PART 2 – DETAILED VISUAL INSPECTION

Figure A.12 (g) – Pier Cap

Condition State: Poor	Performance Deficiency: None
Narrow to medium map cracking in pier cap looks like AAR but, the structure is built prior to 1986 (the implementation of the Aggregate Resources Act). This map cracking could be Delayed Ettringite Formation (DEF) as it is a large concrete element.	Inspector should monitor cracking to observe the rate of deterioration.

PART 2 – DETAILED VISUAL INSPECTION

A.13 RETAINING WALLS

Figure A.13 (a) Precast Concrete Retaining Wall

Condition State: Excellent	Performance Deficiency: None
	No evidence of movement. Wall satisfactorily retaining fill

Figure A.13 (b) Pre-Cast Concrete Retaining Wall

PART 2 – DETAILED VISUAL INSPECTION

Condition State: Poor	Performance Deficiency: None
Extensive spalling of precast elements with exposed reinforcing steel	Wall satisfactorily retaining fill. Vegetation growth should be removed.

Figure A.13 (c) Cast-in-place Retaining Wall

Condition State: Poor	Performance Deficiency: Continuing Movement/Load Capacity
Median retaining wall was originally plumb and keyed to both EB & WB abutments. Wall appears rotated vertically, but has a curve at ground level, with a horizontal bow along top. Keys and keyways to both abutments damaged, with large section of EB abutment concrete following wall movement (see RH	Wall is failing with root cause insufficient lap length of back face reinforcing steel. Wall was stabilized with deadman anchors before its replacement.

PART 2 – DETAILED VISUAL INSPECTION

photo). LH photo shows large spalls on WB abutment caused by retaining wall movement.	

Figure A.13 (d) Bag-mortar Retaining Wall

Condition State: Fair	**Performance Deficiency: None**
Several areas with large vegetation growing through wall, creating openings in face of wall.	Wall satisfactorily retaining fill. Vegetation growth should be removed.

PART 2 – DETAILED VISUAL INSPECTION

A.14 TRUSSES / ARCHES

Figure A.14 (a) Steel Through Truss Connection

Condition State: Poor	Performance Deficiency: Load Carrying Capacity
Coating is poor on all painted bolts and rivets. Galvanized bolt coating in good condition, but some galvanized bolts have insufficient grip length. Some section loss on primary and secondary members, gusset plates and bolts/rivets. Evidence of rust jacking on some built-up members.	Possible loss of load carrying capacity. Joint very congested, with difficult access for assessing condition of many bolts/rivets within the top chord. Stitch welding visible on top chord cover plates. Bridge should have a fatigue inspection performed with attention paid to areas with stitch welding, rust jacking and section loss.

PART 2 – DETAILED VISUAL INSPECTION

Figure A.14 (b) Sway Frame Connection

Condition State: Fair	**Performance Deficiency: None**
Medium corrosion over more than 40% of the connection. Some evidence of section loss on sway frame to end post gusset plate.	An evaluation of gusset plate thickness and capacity should be performed if bridge is to remain in service.

PART 2 – DETAILED VISUAL INSPECTION

Figure A.14 (c) Vertical Member of Steel Through Truss

Condition State: Poor	**Performance Deficiency: Load Carrying Capacity**
Section loss 15% to 20% on panel used to reinforce vertical member	Possible loss of load carrying capacity due to loss of section.

PART 2 – DETAILED VISUAL INSPECTION

Figure A.14 (d) Concrete Bowstring Arch

Condition State: Fair	Performance Deficiency: None
Some scaling, spalling and cracking on the surface	Marginal loss of performance. Material defects unlikely to cause reduction in load carrying capacity

Figure A.14 (e) Concrete Spandrel Arch

PART 2 – DETAILED VISUAL INSPECTION

Condition State: Poor	**Performance Deficiency: None**
Very wide crack in the arch rib	Crack extends about 100 mm into the rib. Material defects unlikely to cause reduction in load carrying capacity

APPENDIX B – COMBINED SUMMARY OF MATERIAL DEFECTS AND CONDITION STATES

This appendix contains summaries for material defects and condition states described in Part 2, Section 2.5.

