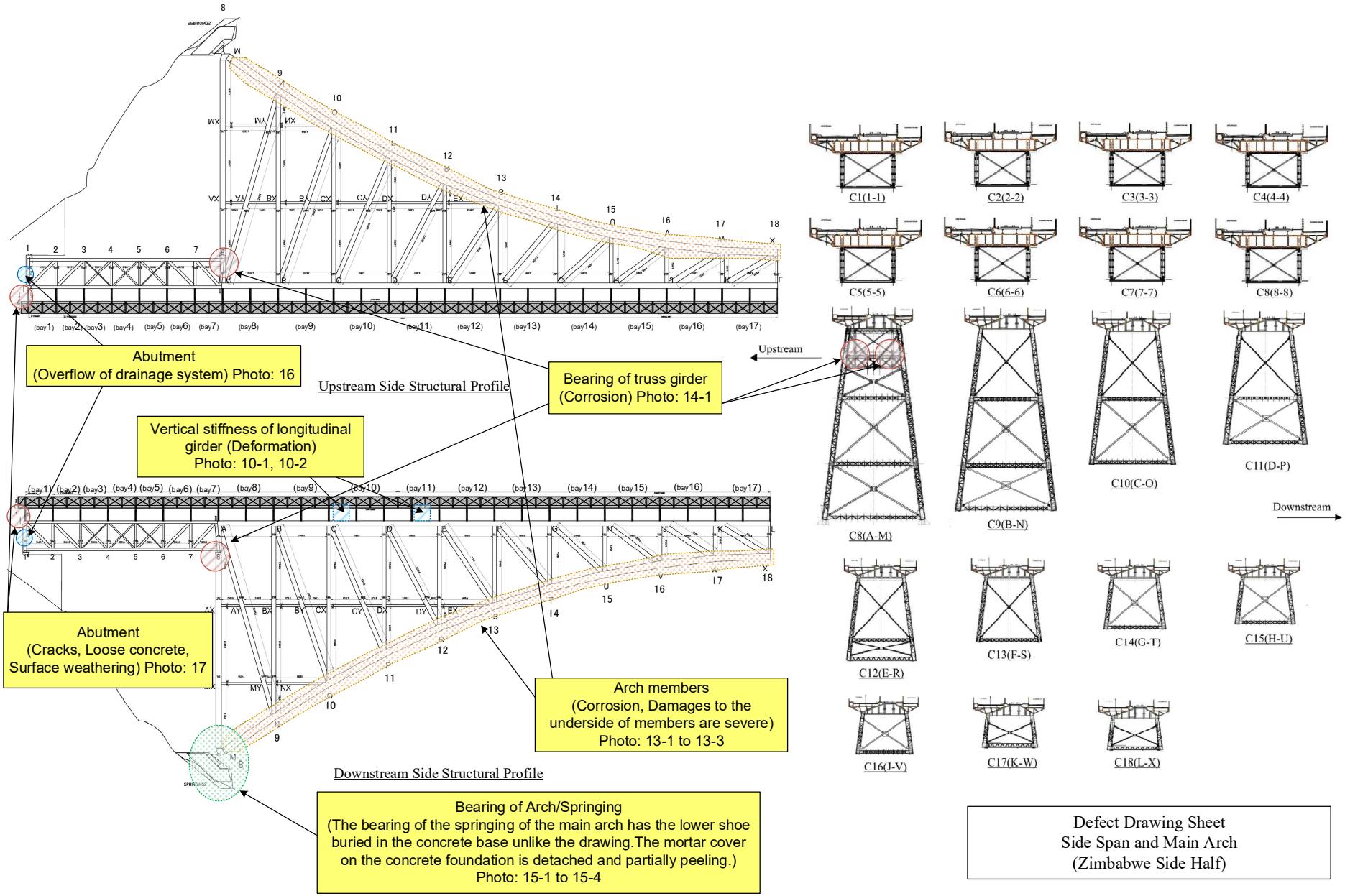
Date:		Contractor Name:				Contract Ref. No. :			Province:	
Bridge No.:		Bridge Name:			Road No.:		Road Name:		Location:	
		Victoria Falls Bridge								
No.	(1) Bridge Component	(2) Sub-Component	(3) Defect Type	(4) Condition Rating	(5) Quantity (Unit)	(6) Proposed Action	(7) New/ Existing	(8) Date of Detection	(9) Remarks	
1	Expansion joint/ Zimbabwe side	Roadway	No sealant	Fair	L=5 m	Monitoring	Existing	Apr-22	A steel tray is installed under the expansion joint for the full width of the bridge, but the tray does not have a drainage pipe. Photo: 1-1, 1-3	
2	Expansion joint/ Zimbabwe side	Footway	Covered with soil & gravel	Fair	Cleaning	RM Repair	Existing	April 2022	Photo: 1-2	
3	Expansion joint/ Zambia side	Footway	Covered with soil & gravel	Fair	Cleaning	RM Repair	Existing	April 2022	Photo: 2-1	
4	Expansion joint/ Zambia side	Roadway	Damage to the adjacent pavement	Poor	L=6.0m	MM Repair	Existing	April 2022	Need to repair the joint and the adjacent pavement. Photo: 2-2	
5	Deck/ Steel troughing	Roadway	Corrosion	Poor	Entire roadway	MM Repair	Existing	April 2022	Repainting (with Pavement repair) Photo: 3	
6	Deck/ Steel troughing	Railway	Corrosion	Bad	Entire railway	MM Repair	Existing	April 2022	Partially replace the troughs and track materials sequentially. Photo: 4	
7	Deck/ Steel troughing	Footway	Corrosion	Fair	Entire footway	MM Repair	Existing	April 2022	Repainting (with Pavement repair) Photo: 5	
8	Pavement	Roadway	Cracks (or Construction joints)	Fair	Entire roadway	MM Repair	Existing	April 2022	Replacement of pavement and installation of waterproof layer Photo: 6-1, 6-2	
9	Pavement	Footway	Cracks (or Construction joints)	Fair	Entire footway	MM Repair	Existing	April 2022	Replacement of pavement and installation of waterproof layer Photo: 7	

