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BRIDGE REHABILITATION DETAILING MANUAL (BRDM)
(COMMENTARY ON MTO STRUCTURE REHABILITATION MANUAL)

by

Behnam Mehraie, B.Sc, Azad University, Tehran, Iran, 2000

A Project presented to Ryerson Univerisy
in partial fulfillment of the requirements for the degree of
Master of Engineering in the Program of Civil Engineering

Toronto, Ontario, Canada, 2007

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ABSTRACT

Bridge Rehabilitation Detailing Manual (BRDM) (Commentary on MTO Structure Rehabilitation Manual), Master of Engineering, 2007, Behnam Mehraie, Civil Engineering, Ryerson University

The Ministry of Transportation of Ontario (MTO) has developed few manuals that deal with inspection and rehabilitation of bridges; such as OSIM (Ontario Structural Inspection Manual), SRM (Structure Rehabilitation Manual), OPSS (Ontario Provincial Standards Specifications) and OPSD (Ontario Provincial Standards Drawings). Most of these manuals except OPSD do not provide detailed sketches to clarify the theory; therefore, practicing engineers in rehabilitation industry have difficulties during design and construction of rehabilitation projects. The main objective of this project is to provide a manual called “Bridge Rehabilitation Detailing Manual (BRDM)” for clarifying practicing engineers’ problems.

This manual presents the results of a wide research and studies on rehabilitation of about 80 bridges in Ontario. Most of these bridges are located at major locations of Ontario with high volume of traffic going over. Out of the 80 bridges, 62 bridges have been considered as case-studies since they were designed and detailed by top ranked and well-known consulting firms in rehabilitation industry. The most common deteriorations and relevant rehabilitation methods were categorized in a database to help the development of the BRDM. This has been combined with MTO’s manuals to result and act as commentary of MTO Rehabilitation Manual.

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DEDICATED TO MY SUPPORTIVE FAMILY

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List of Symbols, Abbreviations and Definitions

For the purpose of BRDM manual the followings apply:

+	Locations and directions are only shown as examples
**	Only for example purpose and it depends on project needs and design criteria
<i>AADT</i>	Average Annual Daily Traffic
<i>Abut.</i>	Abutment
<i>Abutment</i>	A substructure unit which supports the end of the structure and retains the approach fill. [7]
<i>Auxiliary-Components</i>	Any component which does not share in the load carrying capacity of the structure [7]
<i>App. Slab</i>	Approach Slab
<i>B , Bot.</i>	Bottom
<i>BRDM .</i>	Bridge Rehabilitation Detailing Manual
<i>BRGS</i>	Bearings
<i>C</i>	Designation for epoxy coated bar
<i>C/C</i>	Center To Center
<i>CA</i>	Contract Administrator
<i>CFRP</i>	Carbon Fiber Reinforced Polymer
<i>C.J.</i>	Construction Joint
<i>CHBDC</i>	Canadian Highway Bridge Design Code
<i>C.L.</i>	Centerline
<i>Cont.</i>	Continues
<i>CSA</i>	Canadian Standard Association

<i>CPCI</i>	Canadian Prestressed Concrete Institute
<i>Defect</i>	An identifiable, unwanted condition that was not part of the original intent of design. [7]
<i>Detailed Visual-Inspection</i>	An element by element visual assessment of material defects, performance deficiencies and maintenance needs of a structure. [7]
<i>Deterioration</i>	A defect that has occurred over a period of time. [7]
<i>Dia.</i>	Diameter
<i>DSM</i>	Designated Sources for Materials
<i>DWG</i>	Drawing
<i>DWLS</i>	Dowels
<i>E.F.</i>	Each Face
<i>Elements</i>	The individual parts of a structure defined for inspection purposes. Several bridge components may be grouped together to form one bridge element for inspection purposes. [7]
<i>Eq. Sp.</i>	Equally Spaced
<i>Evaluation</i>	The determination of the load carrying capacity of structures in accordance with the requirements of CHBDC
<i>Exist.</i>	Existing
<i>Exp. J.</i>	Expansion Joint
<i>HPC</i>	High Performance Concrete
<i>I.F.</i>	Interior Face
<i>O.F.</i>	Outer Face
<i>Long. Exp. Jt..</i>	Longitudinal Expansion Joint
<i>Memb.</i>	Membrane
<i>MTO</i>	Ontario Ministry of Transportation
<i>MTO Manuals</i>	In BRDM means OSIM, SRM, OPSS, OPSD and Structural Manual.
<i>NDT</i>	Non-Destructive Test
<i>OPSD</i>	Ontario Provincial Standards Drawings
<i>OPSS</i>	Ontario Provincial Standards Specifications
<i>OSIM</i>	Ontario Structure Inspection Manual
<i>Primary Components</i>	The main load carrying components of the structure.

<i>Rehabilitation</i>	Any modification, alteration, retrofitting or improvement to a structure sub-system or to the structure which is aimed at correcting existing defects or deficiencies.[7]
<i>Repair</i>	Any modification, alteration, retrofitting or improvement to a component of the structure which is aimed at correcting existing defects or deficiencies.[7]
<i>Retaining Wall</i>	(iv) Any structure that holds back fill and is not connected to a bridge
<i>Reinf.</i>	Reinforcement
<i>S</i>	Designation for Stainless bar
<i>SBGR</i>	Steel Beam Guide Rail
<i>Secondary-Components</i>	Any component which helps to distribute loads to primary components, or carries wind loads, or stabilizes primary components. [7]
<i>SRM</i>	Structure Rehabilitation Manual
<i>T</i>	Top
<i>Thk.</i>	Thickness
<i>Typ.</i>	Typical

LIST OF LEGENDS

}	Concrete Removal Or New Asphalt Or Asphalt Removal
<i>Note: As different designers use these two legends differently, in BRDM usage of both is practiced. The main approach is to distinguish between concrete and asphalt.</i>
New Concrete
Existing Concrete to Remain
Existing Reinforcing Bars
New Reinforcing Bars

CHAPTER 1 – INTRODUCTION

1.1. History

Rehabilitation of infrastructure in Ontario did not become necessary until much of it began to reach the end of its service life, during the 1970's. Unfortunately, this coincided with a change in the focus of municipal spending. Quality-of-life opportunities such as parks and recreation and social services, began to make a greater claim on municipal budgets.

Over the past three decades, because of budgetary constraints, all the levels of government federal, provincial and municipal have considerably decreased their fiscal commitments to infrastructure, leading to the adoption of stop-gap measures and neglect.

Under the jurisdiction of MTO, there are approximately 3,000 bridges, 300 culverts of more than 6 m in span and 1,400 culverts of 3 to 6 m. Most of these bridges are more than 25 years old and many of them considerably older. There is growing concern that inadequate funding for the maintenance, upgrading and repair of infrastructure is leading to a decrease in durability of structures. Inadequate funding has resulted in a “gap” between real needs and actual expenditures.

The traffic volume is increasing over bridges every year in all of the provinces in Canada. Consequently additional loading is added over bridges. In addition to traffic, the usage of de-icing salts can severely damage the structure. All in one, combination of additional loadings and de-icers are the major causes of deteriorations on each component of structures.

In general, Canadian highways, roadways and bridges are in poor conditions. Due to deferred maintenance over nearly three decades, the infrastructures have continued to deteriorate. MTO has been planning to allocate a budget for rehabilitation and increasing the service life of bridges.

Bridge rehabilitation involves structural or functional upgrades to an existing bridge. Rehabilitation work can be classified as minor or major rehabilitation. Minor rehabilitation addresses non-structural repair such as concrete surface repair, deck overlays, joint and bearing restoration, steel secondary member repair, and minor repair to primary steel

members. Major rehabilitation involves structural repair or replacement of primary bridge elements, pier cap or pier replacement, superstructure replacement, bridge widening, and primary member replacement or strengthening.

Most of the rehabilitation projects should have a life cycle cost analysis to confirm that the rehabilitation is preferred over replacement.

1.2. Outline

This manual briefly consists of the following chapters and information:

Chapter-1 introduces the usage and recommendations of BRDM.

Chapter-2 provides the history of rehabilitation in Ontario, the process of rehabilitation projects and assists the practicing engineers to become familiar with condition survey and bridge management system.

Chapter-3 summarizes the causes and repair solutions of concrete and asphalt deteriorations.

Chapter-4 focuses on the commentary for SRM clauses to make it more understandable by providing additional considerations to SRM and referring to relevant detailed sketches and drawings. This chapter should be used in conjunction with Appendices.

Appendices include detailing sketches as the collection of removals and repairs of each bridge component based on the structure type.

1.3. Scope of BRDM

The main approach of this manual is to provide additional information and sketches to MTO manuals such as; OSIM (Ontario Structural Inspection Manual), SRM (Structure Rehabilitation Manual), OPSS (Ontario Provincial Standards Specifications), OPSD (Ontario Provincial Standards Drawings), Structural Manual and CHBDC.

As a guideline this manual is developed to assist engineers to become more familiar with the procedure of rehabilitation projects in Ontario and extend their engineering knowledge with the detailed rehabilitation concept of concrete bridges.

The SRM commentary section is developed by collecting the information from about 80 rehabilitated bridges designed and constructed by top-ranked firms in Ontario. A database of all defects and repair methods of 62 bridges was created and the common practices of repair methods were selected as the summary of the database. As a result, by matching the summarized repair methods with MTO manuals, standards and specifications; SRM commentary section was developed to save time for engineers, designers and drafters to use the detailed sketches in Appendices as useful “samples”.

There are few considerations for the usage of BRDM:

- Steel Bridges are not covered in this manual, but composite plate girders are included;
- It is recommended to use this manual jointly with MTO manuals and CHBDC especially for the accuracy of dimensions and notes;
- Reinforcements shown in sketches shall be considered as examples. Design of reinforcement should be done or reviewed by a licensed professional engineer.
- Sketches are not to scale.

1.4. Types of Concrete Bridges

The following types of concrete bridges are covered in this manual and are shown in Figure 1.1:

- 1) Rigid Frame Bridge (Fig. 1.1a)
- 2) Concrete Deck slab on:
 - 2-1) CPCI Beam (Fig. 1.1b)
 - 2-2) Plate Girder (Fig. 1.1b)
 - 2-3) T-Beam (Fig. 1.1b)
 - 2-4) Concrete Box Girder (Fig. 1.1c)
- 3) Post-tensioned concrete slab with or without voids (Fig. 1.1d)

Figure 1.1- Types of Concrete Bridges: a) Rigid Frame Bridge, b) Concrete Deck slab on CPCI Beam or T-Beam or Plate- Girder, c) Concrete Deck slab on Concrete Box Girder d) Post-tensioned concrete slab with or without voids [7]

CHAPTER 2 – OVERVIEW OF THE REHABILITATION PROCEDURE IN ONTARIO

2.1. Procedure of Rehabilitation Projects in Ontario

According to MTO inspection program, bridges in Ontario should be inspected visually and monitored every 2 years. Based on the inspection report if more detailed information is needed, the structure should be evaluated by condition survey and non-destructive testing.

All of these inspection data should be stored in a “Bridge Management System (BMS)”. The output information from the BMS can assist MTO project managers to prioritize the rehabilitation projects and allocate funds based on the budget. Finally, the design of each rehabilitation project will be assigned to the eligible consulting engineering firm that can win the proposal.

2.1.1 Inspection and Inventory (Data Storage)

The inspection philosophy is to record defect severity and extent separately, requiring the inspector to record the quantity of defects in four different condition states for each bridge component as shown in Table 2.1. These condition states are Excellent, Good, Fair and Poor [4]. This assessment is based on visual observations, however, some non-destructive testing such as hammer tapping, chain drag and radar test for delimitation survey will be required to determine or verify areas in poor condition. For further details of the structural inspection and methods of rating the condition of each component, refer to OSIM and SRM.

Table 2.1- Ontario Structural Components [4]

Group	Component
Abutments	Abutment walls, Ballast walls, Bearings, Wingwalls
Approaches	Approach slabs, Curb /gutters, Drainage system, all Sidewalk, Wearing surface
Barriers	Barrier and Parapet walls, Hand railings, Posts
Beams/Main	Diaphragms
Longitudinal	Floor Beams

Elements	Girders, Inside Boxes, Stringers
Bracing	Bracing
Coatings	Railing Coatings, Structural steel coating
Culvert	Barrels, Inlet and outlet component
Decks	Deck Top, Drainage System, Soffit, Wearing surface
Embankments and Streams	Slope Protection, Streams and waterways
Foundation	Foundation
Joints	Armouring/retaining devices, Concrete end dams, Seals
Piers	Shafts/Columns/pile, Bearings, Caps,
Retaining Walls	Retaining Walls and Barriers on wall
Sidewalk	Curbs, sidewalks and medians

By recording the quantities and severity-extent condition state distribution of each element, repair quantities are directly estimated, and types of repairs can be recommended by inspector and professional engineer.

The main objectives of the structural inspections are to:

1. Identify maintenance, repair and rehabilitation needs of structures;
2. Provide a basis for a bridge management system to plan and fund the maintenance and rehabilitation of structures; and,
3. Protect and prolong the service life of structures.

MTO carries out a detailed visual inspection of its bridges once every 2 years and once every 4 years of its culverts according to the Ontario Structure Inspection Manual since 1985 to extend and monitor the service life of structures [3][7].

2.1.2 Condition Survey Report

The purpose of conducting a condition survey is to determine and document the deterioration of the structure to establish the type of rehabilitation and prepare the contract documents. Inspectors should provide a report with sufficient details including drawings of cracks and deteriorated areas, photographs and results of core samples (Table 2.2). Based on the condition survey report, engineers can identify different kinds of distresses.

In general, the procedures followed to conduct the condition survey are those defined in Part 1 of the MTO Structural Rehabilitation Manual. This involves the observation and recording of surface defects, grid layouts (usually 1.0 m x 1.0 m or 1.5 m x 1.5 m), delaminations, surface deterioration, corrosion potentials, asphalt sawn samples (Figure 2.1) and physical testing of concrete cores (Figure 2.2).

The detailed condition survey should preferably be carried out no more than two years prior to the proposed rehabilitation. However, for exposed concrete components such as barrier walls, abutments and piers and the concrete delamination survey should be updated the year before the construction of rehabilitation for the portion of the components that are exposed to chlorides. In Canada due to severe cold weather salt spraying is applied all over the major highways and roadways during winter. As it is explained in more details in Chapter 3, structure components vulnerable to deicing salts severely get damaged as the result of chloride ions and salt penetration into the concrete to cause corrosion and scaling. Therefore, it is significant to ensure the condition of these exposed components a year before the construction of repair and rehabilitation.

There are the various kinds of condition surveys as noted in SRM [8]:

1. Delamination and Surface Deterioration Survey
2. Corrosion Potential Survey
3. Concrete Cover Survey
4. Expansion Joint Survey
5. Concrete Coring and Testing

Table 2.2 – Sample of Sawn Asphalt Sample Log

Core No.		C1	C2	C3
Location (between gridlines)		'T' + '1'	'D' + '6'	'A' + '3'
Diameter, mm		100.0	100.0	100.0
Thickness of Asphalt, mm		75	60	65
Thickness of Asphalt @ Nearest Grid Point		75	60	65
Thickness of Concrete, mm		135	135	115
Full Depth (yes/no)		N	N	N
Condition of Asphalt ⁽¹⁾		Good	Good	Good
Waterproofing (W/P) Type		Hot-applied rubberized membrane		
Condition of W/P ⁽¹⁾		G	G	G
W/P Thickness, mm		5-7	5-7	5-7
Bond of Asphalt or W/P to Concrete		G	G	G
Defects in Concrete ⁽²⁾		-	-	-
Condition of Rebar ⁽³⁾		N/A	N/A	Good
Corrosion Potential		-0.28	-0.22	-0.28
Compressive Strength, MPa				
Chloride Content	0-10 mm		0.124	
% Chloride by Weight of Concrete	20-30 mm		0.113	
	40-50 mm		0.073	
	60-70 mm		0.051	
	80-90 mm		0.040	
AIR VOIDS	Air Content, %	3.7		
	Spec. Surf., mm ² /mm ³	31.1		
	Spacing Factor, mm	0.187		
TEST LABORATORY		DBAL	CTL Ltd.	
REMARKS				Concrete cover to reinforcing steel = 115 mm

1. Condition-G=Good, F=Fair, P=Poor.
2. Defects-C= Cracked, D= Delamination, R= Rough, Sc= Scaling, S= Spalling
3. Condition Rebar-LR= Light Rust, SR= Severe Rust, N/A= No rebar exposed

Fig. 2.1 - Sawn Asphalt Sample from Condition Survey report

Fig. 2.2 - Core photograph and sketch from Condition Survey report

2.1.2.1 Half-Cell Test

One of the most important tests that is usual in a condition survey is “the corrosion potential survey”, which is used to measure corrosion potential of reinforcing steel at the time of the test.

Half-Cell testing (Figure 2.3) estimates the electrical half-cell potential of reinforcing steel in concrete structures for the purpose of determining the potential for corrosion activity in the reinforcement bars at the time of testing.

When corrosion occurs, the ferric oxide protective layer surrounding the reinforcing steel breaks down, an electro-chemical reaction will occur. This reaction is accelerated by water, oxygen, contaminants such as salt and also by expansive cracks caused by corrosion.

Fig. 2.3 - Half Cell Potential Equipment (Courtesy Hammond Concrete Testing)

The half-cell method is described in ASTM C876-80, "Standard Test Method for Half-Cell Potentials of Reinforcing Steel in Concrete". In this method, the electrical potential between a rebar and a reference electrode, normally a copper/copper sulphate cell, in contact with the concrete surface, is measured using a high resistance volt meter (Fig.2.4).

The numerical values obtained using a copper-copper sulphate half-cell is indicative of conditions as listed below:

- If potentials over an area are numerically less than **-0.20 V**, there is a greater than 90% probability that no reinforcing steel corrosion is occurring in that area at the time of measurement.
- If the potentials over an area are in the range **-0.20 V to -0.35 V**, corrosion activity of the reinforcing steel in that area is uncertain.
- If potentials over an area are numerically greater than **-0.35 V**, there is a greater than 90% probability that reinforcing steel corrosion is occurring in that area at the time of measurement.

Fig. 2.4 - Half Cell measuring circuit

Designers should have the corrosion potential survey report to decide on removal areas. As shown in Figure 2.5, a half cell contour plot can distinguish corrosion potential of different areas.