B 1: Summary - Concrete

DEFECT	CONDITION STATE		
	GOOD (LIGHT)	FAIR (MEDIUM)	POOR (SEVERE)
Scaling	Local flaking/loss of surface portion of concrete or mortar due to freeze-thaw		
	Up to 5 mm depth	6 - 10 mm depth	> 10 mm depth
Disintegration	Physical deterioration or breaking down of the concrete into small fragments		
			All
Erosion	Deterioration of concrete brought about by water-borne sand and gravel particles scrubbing against surfaces		
			All
Corrosion of Reinforcement	Deterioration of reinforcement by electrolysis		
	Due to drains/chairs	Rust stains from reinforcement	Exposed reinforcement with rust
Delamination	Discontinuity of the surface concrete which is substantially, but not completely detached from concrete below or above it.		
			All
Spalling	Fragments which have been detached from a larger concrete mass		
			All
Cracking	Linear fracture which extends partly or completely through the member.		
	< 0.3 mm	0.3 - 1.0 mm wide	> 1.0 mm wide
Alkali-Aggregate Reaction	Aggregates react adversely with the alkalies in cement to produce a highly expansive alkali-silica gel		

PART 2 – DETAILED VISUAL INSPECTION

DEFECT	CONDITION STATE		
	GOOD (LIGHT)	FAIR (MEDIUM)	POOR (SEVERE)
Alkali-Aggregate Reaction (cont.)	Hairline pattern cracks < 0.1 mm	Narrow pattern cracks 0.1 - 0.3 mm wide	Medium-wide pattern cracks > 0.3 mm wide
Honeycombing	Produced due to the improper or incomplete vibration of the concrete which results in voids being left in the concrete where the mortar failed to completely fill the spaces between the coarse aggregate particles		
	Holes up to 25 mm diameter	Holes 25 - 50 mm diameter	Holes more than 50 mm diameter
Pop-Outs	Shallow conical depressions resulting from the breaking away of small portions of the concrete surface, due to the expansion of some aggregates due to frost action.		
	Holes up to 25 mm diameter	Holes 25 - 50 mm diameter	Holes more than 50 mm diameter
Stratification	Separation of concrete into layers prior to hardening, due to over- vibration.		
		ALL	
Segregation	Concrete not uniform due to falling concrete (poor placement)		
		ALL	
Cold Joints	Caused by hardened concrete prior to the next adjacent pour		
		ALL	
Deposits	Water seeped through concrete, leaching chemicals and depositing them on the surface - efflorescence		
		ALL	
Abrasion	Wearing caused by vehicles or snow-plough blades		
		ALL	
Wear	Result of dynamic and/or frictional forces generated by vehicular traffic, coupled with the abrasive influx of sand, dirt and debris		
		ALL	
Slippery Concrete Surface	Smooth surface resulting from the polishing of the concrete deck surface by the action of repetitive vehicular traffic		
		ALL* include suspected performances deficiency of "slippery surface"	
Active Wet Areas	Concrete surface is wet or damp due to salt contaminated water		

PART 2 – DETAILED VISUAL INSPECTION

DEFECT	CONDITION STATE		
	GOOD (LIGHT)	FAIR (MEDIUM)	POOR (SEVERE)
Active Wet Areas (cont.)		Wet but no cracks	Wet with cracks

B 2 Summary - Steel / Aluminium

(Ref.: Part 2, Sections 2.5.6 and 2.5.7)