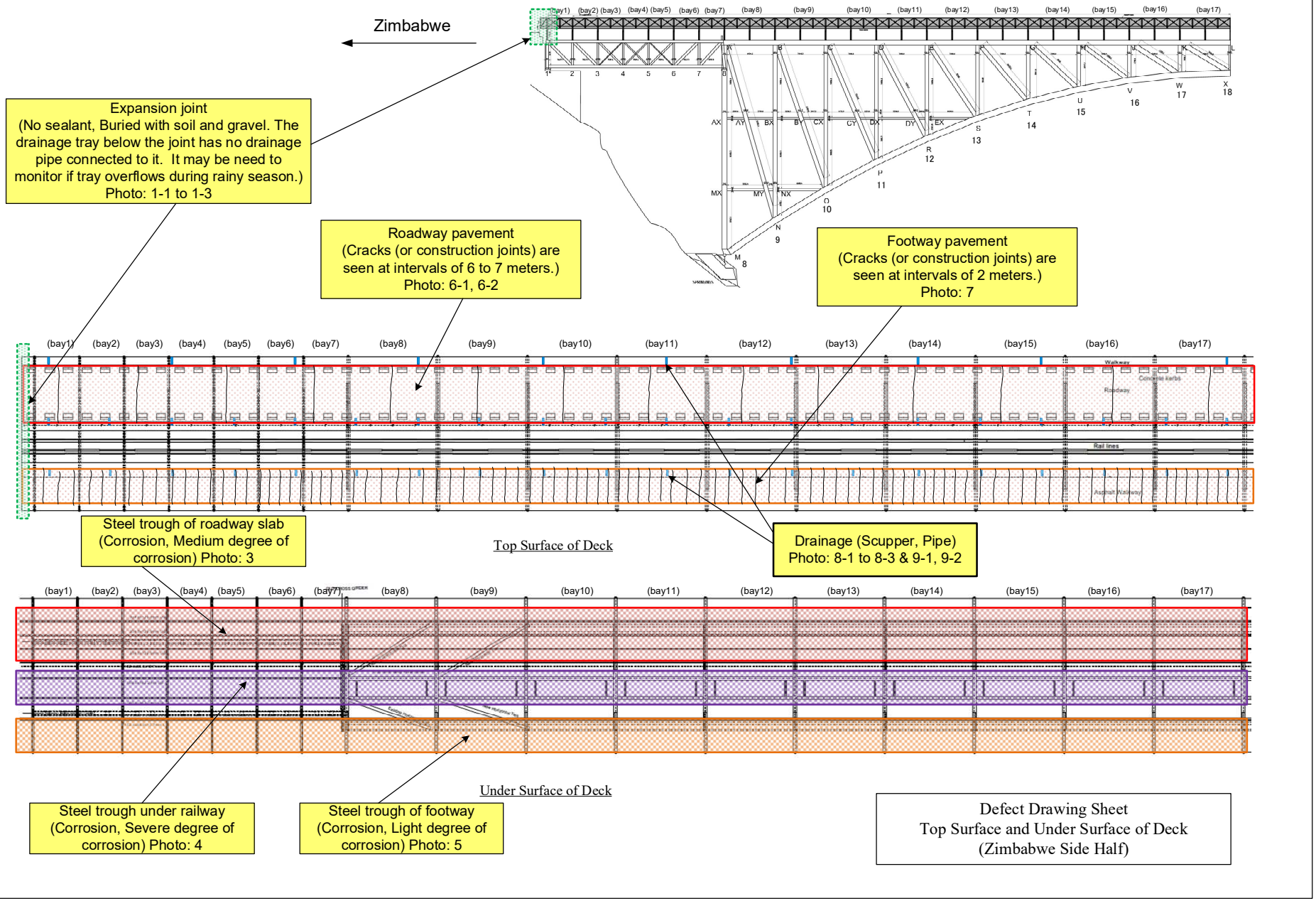
10	Drainage	Roadway	Insufficient pipes	Poor	Entire bridge	MM Repair	Existing	April 2022	The pipe should extend to the outside of the bridge. Photo: 8-1 to 8-3
11	Drainage	Footway	Insufficient pipes	Poor	Entire bridge	MM Repair	Existing	April 2022	The pipe should extend to the outside of the bridge. Photo: 9-1, 9-2
12	Superstructure	Longitudinal girder	Deformed (Buckling)	Fair	2 locations	MM Repair	Existing	Nov. 2021	Vertical stiffener of the girder is deformed. (bay 10 & 11) Photo: 10-1, 10-2
13	Arch	Horizontal member	Deformation (Buckling)	Fair	2 locations	MM Repair	Existing	Nov. 2021	The flanges of the horizontal members are deformed (bay 25, 27). Photo: 11-1, 11-2
14	Arch	Grid point	Missing ribet	Fair	1 location	MM Repair	Existing	Nov. 2021	Installation of a bolt is necessary. Photo: 12
15	Arch	Grid points	Corrosion	Poor	Many of arch members	MM Repair	Existing	Nov. 2021	Rusting has occurred on many of the members inside the arch main structure. By the drone survey, the underside of the Arch Liv has areas of rusting. Repainting is necessary. Photo: 13-1 to 13-3
16	Bearing (Truss span)	Fixed bearing	Corrosion	Bad	4 bearings	In-depth inspection & MM Repair	Existing	April 2022	Fixed bearings of truss span at the arch side are corroded. Repair or replacement is needed. Photo: 14-1, 14-2
17	Bearing (Truss span)	Movable bearing			4 bearings	In-depth Inspection	Existing	April 2022	Movable bearings of truss span are covered with the boxes. Condition inside boxes is unknown. Photo: 14-3
18	Bearing (Arch)	Zimbabwe side	Lower shoes buried Mortar cover detached	Fair	4 bearings	In-depth inspection RM Repair	Existing	April 2022	The bearing of the springing of the main arch has the lower shoe buried in the concrete base unlike the drawing.The mortar cover on the concrete foundation is detached and partially peeling. Photo: 15-1 to15-4
19	Abutment	Zimbabwe side	Overflow of drainage system	Fair	1 location	Monitoring	Existing	April 2022	The drainage system installed in the abutment wall is overflowing. Photo: 16
20	Abutment	Zimbabwe side	Cracks	Poor	Several locations	RM Repair	Existing	April 2022	Cracks, loose concrete, and other damage have occurred on the front and top surfaces of the abutment. Photo: 17-1, 17-2

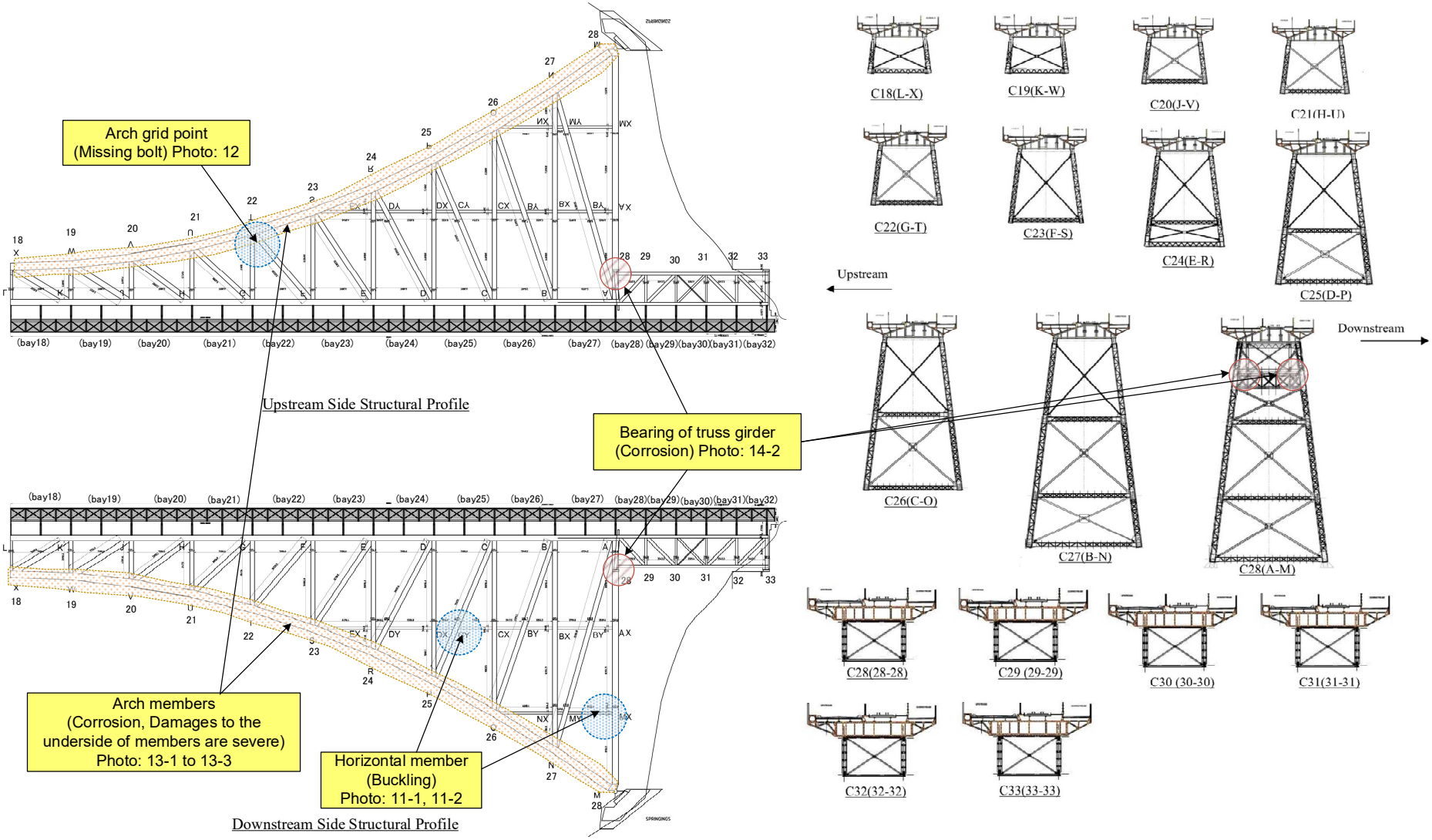
Note: - To categorize (1) Bridge Component, (2) Sub-component and (3) Defect type, refer to Table 5-3-1b.

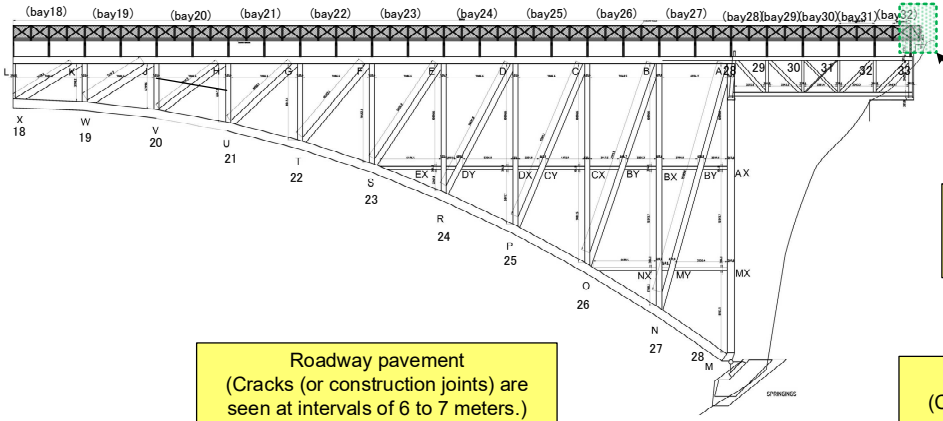
To determine (4) Condition rating and (6) Proposed action, refer to the Table 1 and Table 2 with Figure 1, respectively.

(7) New/Existing means damage newly identified in this inspection/already identified in previous inspection.