Fig. 2.5 – Typical Half Cell Contour Plot

2.1.3 Bridge Management System (BMS)

The numbers of structures are increasing every year and the funds for the highways and roads have been decreasing more and more; therefore, it is difficult to control and manage the durability of bridges. A powerful tool is required to monitor the budgets, costs and performances of bridges. For instance in Ontario, Ministry of Transportation of Ontario (MTO) is responsible for the management of most of the bridges, excepts the ones owned by the other organizations such as City of Toronto and Toronto Transit Commission (TTC), which are in minority. As a result MTO Bridge office has decided since 1980's to implement Ontario Bridge Management System (OBMS) as a solution.

OBMS is designed as a “Decision Support Model” as shown in Figure 2.6. The decision-making processes served by the system include: Inventory, Monitoring, Analysis of Bridge, Analysis of the economic models, Priority setting and Budgeting/funding allocation. Due to make the decision, BMS is designed to include four basic components:

1- *Inspection and Inventory (Data storage)*, which was described in sub-section 2.1.1

2- *The Element Level (Deterioration model)* uses Markovian deterioration model, a set of feasible treatments and a long-term cost model to produce multiple Element Alternatives, each of which is a possible corrective action to respond to deteriorated conditions [3].

The Markovian model takes advantage of the discrete condition states identified for inspections to provide a simple way of describing the likelihood of each possible change in condition over the time as shown in Figure 2.7.

Although it is possible to predict deterioration with other forms of models, including deterministic models, the Markovian model is particularly suitable for the available condition data. The model expresses its predictions in the same form as inspections as a distribution of the element among condition states,

Figure 2.6 - Decision Support Model [3]

Figure 2.7 – Markovian Model [3]

3- *The Project Level (Cost model)* estimates project alternatives based on tender item unit costs. The unit costs maintained by MTO are based on actual contract history and updated continuously. The project level combines Element Alternatives into Project Alternatives, each of which represents a possible multi-year strategy to maintain service on a bridge. The tool uses models of initial costs and life cycle costs to evaluate the Project Alternatives as shown in Figure 2.8.

Figure 2.8 - Project Alternatives in Cost Model [3]

4- *The Network Level (Optimization model)* based on “Deterioration” and “Cost” models determines the minimum cost maintenance, rehabilitation and repair for bridge elements using life-cycle cost analysis.

2.1.4 Consulting Engineering Firm Responsibilities

The consulting engineering firm is responsible for the following tasks:

- Evaluation of the load carrying capacity of the bridge as described in the CHBDC as stated in subsection 1.2.5 of SRM;
- Studying the condition survey report and its recommendations to locate the deteriorated locations;
- Reviewing the preliminary scope of the expected rehabilitation work. The designer will review this scope, and through preliminary design analysis, determine whether the expected work is the optimal course for improvements to the bridge. It is very important that the contract clearly describes the expected repairs and the extent of work to avoid excessive and costly changes in the field;
- Considering the latest rehabilitation standards and drawings;
- Developing sketches for drafters to create the drawings based on :
 - Structural Manual, OSIM, SRM, OPSS and OPSD;
 - Condition Survey report, and;
 - Bridge Rehabilitation Detailing Manual.

2.1.4.1 Drawings

The first drawing created for a rehabilitation bridge project is called “**General Arrangement**” or GA (Figure 2.9) which contains:

- **Plan, Elevation and Sections** – As seen in Fig. 2.9, the drawing is divided into two sections side by side. The left hand side of the drawing deals with existing conditions and removals while the right hand side shows rehabilitated portion;
- **General Notes** - This must cover the requirements that are specific to the particular project. These general notes will include “Class of Concrete”, “Clear Cover to Reinforcing Steel”, “Reinforcing Steel Properties”, “Retained Soil System” (where

applicable) and “Construction Notes”. For more details refer to subsections 2.5.7 and 2.5.8 of MTO Structural Manual and ;

- **List of drawings;**
- **List of Applicable Standard Drawings;**
- **List of abbreviations, and;**
- **Scope of rehabilitation work - Notes for removals and rehabilitations.**

It should be noted that different types of hatches should be shown in all of the removal and repair detailed drawings as mentioned in Chapter 1. This will distinguish portions such as “concrete to remain”, “concrete and asphalt removal” and “new concrete and new asphalt”. This format is also used in sketches of this manual.

CHAPTER 3 - DETERIORATION OF ASPHALT AND CONCRETE

3.1. Common Deteriorations

According to inspection reports and condition survey, there are several major deterioration types which most of the bridges in Ontario are dealing with:

1. *Corrosion* which is the biggest problem for concrete and steel bridges in Canada. The solution is still under research by many universities material scientists and engineers.
2. *Scaling, cracks* on concrete and loss of layers of concrete starting gradually from top surface due to reaction of deicer salts that are used during winter with concrete during Freeze-Thaw cycles.
3. *Leakage* of water and salt spraying from expansion joints to the end of abutments (end of girders and bearing) are the obvious reasons of corrosion and deterioration at these areas.

Consequently, potholes, ruts, structural cracks and poor bridge conditions contribute to traffic tie-ups, lost time, wasted fuel and many more. Unfortunately some of the poorest conditions are found at the most critical locations in Ontario.

It should be noted that to provide the repair method for a deteriorated component, the designer should be familiar with the types of defects and the possible reasons of deterioration to know how to prevent this problem. Therefore, this chapter has covered briefly the most common deterioration types of asphalt and concrete.

3.2. Asphalt

Asphalt has been widely used since 1920, though in ancient times asphalt was already used for road-building. The viscous nature of the bitumen binder allows asphalt concrete to sustain significant plastic deformation, although fatigue from repeated loading over time is the most common failure mechanism.

Not only asphalt pavement is highly used as road surfaces, but also it is recommended to do asphalt pavement as a wearing surface on concrete deck to have durable structure. A waterproofing membrane is often placed on the deck surface between the deck top surface and the asphalt pavement to provide protection to the deck surface against de-icers and moisture.

3.2.1. Deterioration Processes

Asphalt deterioration is due to environmental and traffic loading factors and results in worsening pavement condition and ride quality.

Asphalt deteriorates from two general processes: **fatigue** and **aging**. Each deterioration process has its own set of pavement distresses (defects) that are caused by the process. [11]

3.2.1.1. Fatigue

Fatigue results from heavy axle loads (Figure 3.1). As the asphalt bends from heavy wheel loads, its ability to flex is consumed. This is much like what happens when you bend a paperclip back and forth. You can only bend it so many times until it breaks. With sufficient bending, the pavement begins to crack at the bottom. The failure at the bottom of the pavement structure will affect all layers. This appears at the surface as alligator cracking, rutting, or sags. Shoving is another fatigue related distress that occurs generally only in the top layer. Fatigue failures are best repaired by removal and replacement of the asphalt in the affected areas. These repairs are commonly called digouts. Generally, when the area of digouts reaches approximately 10 percent of the total area of the roadway, the pavement is considered to have reached its useful life and requires major repair. Most fatigue damage results from heavy trucks and buses. One truck does the same damage as up to 14,000 cars. [11]

Figure 3.1 – Fatigue caused by Axel load on a flexible pavement [11]

3.2.1.2. Aging

The main element of the pavement section that ages is the asphalt concrete layer. Asphalt concrete (AC) is composed of aggregates (sand and gravel) and asphalt cement (a binder made of petroleum and/or synthetic materials). As the asphalt binder ages, it shrinks due to loss of its volatile components. During the asphalt shrinkage, the pavement will progressively crack from the resulting tensile stress in the layer. These cracks widen and increase over time until the pavement has a large checkerboard appearance. The aging process also causes the pavement to become stiffer(brittle). The increased stiffness results in additional cracking from loaded vehicles. This load induced cracking from the brittleness of the asphalt concrete is very similar to fatigue cracking in appearance.

Oxidation (from the oxygen carried by water) is the major cause of deterioration of the asphalt concrete binder. Water enters the pavement either from the surface through cracks (top-down defects) or as water vapor from underneath (bottom-up defects). Thus, standing water on an asphalt surface can shorten the life of the surface significantly. As a result, gutters are made of concrete, a material that is not as affected by water.

3.2.2. Defects and Causes

Beside of aging and fatigue, there are few more other factors which cause different kinds of cracks such as:

1) Temperature changes 2) Shrinkage of asphalt 3) Frost action 4) Inadequate bonding 5) Insufficient thickness 6) Weak sub-base and sub-grade 7) Poor drainage on bridge 8) Lack of compaction 9) improper density 10) Poor tack coat 11) Uneven mixture 12) Clay in gravel 13) Excess moisture in sub base and sub-grade 14) Freeze-Thaw 15) Insufficient cooling.

Different types of defects are described as followings.

3.2.2.1 Alligator Cracking (Fatigue)

Interconnected cracking with a pattern resembling alligator skin. This is generally caused by fatigue from heavy traffic. (Figure 3.2.a)

Causes: 1) Inadequate rigid structure 2) Accumulated damage 3) Age hardening 4) Poor drainage

3.2.2.2 Rutting (Permanent Deformation)

Permanent deformation of the pavement in the wheel paths is called *Rutting*. This is mostly common in intersections, where there is braking and stopping traffic. (Figure 3.2b)

Causes: 1) Heavy trucks 2) Slow, stopping & standing traffic 3) Poor aggregate 4) Temperature susceptible asphalt 5) Poor construction 6) Moisture damage 7) Post-construction compaction by traffic

3.2.2.3 Pushing, Shoving and Delamination

"Pushing" and "Shoving" are deformations of the pavement surface. Similar to rutting, they are most common in intersections, where there is braking and stopping traffic. It is easier to detect at intersections and bus stations where transverse striping becomes "wavy". (Figure 3.2c)

"Delaminations" are sections of a surface layer that have come loose from the pavement.

Causes: 1) Unstable Mix 2) Braking, stopping, accelerating traffic 3) Slippage between layers 4) Poor interlayer bond 5) Poor construction 6) Heavy trucks 7) Moisture damage

3.2.2.4 Potholes

They can be caused by a number of factors; however they usually form when water penetrates into the cracks and destroys the underlying structure. Potholes mostly appear when the pavement is most subjected to moisture in the early spring. (Figure 3.2d)

Causes: 1) Inadequate rigid structure 2) Accumulated damage 3) Age hardening 4) Poor drainage

3.2.2.5 Longitudinal and Transverse Cracking

Cracking in the direction of traffic usually appears at the edge of wheel paths specially on crown line due to different slopes of pavement on each side (Figure 3.2e).

Causes: 1) Pavement that is fatigued or "worn out" from heavy traffic (specially the side walls of high pressure truck tires) 2) An unstable base 3) Poor construction

3.2.2.6 Raveling

Loose materials (usually aggregate) that "ravel" from the surface or edges of the pavement, resulting in depressions which may be filled with moisture and become loose. (Figure 3.2f)

Causes: 1) Asphalt binder unable to hold aggregate in place 2) Dusty aggregates 3) Segregation of the mix during construction 4) Low in-place density (insufficient compaction) 5) Aged asphalt binder 6) Stripping (moisture damage)

(a)

(b)

(c)

(d)

(e)

(f)

Figure 3.2- Typical Asphalt defects: a) Alligator Cracking, b) Rutting, c) Shoving d) Potholes e) Cracking f) Raveling

3.2.3. Repair solutions

By becoming familiar with the types and causes of asphalt deteriorations, the most feasible repair solutions can be decided. Since this manual does not concentrate on asphalt, general repair methods are briefly stated:

- a) **Alligator Cracking (Fatigue):** Full depth reclamation or applying thick overlays to strengthen the surface for avoiding further fatigue;
- b) **Rutting (Permanent Deformation):** 1) Micro-surfacing 2) Mill & Fill 3) Overlay 4) Sub-grade reconstruction;
- c) **Pushing, Shoving, Delamination:** 1) Partial or full removal and replacement;
- d) **Potholes:** 1) Excavate and rebuild including sub-grade and sub-base;
- e) **Longitudinal and Transverse Cracking:** 1) Crack seal 2) Chip seal 3) Thin Overlay 4) Reconstruction 5) Improve drainage;
- f) **Raveling:** 1) Crack sealing 2) Chip sealing 3) Micro-surfacing 3) Thin overlay 4) Mill & fill.

Chapter 4 provides further details of asphalt repair and removal according to Ontario standards. Also for inspection of asphalt defects refer to OSIM section 2.7 [7].

3.3. Concrete

This manual focuses on concrete bridges due to being the most common bridges in Ontario. Concrete is reinforced with reinforcement bars or with prestressing steel reinforcement known as prestressed concrete.

3.3.1. Causes of Defects

Designers should diagnose the reasons of deterioration and environmental effects on concrete to find the most accurate and feasible solution. In general, concrete bridges deteriorated due to the followings:

- Lack of curing;
- High permeability;
- High water/cement ratio;

- Early formwork removal;
- Poor construction and incorrect vibration;
- Lack of air-entrained agent;
- Improper design of structure under loading stresses and cyclic loadings;
- Improper mix design to meet compressive strength and protect concrete from environmental attack;
- Poor drainage, and;
- Temperature changes.

3.3.2. Type of Defects

The most common concrete types of defects are described briefly in this section; however, for more details refer to OSIM, section 2 [7].

3.3.2.1. Cracking

Cracks in concrete happen as a result of tensile stresses introduced in the concrete. The build-up of tensile stresses and cracks in concrete maybe due to externally applied loads, external restrained deformations, self-straining forces, differential movements and settlements, corrosion of reinforcement, shrinkage during curing of concrete or excess water in mix, rapid drying and Alkalis Aggregate reactions (reaction of aggregates with the alkalis in cement to produce a highly expansive alkali-silica gel) as shown in Figure 3.3.a.

3.3.2.2. Delamination

As noted in OSIM, delamination is a discontinuity of the surface concrete which is substantially separated but not completely detached from concrete below or above it. This can be identified during inspection by hollow sound results from hammer tapping or chain dragging (Figure 3.3.b).

Causes: 1) Usually delamination results from bleeding water and trapped air below the prematurely closed mortar surface; 2) The primary cause is finishing the surface before bleeding has occurred.

(a)

(b)

Figure 3.3 – a) Cracks due to corrosion of reinforcement in a bridge pier, b) Concrete slab delamination

3.3.2.3. Spalling and popouts

Spalling is a continuation of the delamination process. Basically it is a fragment which has been detached from a concrete mass (Figure 3.4.a).

Causes: 1) The stress due to the corrosion of reinforcing steel or any embedded metal items. For instance, when a corrosive process of a rebar starts, it causes pressure to adjacent concrete microstructure, which creates additional stress. As a result microcrack inside concrete will occur in the beginning of the corrosion process and later on it reached to the surface of concrete and pop-out will happen, 2) In areas of localized high compressive load concentrations.

3.3.2.4. Erosion

Erosion basically occurs when heavy particles suspended in water flowing across concrete surfaces or by wind-borne sand particles impacting on the deck.

Causes: 1) Temperature related expansion and contraction of surface moisture exerts a mechanical action and results in the gradual wearing away of the concrete surface. Exposed aggregates are particularly susceptible due to differences in the rates of expansion among the various constituent materials 2) On riding surfaces due to sudden acceleration of vehicles (Figure 3.4.b).

(a)

(b)

Figure 3.4 – a) Spalling at soffit, b) Erosion

3.3.2.5 Deflection

Deflection or deformation of the deck, girders and columns.

Causes: 1) Overloading, 2) The effects of corrosion, 3) Improper construction methods, 4) Seismic stress, 5) Long-term shrinkage (Figure 3.5.a).

3.3.2.6. Corrosion

Corrosion is the deterioration of reinforcement due to an electrochemical reaction. In initial stages, corrosion may appear as a rust-stain on the concrete surface. Furthermore, the concrete surface will crack around the reinforcement. As a result, concrete cover delaminates and spalls off.

Causes: 1) Lack of concrete cover, 2) Reinforcing steel that has been exposed by spalling, erosion, or cracking, can corrode easily, 3) High water/cement ratio 4) High permeability 5) Being exposed to deicing salts 5) High alkalinity in the concrete promotes corrosion.

6) **Carbonation induced corrosion** can lead to unsightly spalling on structures. Carbonation is the term used to describe the effect of carbon dioxide on a material. Carbonation of cementitious materials results in a lowering of the PH (making the material less alkaline). Therefore, fall in PH results activation of corrosion. Carbonation can happen due to high air pollution and under the soffit of underpass railway bridges.

7) **Chloride Ingress:** Corrosion of reinforcement due to chloride penetration is the most significant threat to the existing reinforced concrete. This happens where structure is

exposed to chloride-rich environment through application of de-icing salts or from the natural environment such as marine environment (Figure 3.5.b).

(a) Deflection

(b) Corrosion at pier and pier cap

Figure 3.5 – a) Deflection, b) Corrosion at pier and pier cap

3.3.2.7. Freeze-Thaw Damage

Concrete exposed to low temperatures and freeze-thaw cycles is at great risk of durability failure if appropriate attentions are not paid. The problems occur due to the freezing of the pore water in the cement paste or from ice formation in susceptible aggregates. Thus damages such as internal cracking, scaling and pop-outs can occur. During thawing ice body inside the concrete pores will create hydraulic pressure and try to find a way to relief the pressure which again results in cracking (Figure 3.6.a).

Causes: 1) Lack of air-entrained agent, 2) High water/cement ratio, 3) High permeability, 4) Poor curing and 5) Excessive finishing

3.3.2.8. Disintegration and Scaling

Disintegration can be described as the deterioration of the concrete into small fragments; individual aggregates, or loss of the surface portion of concrete. Scaling is a milder form of disintegration where the surface mortar flakes off (Figure 3.6.b).

Causes: 1) Components exposed to de-icer salts, 2) Over-vibration and poor construction practices, 3) Plastic shrinkage, 4) Lack of air-entrained agent, 5) High water/cement ratio, 6) High permeability, 7) Poor curing and 8) Excessive finishing

(a)

(b)

Figure 3.6 – a) Freeze and Thaw at deck surface, b) Disintegration and Severe Scaling on bridge concrete barrier wall

3.3.2.9. Efflorescence

White crystallized deposits on surface of concrete are known as efflorescence, which usually noted near hairline or thin cracks and is typically not a structural problem.

Causes: 1) Formed by water and salt seeping through the pores or thin cracks in the concrete. When water evaporates, it leaves behind some minerals that have been leached from the soil, fill, or concrete; 2) Inadequate drainage behind the wall (Figure 3.7.a).

3.3.2.10. Alkali-Aggregate Reaction

It is known as “concrete cancer”. It has two forms *alkali-silica reaction* or *alkali-carbonate reaction*. Reaction of some aggregates with the alkalis in cement cause a highly expansive alkali-silica gel. This reaction generally creates expansion in concrete which results cracking such as “map cracking”, “pattern cracking” surface popouts” and “spalling”(Figure 3.7.b).