DEFECT	CONDITION STATE		
	GOOD (LIGHT)	FAIR (MEDIUM)	POOR (SEVERE)
Corrosion	Deterioration of steel by chemical/electro-chemical reaction resulting from exposure to air, moisture, de-icing salts, industrial fumes and other chemicals/contaminants in the environment in which it is placed		
	No section loss, loose rust/pitt–ng in paint -	< 10% section loss, small scales or flakes -	> 10% section loss, extensive rust/perforations *
	Early signs of patina damage	Flaking of patina	
Permanent Deformations	Steel members can take the form of bending, buckling, twisting or elongation. Corrugate Steel Pipe (CSP) culverts can exhibit cusping (abrupt change in curvature, typically at seam), crimping (local buckling of culvert wall), global deformation (change in original curved shape), and bolt tilting (bearing failure of bolts).		
			For members: ALL (Estimate repair area) *
		Cusping or crimping of culverts <10mm in height.	Cusping or crimping of culverts >10mm in height *
		Global Deformation <10% of culvert diameter	Global Deformation >10% of culvert diameter and reverse curvature *
		Bolt Tilting	
Cracking	Are linear fracture in the steel extending partially or completely through the member. They are mainly caused by fatigue, which can lead to brittle fracture (member cracks completely) through without prior warning)		
	Cracks perpendicular to stress are very serious and should have immediate action taken.		ALL * (Estimate repair area)

PART 2 – DETAILED VISUAL INSPECTION

DEFECT	CONDITION STATE		
	GOOD (LIGHT)	FAIR (MEDIUM)	POOR (SEVERE)
Connection Deficiencies	Loose connections can occur in bolted, riveted or clamped connections. They may be caused by corrosion of the connector, gusset plates or fasteners, excessive vibration, overstressing, cracking, or the lack of proper tightening during construction.		
	Based on the condition of the worst component within the connection		
	Depends on percentage of Loose Bolts or Plan Area with severe corrosion		
	< 5% loose bolts or severe rust	< 10% loose bolts or severe rust or cracks	> 10% loose bolts or severe rust or cracks

* - for CSP culverts, all portions in the Poor Condition State except corrosion without perforations (i.e., cusping, crimping, deformations, cracks, and corrosion with perforations), the area shall be taken to include the entire circumference.

B 3 Summary - Wood

(Ref.: Part 2, Section 2.5.15)

DEFECT	CONDITION STATE		
	GOOD (LIGHT)	FAIR (MEDIUM)	POOR (SEVERE)
Weathering	Gradual deterioration of wood due to exposure to the actions of sun, rain, wind, frost and atmospheric pollutants		
Checks	Longitudinal tissue separations on the side grain of wood members		
Splits	Severe tissue separations extending from the side into the end		
Shakes	Tissue separations which follow the circular annual growth rings, and are visible on the end grain		
Weathering	< 5% into member	5—10% into member	> 10% into member
Checks, Splits, Shakes	< 5% into member	5—10% into member	> 10% into member
Rot or Decay	Biological decomposition of wood caused by micro-organisms called fungi		
	Slight change in colour but wood solid (< 5% loss)	Surface is discoloured and slight hollow sound (5% - 10% loss)	Surface is fibrous or crumbly and hollow sounding or surface and interior is crumbly and wood is weak (> 10 % loss)
Insect Damage	Consequence of the tunnelling/boring by larvae/mature insects through the wood resulting in loss of section		
	Holes are present (< 5% loss)	Holes and insects present (5% - 10% loss)	Extensive/severe holes and insects (> 10% loss)

PART 2 – DETAILED VISUAL INSPECTION

DEFECT	CONDITION STATE		
	GOOD (LIGHT)	FAIR (MEDIUM)	POOR (SEVERE)
Abrasion and Wear	Deterioration of wood brought about by vehicles or snowplough blades scraping against wood surfaces, coupled with the abrasive influence of sand, dirt or debris.		
	< 5% loss	5% - 10% loss	> 10% loss

DEFECT	CONDITION STATE		
	GOOD (LIGHT)	FAIR (MEDIUM)	POOR (SEVERE)
Cracking, Splintering, Crushing and Shattering	Physical damage which results from vehicular collision from overloading of a member		
	< 5% loss	5% - 10% loss	> 10% loss
Fire and Chemical Damage	Fire is evidenced by charring and is usually confined to the wood surface. Chemical damage may result from the use of non preservative chemicals on the wood surface over a long period of time		
	Slight charring or softening with < 5% section loss	Deeper charring or softening with slight loose connectors with 5% - 10% section loss	Extensive damage with loose and severely deformed connectors > 10% section loss
Connection Deficiencies	Connections are loosened due to repetitive or dynamic loads, wear or decay of members connected and corrosion of the connectors		
	< 5% loose bolts or severe rust	< 10% loose bolts or severe rust	> 10% loose bolts or severe rust

B 4 Summary - Masonry

(Ref.: Part 2, Section 2.5.14).