Abutment
(Overflow of drainage system) Photo: 16
Upstream Side Structural Profile
Bearing of truss girder
(Corrosion) Photo: 14-1
Vertical stiffness of longitudinal girder (Deformation)
Photo: 10-1, 10-2
Abutment
(Cracks, Loose concrete, Surface weathering) Photo: 17
Arch members
(Corrosion, Damages to the underside of members are severe)
Photo: 13-1 to 13-3
Downstream Side Structural Profile
Bearing of Arch/Springing
(The bearing of the springing of the main arch has the lower shoe buried in the concrete base unlike the drawing.The mortar cover on the concrete foundation is detached and partially peeling.)
Photo: 15-1 to 15-4
Upstream
Downstream
C1(1-1)
C2(2-2)
C3(3-3)
C4(4-4)
C5(5-5)
C6(6-6)
C7(7-7)
C8(8-8)
C8(A-M)
C9(B-N)
C10(C-O)
C11(D-P)
C12(E-R)
C13(F-S)
C14(G-T)
C15(H-U)
C16(J-V)
C17(K-W)
C18(L-X)
Defect Drawing Sheet
Side Span and Main Arch
(Zimbabwe Side Half)


Zimbabwe
Expansion joint
(No sealant, Buried with soil and gravel. The drainage tray below the joint has no drainage pipe connected to it. It may be need to monitor if tray overflows during rainy season.)
Photo: 1-1 to 1-3
Roadway pavement
(Cracks (or construction joints) are seen at intervals of 6 to 7 meters.)
Photo: 6-1, 6-2
Footway pavement
(Cracks (or construction joints) are seen at intervals of 2 meters.)
Photo: 7
(bay1) (bay2) (bay3) (bay4) (bay5) (bay6) (bay7) (bay8) (bay9) (bay10) (bay11) (bay12) (bay13) (bay14) (bay15) (bay16) (bay17)
Walkway
Concrete kerbs
Roadway
Rail lines
Asphalt Walkway
Steel trough of roadway slab
(Corrosion, Medium degree of corrosion) Photo: 3
Top Surface of Deck
Drainage (Scupper, Pipe)
Photo: 8-1 to 8-3 & 9-1, 9-2
Under Surface of Deck
Steel trough under railway
(Corrosion, Severe degree of corrosion) Photo: 4
Steel trough of footway
(Corrosion, Light degree of corrosion) Photo: 5
Defect Drawing Sheet
Top Surface and Under Surface of Deck
(Zimbabwe Side Half)

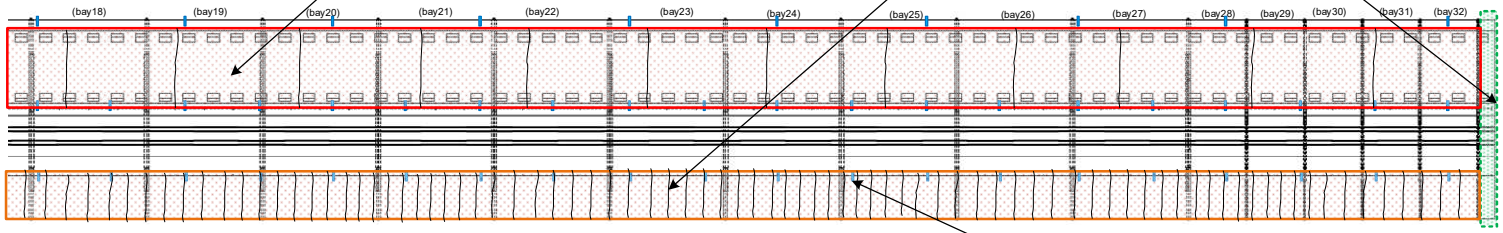

Arch grid point
(Missing bolt) Photo: 12
Upstream Side Structural Profile
Bearing of truss girder
(Corrosion) Photo: 14-2
Arch members
(Corrosion, Damages to the
underside of members are severe)
Photo: 13-1 to 13-3
Horizontal member
(Buckling)
Photo: 11-1, 11-2
Downstream Side Structural Profile
Upstream
Downstream
C18(L-X)
C19(K-W)
C20(J-V)
C21(H-U)
C22(G-T)
C23(F-S)
C24(E-R)
C25(D-P)
C26(C-O)
C27(B-N)
C28(A-M)
C28(28-28)
C29 (29-29)
C30 (30-30)
C31(31-31)
C32(32-32)
C33(33-33)
Defect Drawing Sheet
Side Span and Main Arch
(Zambia Side Half)



Expansion joint
(Deterioration of sealant, Damage to adjacent pavement)
Photo: 2-1, 2-2

Roadway pavement
(Cracks (or construction joints) are seen at intervals of 6 to 7 meters.)
Photo: 6-1, 6-2

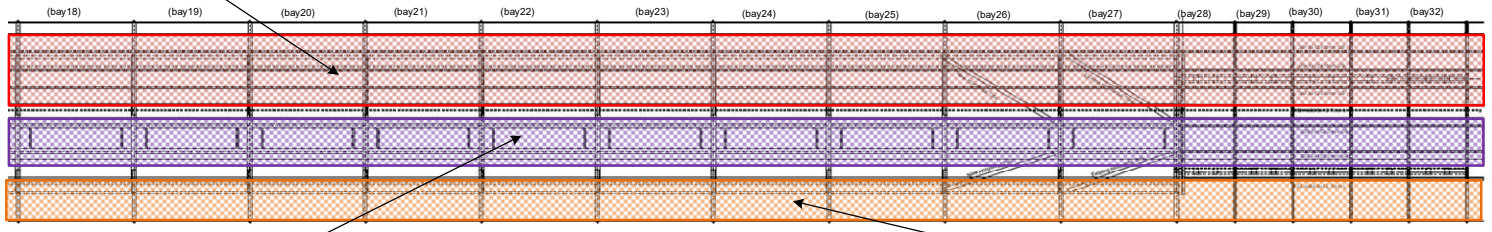
Footway pavement
(Cracks (or construction joints) are seen at intervals of 2 meters.) Photo: 7



Steel trough of roadway slab
(Corrosion, Medium degree of corrosion) Photo: 3

Top Surface of Deck

: Drainage (Scupper, Pipe)



Steel trough under railway
(Corrosion, Severe degree of corrosion) Photo: 4

Under Surface of Deck

Steel trough of footway
(Corrosion, Light degree of corrosion) Photo: 5

Defect Drawing Sheet
Top Surface and Under Surface of Deck
(Zambia Side Half)

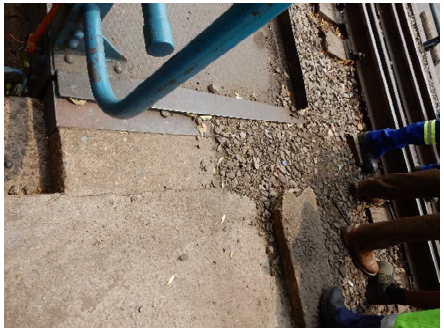
Photo Record Sheet (Bridge Name: Victoria Falls Bridge)

Contractor Name:	Contract Ref. No.:	Province:

No. :	1-1
Date:	2022/04/21
Location:	Expansion joint (Zimbabwe side)
Defect Type:	
Description:	It is considered a simple butt joint. A steel tray is installed under the expansion joint for the full width of the bridge, but the tray does not have a drainage pipe.

No.:	1-2
Date:	2022/04/21
Location:	Expansion joint (Zimbabwe side)
Defect Type	Buried with soil and gravel
Description:	Same as the left column. The tops of the joints need to be cleaned.

No.:	1-3
Date:	2019/09/25
Location:	Expansion joint (Zimbabwe side)
Defect Type:	Drainage tray has no drainage pipe
Description:	The drainage tray below the joint has no drainage pipe connected to it. It may be need to monitor if tray overflows during rainy season.



No.:	2-1
Date:	2022/04/21
Location:	Expansion joint (Zambia side, Footway)
Defect Type	Buried with soil and gravel
Description:	The tops of the joints need to be cleaned.

No.:	2-2
Date:	2022/04/21
Location:	Expansion joint (Zambia side, Roadway)
Defect Type	Damage to the adjacent pavement
Description:	Need to repair the joint and the adjacent pavement.

No.:	3
Date:	2022/04/21
Location:	Deck/Steel troughing (Roadway)
Defect Type:	Corrosion
Description:	The troughs on the underside of the roadway are corroding due to leakage from gaps (1 cm) between the troughs along the entire length.

No.:	4
Date:	2022/04/21
Location:	Deck/Steel troughing (Railway)
Defect Type	Corrosion
Description:	The troughs on the underside of the railway are corroding due to leakage from gaps (1 cm) between the troughs along the entire length.

No.:	5
Date:	2022/04/21
Location:	Deck/Steel troughing (Footway)
Defect Type	Corrosion
Description:	The troughs on the underside of the footway are corroding due to leakage from gaps (1 cm) between the troughs along the entire length.

No.:	6-1
Date:	2022/04/21
Location:	Pavement (Roadway)
Defect Type:	Cracks (or Construction joints)
Description:	Transverse cracks (or construction joints) in the roadway pavement at 7 to 8 m intervals are suspected to be leaking from these cracks.