Causes: 1) Aggregates with silica materials (ASR) or from dolomitic rocks (ACR), 2) moisture, 3) plastic shrinkage, 4) poor curing, 5) alkali cement and 6) High permeability

(a)

(b)

Figure 3.7 – a) Efflorescence at fascia and beam, b) Alkali-Aggregate Reaction on deck end [13]

3.3.2.11. Sulfate Attack

Sulfates are often present in groundwater, particularly when high proportions of clay are present in the soil, and seawater has sulfates as a major constituent. There are different types of damages caused by the sulfate attack such as cracking, expansion, softening and disintegration of cement paste (Figure 3.8.a).

Causes: 1) Groundwater carrying sulfate ions rises in the concrete by capillary action. It evaporates as it approaches the evaporation point especially during wetting and drying cycles. Therefore, sulfates in penetrated groundwater will react with cement and cause cracking and expansion, 2) Salts are crystallized at the surface and it is exactly like efflorescence and results in two types of pressures: 1- crystal growth, 2- hydration pressure, 3) high permeability and 4) cement type

3.3.2.12 Microbiological induced attack

This type of deterioration is caused by biological organisms such as microbiological induced corrosion. Usually this can be seen on surfaces of bridges' sidewalks which deep cracks initiated (Figure 3.8.c).

Causes: 1) *Physical attack:* happens by growth of plants gradually in soils.

2) *Chemical Attack:* Chemical wastes can easily damage either concrete or steel structures

3) sulfur-oxidizing bacteria

3.3.2.13 Acid and chemical attack

Acid attack occurs in bridge piers and footings located in marine environments which have been affected by deposits of sewer.

Causes: 1) The main deterioration is corrosion caused by bacteria results from sewer residue penetrated in concrete; 2) Both sulfuric acid and carbonic acid are common constituents of acid ground waters. Usually these affect footing, abutment and approach slabs (Figure 3.8.b).

(a)

(b)

(c)

Figure 3.8 – a) Concrete sample destructed by Sulfate Attack [14], **b)** pylon is degraded as chemical acid attacks the lime in the concrete, exposing the aggregate [15], **c)** Microbiological induced attack on sidewalk,

3.3.3. Repair Solutions

Depends on how severe are these defects (according to the condition survey report), the designer should refer and use the relevant matrix and flowchart in the appendices of the Structure Rehabilitation Manual [8]. For example, in case of crack repair, appendix 2.F from SRM should be used to decide the repair method.

For deteriorations such as chemical attacks, the use of the proper repair material is the main concern after the proper repair method. This will limit the recurring of the deterioration. For instance, using less permeable concrete is recommended for concrete patching. Also, replacing black reinforcements with epoxy coated or stainless steels might be advised by MTO in some components of structures to avoid corrosion.

CHAPTER 4 – COMMENTARY ON MTO STRUCTURE REHABILITATION MANUAL

4.1. General

Selecting rehabilitation method is often a difficult process, which involves consideration of a large number of factors. The engineer responsible for the project should study the condition of the structure, compute life cycle cost analysis and compare the rehabilitation alternatives cost. Also the history of the existing structure should be reviewed and recorded.

MTO Structure Rehabilitation Manual is certainly one of the most useful references for rehabilitation projects. This manual has covered almost all of the important aspects of rehabilitation. As stated in Chapter 1, most of the practicing engineers without rehabilitation experience can hardly understand the illustration and the theory of this manual to design rehabilitation details and create drawings. The only gap and shortage is not having detailed sketches for each repair method to illustrate the theory for these practicing engineers. Therefore, this chapter of BRDM will fill this gap and will serve as a commentary to the Structure Rehab Manual (SRM).

Most of the common repair methods of concrete bridges from the SRM have been expanded to better explanations with relevant figures located in the appendices of the BRDM. Similar to commentary of any design code, each subsection in this chapter refers to related subsection in the SRM with the same subsection number followed by letter “C” which denotes “Commentary”. For example, subsection C2.4.2 in the BRDM describes the commentary of subsection 2.4.2 of the Structure Rehab Manual.

4.2. Significant Rehabilitation Concerns

Some aspects of the stainless steel, coated reinforcement and High Performance Concrete (HPC) will be discussed to provide a better idea of the importance of them in rehabilitation industry and their key roles in durability and service life of concrete bridges:

- **Stainless steel's** resistance to corrosion and low maintenance has made it an ideal durable material not only for commercial applications, but also for usages in concrete bridges. MTO began to use this material in the 1990's for top layer reinforcement in the bridge decks for major carrying strategic highways with 100,000 AADT or more. Also it is used in other superstructure components such as barrier walls, parapet walls, sidewalks and expansion joint dams that are exposed to direct salt splash [8] [9]. One of the disadvantages of stainless steel is being expensive.
- **Epoxy Coated Reinforcing Steel** is a method for protecting reinforcement from corrosion; however, epoxy coatings are susceptible to material handling damage, which in some cases have accelerated the corrosion process. Epoxy coatings are also costly and can increase 50% to 60% to the cost of the reinforcement. This type of reinforcement is used in locations exposed to salt-induced corrosion. In general, it can be used at top reinforcement layer of bridge decks, surfaces of curbs, sidewalks, medians, parapet and barrier walls, surfaces of abutment and pier exposed to salt-splash, ballast walls and approach slabs [9]. The usage of coated reinforcing steel can increase the durability and service life of the structure.
- **High Performance Concrete (HPC)** is a specialized series of concretes designed to provide several benefits to the reinforced concrete bridges such as early high strength, longer service life, very low permeability, ease of placement and consolidation without affecting strength. HPC is used for all bridge components with the exception of footings and some types of patch repair methods.

4.3. Commentary

The following commentaries provide additional explanations to subsections of the SRM.

C2.4.1 Patch Repairs

Patch repairs are used where extent of surface deterioration is not adequate to provide a concrete overlay or concrete cover (Figures 4.1 and 4.2). This usually happens in cases such as scaling, disintegration, corrosion, spalling and delamination that do not cover a large area.

Figure 4.1-Abutment poor condition- Severe spalling and delaminations with exposed corroded reinforcement

Figure 4.2 -Removal of vertical surfaces to prepare for patch repair

The Ministry's policy is to remove concrete in bridge decks where the corrosion potentials are more negative than **-0.35 volt**. This policy also applies to the other components which half cell test can be applied. In these areas concrete is removed to a depth of **25mm** below the first layer of reinforcing steel, where the concrete is otherwise sound, except for rebars larger than 25mm in diameter where the depth of concrete removal should be to the sound concrete only. In areas of unsound concrete, the depth of removal may extend beyond the 25mm limit until sound concrete is reached [8].

For all other concrete removals demarcated by the Contract Administrator, such as scaling, concrete shall be removed as follows: (OPSS 928.07.08.01.02)

1. To the sound concrete till an overlay of refacing is specified; or
2. To the sound concrete for a uniform depth of at least **50 mm**, when an overlay or refacing is not specified.

The removal of concrete from the top surface of a structure, to a specified depth achieved by the milling action of cutting teeth fitted to a rotating head is called **Scarifying** [10].

Prior to scarifying, all sand and debris shall be removed from the surface of the structure to be scarified. The **maximum depth** of scarifying shall be **10mm**. (OPSS 928.07.05) [10]

The perimeter of the removal area shall have a 1:1 sloped face for the full depth of the removal area. The perimeter of the removal area shall have a face perpendicular to the original concrete surface for the specified depth of the removal area (OPSS 928.07.08.01.01) [10].

If deep removal would affect the capacity of the bridge components, or result in a costly rehabilitation alternative, then it is advisable to consider another practical method that does not involve such removals [8].

Conventional concrete, silica fume shotcrete or proprietary patching materials should be used in patch repairs, depending on the size and dimensions of the repair area. High performance concrete is not recommended to apply in patch repairs, regardless of the remaining life of the bridge or its exposure condition [9]. In this manual, “normal concrete patches” is the only one covered. As it is described in subsection 2.4.1.1 of the rehabilitation manual, the minimum depth repair depends on where and how this patch is applied such as vertical or horizontal surfaces.

It should be noted that the concrete patching shall not be carried out when the air or existing concrete surface temperature is below 10°C or likely to fall below 10°C, or is above 30°C. (OPSS 930.07.06.02) [10]

Applicable Drawings:

- **BRDM-2.4.1.1-1 to BRDM-2.4.1.1-3** for “Vertical” surfaces except pier-column
- Refer to **C3.3.1** and **C3.3.2** for “Horizontal” surfaces.

C2.4.2 Concrete Refacing or Encasement

The Structure Rehabilitation Manual has covered this section in details. In general, this method can be used for most components with extensive deterioration, except deck soffit and bridge deck riding surfaces. High performance concrete can be applied in case of severe chloride exposure.

Applicable Drawing:

- **BRDM-2.4.2-1 to BRDM-2.4.2-7** for refacing wingwall / retaining wall, piercap, and pier column.
- The procedure of pier refacing is explained at **BRDM-2.4.2-5**.

C2.4.3 Concrete Overlays

Placing a layer of new concrete bonded on properly prepared concrete deck will increase the service life of that deck. All concrete surfaces against which overlay will be placed shall be abrasive blast cleaned. The abrasive blast cleaning shall be of such an extent to expose and clean the coarse aggregate and remove all dirt, laitance and hardened concrete slurry. Any oil or grease on the surface of the concrete shall be removed using hand tools. (OPSS 929.07.04)[10]

The **minimum thickness** of the overlay shall be **35mm** for the latex modified concrete overlay and **45mm** for the concrete overlay, (OPSS 930.07.04.02) [10]. Usually for normal concrete overlay the common practice is **60mm** thickness of **30MPa** and **50mm** thickness for latex modified concrete [8].

“High Performance Concrete Overlay” method is not available in current the MTO specifications and this should not be specified [9].

Applicable Drawings:

- **BRDM-2.4.5-4 to BRDM-2.4.5-6**
- **BRDM-3.3.1-1 and BRDM-3.3.1-2**

C2.4.5 Waterproofing and Asphalt Paving

Formerly applying asphalt paving was not necessary for bridges, however deteriorations of deck due to de-icing salts and moisture penetration to the naked surface of the deck caused many problems such as pot-holes, scaling, disintegration, corrosion and delamination. Asphalt paved was used to prevent the above mentioned problems, though this problem was done by applying asphalt pavement, but this again was not sufficient due to the high permeability of the asphalt; consequently, waterproofing has been added to this system. In general, it is recommended to state on the drawings “Asphalt and Waterproofing System,

90mm total” [9]. In the case of increasing the thickness of asphalt and adding concrete overlay, the evaluation of bridge is necessary.

Figure 4.3-Moderate Alligator Cracking

Applicable Drawings:

- **BRDM-2.4.5-1 to BRDM-2.4.5-6**
- **OPSD-3370.100** Bridge Deck Waterproofing-Hot applied asphalt membrane with protection board [18]
- **OPSD-3906.030** Bridge Deck Waterproofing Details at Active Wide Cracks Greater than 2mm and Construction Joints [18]

C2.4.6 Cathodic Protection

Cathodic protection (CP) has proved to be an effective tool for corrosion resistance. The theory of CP is to apply sufficient electrical current to the surface of the reinforcement so that corrosion does not occur. In order for CP to function properly the reinforcement must be continuously electrically connected; this is usually found in structures with black steel reinforcement. For structures constructed with epoxy-coated reinforcement, the reinforcement may or may not be continuous depending on the condition of the coating. If not, the reinforcement is made continuous before CP is applied. There are two types of CP systems: **impressed current**, in which an external source of AC power is required to

provide electrical current to the embedded reinforcing steel through an anode placed on the concrete surface, and **sacrificial anode systems**, in which electrical current is generated by the potential difference between the anode and reinforcing steel, and no external source of current is required. Since 1974, only impressed current systems have been installed in Ontario bridge decks. [5]

Figure 4.4 - Workers place the activated overlay of a new sacrificial anode Cathodic protection system in the North Otter Creek Bridge, Highway 9 [5]

Impressed current systems require an uninterrupted AC power supply and ongoing monitoring and maintenance if effective corrosion protection is needed for long run. This requires dedicated personnel and has significant ongoing operating costs. Three different Anode Systems are used by MTO as shown in Figure 4.5.

(a)

(b)

(c)

Figure 4.5 – Anode Systems a) Galvashield mesh anode with zinc and glass fibre mesh
b) Galvashield strip anode with zinc "chain" anode c) Galvostrip anode with zinc rods covered by a carbon fibre mesh [5]

Applicable Drawing:

- BRDM-2.4.6 Series

C2.4.11 Concrete Partial or Complete Replacement

The replacement option is always a consideration for any component in poor condition. There are different types of concrete removal according to OPSS 928.03 [10]:

1. **Concrete Removal – Full Depth** is the concrete removal that applies to the full or partial length removals of the entire thickness of curbs, sidewalks, medians, wingwalls, barrier walls, parapet walls, ballast walls and approach slabs. This also applied to localized removals extending the full thickness of slab decks and culverts.
2. **Concrete Removal – Partial Depth – Type A** is the concrete removal that applies to the top surface of decks, including removals over the round voids on post tensioned structures, the top and inside faces of concrete barrier walls, parapet walls, sidewalks, curbs and the floor slabs of culverts and tunnels.
3. **Concrete Removal – Partial Depth – Type B** is concrete removal that applies to the deck soffit and fascia of bridge decks, soffit of the top slab of culverts and tunnels, girders, diaphragms and outside face of concrete barrier walls and parapet walls.
4. **Concrete Removal – Partial Depth – Type C** is the concrete removal that differs from the above mentioned ones – partial depth – type A and B that applies to abutments, wingwalls, pier columns and caps, bearing seats, retaining walls and vertical walls of culverts and tunnels.

Applicable Drawings:

- “Full” depth removal : **BRDM-2.4-11**
- “Partial” depth removal : **BRDM-3.3.1-1, BRDM-3.3.1-2, BRDM-3.6.2-1 to BRDM-3.6.2-3 and BRDM-3.8-1**

C3.3.1 Bridge Deck Riding Surfaces

The following components are considered as bridge deck riding surfaces components in this manual:

- Decks; (See C3.3.1, C3.3.2, C3.3.3 and C3.3.4)
- Wearing Surfaces; (See C2.4.5)
- Curbs and Sidewalks; (See C3.8)
- Approach Slabs; (See C3.10)
- Drainage; (Not covered in BRDM)

Structure Rehabilitation Manual provided several useful matrix and flowcharts to choose the most suitable method of repair.

Applicable Drawings:

- **BRDM-3.3.1-1** and **BRDM-3.3.1-2** provide the cases of removal : **1)** Without scarifying , **2)** With scarifying

C3.3.2 Bridge Deck Soffit

The soffit of bridge decks may deteriorate due to carbonation, insufficient concrete cover, poor construction, vibration, corrosion and delamination (Figure 4.6).

Figure 4.6 - Very severe spalling and exposed corroded reinforcement at soffit

It should be noted that underneath the open longitudinal joint of median curb with the absence of the drainage system on the bridge deck and without any sealers, water will leak on the surface of the soffit, which will lead to corrosion of reinforcement, efflorescence and spalling of concrete (Figure 4.7).

Figure 4.7 - Very severe spalling, efflorescence and exposed corroded reinforcement under median curb joint

For soffit repair works, the designer should review the existing vertical clearance under the bridge and select a rehabilitation method that would not adversely affect the clearance for traffic, either temporarily during construction or in the permanent condition [8].

Applicable Drawing:

- BRDM-3.3.2-1

C3.3.3 Bridge Deck Fascia and Cantilever

Fascia and cantilever have different definitions based on the different types of bridges as shown on figure 4.8. Their deteriorations are caused by water drip from barrier wall and usually they do not affect the function of structure, unless in case of the poor condition, but it will have effect on aesthetic point of view.

Concrete Patches or refacing the entire concrete fascia are usually the most common repair methods. Also when the installation of new concrete barrier walls is required, replacing the fascia is suggested.

Figure 4.8 – Schematic drawing of typical fascias and cantilevers [7]

Figure 4.9 – Corrosion and longitudinal cracks along Fascia

Figure 4.10 – Spalls, longitudinal wide cracks and stains at Fascia; Severe corrosion at Steel Beam Guide Rail

Applicable Drawing:

- BRDM-3.7-2 and BRDM-3.8-7

C3.3.4 Bridge Deck Replacement Option

Depending on the deterioration of the bridge deck, the most suitable rehabilitation method for bridge deck can be selected from the SRM flow charts and matrices. In order to provide durability and longer service life for the bridge deck with high volume of traffic, bridge deck replacement would be the preferred option. This requires an in depth study of the life cycle analysis and traffic management cost. Bridge deck replacement becomes complicated for thick deck slabs such as post-tensioned decks and rigid frames mainly because of the construction staging and installation of temporary supports.

Figure 4.11-Bridge deck removal to replace with new deck at intersection of Hwy 401 and Yonge Street in North York, Ontario

Applicable Drawing:

- **BRDM-3.6.2-6 to BRDM-3.6.2-9 and BRDM-3.9-12 to BRDM-3.9-16**

C3.4 Concrete Beams, Girders and Misc. Superstructure Components

The following components are to be considered as superstructures in this manual:

- Beams and girders;
- Thick Slabs;
- Diaphragms;

Leakage from expansion joint causes spalling and corrosion at beams ends. Beams ends should be repaired as soon as signs of deterioration are visible and before the concrete cover loss gets worse and it approaches to the top surface of bearing (Figure 4.12). The replacement of beams is only recommended when there is deck replacement or beams have been deflected.

For plate girders coating can be the best solution. Also, in case of deflection in plate girders, if strengthening the plates can be sufficient there is no need to replace the deck or girders.

Figure 4.12- Severe corrosion and spalling of the end beam

Applicable Drawing:

- **BRDM-3.4 Series**

C3.5 Substructure Components

The following components are to be considered as substructures in this manual:

- Foundations (Figure 4.13b);
- Ballast wall and bearing seat (Figure 4.13b);
- Abutment, piers and pier Caps ((Figure 4.13a), and;
- Retaining walls and wingwalls ((Figure 4.13b);

Rehabilitation of foundations is not covered in this manual since methods of rehabilitation are different for each specific defect and also require detail design and evaluation of structure. Also ballast wall and bearing seats are described under subsections C3.9 and C9.3, respectively.

Figure 4.13- Schematic drawing of substructure components

C3.5.1 Abutment

An abutment is an end support of a bridge superstructure. It is used to transmit the reaction of superstructure to the foundations, to retain the earth filling and to connect the superstructure to the approach roads.