DEFECT	CONDITION STATE		
	GOOD (LIGHT)	FAIR (MEDIUM)	POOR (SEVERE)
Cracking	Incomplete separation into one or more parts with or without space between		
	< 0.3 mm wide	0.3 to 1.0 mm wide	> 1.0 mm wide
Splitting	The opening of seams or cracks in the stone leading to the breaking of the stone into large fragments		
Spalling	The breaking or chipping away of pieces of the stone from a larger stone		
Disintegration	Gradual breakdown of the stone into small fragments, pieces or particles		

PART 2 – DETAILED VISUAL INSPECTION

DEFECT	CONDITION STATE		
	GOOD (LIGHT)	FAIR (MEDIUM)	POOR (SEVERE)
Splitting, Spalling Disintegration	Hairline cracking and minor loss of stone surface with section loss < 50 mm	Narrow cracking or chipping away of stone with section loss 50 to 100 mm	Extensive spalling and disintegration of stone with section loss > 100 mm
Loss of Mortar or Stone	Result of the destructive actions of frost, erosion, plant growth or softening by water containing dissolved sulphates or chlorides.		
	Mortar lost from joints in a few places to a depth of 20 mm	Mortar lost from joints over an extended area to a depth of 20 to 50 mm	Extensive mortar/stone loss endangering the stability of the structure

B 5 Summary - Asphalt Wearing Surface

(Ref.: Part 2, Section 2.5.8.)

DEFECT		CONDITION STATE		
		GOOD (LIGHT)	FAIR (MEDIUM)	POOR (SEVERE)
Crack	Pattern (e.g., Map, alligator, radial, edge) and isolated	Linear fracture extending partially or completely through the pavement		
		1—5 mm wide	6—10 mm wide	> 10 mm wide
Bond Defects	Loss of bond	Widespread loss of bond and delamination may occur between the asphalt pavement and deck surface, between the waterproofing and the deck surface, between the waterproofing and the asphalt pavement or between individual lifts of pavement		
		< 150 mm in diameter	150—300 mm in diameter	> 300 mm in diameter
	Rippling	The formation of transverse undulations in the pavement surface consisting of closely spaced valleys and crests		
		A few noticeable bumps	Several bumps producing a rough ride	Numerous bumps producing a very rough ride and difficulty maintaining control of vehicle
Surface Defects	Ravelling	Progressive deterioration and loss of the pavement material from surface downward		
		Noticeable loss of pavement material	Shallow disintegration of pavement with an open texture appearance	Shallow to deep disintegration of pavement with small/numerous potholes, open texture and loose surface material
	Slippery Surface	May result from flushing or from the polishing of the coarse surface aggregates by the action of repetitive vehicular traffic		

PART 2 – DETAILED VISUAL INSPECTION

		There are no severity descriptions given for slippery surfaces as this is a serious and potentially hazardous situation resulting in loss of riding comfort and loss of vehicle control (indicate suspected perform deficiency of slippery surface)

DEFECT		CONDITION STATE		
		GOOD (LIGHT)	FAIR (MEDIUM)	POOR (SEVERE)
Surface Defects	Flushing	The migration of asphalt upwards to the pavement surface in pavements with too much asphalt in the mix.		
		Visible colouring of the pavement surface occurring in localized areas	Distinctive colouring of the pavement surface with excess asphalt free on the pavement surface	Excessive free asphalt gives the pavement surface a “wet look”. Visible imprints left from footprints or vehicular traffic
Surface Distortion	Wheel track rutting	The formation of longitudinal depressions in the pavement at the locations of the wheel tracks of vehicles		
		Rutting < 10 mm deep	Rutting 10 to 20 mm deep	Rutting > 20 mm deep
Local Underlying Defects	Potholes	Bowl-shaped holes in the pavement caused by the penetration of water through the pavement and subsequent heaving of the pavement due to freezing of the entrapped water and breaking up of the pavement due to traffic action		
		< 10 mm deep	10 to 20 mm deep	> 20 mm deep
	Protrusions (Delaminations)	Local delamination is visible as protrusions or bumps (often circular in shape)		
		< 10 mm in height	10 to 20 mm in height	> 20 mm in height

B 6 Summary - Asphalt-Covered Concrete Deck

(Ref.: Part 2, Section 2.5.8).