No.:	6-2
Date:	2022/04/21
Location:	Pavement (Roadway)
Defect Type	Cracks (or Construction joints)
Description	Transverse cracks (or construction joints) in the roadway pavement at 7 to 8 m intervals are suspected to be leaking from these cracks.

No.:	7
Date:	2022/04/21
Location:	Pavement (Footway)
Defect Type	Cracks (or Construction joints)
Description:	Transverse cracks (or construction joints) in the footway pavement at 2 m intervals are suspected to be leaking from these cracks.

No.:	8-1
Date:	2022/04/21
Location:	Drainage (Roadway)
Defect Type:	
Description:	Scupper in the roadway.

No.:	8-2
Date:	2022/04/21
Location:	Drainage (Roadway)
Defect Type	The outlets of pipes are in the extent of the bridge.
Description:	The pipes are short and those outlets are extent of the bridge. The drainage pipes should be lead to the outside of the bridge.

No.:	8-3
Date:	2022/04/21
Location:	Drainage (Roadway)
Defect Type	Same as left column.
Description:	Same as left column.

No.:	9-1
Date:	2022/04/21
Location:	Drainage (Footway)
Defect Type:	
Description:	Scupper in the footway.

No.:	9-2
Date:	2022/04/21
Location:	Drainage (Footway)
Defect Type	The outlets of pipes are in the extent of the bridge.
Description:	The pipes are short and those outlets are extent of the bridge. The drainage pipes should be lead to the outside of the bridge.

No.:	10-1
Date:	2021/11/07
Location:	Superstructure (Longitudinal girder)
Defect Type	Deformation (Buckling)
Description:	Vertical stiffener of the girder is deformed. (bay 10)

No.:	10-2
Date:	2021/11/07
Location:	Superstructure (Longitudinal girder)
Defect Type:	Deformation (Buckling)
Description:	Vertical stiffener of the girder is deformed. (bay 11)

No.:	11-1
Date:	2021/11/08
Location:	Arch (Horizontal member, bay 25)
Defect Type	Deformation (Buckling)
Description:	The flange of the horizontal member is deformed.

No.:	11-2
Date:	2021/11/08
Location:	Arch (Horizontal member, bay 27)
Defect Type	Deformation (Buckling)
Description:	The flange of the horizontal member is deformed.

No.:	12
Date:	2021/11/08
Location:	Arch (Grid point, bay 21, 22)
Defect Type:	Missing ribet
Description:	1 ribet is missing on the splice plate.

No.:	13-1
Date:	2021/11/08
Location:	Arch member (Grid points)
Defect Type	Corrosion
Description:	Rusting has occurred on many of the members inside the arch main structure. By the drone survey, the underside of the Arch Liv has areas of rusting.

No.:	13-2
Date:	2021/11/08
Location:	Arch member (Grid points)
Defect Type	Corrosion
Description:	Same as left column.

No.:	13-3
Date:	2021/11/08
Location:	Arch member (Grid points)
Defect Type:	Corrosion
Description:	Same as left column.

No.:	14-1
Date:	2022/04/21
Location:	Fixed Bearing (Zimbabwe side truss)
Defect Type	Corrosion
Description:	Fixed bearings of truss span at the arch side are corroded.

No.:	14-2
Date:	2022/04/21
Location:	Fixed Bearing (Zambia side truss)
Defect Type	Corrosion
Description:	Same as left column.

No.:	14-3
Date:	2022/04/21
Location:	Movable Bearing (Zambia side truss)
Defect Type:	
Description:	Movable bearings of truss span are covered with the boxes. Condition inside boxes is unknown.

No.:	15-1
Date:	2022/04/21
Location:	Arch Bearing (Zim, Downstream side)
Defect Type	Lower shoe is buried
Description:	The bearing of the springing of the main arch has the lower shoe buried in the concrete base unlike the drawing.

No.:	15-2
Date:	2022/04/21
Location:	Arch Bearing (Zim, Downstream side)
Defect Type	Lower shoe is buried
Description:	Same as left column.

No.:	15-3
Date:	2019/09/25
Location:	Arch Bearing (Zim, Downstream side)
Defect Type:	Mortar cover detached
Description:	The mortar cover on the concrete foundation is detached and partially peeling.

No.:	15-4
Date:	2019/09/25
Location:	Arch Bearing (Zim, Upstream side)
Defect Type	Mortar cover detached
Description:	The mortar cover on the concrete foundation is detached and partially peeling.

No.:	17-2
Date:	2022/04/21
Location:	Abutment (Zimbabwe side)
Defect Type	Cracks, Loose Concrete, Surface weathering
Description:	Same as the above

No.:	16
Date:	2022/04/21
Location:	Abutment (Zimbabwe side)
Defect Type	Overflow of drainage system
Description:	The drainage system installed in the abutment wall is overflowing.

No.:	
Date:	
Location:	
Defect Type:	
Description:	

No.:	17-1
Date:	2022/04/21
Location:	Abutment (Zimbabwe side)
Defect Type:	Cracks, Loose Concrete, Surface weathering
Description:	Cracks, loose concrete, and other damage have occurred on the front and top surfaces of the abutment.

No.:	
Date:	
Location:	
Defect Type:	
Description:	

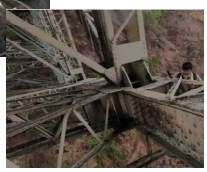
5-4-3 Routine Maintenance

(1) Defects and Causes

The defects observed in steel arch bridges and their causes are described below. For the defects common to general bridges, please see "Bridge Routine maintenance Guideline, 3-6 Types of Defects and Causes".

Table 5-4-2 Defects and Causes of Victoria Falls Bridge

Location	Defects	Photography	Probable Causes
Expansion Joint/Zimbabwe side	Roadway --- No sealant Footway --- Covered with gravel and sand	 Roadway  Footway	•Roadway The sealant was not originally installed. Or fell out of place. •Footway The gravel and sand flowed from the railway.
Expansion Joint/Zambia side	Roadway --- Adjacent pavement is damaged and partially none Footway --- Partially covered with gravel and sand	 Footway  Roadway	•Roadway Heavy vehicles coming down the curved hill and impacting the joint as it enters the bridge. •Footway The gravel and sand flowed from the railway.
Deck Steel Troughing	Roadway --- Corrosion (Poor) Footway --- Corrosion (Fair) Railway --- Corrosion (Bad)	Railway   Roadway  Footway	•The troughs on the underside of the railway track section (ballasted section) are corroding due to leakage from gaps (1 cm) between the troughs along the entire length. •The upstream side carriageway section, also shows corrosion along its entire length for the same reason, but it is not as advanced as in the track section. •For the downstream side footway section, similar to the carriageway section, corrosion is observed in the trough over the entire length, and is at the light level of corrosion than in the carriageway section. •The cause of the corrosion of those trough members is likely due to rainwater seeping from the bridge face through the trough joints (1 cm wide gap) to the underside of the trough.
Pavement	Roadway --- Cracks (or Construction joints) Footway --- Cracks (or Construction joints)	 Roadway  Footway	•Equally spaced transverse cracks in the floor slab pavement above the footpath suggest water leakage from these cracks. (about 2m spacing) •In the carriageway pavement also, equally spaced transverse cracks are seen. (7 to 8 m spacing) •Those cracks may be probable to be construction joints.
Drainage	Rordway & Footway--- The drainage pipes are short and drip rainwater inside the bridge.	 Scupper & Pipe (Roadway)  Scupper & Pipe (Footway)	During the design stage, the drainage pipes were not considered to lead the water out of the bridge

Location	Defects	Photography	Probable Causes
Superstructure/ Longitudinal Girder	Deformation of vertical stiffeness	 Girder in bay 10  Girder in bay 11	Temporarily large forces (bending moment and shear force) acted on the steel girder web, causing some of the vertical stiffeners to buckle. Or, external forces acted on the vertical stiffeners. The steel girder seems to maintain its load-bearing capacity thereafter.
Arch/ Horizontal member	Deformation (Buckling)	 Horizontal member in bay 25 Horizontal member in bay 27 	Some force acted on the horizontal member and buckled the flange in that area.
Arch/ Grid points	Missing Ribets & Corrosion	 Missing ribet  Corrosion  Corrosion  Corrosion	•Missing bolts --- Ribet broken or loosened •Corrosion --- This may be due to rainwater and water from Victoria Falls spraying on the bridge and stagnating along the arch ribs. •For arch structures, the Arch Main Structure (Arch Riv, Upper Cord Members, Vertical Members, Diagonal Members and Horizontal Members) has been repaired with timely painting. But the underside of the Arch Riv has areas of rusting (Drone survey results). And, rusting has occurred on many of the members inside the Arch Main Structure (Horizontal Members perpendicular to the bridge axis, Sway Bracings, Transverse members and other supporting members).
Bearing of Arch (Springing)	Zimbabwe side downstream bearing --- Internal void noise (percussion inspection) All Bearings --- the lower shoes are buried in the concrete bases. (different from the original drawings)	 Lower shoe buried  Void inside the foundation	•Inside void --- .The mortar cover on the concrete foundation is detached and partially peeling. •Lower shoes buried in concrete foundation --- May have been changed during construction.
Bearing of Truss/ Arch side	Corrosion	 Zimbabwe side truss  Zambia side truss	This may be due to rainwater and water from Victoria Falls spraying on the bridge and stagnating at the bearings.