The main deteriorations inspected in abutments are spalling, corrosion and efflorescence due to water leakage from expansion joint (Figure 4.14). This can be prevented by eliminating the expansion joints. Also, with insufficient concrete cover, moisture, sulfate and chloride ions can easily penetrate into the abutment from backfill (Figure 4.15). Therefore, well-compacted backfill with proper drainage system is required.

Figure 4.14 - Spalling and corrosion in wingwall; staining and severe efflorescence in abutment wall

Figure 4.15 - Poor condition of a bridge Abutment (Yonge Street, Toronto). Severe corrosion, spalling and delaminations

Applicable Drawings:

- **BRDM-3.9-1 to BRDM-3.9-5**

C3.5.b Wingwall

Wingwall is required to retain the backfill soil. Similar to abutment to prevent any deterioration from backfill, well-compacted backfill with proper drainage system is needed. Usually deterioration due alkali-aggregate reaction (AAR) is observed which creates pattern cracking on the surface. Also water leakage from fascia will cause corrosion, efflorescence and consequently cracking adjacent to fascia (Figure 4.16). Hence most of the deteriorations occur on top portion of wingwall.

Figure 4.16- Spalling, staining and severe efflorescence in wingwall

Applicable Drawings:

- **BRDM-2.4.2-1** : Refacing Top Portion
- **BRDM-3.5-1** to **BRDM-3.5-6**, **BRDM-3.8-2** to **BRDM-3.8-4** for removal of top portion.

C3.5.3 Piers

Pier is a substructure unit that supports the spans of a multi-span superstructure at an intermediate location between its abutments

Inadequate concrete cover and water leakage from joints will cause cracking (Figures 4.17 and 4.18) and corrosion at piers. Plastic shrinkage, lack of curing and early removal of form works are the other reasons of pattern cracking occurring on pier.

As mentioned in C2.4.2, one of the repair methods is refacing the pier, especially when deterioration has happened all around the pier. The other causes of deterioration are due to structural deficiencies which are:

- Improper design of footing or poor soil type which leads to settlement
- Movement at top of pier should be predicted by using proper joints or accurate fix connection to the deck.

Applicable Drawings:

- Refacing : **BRDM-2.4.2-4 to 2.4.2-7**
- Repair : **BRDM-3.5-7 and BRDM-3.5-8**

Figure 4.17- Wide pattern cracking in rectangular pier due to reinforcement corrosion caused by the leakage of drainage pipe adjacent to the pier

Figure 4.18- Wide pattern cracking and scaling in circular pier

C3.5.4 Pier Cap

Pier cap is basically a large horizontal concrete beam on which the girders sit. It is also located at top of piers. Water dripping and leaking from the fascia (Figure 4.19) or from the joints (Figure 4.20) can cause severe spalling and corrosion. The more severe defect is caused by concentration of icicles at the bottom corners of pier cap.

Figure 4.19- Severe spalling due to water drip on pier cap

Figure 4.20-Very severe spalling and staining on pier cap

Applicable Drawings:

- Refacing pier cap : **BRDM-2.4.2-2** and **BRDM-2.4.2-3**
- Repair : **BRDM-3.5-9**

C3.6 Railing Systems and Walls

Railing Systems are located at the outermost side limits of the roadway or sidewalk, and may also be located along the median for separation of two way traffic. There are three different types of walls 1) Steel beam guide rail, 2) Parapet walls and 3) Barrier walls.

C3.6.1 Steel Beam Guide Rail

Guide rails can be divided to side (Figure 4.21) and median guide rails. Deterioration of the steel beam guide rails are due to corrosion because of the presence of moisture and salt splashing and carbonation; also, due to deformation as a cause of car collision. Railings which do not meet the current CHBDC requirements should be replaced/upgraded by either new railing or concrete barrier walls.

Figure 4.21 – Side steel beam guide rail over a timber bridge

Applicable Drawings:

- **BRDM-3.6.1** series
- **SS110-21** Railing for barrier/parapet wall
- **OPSD-900** Fencing, Guide Rails [18]

C3.6.2 Parapet Wall

Parapet Walls are rectangular reinforced concrete walls, which commonly support posts and two tube rails or other rails configurations. The most general usage of parapet walls is in sidewalks. The main deterioration is caused by corrosion of railings (Figure 4.22) or corrosion of reinforcement of parapet walls due to being located at salt splash zone (Figures 4.23 and 4.24).

Figure 4.22- Very severe section loss of old type of railing section and coating due to corrosion

Figure 4.23- Severe spalling areas on Parapet wall with exposed corroded reinforcement

Figure 4.24- Very Severe, scaling and disintegration on parapet wall

Applicable Drawings:

- **BRDM-2.4.2-1, BRDM-3.5-4 to BRDM-3.5-6, BRDM-3.6.2 series, BRDM-3.7 series, BRDM-3.8-1 to BRDM-3.8-9, BRDM-3.8-14, BRDM-3.9-6 to BRDM-3.9-16**
- **SS110-21** Railing for barrier/parapet wall
- **SS110-52** Parapet wall with railing performance level 2 [9]
- **SS110-53** Parapet wall with S/W & railing performance level 2 [9]
- **SS110-56** Parapet wall with railing – PL2 Stainless Steel Rebar [9]
- **SS110-57** Parapet wall with S/W & railing – PL2 Stainless Steel Rebar[9]
- **OPSD-3904.04** Drip Detail [18]

C3.6.3 Barrier Walls

Barrier walls are reinforced concrete walls with a sloping front face that provides a better function than straight faces (like Parapet walls) in case of vehicle collision.

As mentioned earlier, barrier walls and parapet walls are located in salt splash zones. Therefore, using stainless steel reinforcement will provide better protection against corrosion. Also, dumping snow and ice by snow plows over barrier walls causes serious deteriorations due to usages of deicing salts.

In addition, different types of deterioration occur due to water dripping from the barrier walls and railings to the fascia and soffits. There is a drip detail for barrier walls provided in the OPSD-3904.04 to prevent this problem by blocking running water from fascia to soffit.

There is a common type of cracking on barrier walls that is the widespread premature cracking (Figure 4.25). This cracking can lead to premature corrosion of the reinforcing steel and spalling of the protective concrete cover. The causes of these crackings can be *thermal stresses*, *shrinkage* due to non-uniform cement hydration and *movement of traffic* on the bridge during construction, which causes deck deflection and strain.

Figure 4.25- Cracking on the barrier wall of Vachon bridge, Laval [20]

Applicable Drawings:

- **BRDM-3.5-1 to BRDM-3.5-3 and BRDM-3.9-1 to BRDM-3.9-5**
- **SS110-21** Railing for barrier/parapet wall
- **SS110-50** Barrier wall with railing performance level 2 [9]
- **SS110-51** Barrier wall with S/W & railing performance level 2 [9]
- **SS110-54** Barrier wall with railing – PL2 Stainless Steel Rebar [9]
- **SS110-61** Barrier wall W/O railing – PL3 Stainless Steel Rebar [9]
- **SS110-62** Reinforced Concrete Median Barrier Wall on Structures Type 1 [9]
- **OPSD-3904.04** Drip Detail [18]

C3.7 Sidewalks

Figure 4.26 demonstrates sidewalk definition which should have a width of more than 1.5m and also according to the Structure Rehabilitation Manual, the height in any case of rehabilitation should be more than 150mm. Snow dumping and usage of deicers are the most obvious causes of deteriorations. This will cause scaling and disintegration of the concrete cover and with time loss of concrete cover, corrosion of exposed reinforcement will propagate at a faster rate (Figure 4.27).

Figure 4.26 – Schematic drawing of a typical sidewalk [7]

Figure 4.27- Severe scaling and disintegration due to freezing/thawing cycle and de-icer [19]

Applicable Drawing:

- BRDM-3.7-1 to BRDM-3.7-3

C3.8 Curbs and Medians

Curbs are similar to sidewalk, however their width is less than 1.5m and it is recommended to have minimum height of 150mm after any rehabilitation (Figure 4.28). Median curb width depends on the road and bridge widths and acts as a separator of the highway.

Similar to the sidewalks (Figure 4.29), snow plow blades while shoveling the roadways may hit the curb and cause longitudinal cracks along the roadway. This would facilitate the ingress of water and de-icer through cracks into the concrete; therefore, after freeze-thaw cycle severe spalling of concrete cover and corrosion of steel reinforcement occurs (Figure 4.30).

Applicable Drawing:

- **Median Curbs :** BRDM-3.6.1-7, BRDM-3.6.1-8, BRDM-3.6.1-11 to BRDM-3.6.1-15, BRDM-3.8-10 to BRDM-3.8-13 , BRDM-5.1-1 and BRDM-5.1-2
- **Side Curbs :** BRDM-3.6.2-4 to BRDM-3.6.2-9, BRDM-3.8-1 to BRDM-3.8-9 and BRDM-3.8-14
- **OPSD 600** Curb and Gutters [18]

Figure 4.28 – Schematic drawing of a typical curb [7]

Figure 4.29 – Curb in poor condition with severe concrete cover spalling, delamination, disintegration and exposed corroded reinforcement

Figure 4.30 –Severe spalling in concrete median curb with exposed corroded reinforcement

C3.9 Ballast Walls

As seen in Figure 4.32, the top thin portion of abutment is called “ballast wall”. The common defects of ballast walls are delamination, spalling and corrosion of reinforcement due to direct leakage of water and chloride ions from expansion joint to the front face, moisture penetration and sulfate attack through backfill from the back face. Loss of section gradually may affect the capacity of the wall to retain backfill. The common repair methods are eliminating expansion joints at the top of abutment and providing a better drainage system in the backfill. The common practice is reconstruction of top portion or whole section of ballast wall.

Figure 4.31 – Concrete ballast wall-Very severe delamination, spalling of concrete cover and corrosion of exposed reinforcement [7]

Applicable Drawings:

- BRDM-3.9 series

C3.10 Approach Slabs

Approach Slabs are located at each end of the structure, however, they may not be designed for some of the structures located on roads with normal traffic on gravel roads [7]. One end of the approach slab is anchored to the ballast wall or abutment wall (Figure

4.32). If approach slab is not used, because of backfill settlement and abutment movement, bump will develop adjacent to the abutment over the backfill. Approach slabs deterioration types are similar to that of the bridge decks however, more pot-holes than the bridge deck since water and sulfate ions can also penetrate easily from underground surfaces to bottom surface of approach slabs (Figure 4.33).

The new bridge design standards in Ontario provide shorter approach slabs length. 6m approach slabs shall be used on structures on all paved roads and on roads that are to be paved in the near future [9]. The old approach slabs were about 10m. For replacement of the old 10m approach slab with the new 6m one, the remaining 4m should be filled with concrete sub-base. Also as the new approach slabs are thinner than old types, the depth difference should be filled with non-shrinkable grout.

Figure 4.32- Typical details of bridge end

Figure 4.33- Typical deterioration condition of an approach slab with longitudinal crack and transversal wide crack in connection with Expansion Joint

Applicable Drawings:

- **BRDM-3.9** series
- **SS116-1** 6000 mm Approach Slab [9]

C5.1 Repairs to Damaged Steel Members

Since BRDM only focuses on concrete members, so the only defect on steel components covered in this manual is deterioration of diaphragm between plate girders. As shown in the applicable drawing BRDM-5.1 series, the concrete deteriorated diaphragm is recommended to be replaced with steel diaphragm for slab on plate girders bridges.

Applicable Drawing:

- **BRDM-5.1** series

C9.2.1 Strip Seal Joints

Strip seal expansion joints consist of a molded neoprene rubber gland locked in the cavities of two parallel steel rail sections. Strip seal expansion joints may be used when the following conditions exist:

- 1) When the length contributing to expansion is less than 20 meters, and the skew is greater than 35 degrees.
- 2) When the length contributing to expansion is greater than or equal to 20 meters and less than or equal to 75 meters, and the skew is greater than 25 degrees.

Expansion joints with loose anchorage caused by thermal stress or vehicle hitting can not provide the sufficient movement of structure due to expansion and contraction. Therefore, it is recommended to repair or replace them. Existing expansion joints without steel armouring should be replaced with an armoured joint (Figure 4.34).

Also, due to the movement of structure, the area between concrete deck and expansion joint will have transversal crack along the bridge width. Concrete deck spalling adjacent to expansion joint will occur if crack treatment was not implemented (Figure 4.35).

There has been a serious consideration by MTO for eliminating expansion joints at abutments to prevent water and de-icer leakage from top of expansion joints to bearing, beam ends and abutment. See Subsection 13.1.1 from Structural Manual [9] for the guideline of expansion joint design and assembling.

Applicable Drawings:

- **BRDM-9.2-1 , BRDM-3.6-1 series, BRDM-3.9 series**
- **Fig. 9.9.1** Longitudinal Deck Joint (Structural Manual) [9]
- **SS113-10** Strip Seal Expansion Joint Assembly For Barrier Walls [9]
- **SS113-11** Strip Seal Expansion Joint Assembly For Barrier Walls with [9]
Drainage System

- **SS113-12** Strip Seal Expansion Joint – Type “A” Details [9]
- **SS113-13** Strip Seal Expansion Joint – Type “C” Details [9]
- **SS113-15** Strip Seal Expansion Joint For Parapet Walls [9]
- **SS113-16** Strip Seal Expansion Joint Assembly For Parapet Walls with [9]
Drainage System
- **SS113-20** Modula Expansion Joint with Injection Hose System-Assembly [9]
- **SS113-21** Modula Expansion Joint with Injection Hose System-Details I [9]
- **SS113-22** Modula Expansion Joint with Injection Hose System-Details II [9]

Figure 4.34-Delamination, spalling and missing steel armourings at expansion joint

Figure 4.35-Wide longitudinal crack along both sides of expansion joint

C9.2.2 Open Joints

Open joints consist of an open gap between two adjacent bridges which the top surface of fascias might be protected by armouring. This gap is usually provided to allow the movement between the bridges. This will also allow the flow of water and debris through the joint, which usually causes corrosion and spalling of fascias and cantilevers. It is recommended to have the proper drainage system to direct the water away from the joint and replace the open joint with sealed joint.

Figure 4.36- Longitudinal open median joint with severe spalling of concrete and corrosion of reinforcing steel in the fascia of joint and soffit of the deck due water leakage

Applicable Drawings:

- BRDM-3.8.11 to BRDM-3.8.13
- BRDM-9.2-2

C9.3 Bearings

Bearings are normally located at the interface between the superstructure and substructure. In some structures bearings are not needed such as culverts and rigid frames. Bearings should have the ability to support and transfer loads from the superstructure to the supports. Bearings may corrode due to water leakage from expansion joints.

Bridge Jacking is used for replacing bearings (Figure 4.37). With different thickness of bearings and dead load of the structure, there are different types of jacking.

Figure 4.37-Jacking up the bridge for bearing replacement

Applicable Drawings:

- **BRDM-3.4** series and **BRDM-11.4** series

C11.4 Jacking

See C3.4 and C9.3 for complete details.

Applicable Drawings:

- **BRDM-11.4** series

C11.6 Utilities

Utilities such as bell ducts, which usually are located on the sidewalks and curbs, rarely corrode due to moisture and salt penetration from sidewalk unless the sidewalk concrete is permeable. However, sometimes rehabilitation of sidewalk does not include utilities ducts and it is only partial concrete patching then this should be clarified and mentioned on the drawings. Abandoned ducts on the sidewalks and curbs should be filled with grout if dowels for barrier walls are to be installed at that location.

The other issue will be replacing a light pole with the new one by paying attention to de-energizing the existing one before removal. Light pole base concrete and base plate deteriorated due to water and salt splashing from roadway.

Figure 4.38-Light Pole

Applicable Drawing:

- **BRDM-11.6**
- **OPSD-3911.000** (For light pole base reconstruction in case of concrete Parapet wall) [18]
- **OPSD-3912.000** (For light pole base reconstruction in case of concrete Barrier wall) [18]
- **SS9-15** Provision for Future Light Pole Base [9]
- **SS9-16** Retrofit Light Pole Base [9]

Note: subsections C11.50, C11.51, C11.52 and C11.53 are additional subsections to the original Structure Rehabilitation Manual.

C11.50 Temporary Protection System

Repair of the deck soffit and cantilevers require temporary protection system (Figure 4.39). This usually is shown as a dashed line on the drawings. Contractors should be responsible for installing this system.

Figure 4.39-Temporary Protection system for soffit repair [17]

Applicable Drawing:

- BRDM-11.50-1
- BRDM-11.50-2

C11.51 Installation of Debris Platform

Providing a working platform and debris protection is mandatory during the construction to prevent debris fallen to roadway (Figure 4.40). There are different systems of debris platforms and the choice of the system depends on the needs of protection. Usually designers do not provide exact details of this platform, just a general figure is sufficient.

Figure 4.40- Working and debris protection platform [16]

Applicable Drawing:

- BRDM-11.51

C11.52 Embankments Slope Protection

Slope fills or cuts in the vicinity of the structure is called *Embankments*. The main purpose of the embankments is to provide a stable change of grade between the roadway and the surrounding ground surface, streams or other roadways under the structure as shown in Figure 4.41.

Embankments may deteriorate due to erosion, piping, washout and scour. Thus, the best repair method to prevent these problems is *slope protection*. Also this will control the growth of the grass and vegetation (Figure 4.42).

Figure 4.41 – Abutment and embankment in poor condition due to water leakage from expansion joints over top and front face of abutment and also embankment. Wide cracks on embankment and corrosion cracks and stains on abutment surface.

Figure 4.42 – Concrete sloped paving

Applicable Drawings:

- **SS 116-10** Details of Concrete Slope Paving [9]
- **SS16-20** Rock Slope Protection With Berm [9]
- **SS16-21** Rock Slope Protection Without Berm[9]

C11.53 Conversion of Conventional Abutment to Integral Abutment

As mentioned earlier, due to water leakage from expansion joint severe deterioration can occur such as spalling and corrosion end of the beams, bearings, ballast walls and abutment face (Figure 4.43). This problem can be solved by converting the top portion of the conventional abutments to integral abutments.

In integral abutments, expansion joints will be installed at the end of approach slabs to provide expansion and contraction of the structure thermal changes. With the elimination of the expansion joints at top of abutments, the durability of the abutment, bearings and beams will increase.