DEFECT			CONDITION STATE		
			GOOD (LIGHT)	FAIR (MEDIUM)	POOR (SEVERE)
BOTTOM-UP	Wide Isolated Cracks	Transverse, longitudinal cracks	Longitudinal – parallel to the direction of travel, and generally located at or near the centre of the wheel track, pavement edge or centre-line of bridge Transverse – across pavement either fully or partially		
				> 10 mm wide single cracks	
	Local Underlying Defects	Potholes	Bowl-shaped holes in the pavement caused by the penetration of water through the pavement and subsequent heaving of the pavement due to freezing of the entrapped water and breaking up of the pavement due to traffic action		

PART 2 – DETAILED VISUAL INSPECTION

DEFECT			CONDITION STATE		
			GOOD (LIGHT)	FAIR (MEDIUM)	POOR (SEVERE)
					ALL
		Protrusions (Delaminations)	Local delamination is visible as protrusions or bumps (often circular in shape)		
				ALL	

DEFECT			CONDITION STATE		
			GOOD (LIGHT)	FAIR (MEDIUM)	POOR (SEVERE)
	Pattern Cracks	Map, edge, alligator, radial	Incomplete separation into one or more parts with or without space between		
					ALL
TOP – DOWN DEFECTS	Bond Defects	Loss of bond	Widespread loss of bond and delamination may occur between the asphalt pavement and deck surface, between the waterproofing and the deck surface, between the waterproofing and the asphalt pavement or between individual lifts of pavement		
			ALL		
		Rippling	The formation of transverse undulations in the pavement surface consisting of closely spaced valleys and crests		
			ALL		
	Surface Defects	Ravelling	Progressive deterioration and loss of the pavement material from the surface downward		
			ALL		
		Slippery Surface	May result from flushing or from the polishing of the coarse surface aggregates by the action of repetitive vehicular traffic		
			ALL		
		Flushing	The migration of asphalt upwards to the pavement surface in pavements with too much asphalt in the mix.		
			ALL		
	Surface Distortion	Wheel track rutting	The formation of longitudinal depressions in the pavement at the locations of the wheel tracks of vehicles		
			ALL		
	Light and Medium Isolated Cracks	Isolated cracks and Transverse, longitudinal cracks	Linear fracture extending partially or completely through the pavement		
			< 10 mm		

PART 2 – DETAILED VISUAL INSPECTION

B 7 Summary - Coating

(Ref.: Part 2, Section 2.5.5).