Location	Defects	Photography	Probable Causes
Abutment/ Zimbabwe side	Overflow of drainage system		The drainage system attached to the front of the abutment was overflowed the allowable amount of flow in April 2022 during the rainy season.
Abutment/ Zimbabwe side	Cracks, Loose Concrete, Surface weathering		Over the long years (117 years), the concrete surface has weathered and cracks and other damage have occurred.

(2) Routine Maintenance Activities

The standard routine maintenance activities of the steel arch bridge are shown in Table 5-4-3.

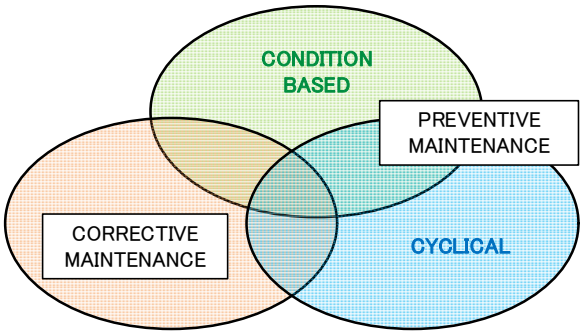


Figure 5-4-2 Treatment Categories

Table 5-4-3 Routine Maintenance Activity List (Victoria Falls bridge)

Activity No.	Activity Item	Frequency	Classification	Applied Item	
				Chapter 4	Chapter 5
	(Deck)				
1-1	Clean deck and gutters	Yearly	Preventive(Cycl.)	4-1	
1-2	Clean deck drains/scuppers	Yearly	Preventive(Cycl.)	4-1	
1-3	Clean joint	Yearly	Preventive(Cycl.)	4-1	
1-4	Joint sealing	As needed	Corrective	4-9	
1-5	Deck repair – Coating on /injection/caulking into cracks	As needed	Preventive(CB.)	4-6/4-7/4-8	
1-6	Deck repair – Pavement Patching	As needed	Corrective	4-11	
1-7	Deck repair – Concrete Deck Patching	As needed	Corrective	4-3	
1-8	Touch-up/re- painting on metal form	As needed	Preventive(CB.)	4-4	
1-9	Collision damage repair to railing/parapet	As needed	Corrective	4-10	
1-10	Repair to damaged curb/sidewalk	As needed	Corrective	4-11	
1-11	Drain extensions	As needed	Preventive(CB.)	4-12	
	(Superstructure)				
2-1	Clean steel members	2 years	Preventive(Cycl.)	4-1	
2-2	Touch-up/re- painting on steel members	As needed	Preventive(CB.)	4-4	
	(Substructure)				
3-1	Clean abutments/springings/ bearings	2 years	Preventive(Cycl.)	4-1	
3-2	Repairs to slope protection	As needed	Preventive(CB.)	4-15	
3-3	Repair to scour protections around springings	As needed	Preventive(CB.)	4-16	
	(Site)				
4-1	Vegetation control and rubbish removal around substructures	Quarterly	Preventive(Cycl.)	4-13	
4-2	Removal of debris/driftwoods from waterway	As needed	Preventive(CB.)	4-14	

Celebrating its 117th year of service in 2022, the Victoria Falls Bridge is still fully functioning today.

However, corrosion is ongoing in the Deck steel troughs, Steel members and those grid points of the Arch structure, and Bearings of trusses which are on the arch ends. The concrete foundations of the arch bearings have different shapes from the original design drawing, and the lower portions of the shoes are buried in the foundations.

Though detailed inspections and major repairs are recommended for the above defects, this section proposes these detailed inspections and major repairs, and also recommends routine maintenance activities that should be implemented as routine maintenance management.

Table 5-4-4 shows the recommended maintenance activities for the defects observed during the inspection of Victoria Falls Bridge.

Table 5-4-4a Recommended Maintenance Activities for Victoria Falls Bridge (1/3)

No.	Bridge Component/ Sub-Component	Defect Type	Routine Maintenance Activity	Applied Item in Chapter 4 and 5	Other Activities/Remarks
1	Expansion Joint/ Zimbabwe side	Roadway --- No sealant Footway --- Covered with gravel and sand	1-3 Clean joint	4-1 Cleaning/Desilting	A steel tray is installed under the expansion joint for the full width of the bridge, but the tray does not have a drainage pipe. It may be need to monitor if tray overflows during rainy season. The gravel on the footway should be removed and the pavement repaired if necessary.
2	Expansion Joint/ Zambia side	Roadway --- Adjacent pavement is damaged and partially none Footway --- Partially covered with gravel and sand	1-1 Clean deck and gutters	4-1 Cleaning/Desilting	Roadway --- Replace the expansion joint and repair the adjacent pavement.(MM Repair) Footway --- Remove the gravel and sand on the footway (RM Reapair)
3	Deck Steel Troughing/ Roadway, Footway, Railway	Roadway --- Corrosion (Poor) Footway --- Corrosion (Fair) Railway --- Corrosion (Bad)	1-8 Touch-up/Re-painting on metal form 1-7 Deck repair-Concrete deck patching	4-4 Touch-up/Re-painting 4-3 Concrete deck patching	Roadway & Footway (MM Repair) 1. Remove the pavement and place the waterproof layer, and construct the new pavement. 2. Repaint the underside of the troughs and seams. Railway (MM Repair) Partially replace the troughs and track materials sequentially. The new troughs (or other deck members) should be seamlessly placed.

Table 5-4-4b Recommended Maintenance Activities for Victoria Falls Bridge (2/3)

No.	Bridge Component/ Sub-Component	Defect Type	Routine Maintenance Activity	Applied Item in Chapter 4 and 5	Other Activities/Remarks
4	Pavement/ Roadway, Footway	Roadway --- Cracks (or Construction joints) Footway --- Cracks (or Construction joints)	1-6 Deck repair-Pavement patching	4-2 Bituminous pavemenrt patching	Roadway & Footway (MM Repair) 1. Remove the pavement and place the waterproof layer, and construct the new pavement.
5	Drainage/ Scupper, Pipe	Rordway & Footway--- The drainage pipes are short and drip rainwater inside the bridge.	-	-	Drainage system (MM Repair) All drainage outlets will be connected to drainage pipes, and the water coming out of those outlets is directed out of the bridge by the drainage pipes.
5	Superstructure/ Longitudinal Girder	Deformation of vertical stiffeness	-	-	Monitoring is necessary. Periodically monitor the girder web and vertical stiffeners for defects including deformation, over the entire length of the bridge.
6	Arch/ Horizontal member	Deformation (Buckling)	-	-	Monitoring is necessary.
7	Arch/ Grid points	Missing ribets & Corrosion	2-2 Touch-up/Re-painting on steel members	4-4 Touch-up/Re-painting	Arch members (MM Repair) There is an urgent need to repaint the arch members. In particular, arch ribs and the horizontal members that join them are susceptible to corrosion because they are exposed to the spray of water from the Victoria Falls. The upstream members are expected to corrode the fastest.

Table 5-4-4c Recommended Maintenance Activities for Victoria Falls Bridge (3/3)

No.	Bridge Component/ Sub-Component	Defect Type	Routine Maintenance Activity	Applied Item in Chapter 4 and 5	Other Activities/Remarks
8	Bearing of Arch (Springing)	Zimbabwe side downstream bearing ---The mortar cover on the concrete foundation is detached and partially peeling. (percussion inspection) All Bearings --- the lower shoes are buried in the concrete bases. (different from the original drawings)	-	-	All concrete foundations of arch bearings (MM Repair) 1. Remove the existing concrete mortar layer and cover the surface with PCM (polymer cement mortar). All bearings of arch (In-depth Inspection) 1. Investigate the integrity of the bearing inside the concrete.
9	Bearing of Truss/ on arch end	Corrosion	-	-	All bearings of truss (In-depth Inspection) 1. Conduct a detailed inspection to examine the corrosion conditions of the four bearings in detail and determine the percentage of cross-sectional defects, presence of functional failures, etc. 2. Based on the evaluation results, determine whether repair or reinforcement is feasible. 3. Based on the evaluation of repair or reinforcement, select countermeasure work such as routine maintenance repair, large-scale repair, or replacement.
10	Abutment/ Zimbabwe side	Overflow of drainage system	-	-	Monitoring is necessary. Monitor the condition of the drainage system every three months to determine if improvements to the system are needed.
11	Abutment/ Zimbabwe side	Cracks, loose concrete and surface weathering	3-2 Coating on /injection/caulking into cracks	4-6 Coating 4-7 Epoxy injection 4-8 Caulking	

5-4-4 Routine Maintenance and Repair Method

If there are any items that should be added as routine maintenance activities of Victoria Falls Bridge, add them to Table 5-4-3 and describe the contents, methods, materials used, and equipment in "5-4-4 Routine Maintenance and Repair method".