Figure 4.43- Deterioration of end beam, abutment and bearing due to leakage from expansion joint in conventional abutment

Applicable Drawings:

- BRDM-3.9 series

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APPENDIX C2

REPAIRS AT AREAS WITH
CONCRETE COVER > 70mm

REPAIRS AT AREAS WITH
CONCRETE COVER < 70mm

LOCAL CONCRETE REPAIR DETAIL VERTICAL SURFACE (WITHOUT STEEL MESH)

LOCAL CONCRETE REPAIR DETAIL OF VERTICAL SURFACES (WITHOUT STEEL MESH)
(ABUTMENT, WINGWALLS AND RETAINING WALLS)

BRDM-2.4.1.1-1

LOCAL CONCRETE REPAIR DETAIL VERTICAL SURFACE (WITH STEEL MESH)

LOCAL CONCRETE REPAIR DETAIL OF VERTICAL SURFACES (WITH STEEL MESH)
(ABUTMENT, WINGWALLS AND RETAINING WALLS)

BRDM-2.4.1.1-2

LOCAL CONCRETE REPAIR DETAIL
FOR EXISTING REBAR NOT EXPOSED
AND CONCRETE NOT DELAMINATED

LOCAL CONCRETE REPAIR DETAIL OF VERTICAL SURFACES (FOR EXISTING REBAR NOT EXPOSED) (ABUTMENT, WINGWALLS AND RETAINING WALLS)

BRDM-2.4.1.1-3

Note:

- 1- This drawing is to be used in conjunction with BRDM-2.4.2-3.
- 2- Repair shall be carried out after deck removal, to ensure light loading on cap beam.
- 3- Follow concrete pour sequence as shown in this drawing.
- 4- (21) denotes pour sequences. (21) and (22), (23) and (24) should be apart for five days minimum.

PIER CAP BEAM REFACE 1

DIMENSIONS SHOWN IN () ARE BEFORE REFACING

TYPICAL REFACING DETAIL A

Note:

- This drawing is to be used in conjunction with BRDM-2.4.2-2

REFACING PIER CAP - SECTION AND DETAIL

BRDM-2.4.2-3

REMOVALS

NEW CONSTRUCTION

Note:
- This drawing is to be used in conjunction with BRDM-2.4.2-5, BRDM-2.4.2-6 and BRDM-2.4.2-7.

REFACING PIER COLUMN – ELEVATION

BRDM-2.4.2-4

REMOVAL AND REPAIR NOTES:

1. REMOVAL AND REPAIR OF PIER COLUMNS SHALL BE CARRIED OUT ONE PIER COLUMN AT A TIME.
2. REMOVAL TO BE STAGED SUCH THAT NOT MORE THAN ONE THIRD OF THE PERIMETER OF THE COLUMN IN ANY HORIZONTAL SECTION IS REMOVED AND REPAIRED AT ANY ONE TIME.
3. OUTLINE OF THE NEW CONCRETE FOR REPAIRS SHALL COINCIDE WITH THE OUTLINE OF THE REMOVALS.

COLUMN REFACING PROCEDURE:

1. SAWCUT AND REMOVE DELAMINATED LOOSE AND DETERIORATED CONCRETE, ABRASIVE BLAST CLEAN CONCRETE AND REINFORCING STEEL AND REPAIR WITH CONCRETE. REQUIREMENTS AND RESTRICTIONS SPECIFIED UNDER COLUMN REMOVAL AND REPAIR NOTES SHALL APPLY.
2. ROUGHEN AND BLAST CLEAN SURFACE OF COLUMN WITH NO DETERIORATION.
3. INSTALL FASTENERS AND FABRIC REINFORCEMENT.
4. FORM AND CAST NEW REFACING CONCRETE.

Note:

- This drawing is to be used in conjunction with BRDM-2.4.2-4, BRDM-2.4.2-6 and BRDM-2.4.2-7.

REFACING PIER COLUMN – NOTES

BRDM-2.4.2-5

Note:

- This drawing is to be used in conjunction with BRDM-2.4.2.4, BRDM-2.4.2.5 and BRDM-2.4.2.7.

REFACING PIER COLUMN - SECTIONS

BRDM-2.4.2-6

CONCRETE SURFACE
WITH DEEP DETERIORATION

CONCRETE SURFACE
WITH SHALLOW DETERIORATION

CONCRETE SURFACE
WITH NO SIGNIFICANT DETERIORATION

DETAIL 1-1

REFACING DETAILS FOR PIER COLUMNS

Note:

- This drawing is to be used in conjunction with BRDM-2.4.2-4, BRDM-2.4.2-5 and BRDM-2.4.2-6.

REFACING PIER COLUMN - DETAILS

BRDM-2.4.2-7

WATERPROOFING DETAILS

Note:

- See OPD-3906.02 for treatment at curbs.
- All concrete surfaces to be tack coated prior to membrane application.
- Protection board detail has been omitted for clarity.

WATERPROOFING DETAILS

BRDM-2.4.5-1

Note:

- This drawing is to be used in conjunction with BRDM-3.6.1-2 AND BRDM-3.6.1-3..

ASPHALT AND WATERPROOFING REMOVALS AND NEW CONSTRUCTION DETAILS (1)

BRDM-2.4.5-2

A **B** **REMOVAL**

(DETAIL 'B' SIMILAR EXCEPT NO WATERPROOFING SYSTEM AND SCARIFYING FOR THE APPROACH SLAB)

E

C **D** **REHABILITATED**

(DETAIL 'D' SIMILAR EXCEPT NO WATERPROOFING SYSTEM INDICATED AND CONCRETE OVERLAY FOR THE APPROACH SLAB)

Note:

- This drawing is to be used in conjunction with BRDM-3.6.1-7 and BRDM-3.6.1-8.

ASPHALT AND WATERPROOFING REMOVALS AND NEW CONSTRUCTION DETAILS (2)

BRDM-2.4.5-3

ASPHALT AND PARTIAL CONCRETE REMOVAL AT DECK

ASPHALT AND PARTIAL CONCRETE REPAIR AT DECK

ASPHALT AND PARTIAL CONCRETE REMOVAL AT DECK

Note :

- This drawing is to be used in conjunction with BRDM-2.4.5-6.

ASPHALT AND PARTIAL CONCRETE REMOVAL "AT DECK - BESIDE BARRIER WALL" (2)

BRDM-2.4.5-5

ASPHALT AND PARTIAL CONCRETE REPAIR AT DECK

Note :

- This drawing is to be used in conjunction with BRDM-2.4.5-5.

ASPHALT AND PARTIAL CONCRETE REPAIR "AT DECK - BESIDE BARRIER WALL" (2)

BRDM-2.4.5-6

REMOVALS OF EXISTING CATHODIC PROTECTION SYSTEM FROM DECK (REPAIR TO TOP OF DECK)

Note :

- This drawing is to be used in conjunction with BRDM-2.4.6-2

CATHODIC PROTECTION REMOVAL

BRDM-2.4.6-1

SCOPE OF WORK

1. ENSURE ALL POWER SUPPLY TO THE CATHODIC PROTECTION SYSTEM IS DISCONNECTED.
2. SAWCUT & REMOVE EXISTING PROBES FROM TOP OF THE DECK.
3. REMOVE ANODES, INCLUDING EPOXY ASBESTOS PASTE.
4. SAWCUT & REMOVE EXISTING FEEDER WIRES ALONG CURB & GUTTER.
5. CUT & REMOVE THE WIRES & CONDUIT FROM FULL DEPTH HOLES THRU THE DECK.
6. SCARIFY EXISTING DECK SURFACE TO A DEPTH OF **mm.
7. ABRASIVE BLAST CLEAN CONCRETE SURFACE, ENLARGE TOP OF HOLE AND FILL HOLES WITH NON SHRINK GROUT.

Note :

- This drawing is to be used in conjunction with BRDM-2.4.6-1

CATHODIC PROTECTION REMOVAL-NOTES

BRDM-2.4.6-2

CATHODIC PROTECTION CONNECTIONS – EXISTING CONDITION

Note :

- This drawing is to be used in conjunction with BRDM-2.4.6-4, BRDM-2.4.6-5 and BRDM-2.4.6-6.

CATHODIC PROTECTION RELOCATING – EXISTING CONDITION

BRDM-2.4.6-3

CATHODIC PROTECTION CONNECTIONS – RELOCATED CONDITION AT EAST SIDE

Note :

- This drawing is to be used in conjunction with BRDM-2.4.6-3, BRDM-2.4.6-5 and BRDM-2.4.6-6.

CATHODIC PROTECTION RELOCATING – SECTIONS (1)

BRDM-2.4.6-4

Note :

- This drawing is to be used in conjunction with BRDM-2.4.6-3, BRDM-2.4.6-4 and BRDM-2.4.6-6.

CATHODIC PROTECTION RELOCATING – SECTIONS (2)

BRDM-2.4.6-5

NOTE:

1. DO NOT COMMENCE SAWCUTTING AND REMOVAL OF PARAPET WALLS UNLESS RELOCATION OF CATHODIC PROTECTION CONDUITS AND JUNCTION BOXES ARE COMPLETED AND RE-COMMISSIONED. REFER TO THE SPECIFICATION FOR TECHNICAL REQUIREMENTS FOR SPLICING OF DISTRIBUTION BARS AND CABLES.
2. TO EXPOSE EXISTING WIRING, CHIP OUT THE EXISTING JUNCTION BOX IN THE WALL CAREFULLY AND FOLLOW THE WIRING DOWN INTO THE SLAB. DO NOT DAMAGE THE EXISTING CABLES INSULATION.
3. ALL CRITICAL STAGES OF CATHODIC PROTECTION CONNECTION RE-ROUTING WORK SHALL BE INSPECTED BY A CORROSION SPECIALIST BEFORE PROCEEDING FURTHER.

RECOMMENDED CONSTRUCTION SEQUENCE:

1. DE-COMMISSION THE EXISTING CATHODIC PROTECTION SYSTEM.
2. LOCATE THE DISTRIBUTION BARS OF THE CATHODIC PROTECTION SYSTEM AND LOCALLY REMOVE CONCRETE PROTECTION SYSTEM AND LOCALLY REMOVE CONCRETE TO EXPOSE THE WIRING.
3. CORE 64 mm DIAMETER HOLES THROUGH THE DECK, INSTALL 50 mm I.D. PVC PIPE AND GROUT WITH EPOXY.
4. EXTEND DISTRIBUTION BARS AND CABLES AND RE-ROUTE TO UNDERSIDE OF THE DECK.
5. PLUG AND SEAL THE PVC PIPE WITH SILICONE SEAL.
6. INSTALL THE NEW JUNCTION BOX AND CONDUITS AND COMPLETE THE NEW WIRING AND CONNECTION.
7. RE-COMMISSION THE CATHODIC PROTECTION SYSTEM. TEST THE SYSTEM UNDER MINISTRY'S SUPERVISION.
8. UPON SUCCESSFUL RE-COMMISSIONING OF THE CATHODIC PROTECTION SYSTEM, PATCH REPAIR CURB AT THE DISTRIBUTION BAR LOCATION WITH NEW CONCRETE.
9. DISMANTLE EXISTING JUNCTION BOXES AND CONDUITS ON THE PARAPET WALL.
10. PROCEED WITH PARAPET WALL REMOVAL AND NORMAL STRUCTURAL REHABILITATION.

Note :

- This drawing is to be used in conjunction with BRDM-2.4.6-3, BRDM-2.4.6-4 and BRDM-2.4.6-5.

CATHODIC PROTECTION RELOCATING – NOTES

BRDM-2.4.6-6

FULL DEPTH DECK REPAIR DETAIL

APPENDIX C3

TYPICAL PARTIAL DEPTH CONCRETE REMOVAL
DECK SURFACE (OR APPROACH SLAB SURFACE)

WITHOUT SCARIFYING

TYPICAL PARTIAL DEPTH CONCRETE REPAIR
DECK SURFACE (OR APPROACH SLAB SURFACE)

TYPICAL PLAN-REMOVAL DETAIL

Note:

- 1- This drawing is to be used in conjunction with BRDM-3.3.1-2.
- 2- For Concrete overlay thickness less than 100mm but greater than 60mm use galvanized steel MW 51.6 x MW 51.6 placed at middepth.
- 3- Where indicated on drawing that a sawcut is required to delineate areas of concrete removal, the sawcut shall be 25mm deep or to the first layer of reinforcing steel, whichever is less.

BRIDGE DECK/APPROACH SLAB RIDING SURFACE REMOVAL AND REPAIR
“WITHOUT SCARIFYING”

BRDM-3.3.1-1

**TYPICAL PARTIAL DEPTH CONCRETE REMOVAL
DECK SURFACE (OR APPROACH SLAB SURFACE)**

**TYPICAL PARTIAL DEPTH CONCRETE REPAIR
(FOR CONCRETE OVERLAY = < 60mm)
DECK SURFACE (OR APPROACH SLAB SURFACE)**

**TYPICAL PARTIAL DEPTH CONCRETE REPAIR
(FOR CONCRETE OVERLAY 60mm TO 100mm THICK)
DECK SURFACE (OR APPROACH SLAB SURFACE)**

WITH SCARIFYING

Note:

- 1- For Concrete overlay thickness less than 100mm but greater than 60mm use galvanized steel MW 51.6 x MW 51.6 placed at mid-depth.
- 2- Wire fabric shall be hot dipped galvanized in accordance with CSA standard G189.
- 3- This drawing is to be used in conjunction with BRDM-3.3.1-1.

BRIDGE DECK/APPROACH SLAB RIDING SURFACE REMOVAL AND REPAIR
“WITH CARIFYING”

BRDM-3.3.1-2

REMOVAL

DECK SOFFIT REPAIRS

REPAIR

TYPICAL REPAIR DETAIL FOR SOFFIT (TYPE "B")

BRDM-3.3.2-1

Note:

- See drawing BRDM 3.3.3-1 for repair of fascia at “Rigid Frame”.

TYPICAL REPAIR DETAIL FOR FASCIA (TYPE “B”)	BRDM-3.3.3-1

Note:
- This drawing is to be used in conjunction with BRDM-3.4-2, BRDM-3.4-3, BRDM-11.4-1 and BRDM-11.4-2.

BOX GIRDER REPAIR

BRDM-3.4-1

CONSTRUCTION SEQUENCE FOR THE REPAIR OF BOX GIRDER-END SOFFIT AT THE ABUTMENTS AND BEARING REPLACEMENT:

1. REMOVE DETERIORATED CONCRETE AND REPAIR BOX GIRDERS END SOFFITS AT ABUTMENTS OUTSIDE BEARING AREA (AREA 'C') AND REMOVE DETERIORATED CONCRETE AND REPAIR VERTICAL FACES OF ABUTMENT WALLS AT LOCATION OF JACKING PEDESTALS AS DIRECTED BY THE CONTRACT ADMINISTRATOR. REMOVAL AND REPAIR OF THE DETERIORATED CONCRETE SHALL EXTEND MIN.100mm BEYOND JACKING BEARING PLATE.
2. INSTALL JACKING PEDESTALS AND JACKS FOR ENTIRE WIDTH OF THE BRIDGE AT ABUTMENTS.
3. WHEN THE CONCRETE AT BOX GIRDER SOFFITS (AREA "C") HAS ATTAINED A COMPRESSIVE STRENGTH OF 25 MPa JACK UP THE ENTIRE WIDTH OF THE DECK SIMULTANEOUSLY BY 6mm TO 10mm AND TRANSFER THE GIRDER LOADING TO THE TEMPORARY SUPPORTS. REMOVE EXISTING BEARINGS.
4. THE CONTRACTOR HAS TO ENSURE THAT UNEQUAL JACKING ACROSS THE WIDTH OF DECK DOES NOT OCCUR.
5. REMOVE TOP PORTION OF BEARING SEAT AREAS (AREA 'B') AT LOCATIONS AS DIRECTED BY THE CONTRACT ADMINISTRATOR FOR THE ENTIRE WIDTH OF THE BRIDGE, AS PER DETAILS SHOWN ON THE DRAWINGS. CONTRACTOR SHALL ENSURE NO DAMAGE OCCURS TO THE EXISTING REINFORCING STEEL.
6. REMOVE ALL DETERIORATED CONCRETE FROM BOX GIRDERS END SOFFIT AT BEARING AREA (AREA 'D') AS DIRECTED BY THE CONTRACT ADMINISTRATOR. CONTRACTOR SHALL ENSURE NO DAMAGE OCCURS TO THE EXISTING PRESTRESSING STRANDS AND REINFORCING STEEL:-
7. CARRY OUT BOX GIRDER-END SOFFIT REPAIR AT BEARING AREA (AREA 'D'), AS PER DETAIL SHOWN ON THE DRAWING.

Note:

- This drawing is to be used in conjunction with BRDM-3.4-1 , BRDM-3.4-3 , BRDM-11.4-1 and BRDM-11.4-2.

BOX GIRDER REPAIR – NOTES (1)

BRDM-3.4-2

CONSTRUCTION SEQUENCE FOR THE REPAIR OF BOX GIRDER-END SOFFIT AT THE ABUTMENTS AND BEARING REPLACEMENT (CONT'D):

8. RECONSTRUCT BEARING SEAT (AREA 'B') TO ITS ORIGINAL SHAPE AND ELEVATION.
9. WHEN THE CONCRETE IN THE BEARING SEATS AND BOX GIRDER SOFFITS HAS ATTAINED A COMPRESSIVE STRENGTH OF 25 MPa, INSTALL NEW BEARING PADS AT ABUTMENTS AND REMOVE THE TEMPORARY SUPPORTS. LOWER THE DECK AND TRANSFER THE LOAD BACK TO THE BEARINGS.
10. FOLLOWING THE STAGED REMOVAL OF EXISTING ABUTMENT DIAPHRAGMS REMOVE DETERIORATED CONCRETE AND REPAIR WITH CONCRETE NON-BEARING AREAS AT TOP OF ABUTMENTS (AREA 'A') FOR THE ENTIRE WIDTH OF THE BRIDGE.
11. REMOVE JACKING PEDESTALS INCLUDING ANCHORS INTO ABUTMENT WALLS, REPAIR HOLES WITH APPROVED GROUT FROM THE MTO DSM LIST AND REPAIR CONCRETE FACE OF ABUTMENTS.

Note:

- This drawing is to be used in conjunction with BRDM-3.4-1, BRDM-3.4-2, BRDM-11.4-1 and BRDM-11.4-2.

BOX GIRDER REPAIR – NOTES (2)

BRDM-3.4-3

GIRDER END REPAIRS - ELEVATION

Note:
- This drawing is to be used in conjunction with BRDM-3.4-5, BRDM-3.4-6, BRDM-11.4-3 and BRDM-11.4-4.

CPCI GIRDER REPAIR

BRDM-3.4-4

CONSTRUCTION SEQUENCE FOR THE REPAIR OF GIRDER-END SOFFIT AT THE ABUTMENTS AND BEARING REPLACEMENT:

1. REMOVE DETERIORATED CONCRETE AND REPAIR GIRDERS END SOFFITS AT ABUTMENTS OUTSIDE BEARING AREA (AREA 'C') AND REMOVE DETERIORATED CONCRETE AND REPAIR VERTICAL FACES OF ABUTMENT WALLS AT LOCATION OF JACKING PEDESTALS AS DIRECTED BY THE CONTRACT ADMINISTRATOR. REMOVAL AND REPAIR OF THE DETERIORATED CONCRETE SHALL EXTEND MIN. 100mm BEYOND JACKING BEARING PLATE.
2. INSTALL JACKING PEDESTALS AND JACKS FOR ENTIRE WIDTH OF THE BRIDGE AT ABUTMENTS.
3. WHEN THE CONCRETE AT GIRDER SOFFITS (AREA "C") HAS ATTAINED A COMPRESSIVE STRENGTH OF 25 MPa JACK UP THE ENTIRE WIDTH OF THE DECK SIMULTANEOUSLY BY 6mm TO 10mm AND TRANSFER THE GIRDER LOADING TO THE TEMPORARY SUPPORTS. REMOVE EXISTING BEARINGS.
4. THE CONTRACTOR HAS TO ENSURE THAT UNEQUAL JACKING ACROSS THE WIDTH OF DECK DOES NOT OCCUR.
5. REMOVE TOP PORTION OF BEARING SEAT AREAS (AREA 'B') AT LOCATIONS AS DIRECTED BY THE CONTRACT ADMINISTRATOR FOR THE ENTIRE WIDTH OF THE BRIDGE, AS PER DETAILS SHOWN ON THE DRAWINGS. CONTRACTOR SHALL ENSURE NO DAMAGE OCCURS TO THE EXISTING REINFORCING STEEL.
6. REMOVE ALL DETERIORATED CONCRETE FROM GIRDERS END SOFFIT AT BEARING AREA (AREA 'D') AS DIRECTED BY THE CONTRACT ADMINISTRATOR. CONTRACTOR SHALL ENSURE NO DAMAGE OCCURS TO THE EXISTING PRESTRESSING STRANDS AND REINFORCING STEEL.
7. CARRY OUT GIRDER-END SOFFIT REPAIR AT BEARING AREA (AREA 'D'), AS PER DETAIL SHOWN ON THE DRAWING.
8. RECONSTRUCT BEARING SEAT (AREA 'B') TO ITS ORIGINAL SHAPE AND ELEVATION.

Note:

- This drawing is to be used in conjunction with BRDM-3.4-4, BRDM-3.4-6, BRDM-11.4-3 and BRDM-11.4-4.

CPCI GIRDER REPAIR – NOTES (1)

BRDM-3.4-5

CONSTRUCTION SEQUENCE FOR THE REPAIR OF GIRDER-END SOFFIT AT THE ABUTMENTS AND BEARING REPLACEMENT (CONT'D):

9. WHEN THE CONCRETE IN THE BEARING SEATS AND GIRDER SOFFITS HAS ATTAINED A COMPRESSIVE STRENGTH OF 25 MPa, INSTALL NEW BEARING PADS AT ABUTMENTS AND REMOVE THE TEMPORARY SUPPORTS. LOWER THE DECK AND TRANSFER THE LOAD BACK TO THE BEARINGS.
10. FOLLOWING THE STAGED REMOVAL OF EXISTING ABUTMENT DIAPHRAGMS REMOVE DETERIORATED CONCRETE AND REPAIR WITH CONCRETE NON-BEARING AREAS AT TOP OF ABUTMENTS (AREA 'A') FOR THE ENTIRE WIDTH OF THE BRIDGE.
11. REMOVE JACKING PEDESTALS INCLUDING ANCHORS INTO ABUTMENT WALLS, REPAIR HOLES WITH APPROVED GROUT FROM THE MTO DSM LIST AND REPAIR CONCRETE FACE OF ABUTMENTS.

Note:

- This drawing is to be used in conjunction with BRDM-3.4-4, BRDM-3.4-5, BRDM-11.4-3 and BRDM-11.4-4.

CPCI GIRDER REPAIR – NOTES (2)

BRDM-3.4-6

REMOVAL DETAIL FOR BEAM AND SOFFIT

REPAIR DETAIL FOR BEAM AND SOFFIT

Note:

- This drawing is to be used in conjunction with BRDM-3.4-8.

T-BEAM WEB REPAIR

BRDM-3.4-7

TYPICAL T-BEAM FLANGE REPAIR DETAIL

Note:

- 1- Repair to existing T-Beam flanges including haunch area shall be full depth repair.
- 2- Repair to the tip of T-Beam flange. The minimum dimension of concrete removal shall be 200mm in the transverse direction.
- 3- This drawing is to be used in conjunction with BRDM-3.4-7.

T-BEAM FLANGE REPAIR

BRDM-3.4-8

DECK END REPAIRS - SECTION

DECK END REPAIRS - ELEVATION

Note:
- This drawing is to be used in conjunction with BRDM-3.4-10, BRDM-3.4-11, BRDM-11.4-5 and BRDM-11.4-6.

CONSTRUCTION SEQUENCE FOR THE REPAIR OF DECK-END SOFFIT AT THE ABUTMENTS (REPAIR WORK TO DECK-END SOFFIT AT THE PIERS SIMILAR) AND BEARING REPLACEMENT:

1. REMOVE DETERIORATED CONCRETE AND REPAIR CONCRETE END SOFFIT OUTSIDE BEARING AREA (AREA 'A') AND REMOVE DETERIORATED CONCRETE AND REPAIR VERTICAL FACES OF ABUTMENT WALLS AT LOCATION OF JACKING PEDESTALS AS DIRECTED BY THE CONTRACT ADMINISTRATOR. REMOVAL AND REPAIR OF THE DETERIORATED CONCRETE SHALL BE MIN. 100mm BEYOND THE JACKING BEARING PLATE.
2. INSTALL JACKING PEDESTALS, JACKS AND TEMPORARY SUPPORTS FOR ENTIRE WIDTH OF THE BRIDGE ABUTMENTS.
3. WHEN THE CONCRETE AT DECK SOFFITS (AREA "A") HAS ATTAINED A COMPRESSIVE STRENGTH OF 25 MPa JACK UP THE ENTIRE WIDTH OF THE DECK SIMULTANEOUSLY BY 6mm TO 8mm (INITIAL JACKING) AND TRANSFER THE LOADING TO THE TEMPORARY SUPPORTS. REMOVE EXISTING BEARING PADS.
4. REMOVE TOP PORTION OF BEARING SEAT AREAS (AREA 'B') AT ABUTMENTS AS DIRECTED BY THE CONTRACT ADMINISTRATOR FOR THE ENTIRE WIDTH OF THE BRIDGE, AS PER DETAILS SHOWN ON THE DRAWINGS. CONTRACTOR SHALL ENSURE NO DAMAGE OCCURS TO THE EXISTING REINFORCING STEEL.
5. REMOVE ALL DETERIORATED CONCRETE FROM THE DECK END SOFFIT AT BEARING AREA (AREA 'C') AS DIRECTED BY THE CONTRACT ADMINISTRATOR. CONTRACTOR SHALL ENSURE NO DAMAGE OCCURS TO THE EXISTING PRESTRESSING STRANDS AND REINFORCING STEEL.
6. CARRY OUT DECK-END SOFFIT REPAIR AT BEARING AREA (AREA 'C'), AS PER DETAIL SHOWN ON THE DRAWING.
7. RECONSTRUCT BEARING SEAT AT ABUTMENTS (AREA 'B') TO ITS ORIGINAL SHAPE AND ELEVATION.

Note:

- This drawing is to be used in conjunction with BRDM-3.4-9, BRDM-3.4-11, BRDM-11.4-5 and BRDM-11.4-6.

POST-TENSIONED BRIDGE DECK END REPAIR (CASE "A") – NOTES (1)

BRDM-3.4-10

CONSTRUCTION SEQUENCE FOR THE REPAIR OF DECK-END SOFFIT AT THE ABUTMENTS (REPAIR WORK TO DECK-END SOFFIT AT THE PIERS SIMILAR) AND BEARING REPLACEMENT (CONT'D):

8. WHEN THE CONCRETE IN THE BEARING SEATS AND DECK SOFFITS HAS ATTAINED A COMPRESSIVE STRENGTH OF 25 MPa, ADDITIONALLY JACK UP THE ENTIRE WIDTH OF THE DECK SIMULTANEOUSLY, INSTALL NEW BEARING PADS AT ABUTMENTS AND LOWER THE DECK AND TRANSFER THE LOAD BACK TO THE BEARINGS AND REMOVE THE TEMPORARY SUPPORTS.
9. REMOVE JACKING PEDESTALS INCLUDING ANCHORS INTO CONCRETE, REPAIR HOLES WITH APPROVED GROUT FROM THE MTO DSM LIST AND REPAIR CONCRETE FACE OF ABUTMENTS.

Note:

- This drawing is to be used in conjunction with BRDM-3.4-9, BRDM-3.4-10, BRDM-11.4-5 and BRDM-11.4-6.

POST-TENSIONED BRIDGE DECK END REPAIR (CASE "A") – NOTES (2)

BRDM-3.4-11

DECK END REPAIRS - SECTION

DECK END REPAIRS - ELEVATION

Note:

- This drawing is to be used in conjunction with BRDM-3.4-13, BRDM-3.4-14, BRDM-11.4-7, BRDM-11.4-8 and BRDM-11.4-9.

POST-TENSIONED BRIDGE DECK END REPAIR (CASE "B")

BRDM-3.4-12

CONSTRUCTION SEQUENCE FOR THE REPAIR OF DECK-END SOFFIT AT THE ABUTMENTS (REPAIR WORK TO DECK-END SOFFIT AT THE PIERS SIMILAR) AND BEARING REPLACEMENT

1. REMOVE DETERIORATED CONCRETE AND REPAIR DECK END SOFFIT OUTSIDE BEARING AREA (AREA 'C') AND REMOVE DETERIORATED CONCRETE AND REPAIR VERTICAL FACES OF ABUTMENT WALLS AND PIER CAPS AT LOCATION OF JACKING PEDESTALS AS DIRECTED BY THE CONTRACT ADMINISTRATOR. REMOVAL AND REPAIR OF THE DETERIORATED CONCRETE SHALL BE MIN. 100mm BEYOND THE JACKING BEARING PLATE.
2. INSTALL JACKING PEDESTALS, JACKS AND TEMPORARY SUPPORTS FOR ENTIRE WIDTH OF THE BRIDGE AT LOCATIONS INDICATED ON THE DRAWINGS.
3. WHEN THE CONCRETE AT DECK SOFFITS (AREA "C") HAS ATTAINED A COMPRESSIVE STRENGTH OF 25 MPa JACK UP THE ENTIRE WIDTH OF THE DECK SIMULTANEOUSLY BY 6mm (INITIAL JACKING) AND TRANSFER THE GIRDER LOADING TO THE TEMPORARY SUPPORTS. REMOVE EXISTING BEARING PADS.
4. REMOVE TOP PORTION OF BEARING SEAT AREAS (AREA 'B') AT LOCATIONS AS DIRECTED BY THE CONTRACT ADMINISTRATOR FOR THE ENTIRE WIDTH OF THE BRIDGE, AS PER DETAILS SHOWN ON THE DRAWINGS. CONTRACTOR SHALL ENSURE NO DAMAGE OCCURS TO THE EXISTING REINFORCING STEEL.
5. REMOVE ALL DETERIORATED CONCRETE FROM THE DECK END SOFFIT AT BEARING AREA (AREA 'D') AS DIRECTED BY THE CONTRACT ADMINISTRATOR. CONTRACTOR SHALL ENSURE NO DAMAGE OCCURS TO THE EXISTING PRESTRESSING STRANDS AND REINFORCING STEEL.
6. CARRY OUT DECK-END SOFFIT REPAIR AT BEARING AREA (AREA 'D'), AS PER DETAIL SHOWN ON THE DRAWING.

Note:

- This drawing is to be used in conjunction with BRDM-3.4-12, BRDM-3.4-14, BRDM-11.4-7, BRDM-11.4-8 and BRDM-11.4-9.

POST-TENSIONED BRIDGE DECK END REPAIR (CASE "B") – NOTES (1)

BRDM-3.4-13

CONSTRUCTION SEQUENCE FOR THE REPAIR OF DECK-END SOFFIT AT THE ABUTMENTS (REPAIR WORK TO DECK-END SOFFIT AT THE PIERS SIMILAR) AND BEARING REPLACEMENT (CONT'D):

7. CONSTRUCT BEARING SEAT (AREA 'B') TO ITS ORIGINAL SHAPE AND ELEVATION. WHEN THE CONCRETE IN THE BEARING SEATS AND DECKR SOFFITS HAS ATTAINED A COMPRESSIVE STRENGTH OF 25 MPa, ADDITIONALLY JACK UP THE ENTIRE WIDTH OF THE DECK SIMULTANEOUSLY, INSTALL NEW BEARING PADS AT ABUTMENTS AND PIERS AND REMOVE THE TEMPORARY SUPPORTS. LOWER THE DECK AND TRANSFER THE LOAD BACK TO THE BEARINGS.
8. FOLLOW THE REMOVAL OF EXISTING ABUTMENT DIAPHRAGMS WITH CONCRETE REPAIR, NON-BEARING AREAS AT TOP OF ABUTMENTS (AREA 'A') FOR THE ENTIRE WIDTH OF THE BRIDGE.
9. REMOVE JACKING PEDESTALS INCLUDING ANCHORS INTO CONCRETE, REPAIR HOLES WITH APPROVED GROUT FROM THE MTO DSM LIST AND REPAIR CONCRETE FACE OF ABUTMENTS/PIER CAPS.

Note:

- This drawing is to be used in conjunction with BRDM-3.4-12, BRDM-3.4-13, BRDM-11.4-7, BRDM-11.4-8 and BRDM-11.4-9.

POST-TENSIONED BRIDGE DECK END REPAIR (CASE "B") – NOTES (2)

BRDM-3.4-14

DECK END REPAIRS - SECTION

Note:

- This drawing is to be used in conjunction with BRDM-3.4-16, BRDM-3.4-17, BRDM-11.4-10 and BRDM-11.4-11.

App. C3-19

CONSTRUCTION SEQUENCE FOR BEARING REPLACEMENT AT ABUTMENTS:

1. REMOVE DETEIORATED CONCRETE AND REPAIR CONCRETE END SOFFIT OUTSIDE BEARING AREA (AREA 'A') AND REMOVE DETERIORATED CONCRETE AND REPAIR VERTICAL FACES OF ABUTMENT WALLS AT LOCATION OF JACKING PEDESTALS AS DIRECTED BY THE CONTRACT ADMINISTRATOR. REMOVAL AND REPAIR OF THE DETERIORATED CONCRETE SHALL BE MIN. 100mm BEYOND THE JACKING BEARING PLATE.
2. INSTALL JACKING PEDESTALS AND JACKS AT THE BRIDGE ABUTMENTS.
3. WHEN THE CONCRETE AT DECK SOFFITS (AREA 'A') HAS ATTAINED A COMPRESSIVE STRENGTH OF 25 MPa JACK UP THE ENTIRE WIDTH OF THE DECK SIMULTANEOUSLY BY 6mm TO 8mm (INITIAL JACKING) AND TRANSFER THE LOADING TO THE TEMPORARY SUPPORTS. REMOVE EXISTING BEARING PADS.
4. REMOVE TOP PORTION OF BEARING SEAT AREAS (AREA 'B') TO THE LIMITS SHOWN ON THE DRAWINGS. CONTRACTOR SHALL ENSURE NO DAMAGE OCCURS TO THE EXISTING REINFORCING STEEL NOT DESIGNATED FOR REMOVAL.
5. ROUGHEN CONCRETE AT THE DECK END SOFFIT AT BEARING AREA (AREA 'C') AND INSTALL DOWELS INTO DECK. THE CONTRACTOR SHALL ENSURE NO DAMAGE OCCURS TO THE EXISTING POST-TENSIONING STRANDS AND REINFORCING STEEL.
6. CONSTRUCT NEW BEARINGS SEATS AT DECK SOFFIT (AREA 'C') AS PER DETAILS SHOWN ON THE DRAWINGS BY FORM AND PUMP METHOD. SOFFIT OF BEARING SEAT AT DECK TO BE CAST LEVEL.

Note:

- This drawing is to be used in conjunction with BRDM-3.4-15, BRDM-3.4-17, BRDM-11.4-10 and BRDM-11.4-11.

POST-TENSIONED BRIDGE DECK END REPAIR (CASE "C") – NOTES (1)

BRDM-3.4-16

CONSTRUCTION SEQUENCE FOR BEARING REPLACEMENT AT ABUTMENTS (CONT'D):

- 7. RECONSTRUCT BEARING SEAT AT ABUTMENTS (AREA 'B') AS PER DETAILS SHOWN ON THE DRAWINGS. TOP OF BEARING SEAT AT ABUTMENTS TO BE CAST LEVEL.
- 8. WHEN THE CONCRETE IN THE BEARING SEATS AND DECK SOFFITS HAS ATTAINED A COMPRESSIVE STRENGTH OF 25 MPa, ADDITIONALLY JACK UP THE ENTIRE WIDTH OF THE DECK SIMULTANEOUSLY, INSTALL NEW BEARING PADS AT ABUTMENTS AND LOWER THE DECK AND TRANSFER THE LOAD BACK TO THE BEARINGS. REMOVE THE TEMPORARY SUPPORTS.
- 9. REMOVE JACKING PEDESTALS INCLUDING ANCHORS INTO CONCRETE, REPAIR HOLES WITH APPROVED GROUT FROM THE MTO DSM LIST AND REPAIR CONCRETE FACES OF ABUTMENTS.

Note:

- This drawing is to be used in conjunction with BRDM-3.4-15, BRDM-3.4-16, BRDM-11.4-10 and BRDM-11.4-11.

POST-TENSIONED BRIDGE DECK END REPAIR (CASE "C") – NOTES (2)		BRDM-3.4-17
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PLAN - ABUTMENT

NOTE: DECK SLAB NOT SHOWN FOR CLARITY

Note:

- 1- For typical sections '1', '2' and '3' see drawings BRDM 3.9 series.
- 2- For typical section '4' see drawings BRDM 3.6 series.
- 3- This drawing is to be used in conjunction with BRDM-3.5-2 and BRDM-3.5-3.

TOP OF ABUTMENT AND WINGWALL REMOVAL-PLAN (WITH CONCRETE BARRIER WALL)

BRDM-3.5-1

Note:

- This drawing is to be used in conjunction with BRDM-3.5-1 and BRDM-3.5-3.

**TOP OF ABUTMENT AND WINGWALL REMOVAL-SECTIONS
(WITH CONCRETE BARRIER WALL)**

BRDM-3.5-2

5

6

Note:

- This drawing is to be used in conjunction with BRDM-3.5-1 and BRDM-3.5-2.