5-5 REOMMENDATIONS FOR THE OPERATION & MAINTENANCE MANUALS OF KAZUNGULA BRIDGE

5-5-1 Effectiveness of the Operation & Maintenance (O & M) Manuals

It is considered that the manuals describe in detail and specifically how to inspect and maintain the targeted elements:

(1) Bearing (Spherical Bearing & Elastomeric Bearing)
(2) Cable Stay Element
(3) Electorical Works (Lighting Elements)
(4) Bridge Expansion Joints
(5) Miscellaneous & Steel Works (Drainage, Cornices, Hand Railing, Hatches)
(6) ERS (Embedded Railway System)
(7) Rail Expansion Joint on Slab Track
(8) Bridge Structural Health Monitoring System

Therefore, maintenance of these elements will be performed using this manual.

5-5-2 Elements to be added in the O & M Manuals and Their Routine Maintenance

5-5-2-1 Elements to be added in the O & M Manuals

The elements which should be added in the O & M Manuals are considered as follows:

(1) Superstructure (PC box girder, Concrete deck slab)
(2) Pylon (Concrete member)
(3) Substructure (Concrete member <Abutment, Pier>, Foundation)
(4) Wearing Course (Asphalt pavement)

As the routine maintenance of special bridges, the followings are suggestions for the maintenance of the above elements.

5-5-2-2 Defects to be inspected in Routine Inspection

Routine Inspection is performed visually from the bridge deck and ground level and the inspection is performed within the reach of sight. The routine inspection shall be performed regularly (eg, every six months).

Table 5-5-1 shows defects that are assumed to ought to be inspected during routine maintenance inspection.

Table 5-5-1 Defects to be inspected in Routine Inspection

Bridge Component	Sub-Component	Defects to be inspected in RoutineInspection
Superstructure	PC box girder	1) Cracks, 2) Abnormal deflection, 3) Abnormal vibration, 4) Water leakage/Free lime, etc.
	Concrete deck slab	1) Crack, 2) Spalling/Loose concrete, 3) Rebar exposure/Rebar corrosion, 4) Water leakage/Free lime, etc.
Pylon	Concrete member	1) Crack, 2) Spalling/Loose concrete, 3) Rebar exposure/Rebar corrosion, 4) Water leakage/Free lime, etc.
Substructure	Concrete member (Abutment, Pier)	1) Crack, 2) Spalling/Loose concrete, 3) Cold joint, 4) Rebar exposure/Rebar corrosion, 5) Water leakage/Free lime, etc.
	Foundation	1) Tilt, 2) Settlement, 3) Scouring, etc.
Wearing Course	Asphalt pavement	1) Potholes, 2) Rutting, 3) Crack, 4) Raveling, 5) Ponding, etc.

5-5-2-3 Routine Maintenance Activities

Routine maintenance consists of cleaning and minor repairs that are frequently needed, and can be carried out with simple tools and equipment. It also includes remedial measures in connection with aging or wear caused by climate or traffic.

Table 5-5-2 shows the routine maintenance activities considered necessary for elements that should be added.

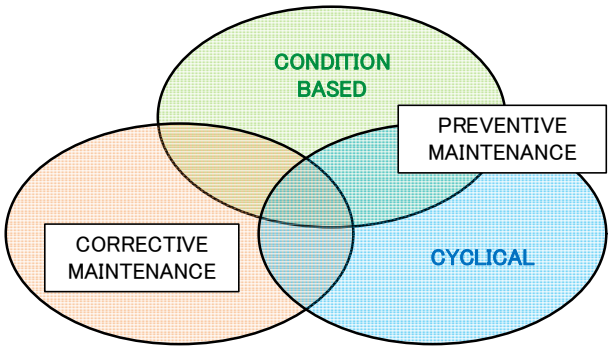


Figure 5-5-1 Treatment Categories

Table 5-5-2 Routine Maintenance Activities of the Added Elements

Bridge Element	Activity item	Frequency	Treatment Category
Superstructure (PC girder, Deck slab)	Clean deck surface/concrete members	Yearly	Preventive (Cycl.)
	Patching on concrete members	As needed	Corrective
	Coating on/injection/ caulking into cracks	As needed	Corrective
Pylon	Patching on concrete members	As needed	Corrective
	Coating on/injection/ caulking into cracks	As needed	Corrective
Substructure	Clean abutments /concrete members	Yearly	Preventive (Cycl.)
	Coating on/injection/ caulking into cracks	As needed	Corrective
	Repair to scour protections	As needed	Corrective
Wearing Course	Patching on asphalt pavement	As needed	Corrective

5-5-3 Maintenance Methods for the Kazungula Bridge using SHMS System

The manual of SHMS details the inspection and maintenance of installed measuring/observation equipment and monitoring devices. However, there is no description of the "Inspection and Maintenance Procedure for Kazungula Bridge using SHMS," which is always necessary, such as the purpose of measurement, the role of each measuring device, timing/frequency of measurement, monitoring method of measurement results, judgment of measurement results, and how to deal with abnormal values when they are measured. It is believed that it has been prepared in some form, but it needs to be added to the Kazungula Bridge Operations and Maintenance Manual.

The following activities are recommended for the maintenance of the Kazungula Bridge using the SHMS system.

5-5-3-1 Measuring and Recording of Variations with Time in Bridge Behavior

(1) Record variations with time in member strain and member temperature obtained from embedded strain and temperature gauges installed in the PC box girders.

(2) Record variations with time in the inclination and temperature of the pylon obtained from the inclinometer and temperature gauge installed in the pylon.

(3) Periodically measure and record the displacement obtained from the displacement gauge at the expansion joint.

(4) Periodically measure and record cable tension using an accelerometer.

(5) In addition to the above, periodically measure the vertical profile (elevation) of the bridge top surface using survey equipment to record variations with time in the deflection shape of the girder.

(6) Meanwhile, record variations with time in wind direction, wind speed, temperature, and humidity.

5-5-3-2 Monitoring of Variations with Time in Bridge Behavior

(1) Monitor the behavior of the actual bridge in contrast to the behavior assumed under design conditions using concrete properties such as strength, modulus of elasticity, creep modulus, and drying shrinkage.

(2) Monitor the stress (strain) and deflection of the girder, pylon displacement, cable tension, etc. in contrast to the design values.

(3) In monitoring, note that majority of the movement of each element, such as girder stresses, deflections, cable tension, pylon displacement, and expansion joint displacement, is related to the behavior of the overall bridge.

5-5-3-3 Implementation Plan of Inspection and Maintenance using SHMS System

"Inspection and Maintenance Procedure for Kazungula Bridge using SHMS" is necessary to be added to the Kazungula Bridge Operations and Maintenance Manual.

It is recommended that the above measurement, recording and monitoring methods would be referred in planning the Inspection and Maintenance Procedure.

5-5-4 Conclusion

(1) It is considered that the manuals describe in detail and specifically how to inspect and maintain the target elements:

① Bearing (Spherical bearing & Elastomeric bearing)
② Cable Stay Element
③ Electric Works (Lighting Element)
④ Bridge Expansion Joint
⑤ Miscellaneous & Steel Works (Drainage, Cornices, Hand Railing, Hatches)
⑥ ERS (Embedded Rail System)
⑦ Rail Expansion Joint on Slab Track

Therefore, maintenance of these elements will be performed using this manual.

(2) The elements which should be added in the O & M Manuals are considered as follows:

① Superstructure (PC box girder, Concrete deck slab)
② Pylon (Concrete member)
③ Substructure (Concrete member <Abutment, Pier>, Foundation)
④ Wearing Course (Asphalt pavement)

(3) Inspection and Maintenance Procedure for Kazungula Bridge using SHMS is necessary to be added to the Operations & Maintenance Manuals of Kazungula Bridge.

CHAPTER 6 EMERGENCY MANAGEMENT AND PLANNING AND EMERGENCY RESPONSE

6-1 DEFINITION OF AN EMERGENCY

An emergency is defined as an unforeseen circumstance or situation that poses a clear and present danger requiring urgent intervention to prevent the worsening of the situation (DIER, 2008). Emergency management and planning on the other hand can be defined as the organization, coordination and implementation of a range of measures to prevent, mitigate, respond to, overcome and recover from the consequences of emergency events affecting the community, road infrastructure and the environment.

In Zambia the common emergencies in the road sector are basically washaways of drainage structures such as culverts, vented drifts and minor bridges. These emergencies normally occur during the rainy season as a result of flash floods.

6-2 EMERGENCY PLANNING AND MANAGEMENT OBJECTIVES

The overall objective of the emergency management and planning is to ensure that the occurrence of risks and hazards are minimized or mitigated on the road network. This is in line with the RDA mandate of providing care and maintenance of the public roads network. The specific objectives of emergency management and planning under this Road Maintenance Strategy shall include the following:

- Preparation for emergencies;
- Response to an emergency;
- Recovery following an emergency
- Identifying key sector players –Disaster mitigation process.
- Prepare and disseminate information on alternative routes and available pontoon services in and around distressed areas.

6-3 EMERGENCY PLANNING AND MANAGEMENT

The RDA will continue to collaborate with the Disaster Management and Mitigation Unit (DMMU) when dealing with emergencies that affect road infrastructure. Under this collaboration, the RDA will be providing the technical expertise and execution of the emergency works while the DMMU will play a coordinating role as well as providing financial support.