**TOP OF ABUTMENT AND WINGWALL REPAIR-SECTIONS
(WITH CONCRETE BARRIER WALL)**

BRDM-3.5-3

Note:

- 1- For typical sections '1', '2' and '3' see drawings BRDM 3.9 series.
- 2- For typical section '4' see drawings BRDM 3.6 series.
- 3- This drawing is to be used in conjunction with BRDM-3.5-5 and BRDM-3.5-6.

TOP OF ABUTMENT AND WINGWALL REMOVAL-PLAN (WITH CONCRETE PARAPET WALL)

BRDM-3.5-4

4

5

Note:

- This drawing is to be used in conjunction with BRDM-3.5-4 and BRDM-3.5-6.

**TOP OF ABUTMENT AND WINGWALL REMOVAL-SECTIONS
(WITH CONCRETE PARAPET WALL)**

BRDM-3.5-5

Note:

- This drawing is to be used in conjunction with BRDM-3.5-4 and BRDM-3.5-5.

**TOP OF ABUTMENT AND WINGWALL REPAIR-SECTIONS
(WITH CONCRETE PARAPET WALL)**

BRDM-3.5-6

ELEVATION

REPAIRS AT AREAS WITH
CONCRETE COVER > 70mm

REPAIRS AT AREAS WITH
CONCRETE COVER < 70mm

TYPICAL REPAIR DETAILS FOR PIER COLUMNS

Note:

- This drawing is to be used in conjunction with BRDM-3.5-8.

PIER COLUMNS REMOVAL AND REPAIR

BRDM-3.5-7

PIER COLUMNS REMOVAL AND REPAIR NOTES:

1. REMOVAL AND REPAIR SHALL BE STAGED SUCH THAT NO MORE THAN ONE THIRD OF THE PERIMETER OF THE COLUMN IN ANY HORIZONTAL SECTION IS REMOVED AND REPAIRED AT A TIME.
2. IF STAGED REPAIR OF PIER COLUMNS IS REQUIRED, LAP REMOVAL AND REPAIR AREAS BY 100mm.
3. REMOVALS SHALL NOT COMMENCE UNTIL CONCRETE PLACED IN PREVIOUS REPAIRED AREAS HAS REACHED A MINIMUM STRENGTH OF 25MPa.
4. REMOVAL AND REPAIR OF PIER COLUMNS SHALL BE ALTERNATED SUCH THAT REMOVAL AND REPAIR AT TWO ADJACENT COLUMNS SHALL NOT BE CARRIED OUT AT THE SAME TIME.
5. SAWCUT TO BE 25mm DEEP OR TO THE FIRST LAYER OF REBARS, WHICHEVER IS LESS.

Note:

- This drawing is to be used in conjunction with BRDM-3.5-7.

PIER COLUMNS REMOVAL AND REPAIR - NOTES

BRDM-3.5-8

REMOVAL

REPAIR

TYPICAL REPAIR DETAIL FOR TOP OF PIER CAP

Note:

- For vertical surface of Pier Cap repair details see BRDM-2.4.1.1-1, BRDM-2.4.1.1-2 and BRDM-2.4.1.1-3.
- For underside of Pier Cap repair details see BRDM-3.3.2-1.

PIER CAP TYPICAL REPAIR DETAIL

BRDM-3.5-9

WITHOUT LONGITUDINAL EXPANSION JOINT

WITH LONGITUDINAL EXPANSION JOINT REMOVAL

SBGR ON DECK - REMOVAL

Note:

- This drawing is to be used in conjunction with BRDM-3.6.1-1.

STEEL BEAM GUIDE RAIL REMOVAL ON "RIGID FRAME" BRIDGE DECK

BRDM-3.6.1-1

Note:

- This drawing is to be used in conjunction with BRDM-3.6.1-1.
- See drawing BRDM-2.4.5-2 for Detail "A".

STEEL BEAM GUIDE RAIL RECONSTRUCTION ON "RIGID FRAME" BRIDGE DECK

BRDM-3.6.1-2

MEDIAN SBGR ON DECK — REMOVAL
WITH LONGITUDINAL EXPANSION JOINT RECONSTRUCTION

MEDIAN TALL WALL ON DECK — RECONSTRUCTION

Note:
- See drawing BRDM-2.4.5-2 for Details “A”, “B” and “C”.

MEDIAN STEEL BEAM GUIDE RAIL REMOVAL AND RECONSTRUCTION ON
“RIGID FRAME” BRIDGE DECK

BRDM-3.6.1-3

Note:

- This drawing is to be used in conjunction with BRDM-3.6.1-5.

**SIDE STEEL BEAM GUIDE RAIL REMOVAL ON "RIGID FRAME" BRIDGE DECK
WITH ELIMINATING LONGITUDINAL EXPANSION JOINT -PLAN**

BRDM-3.6.1-4

AT DECK REMOVAL

AT DECK REHABILITATION

Note:

- This drawing is to be used in conjunction with BRDM-3.6.1-4.

SIDE STEEL BEAM RAIL REMOVAL ON "RIGID FRAME" BRIDGE DECK WITH ELIMINATING LONGITUDINAL EXPANSION JOINT-SECTIONS

BRDM-3.6.1-5

Note:
- This drawing is to be used in conjunction with BRDM-3.6.1-7 and 3.6.1-8

**MEDIAN STEEL BEAM GUIDE RAIL REMOVAL ON "RIGID FRAME" BRIDGE
WITH ELIMINATING LONGITUDINAL EXPANSION JOINT-PLAN**

BRDM-3.6.1-6

- This drawing is to be used in conjunction with BRDM-3.6.1-6 and BRDM-3.6.1-8.
- See drawing BRDM-2.4.5-3 for Details "A", "C" and "E".

MEDIAN STEEL BEAM GUIDE RAIL REMOVAL ON 'RIGID FRAME' BRIDGE 'MID-SPAN AND ABUTMENT' WITH ELIMINATING LONGITUDINAL EXPANSION JOINT-SECTION

BRDM-3.6.1-7

2

SEE REINFORCED CONCRETE MEDIAN BARRIER WALL

15M @ 300 x 300 LONG DOWELS

19mm DIA. DRILLED HOLES

NEW 1-75mm DIA. PVC PLUG FOR LIGHTENING

NEW 250mm APPROACH SLAB

90mm ASPHALT AND WATERPROOFING

CONSTRUCTION JOINT (TYP.)

GRANULAR "A" BACKFILL

LIMIT OF EXCAVATION FOR STRUCTURE

25mm DIA. 150mm DEEP HOLE INTO SOUND CONCRETE AND FILL WITH EPOXY GROUT (TYP.)

1050 MIN.

C HWY

- This drawing is to be used in conjunction with BRDM-3.6.1-6 and BRDM-3.6.1-7.
- See drawing BRDM-2.4.5-3 for Details "C" and "D".

MEDIAN STEEL BEAM GUIDE RAIL REMOVAL ON "RIGID FRAME" BRIDGE "APPROACH SLAB" WITH ELIMINATING LONGITUDINAL EXPANSION JOINT

BRDM-3.6.1-8

SBGR ON DECK — REMOVAL

SBGR ON DECK — REMOVAL

Note:

- This drawing is to be used in conjunction with BRDM-3.6.1-10.

**MEDIAN STEEL BEAM GUIDE RAIL REMOVAL ON "BOX GIRDER" BRIDGE DECK
WITH ELIMINATING LONGITUDINAL EXPANSION JOINT**

BRDM-3.6.1-9

Technical cross-section drawing of a bridge structure, showing a new barrier wall, new asphalt and waterproofing system, and existing concrete box girder. The drawing includes dimensions and labels for various components.

Labels and Dimensions:

- C.L. BARRIER WALL** (Center Line)
- NEW BARRIER WALL SEE SS110-62**
- NEW 75 DIA. DUCT** (Pointed to diamond B)
- NEW ASPHALT AND WATERPROOFING SYSTEM TO MATCH EXISTING** (Pointed to diamond A)
- 5-S15M TLL** (Pointed to diamond A)
- 5-S15M BUL** (Pointed to diamond A)
- C.L. NEW LONG. EXP. JT.** (Center Line New Longitudinal Expansion Joint)
- EXISTING CONCRETE BOX GIRDER**
- STOM Ø 150 (mm)** (Pointed to a rectangular opening in the concrete girder)
- Dimensions:**
 - 500**** (Horizontal distance from barrier wall to center line of expansion joint)
 - 300**** (Horizontal distance from center line of expansion joint to center line of longitudinal expansion joint)
 - 625**** (Horizontal distance from barrier wall to center line of longitudinal expansion joint)

Note:

- This drawing is to be used in conjunction with BRDM-3.6.1-9.

MEDIAN BARRIER RECONSTRUCTION ON "BOX GIRDER" BRIDGE DECK WITH ELIMINATING LONGITUDINAL EXPANSION JOINT

BRDM-3.6.1-10

SBGR ON DECK - REMOVAL

MEDIAN STEEL BEAM GUIDE RAIL REMOVAL ON "BOX GIRDER" BRIDGE DECK
WITH MEDIAN CURB REMOVAL AND ELIMINATING LONGITUDINAL EXPANSION JOINT

BRDM-3.6.1-11

SEGR ON DECK - REMOVAL

BARRIER WALLS ON DECK - REHABILITATION

Note:

- This drawing is to be used in conjunction with BRDM-3.6.1-13.

**MEDIAN STEEL BEAM GUIDE RAIL AND MEDIAN CURB REMOVAL AND GIRDERS REMOVAL
ON "BOX GIRDER" BRIDGE "DECK"**

BRDM-3.6.1-12

SBGR ON APPROACH SLAB - REMOVAL

BARRIER WALLS ON APPROACH SLAB - REHABILITATION

Note:

- This drawing is to be used in conjunction with BRDM-3.6.1-12.

MEDIAN STEEL BEAM GUIDE RAIL AND MEDIAN CURB REMOVAL ON "BOX GIRDER" BRIDGE "APPROACH SLAB"

BRDM-3.6.1-13

SBGR ON DECK - REMOVAL

BARRIER ON DECK - RECONSTRUCTION WITH JOINT ELIMINATION

MEDIAN STEEL BEAM GUIDE RAIL REMOVAL AND MEDIAN CURB REMOVAL ON "CPCI GIRDER" BRIDGE DECK AND ELIMINATING LONGITUDINAL EXPANSION JOINT

BRDM-3.6.1-14

Note:

- See drawing BRDM-2.4.5-3 for Detail "A".

MEDIAN STEEL BEAM GUIDE RAIL AND MEDIUM CURB REMOVAL ON "PLATE GIRDER"
BRIDGE "DECK" AND ELIMINATING LONGITUDINAL EXPANSION JOINT

BRDM-3.6.1-15

PARAPET ON DECK - REMOVAL

BARRIER ON DECK – RECONSTRUCTION

Note:

- See drawing BRDM-2.4.5-2 for Detail "A".
- See drawing BRDM-3.8-1 for removal on Approach Slab.
- See drawing BRDM-3.8-3 for replacing parapet wall with PL3 Barrier wall on Deck.
- See drawing BRDM-3.8-2 for replacing parapet wall with PL3 Barrier wall on Retaining wall.

PARAPET WALL REPLACING WITH CONCRETE BARRIER WALL “SS110-61” ON “RIGID FRAME” BRIDGE DECK

BRDM-3.6.2-1

PARAPET ON DECK - REMOVAL

PARAPET ON WINGWALL AND RETAINING WALL - REMOVAL

Note:

- This drawing is to be used in conjunction with BRDM-3.6.2-3.
- See drawing BRDM-3.8-13 for replacing parapet wall with Concrete Barrier wall (SS110-61) and curb removal.
- See drawing BRDM-3.3.2-2 and BRDM-3.3.3-1 for replacing parapet wall with new Parapet wall with Fascia removal and without Fascia removal, respectively.

PARAPET WALL REMOVAL WITHOUT CURB REMOVAL ON "POST-TENSIONED" BRIDGE DECK	BRDM-3.6.2-2
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BARRIER ON DECK — RECONSTRUCTION

BARRIER ON WINGWALL AND
RETAINING WALL — RECONSTRUCTION

Note:

- This drawing is to be used in conjunction with BRDM-3.6.2-2.
- See drawing BRDM-3.8-4 for replacing parapet wall with Concrete Barrier wall (SS110-61).

**PARAPET WALL REPLACING WITH CONCRETE BARRIER WALL
ON ‘POST-TENSIONED’ BRIDGE DECK**

BRDM-3.6.2-3

BRIDGE DECK — REMOVAL

BRIDGE DECK — REHABILITATED

**PARAPET WALL REPLACING WITH CONCRETE BARRIER WALL
ON CANTILEVER OF "POST-TENSIONED" BRIDGE DECK**

BRDM-3.6.2-4

90mm ASPHALT AND WATERPROOFING
60mm CONCRETE OVERLAY

EXIST. REINFORCEMENT

C20M Ø 225 LAPPED WITH EXIST. REBARS

C.I.

15M Ø 200 TOP
(TYP.)

15M Ø 200 BOT.
(TYP.)

2-15M

2-C15M

DRIP DETAIL

BARRIER WALL REINFORCEMENT (STAINLESS STEEL)

1025

50

350

570

1383** (TYP.)

1110** (TYP.)

ROUGHENED SURFACE AND BONDING AGENT (TYP.)

EXISTING BOX GIRDER

App. C3-50

PARAPET WALL REMOVAL ON DECK

BARRIER WALL RECONSTRUCTION ON DECK

Note:

- See drawing BRDM-3.8-9 for replacing parapet wall with PL3 Barrier Wall. On "CPCI Girder" bridge.

PARAPET WALL REPLACING WITH CONCRETE BARRIER WALL ON "PLATE GIRDER" BRIDGE DECK

BRDM-3.6.2-6

Note:

- This drawing is to be used in conjunction with BRDM-3.6.2.8-8.

**PARAPET WALL REPLACING WITH CONCRETE BARRIER WALL
ON "PLATE GIRDER" BRIDGE DECK REPLACED BY "BOX GIRDER" (1)**

BRDM-3.6.2-7

DECK REINFORCEMENT-CROSS SECTION

Note:

- This drawing is to be used in conjunction with BRDM-3.6.2-7.
- See drawing BRDM-3.9-17 for Mechanical connector detail.

PARAPET WALL REPLACING WITH CONCRETE BARRIER WALL
ON 'PLATE GIRDER' BRIDGE DECK REPLACED BY 'BOX GIRDER' (2)

BRDM-3.6.2-8

REMOVAL-PARAPET WALL, TOP OF DECK

RECONSTRUCTION-BARRIER WALL, TOP OF DECK

PARAPET WALL REPLACING WITH CONCRETE BARRIER WALL
ON "T-BEAM" BRIDGE DECK

BRDM-3.6.2-9

REMOVAL CROSS SECTION

REPAIR CROSS SECTION

SIDEWALK REPAIR WITH DUCTS AND LIGHT POLES REMOVAL
ON "POST-TENSIONED" BRIDGE

BRDM-3.7-1

EXISTING & REMOVALS

REHABILITATED

Note:
- Also see drawing BRDM-3.7-3 for the case of "Normal Deterioration".

SIDEWALK REHABILITATION WITH HIGH DETERIORATION

BRDM-3.7-2

EXISTING & REMOVALS

REHABILITATED

Note:
- See drawing BRDM-3.7-2 for the case of "High Deterioration".

SIDEWALK REHABILITATION WITH NORMAL DETERIORATION

BRDM-3.7-3

CURB REMOVAL AT APPROACH SLAB
WITHOUT APPROACH SLAB REMOVAL

RECONSTRUCTION

NOTE: IF EXISTING DOWEL IS NOT AVAILABLE,
NEW DOWELS SHALL BE PLACED IN THE
HOLES TO PENETRATE 125mm INTO EXISTING APPROACH
SLAB FILL HOLES W/EPOXY AND PLACE DOWELS (TYP.)

Note:

- Also see drawing BRDM-3.8-2 for the case of "With Approach Slab".
- See drawing BRDM-3.6.1-6, BRDM-3.6.1-7 and BRDM-3.6.1-8 for "Median Curb" removal.
- See drawing BRDM-3.8-2 for side curb removal with top of wingwall removal.

**SIDE CURB REMOVAL AT APPROACH SLAB WITHOUT APPROACH SLAB REMOVAL
FOR ALL TYPES OF BRIDGES**

BRDM-3.8-1

CURB REMOVAL AT APPROACH SLAB
WITHOUT APPROACH SLAB REMOVAL

RECONSTRUCTION

Note:

- See drawing BRDM-3.6.1-6, BRDM-3.6.1-7 and BRDM-3.6.1-8 for "Median Curb" removal.
- See drawing BRDM-3.8-1 for side curb removal without top of wingwall removal.

**SIDE CURB AND TOP OF WINGWALL REMOVAL APPROACH SLAB WITHOUT APPROACH
SLAB REMOVAL FOR ALL TYPES OF BRIDGES**

BRDM-3.8-2

BRDM-3.8-3

- See drawing BRDM-3.6.1-6, BRDM-3.6.1-7 and BRDM-3.6.1-8 for “Median Curb” removal.
- See drawing BRDM-3.8-1 for side curb removal without top of wingwall removal.

REHABILITATION

CURB REMOVAL AT APPROACH SLAB
WITH APPROACH SLAB REMOVAL

Note:
- See drawing BRDM-3.8-1 and BRDM-3.8-2 for the case of "Without Approach Slab".

**SIDE CURB AND TOP OF WINGWALL REMOVAL AT APPROACH SLAB WITH APPROACH
SLAB REMOVAL FOR ALL TYPES OF BRIDGES**

BRDM-3.8-4

REHABILITATION

CURB REMOVAL AT APPROACH SLAB(WINGWALL) WITH APPROACH SLAB REMOVAL

Note:

- See drawing BRDM-3.8-1 and BRDM-3.8-2 for the case of "Without Approach Slab".
- See drawing BRDM-3.8-4 for "top of wingwall" removal.

SIDE CURB REMOVAL AT APPROACH SLAB WITH APPROACH SLAB REMOVAL FOR ALL TYPES OF BRIDGES

BRDM-3.8-5

CURB REMOVAL AT DECK WITHOUT DECK REMOVAL

REHABILITATION

SIDE CURB REMOVAL AT DECK WITHOUT DECK REMOVAL ON 'RIGID FRAME' BRIDGE

BRDM-3.8-6

CURB REMOVAL AT DECK
WITH FASCIA AND DECK REMOVAL

REHABILITATION

<p align="center">SIDE CURB REMOVAL AT DECK WITH FASCIA AND PARTIAL DECK REMOVAL ON "RIGID FRAME" BRIDGE</p>	<p align="center">BRDM-3.8-7</p>
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CURB REMOVAL ON DECK

CURB RECONSTRUCTION ON DECK

Note:
- See drawing BRDM-3.6.1-9 to BRDM-3.6.1-12 for "Median Curb" removal.
- See drawing BRDM-2.4.5-2 for Detail "A".