6-3-1 Emergency Preparedness

Emergency preparedness ensures that arrangements and resources are maintained in a state of readiness to be mobilized and deployed for response and recovery to an emergency event. The RDA in close collaboration with DMMU will undertake the following preparedness activities:

i) Fast-tracked procurement procedures for emergencies while working with other key players such as RRU, ZNS, ZA, LRAs and contractors where necessary. This process will facilitate an environment of preparedness to respond rapidly to emergencies that occur on the network.

ii) Ring fence contingency funds in the RSAWPs to ensure readily available resources to

address the emergencies. These resources should be maintained in the RDA Project Account for emergencies for ease of access between December to the months March during which emergencies are likely to occur;

iii) The RDA will also ensure that its Regional Offices have the necessary construction materials and equipment to respond to emergencies as and when they occur;

iv) Conduct a materials data bank study to establish sources or road construction materials;

v) The RDA Regional offices will be required to prepare Emergency Response Plans (ERP) to address any unforeseen occurrences;

vi) Review and update the ERP, any sub-plans and Response Procedures by the RDA;

vii) Procure Frame work and supply contracts in all the 10 Regions in readiness for any emergencies that may occur;

viii) Establish processes for lessons learned including conducting debriefs and reviews of other emergency events or exercises that are relevant to the RDA

ix) Establish an emergency hotline.

Table 6-1 summarizes the RDA's Emergency Preparedness Strategy (EPS) for the period 2015 to 2024. It assigns responsibilities to specific departments, units and/or agencies for various tasks associated with emergency preparedness. The emergency preparedness strategy is fully described in the RDA Road Maintenance Manual.

Table 6-1 Emergency Preparedness Strategy

No.	Activities	Lead Agency	From	To	Department Responsible	Supporting Institution	How
1	Fast tracked Procurement System	RDA/DMMU	2015	2024	Procurement/ Maintenance	NRFA/DMMU	• RDA to undertake Immediate procurement when required
2	Increased Contingency Funds with ring fenced seed funds for emergencies	RDA/NRFA	2015	2024	Planning/Maintenance	NRFA	• RDA to ensure that adequate funds are provided for in the RSAWP for maintenance • NRFA to ensure that adequate funds are available for maintenance • Seed Funds will be kept in the RDA HQ Account
3	Speedy Access to Contingency Funds by Implementing Regions	RDA Regional Office	October 31,2014	2024	Maintenance Dept./Finance	NRFA	• RDA HQ to transfer required funds to the Regional Office within 24 hours from approval.
4	Preparation of Emergency Plans	RDA Regional Office	November 28, 2014	2024	Maintenance	LRAs/DMMU	• Draft a template for emergency plans by November 28, 2014 • Distribute templates to regional offices by December 1, 2014
5	Reviewing & Updating Emergency Plans	RDA Regional	2015	2024	Maintenance	LRAs/DMMU	• Review Emergency Plans every year

		Office					
6	Framework and Supply Contracts in the 10 Regions	RDA – Planning & Design	November 2014	2024	Regional Offices/ Maintenance Dept./Procurement	NRFA	• RDA to procure in advance contractors by October (by December 15, 2014) of every year in all 10 provinces that will be instructed to carry out works during emergencies
7	Material Stockpiling and Equipment in readiness for emergencies – bitumen (standing contract), prefabricated culverts, bailey bridges and many others	RDA	November 2014	2024	Maintenance/Regions	DMMU/NRFA	• Stockpile material to be procured by November of every year before onset of rainy season.
8	Establishing processes for lessons learned including conducting debriefs and reviews of other emergency events or exercises that are relevant to the RDA	RDA	June 2015	June 2024	Monitoring & Evaluation/Maintenance/Audit/Public Relations	DMMU/LRA/NRFA /Provincial and District Administration	• Conduct debriefs on emergency activities on a semi-annual basis
9	Establishment of a 24 hours Customer Service Emergency hotline in all the regions	RDA	January 2015	April 2015	Public Relations	RDA/RTSA	• Establish emergency hotline by November 30, 2014.

Source: RDA Draft Road Maintenance Manual 2014

6-3-2 Emergency Response

The emergency response relate to actions taken to minimize the effects of an emergency event, and to limit the threat to life, disruptions to transportation of goods and services and damage to property and the environment. The RDA will take the lead role in reacting to emergencies while coordinating with other key stakeholders such as the DMMU, ZA, ZNS, RRU and the LRAs where necessary.

Emergency Response covers the following:

i) Initial assessment and reporting of the event, location and identified communication methods;
ii) Detailed technical assessment and preparation of cost estimates;
iii) Request for funding for Force Account works;
iv) Use of standby contracts for materials and equipment for emergency response;
v) Activation of Frame work contracts;
vi) Fast tracked procurement for works;

Table 6-2 is the RDA Emergency Response Strategy (ERS) that shows the reaction time for various activities undertaken to respond to emergencies whilst Table 8 3 shows the category of responses. The ERS is fully described in the Draft 2014 RDA Road Maintenance Manual.

Table 6-2 Emergency Response Strategy

No.	Activities	Lead Agency	Department Responsible	Supporting Institution	Reaction Time (Response Category)			
					P 4	P3	P2	P1
1	Initial assessment and reporting of the event, location and identified communication methods	RDA	Regional Office	Local Road Authorities	Within 1 week	Within 72 hours	Within 48 hours	Within 24 hours
2	Preparation of Cost Estimates;	RDA	Regional Office	Local Road Authorities	Within 1 week	Within 72 hours	Within 48 hours	Within 24 hours
3	Request for funding for Force Account works;	RDA	Maintenance Dept./Regional Offices	NRFA	Within 1 week	Within 72 hours	Within 48 hours	Within 24 hours
4	Use of standby contracts for materials and equipment for emergency response;	Procurement	Maintenance	Regional Office	Within 1 week	Within 72 hours	Within 48hours	Within 24 hours
5	Activation of Frame work contracts;	Procurement	Maintenance	Regional Offices	Within 1 week	Within 72 hours	Within 48hours	Within 24 hours
6	Fast tracked procurement for works	Procurement	Maintenance	DMMU	Within 1 week	Within 72 hours	Within 48hours	Within 24 hours

Source: 2014 Draft RDA Road Maintenance Manual

Figure 6-1 shows the emergency response flow chart through either Force Account or Framework Contract approach. The RDA will maintain to a limited extent Force Account works for emergencies while at the same time use Framework and Supply Contracts to deal with all major emergency works in the regions.

Figure 6-2 shows the RDA Emergencies Organization Chart

Table 6-3 Response Category

No.	Criteria		Response Category
	AADT	Road Class	
1	>3,000	All Trunk Roads	P1
2	1,000<AADT≤3,000	All Main Roads	P2
3	500<AADT≤1,000	All Urban & District Roads	P3
4	≤500	All other roads	P4

Notes:

1. All Trunk Roads regardless of traffic band shall fall in category P1
2. All Main roads regardless of traffic band shall fall in category P2
3. All Urban and District roads regardless of traffic band shall fall in category P3
4. Any road regardless of class with traffic in any of the traffic bands shall qualify to fall into the respective response category defined above

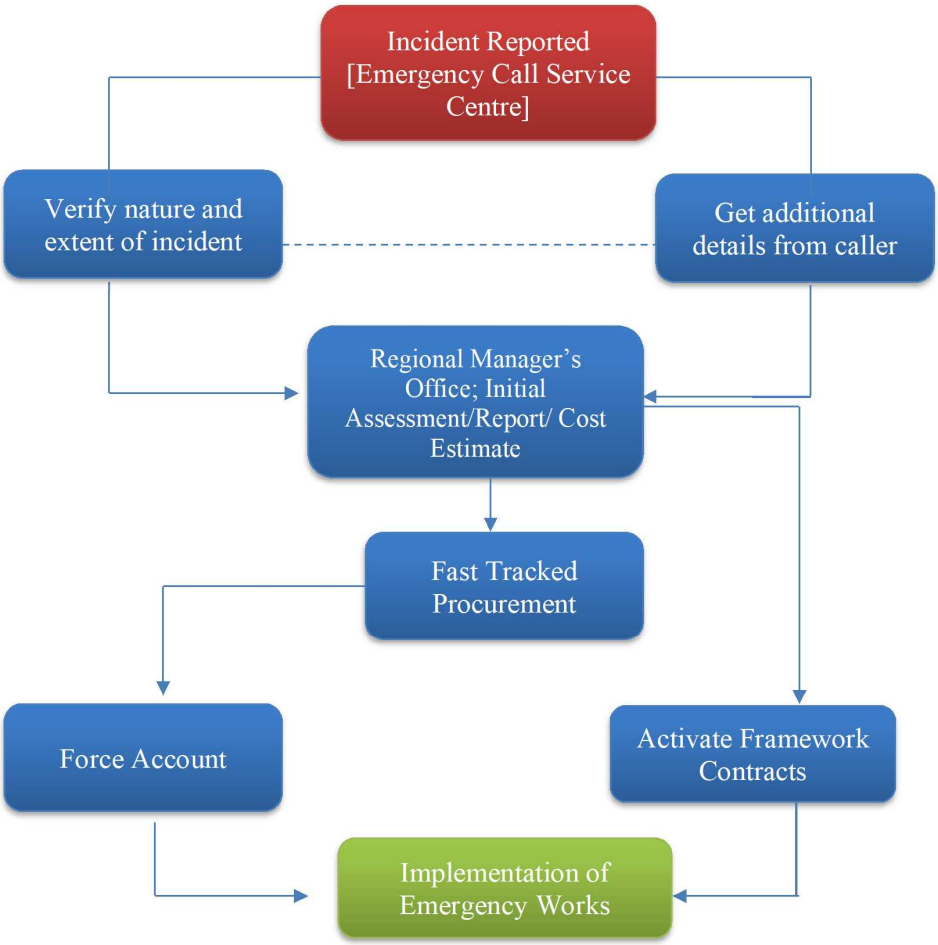


Figure 6-1 Emergency Response Flow Chart

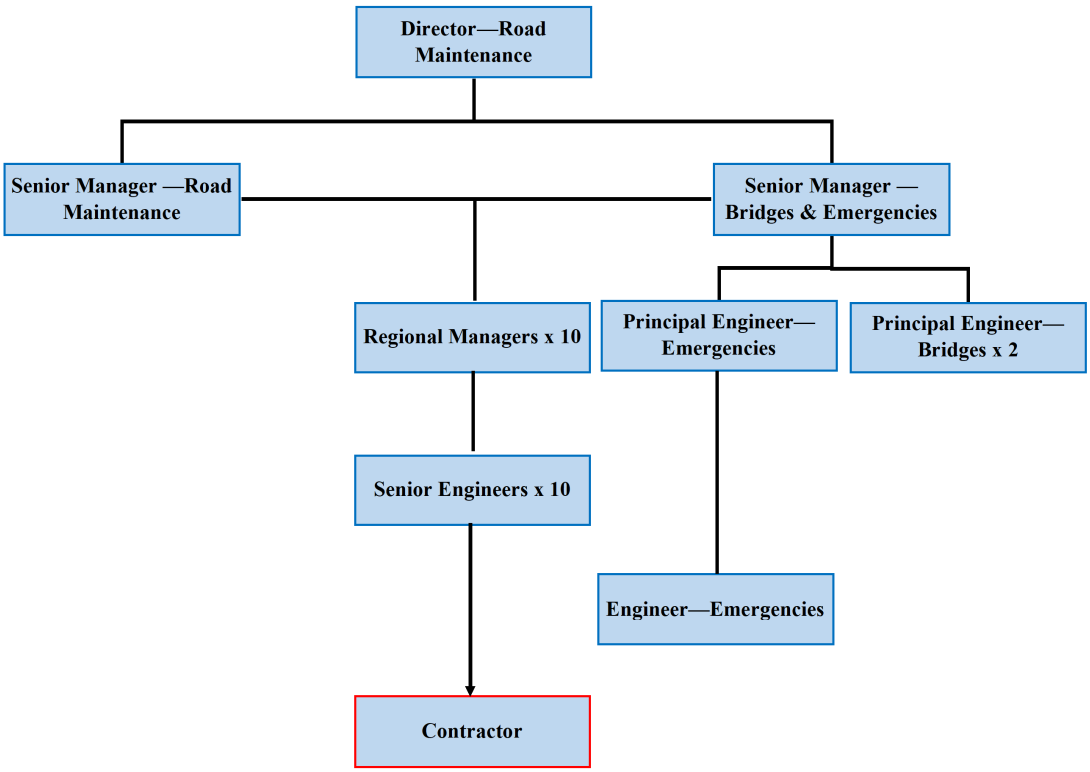


Figure 6-2 The RDA Emergencies Organization Chart

6-4 INITIAL RESPONSE TO EMERGENCIES

6-4-1 Purpose

To remove hazardous elements and debris immediately that endanger the bridge, thus making it clear, safe and passable.

6-4-2 Procedure

1. Install appropriate warning signs, barricades and informative signs.
2. Adopt re-routing traffic scheme or find detour route.
3. Perform initial work to make the bridge safe and passable to vehicular traffic based on the actual needs and suitable conditions.
4. Provide or construct a safe pedestrian passage if detour route is not available and bridge is closed to traffic.
5. Remove debris and hazardous elements and clear the area.

6-4-3 Checkpoint

- Check for alternative detour route.
- Ensure the safety of the bridge structures before opening it to vehicular traffic
- Materials must be readily available as well as the schedule of needed equipment/tools is readily prepared for emergency response.
- Check network in case of emergencies.
- Rapid assessment of the damaged structures is recommended.
- Clean all tools used in the worksite and observe proper housekeeping of tools and equipment.

6-4-4 Photographs

(1) Closure and Detour of traffic

- Install appropriate warning signs and barricades

Photo 6-1 Warning signs and Barricades

(2) Provision of materials for initial response

- Stock materials for emergency response.

Photo 6-2 Dump truck

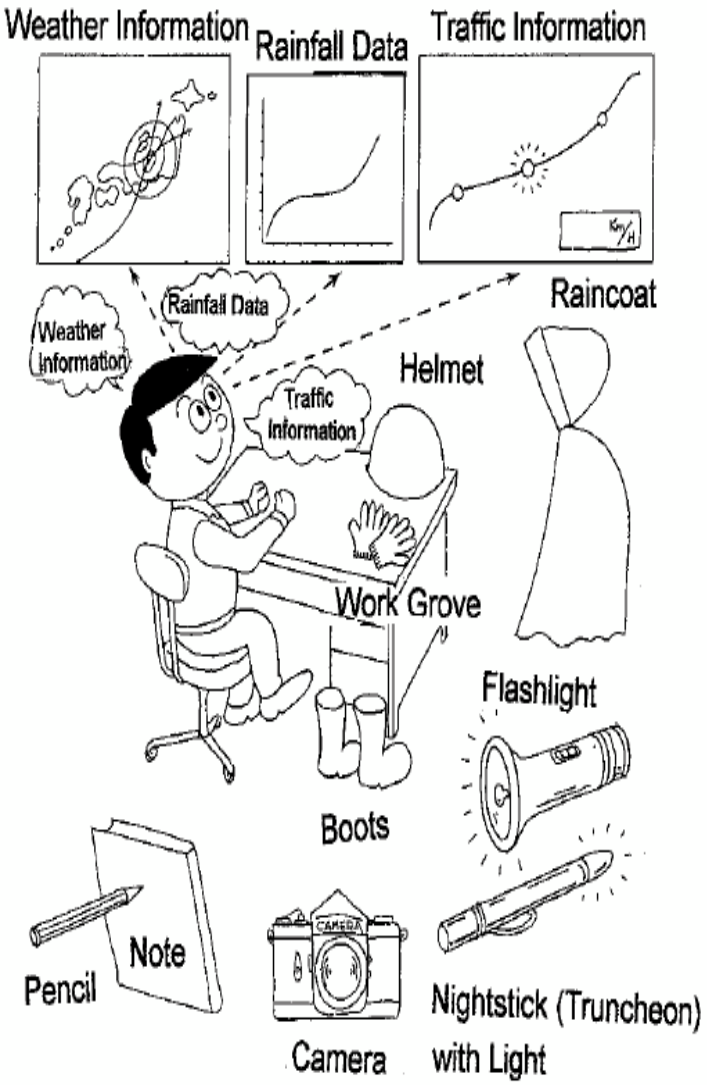
(3) Initial response for keeping bridge safe

- Immediate repair of damaged portion of bridge to ensure safety and stability of structure.

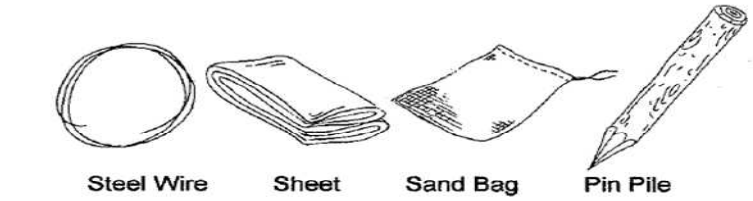
Photo 6-3 Repair around abutments

6-4-5 Additional Information

In an emergency due to unusual weather.

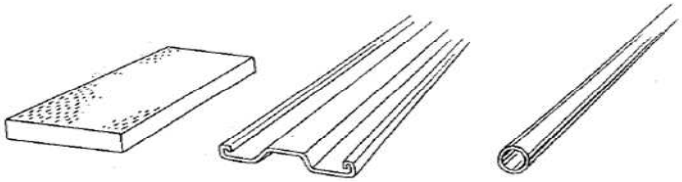


In a disaster, several emergency materials and tools are needed depending on the gravity and magnitude of the disaster. For quick response, prepositioning of needed equipment, materials, and information on emergency hotlines must be readily available, such as the following:



Steel Wire Sheet Sand Bag Pin Pile

Wooden Sheet Pile H-Beam



Lining Steel Sheet Pile Vinyl Chloride Pipe