SIDE CURB REMOVAL ON DECK WITH FASCIA AND PARTIAL DECK REMOVAL ON "BOX GIRDER" BRIDGE	BRDM-3.8-8
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CURB REMOVAL ON DECK

CURB RECONSTRUCTION ON DECK

Note:
- See drawing BRDM-3.6.1-14 and BRDM-3.6.1-15 for median curb removal.

**SIDE CURB REMOVAL ON DECK WITH FASCIA AND PARTIAL DECK REMOVAL
ON "CPCI GIRDER" BRIDGE**

BRDM-3.8-9

EXISTING

REHABILITATED

MEDIAN CURB ON DECK-REPAIR

MEDIAN CURB REMOVAL ON DECK FOR ALL TYPES OF BRIDGES

BRDM-3.8-10

Note:

- This drawing is to be used in conjunction with BRDM-3.8-12 and BRDM-3.8-13

MEDIAN CURB REMOVAL ON "POST-TENSIONED" BRIDGE DECK - STAGE 1

BRDM-3.8-11

MEDIAN CURB - STAGE 2 REMOVAL

Note:
- This drawing is to be used in conjunction with BRDM-3.8-11 and BRDM-3.8-13

MEDIAN CURB REMOVAL ON "POST-TENSIONED" BRIDGE DECK - STAGE 2 (REMOVAL)	BRDM-3.8-12
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MEDIAN CURB - STAGE 2 REHABILITATED

Note:
- This drawing is to be used in conjunction with BRDM-3.8-10 and BRDM-3.8-11.

MEDIAN CURB REMOVAL ON 'POST-TENSIONED' BRIDGE DECK - STAGE 2
(REHABILITATED)

BRDM-3.8-13

CURB REMOVAL AT DECK WITHOUT DECK REMOVAL

Note:
- See drawing BRDM-2.4.5-2 for detail "A".

SIDE CURB REMOVAL ON "POST-TENSIONED" BRIDGE DECK

BRDM-3.8-14

NOTES: -DECK SLAB IS NOT SHOWN FOR CLARITY.

- This drawing is to be used in conjunction with BRDM-3.9-2 to BRDM-3.9-5.

BRDM-3.9-1

- This drawing is to be used in conjunction with BRDM-3.9-1, BRDM-3.9-3 to BRDM-3.9-5.

BRDM-3.9-2

Note:

Note:

- This drawing is to be used in conjunction with BRDM-3.9-1, BRDM-3.9-2, BRDM-3.9-3, BRDM-3.9-4 and BRDM-3.9-5.

**BALLAST WALL RECONSTRUCTED ON ‘POST-TENSIONED’ DECK
PLAN AND CROSS SECTION**

BRDM-3.9-3

Note:

- This drawing is to be used in conjunction with BRDM-3.9-1 to BRDM-3.9-3 and BRDM-3.9-5

BALLAST WALL RECONSTRUCTION ON "POST-TENSIONED" DECK - SECTIONS

BRDM-3.9-4

SUBDRAIN PIPE OUTLET DETAIL **D**

Note:
- This drawing is to be used in conjunction with BRDM-3.9-1 to BRDM-3.9-4.

BALLAST WALL RECONSTRUCTION ON "POST-TENSIONED" DECK - DETAILS	BRDM-3.9-5
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Note:

- This drawing is to be used in conjunction with BRDM-3.9-7 to BRDM-3.9-11.

BALLAST WALL REMOVAL ON "CPCI GIRDER" DECK - PLAN AND CROSS SECTION

BRDM-3.9-6

Note:

- This drawing is to be used in conjunction with BRDM-3.9-6, BRDM-3.9-8 to BRDM-3.9-11.

BALLAST WALL REMOVAL ON "CPIC-GIRTDER" DECK - DETAIL

BRDM-3.9-7

- This drawing is to be used in conjunction with BRDM-3.9-6, BRDM-3.9-7, BRDM-3.9-9 to BRDM-3.9-11.

BRDM-3.9-8

- This drawing is to be used in conjunction with BRDM-3.9-6 to BRDM-3.9-8, BRDM-3.9-10 and BRDM-3.9-11

BALLAST WALL RECONSTRUCTION ON “CPCI-GIRDER” DECK - PLAN AND CROSS SECTION

BRDM-3.9-9

Note:

- This drawing is to be used in conjunction with BRDM-3.9-6 to BRDM-3.9-9 and BRDM-3.9-11.

BALLAST WALL RECONSTRUCTION ON "CPCI GIRDER" DECK - DETAILS

BRDM-3.9-10

- This drawing is to be used in conjunction with BRDM-3.9-6 to BRDM-3.9-10.

BRDM-3.9-11

Note:

- This drawing is to be used in conjunction with BRDM-3.9-13 to BRDM-3.9-16

BALLAST WALL REMOVAL ON "BOX GIRDER" DECK - PLAN AND CROSS SECTION

BRDM-3.9-12

Note:

- This drawing is to be used in conjunction with BRDM-3.9-12 and BRDM-3.9-14 to BRDM-3.9-16.

BALLAST WALL REMOVAL ON "BOX GIRDER" DECK - DETAIL

BRDM-3.9-13

- This drawing is to be used in conjunction with BRDM-3.9-12, BRDM-3.9-13, BRDM-3.9-15 and BRDM-3.9-16.

BRDM-3.9-14

Note:

- This drawing is to be used in conjunction with BRDM-3.9-12 to BRDM-3.9-14 and BRDM-3.9-16.

- This drawing is to be used in conjunction with BRDM-3.9-12 to BRDM-3.9-15.

BRDM-3.9-16

PLAN — ABUTMENT

TYPICAL MECHANICAL CONNECTOR DETAIL A
N.T.S.

NOTE: SIZE OF MECHANICAL CONNECTOR TO MATCH THE REBAR SIZES.

ELEVATION — ABUTMENT

Note:

- This drawing is to be used in conjunction with BRDM-3.9-18 to BRDM-3.9-21.

BALLAST WALL REMOVAL ON "PLATE GIRDER" — PLAN AND CROSS SECTION

BRDM-3.9-17

- This drawing is to be used in conjunction with BRDM-3.9-17, BRDM-3.9-19 to BRDM-3.9-21.

BALLAST WALL REMOVAL WITHOUT EXPANSION JOINT ON "PLATE GIRDER" - SECTION

ADDITIONAL 2014 @
229 x 3000 LG. LF. -

ELEVATION - ABUTMENT

- This drawing is to be used in conjunction with BRDM-3.9-17 to BRDM-3.9-19 and BRDM-3.9-21.

**BALLAST WALL RECONSTRUCTION WITHOUT EXPANSION JOINT ON ‘PLATE GIRDER’
DECK – PLAN AND SECTION**

BRDM-3.9-20

Note:

- This drawing is to be used in conjunction with BRDM-3.9-17 to BRDM-3.9-20.

BALLAST WALL RECONSTRUCTION WITH EXPANSION JOINT ON 'PLATE GIRDER' DECK SECTION

BRDM-3.9-21

APPENDIX C5

REMOVAL CROSS-SECTION

Note:

- This drawing is to be used in conjunction with BRDM-5.1-2 AND BRDM-5.1-3

CONCRETE EXISTING DIAPHRAGM BETWEEN PLATE GIRDERS - REMOVAL

BRDM-5.1-1

REHAB CROSS-SECTION

Note:
 - This drawing is to be used in conjunction with BRDM-5.1-1 AND BRDM-5.1-3

CONCRETE EXISTING DIAPHRAGM BETWEEN PLATE GIRDERS – REPLACE WITH STEEL DIAPHRAGM

BRDM-5.1-2

Note:

- This drawing is to be used in conjunction with BRDM-5.1.1-1 AND BRDM-5.1.1-2

STEEL DIAPHRAGM BETWEEN PLATE GIRDERS - DETAILS

BRDM-5.1-3

APPENDIX C9

REMOVAL

REPAIR

TYPICAL LOCAL REPAIR AT EXPANSION JOINTS AT ABUTMENTS

Note:

- See BRDM-3.6.1-1 to BRDM-3.6.1-7 for longitudinal expansion joint removal on "Rigid Frame" bridge deck.
- See BRDM-3.6.1-9 to BRDM-3.6.1-11 for longitudinal expansion joint removal on "Box Girder" bridge deck.
- See BRDM-3.6.1-14 for longitudinal expansion joint removal on "CPCI Girder" bridge deck.
- See BRDM-3.8-11 to BRDM-3.8-13 for longitudinal expansion joint removal on "Post-tensioned" bridge deck.
- Local removal and repair at expansion joints shall be staged such that removal and repair at both abutment walls shall not be carried out at the same time

EXPANSION JOINT REMOVAL AT ABUTMENT

BRDM-9.2-1

CONSTRUCTION JOINT REPAIR DETAILS
WITH SCARIFYING

CONSTRUCTION JOINT REPAIR DETAILS
WITHOUT SCARIFYING

Note:
- For concrete overlay thickness less than 100mm but greater than 60mm use galvanize steel MW 51.6 x MW 51.6 placed at mid-depth.

CONSTRUCTION JOINT REPAIR	BRDM-9.2-2
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APPENDIX C11

BRDM-11.4-1

BOX GIRDER JACKING DETAIL AND BEARING REMOVAL

Note:
- This drawing is to be used in conjunction with BRDM-11.4-2, BRDM-3.4-1, BRDM-3.4-2 and BRDM-3.4-3.

JACKING NOTES

1. JACKING PEDESTALS SHOWN ON THE DRAWING ARE SCHEMATIC ONLY. THE CONTRACTOR SHALL BE RESPONSIBLE FOR DESIGN OF JACKING SUPPORT SYSTEM AND SHALL SUBMIT DETAILED SHOP DRAWINGS ALONG WITH DESIGN CALCULATIONS TO THE CONTRACT ADMINISTRATOR FOR REVIEW. ALL DRAWINGS SHALL BE STAMPED BY ENGINEER LICENCED IN PROVINCE OF ONTARIO.
2. THE CONTRACTOR SHALL SUBMIT SHOP DRAWINGS FOR JACKING DETAILS INCLUDING ALL EQUIPMENT, TEMPORARY SUPPORTS AND PROCEDURES TO THE CONTRACT ADMINISTRATOR FOR REVIEW. ALL DRAWINGS SHALL BE STAMPED BY AN ENGINEER LICENSED IN THE PROVINCE OF ONTARIO.
3. THE JACKING EQUIPMENT AND PROCEDURES OUTLINED IN THE CONTRACTOR'S SHOP DRAWINGS SHALL BE CERTIFIED IN THE FIELD BY THE ENGINEER RESPONSIBLE FOR THOSE DRAWINGS.
4. PLACE HYDRAULIC JACKS AT LOCATIONS SHOWN. CONNECT THE JACKS TO A SINGLE PUMP USING APPROPRIATE FITTINGS TO ENSURE THAT THE JACKS OPERATE SIMULTANEOUSLY.
5. THE DECK SHALL BE JACKED UP SIMULTANEOUSLY ACROSS THE ENTIRE WIDTH. JACKING MEASUREMENTS SHALL BE RECORDED AND SUPPLIED TO THE CONTRACT ADMINISTRATOR. THE DECK SHALL BE JACKED UP SUFFICIENTLY TO REMOVE PRESSURE ON THE EXISTING BEARING PADS AND FACILITATE THEIR REMOVAL. THE LIFT SHALL BE LIMITED TO A MAXIMUM OF 10mm AND CONTROLLED SO AS TO AVOID DAMAGING ADJACENT AREAS OF THE STRUCTURE.
6. SUPPORT REACTIONS SHOWN FOR THE GIRDERS ARE APPROXIMATE ONLY. THE CONTRACTOR SHALL SUPPLY JACK CAPACITY OF AT LEAST 150% OF THE MAXIMUM THEORETICAL JACKING LOADS CALCULATED FROM THESE GIRDER REACTIONS. THE CONTRACTOR SHALL SUBMIT SHOP DRAWINGS FOR JACKING DETAILS AS REQUIRED IN THE SPECIFICATIONS.

Note:

- This drawing is to be used in conjunction with BRDM-11.4-1, BRDM-3.4-1, BRDM-3.4-2 and BRDM-3.4-3.

BOX GIRDER JACKING DETAIL AND BEARING REMOVAL - NOTES

BRDM-11.4-2

SECTION AT TOP OF ABUTMENT

ORDERS END SOFFIT REPAIR TO BE CARRIED OUT PRIOR TO REMOVAL OF ABUTMENT DIAPHRAGMS AT LOCATIONS AS DIRECTED BY THE CONTRACT ADMINISTRATOR (SEE CONSTRUCTION SEQUENCE ON THIS DRAWING)

Note:

- This drawing is to be used in conjunction with BRDM-11.4.4, BRDM-3.4.4, BRDM-3.4-5 and BRDM-3.4-6.

CPCI GIRDER JACKING DETAIL AND BEARING REMOVAL

BRDM-11.4-3

SECTION AT TOP OF ABUTMENT DECK END SOFFIT REPAIR TO BE CARRIED OUT PRIOR TO REMOVAL OF ABUTMENT. CONTRACTOR TO DESIGN, SUPPLY AND REMOVE JACKING PEDESTALS AT ALL ABUTMENT LOCATIONS

Note:

- This drawing is to be used in conjunction with BRDM-11.4-5, BRDM-3.4-9, BRDM-3.4-10 and BRDM-3.4-11.

POST-TENSIONED BRIDGE JACKING DETAIL AND BEARING REMOVAL (CASE "A")

BRDM-11.4-4

JACKING NOTES

1. JACKING PEDESTALS SHOWN ON THE DRAWING ARE SCHEMATIC ONLY. THE CONTRACTOR SHALL BE RESPONSIBLE FOR DESIGN OF JACKING SUPPORT SYSTEM AND SHALL SUBMIT DETAILED SHOP DRAWINGS ALONG WITH DESIGN CALCULATIONS TO THE CONTRACT ADMINISTRATOR FOR REVIEW. ALL DRAWINGS SHALL BE STAMPED BY ENGINEER LICENSED IN PROVINCE OF ONTARIO.
2. THE CONTRACTOR SHALL SUBMIT SHOP DRAWINGS FOR JACKING DETAILS INCLUDING ALL EQUIPMENT, TEMPORARY SUPPORTS AND PROCEDURES TO THE CONTRACT ADMINISTRATOR FOR REVIEW. ALL DRAWINGS SHALL BE STAMPED BY AN ENGINEER LICENSED IN THE PROVINCE OF ONTARIO.
3. THE JACKING EQUIPMENT AND PROCEDURES OUTLINED IN THE CONTRACTOR'S SHOP DRAWINGS SHALL BE CERTIFIED IN THE FIELD BY THE ENGINEER RESPONSIBLE FOR THOSE DRAWINGS.
4. PLACE HYDRAULIC JACKS AT LOCATIONS SHOWN. CONNECT THE JACKS TO A SINGLE PUMP USING APPROPRIATE FITTINGS TO ENSURE THAT THE JACKS OPERATE SIMULTANEOUSLY. THE DECK SHALL BE JACKED UP SIMULTANEOUSLY ACROSS THE ENTIRE WIDTH. JACKING MEASUREMENTS SHALL BE RECORDED AND SUPPLIED TO THE CONTRACT ADMINISTRATOR.
5. THE DECK SHALL BE JACKED UP SUFFICIENTLY TO REMOVE PRESSURE ON THE EXISTING BEARING PADS AND FACILITATE THEIR REMOVAL. THE LIFT SHALL BE LIMITED TO A MAXIMUM OF 8 mm DURING INITIAL JACKING STAGE AND CONTROLLED SO AS TO AVOID DAMAGING ADJACENT AREAS OF THE STRUCTURE.
6. FOLLOWING THE REPAIR OF THE DECK ENDS AND THE TOP OF THE ABUTMENTS AND PIERS THE DECK SHALL BE ADDITIONALLY JACKED UP TO ACCOMMODATE INSTALLATION OF THE LAMINATED BEARINGS AND LOWERED ONTO THE NEW BEARINGS.
7. SUPPORT REACTIONS SHOWN FOR THE GIRDERS ARE APPROXIMATE ONLY. THE CONTRACTOR SHALL SUPPLY JACK CAPACITY OF AT LEAST 150% OF THE MAXIMUM THEORETICAL JACKING LOADS CALCULATED FROM THESE GIRDER REACTIONS. THE CONTRACTOR SHALL SUBMIT SHOP DRAWINGS FOR JACKING DETAILS AS REQUIRED IN THE SPECIFICATIONS.

Note:

- This drawing is to be used in conjunction with BRDM-11.4-4, BRDM-3.4-9, BRDM-3.4-10 and BRDM-3.4-11.

POST-TENSIONED BRIDGE JACKING DETAIL AND BEARING REMOVAL (CASE "A") - NOTES

BRDM-11.4-5

SECTION AT TOP OF ABUTMENT

DECK END SOFTIT REPAIR TO BE CARRIED OUT PRIOR TO REMOVAL OF EXISTING JACKING PEDESTALS AT LOCATIONS DIRECTED BY THE CONTRACT ADMINISTRATOR. TYPICAL AT ALL ABUTMENT LOCATIONS

Note:

- This drawing is to be used in conjunction with BRDM-11.4-5, BRDM-3.4-12, BRDM-3.4-13 and BRDM-3.4-14.

POST-TENSIONED BRIDGE JACKING DETAIL AND BEARING REMOVAL (CASE "B")

BRDM-11.4-6

SECTION AT TOP OF ABUTMENT
REMOVALS

1 REMOVALS

Note:

- This drawing is to be used in conjunction with BRDM-11.4-5, BRDM-3.4-16 and BRDM-3.4-17.

POST-TENSIONED BRIDGE JACKING DETAIL AND BEARING REMOVAL (CASE "C")

BRDM-11.4-7

ELEVATION OF A RIGID FRAME STRUCTURE

TEMPORARY PROTECTION INSTALLATION FOR “RIGID FRAME” BRIDGE

BRDM-11.50-1

CROSS SECTION OF A POST-TENSIONED BRIDGE

TEMPORARY PROTECTION INSTALLATION FOR "POST-TENSIONED" BRIDGE

BRDM-11.50-2

DEBRIS PLATFORM INSTALLATION

BRDM-11.51-1