<table>
<tr><th colspan="2" rowspan="2">DEFECT</th><th colspan="3">CONDITION STATE</th></tr>
<tr><th>GOOD
(LIGHT)</th><th>FAIR
(MEDIUM)</th><th>POOR
(SEVERE)</th></tr>
<tr><td colspan="2" rowspan="2">Rust Condition Rating</td><td colspan="3">Rust condition rating is a visual rating of the surface appearance and is based on ASTM D610 sketches and is also shown in Part 2, Figure 2.5.5.12</td></tr>
<tr><td>Rust Condition Rating 2</td><td>Rust Condition Rating 3</td><td>Rust Condition Rating 4 or more</td></tr>
<tr><td rowspan="10">Coating Related Defects</td><td rowspan="2">Checking or Crazing</td><td colspan="3">Fine system of minute cracks in a checkerboard pattern.
Caused by weathering and exposure during curing</td></tr>
<tr><td></td><td>ALL</td><td></td></tr>
<tr><td rowspan="2">Cracking</td><td colspan="3">Linear pattern of crack penetrated through coating.
Results from weathering, continuing polymerization or shrinkage</td></tr>
<tr><td></td><td>ALL</td><td></td></tr>
<tr><td rowspan="2">Alligatoring</td><td colspan="3">Large irregular checks across surface.
Caused by non compatible layers of coating and hardening/shrinkage process</td></tr>
<tr><td></td><td>ALL</td><td></td></tr>
<tr><td rowspan="2">Chemical Attack</td><td colspan="3">Coating reacting adversely with air borne chemicals or accidental spills</td></tr>
<tr><td></td><td>ALL</td><td></td></tr>
<tr><td rowspan="2">Chalking</td><td colspan="3">Powdery appearance of coating surface.
Caused by reaction of coating resins to sunlight and process of weathering.</td></tr>
<tr><td>ALL</td><td></td><td></td></tr>
<tr><td rowspan="10">Adhesion Related Defects</td><td rowspan="2">Undercutting</td><td colspan="3">Spreading of corrosion under coating from a break.
Caused by poor surface preparation</td></tr>
<tr><td></td><td></td><td>ALL</td></tr>
<tr><td rowspan="2">Blisters</td><td colspan="3">Dome shaped projections of coating.
Caused by solvent or water trapped within paint film</td></tr>
<tr><td></td><td></td><td>ALL</td></tr>
<tr><td rowspan="2">Intercoat Delamination</td><td colspan="3">One coat separates from another.
Caused by contaminated surfaces or excessive curing between coats</td></tr>
<tr><td></td><td>ALL</td><td></td></tr>
<tr><td rowspan="2">Peeling</td><td colspan="3">Separation of coating from steel due to poor adhesion</td></tr>
<tr><td></td><td></td><td>ALL</td></tr>
<tr><td rowspan="2">Underfilm Corrosion</td><td colspan="3">Corrosion under the coating with the help of from a break.
Caused by poor preparation or porous coating</td></tr>
<tr><td></td><td></td><td>ALL</td></tr>
</table>

PART 2 – DETAILED VISUAL INSPECTION

DEFECT		CONDITION STATE		
		GOOD (LIGHT)	FAIR (MEDIUM)	POOR (SEVERE)
Application Related Defects	Bridging	Coating bridges across tight corner or debris forming void. Void can trap moisture and oxygen		
			ALL	
	Edge Defects	Coating pulls away from sharp edges and corners. Due to insufficient application of coating at edge		
			ALL	
	Shadows	Coating is applied too thin in the shadow of a rivet, bolts, or other abrupt change in surface		
			ALL	
	Overspray	Some paint particle outside spray pattern dry prior to full coating. Leads to some absorbed solvent and a more porous surface		
		ALL		
Application Related Defects	Pinholing	Air bubbles trapped in coating creating voids. Caused by holding spray gun too close		
		ALL		
	Runs	Downward movement of paint. Caused by over-thinning or depositing too much paint at one time		
		ALL		
	Sags	Similar to runs, the downward movement of 'curtain' of paint		
		ALL		
	Pinpoint Rusting	Rusting visible at point locations. Caused by insufficient coating thickness on peaks of blast cleaned substrate		
		Rate based on appearance and Rust Condition Rating		

B 8 Defect Summary Sheet

Table B 8.1 – Defect Summary for Concrete

CONCRETE	Light	Medium	Severe
Scaling	5 mm depth	6-10 mm	> 11 mm
Disintegration			Always Severe
Erosion			Always Severe
Pop Outs	25 mm dia.	25-50 mm	> 50 mm
Honeycombing	25 mm dia.	25-50 mm	> 50 mm
Delamination			Always Severe
Spalling			Always Severe
Corrosion	Rust Stains	< 10% sec loss	> 10%

PART 2 – DETAILED VISUAL INSPECTION

CONCRETE	Light		Medium	Severe
Cracking	Hairline (<0.1 mm)	Narrow (0.1-0.3 mm)	Medium (0.3-1 mm)	Wide (> 1 mm)
Alkai-Aggregate Reaction- ARR	Hairline (<0.1 mm)		Narrow (0.1-0.3 mm)	Med-Wide (> 0.3 mm)
Delayed Ettringite Formation - DEF	Hairline (<0.1 mm)		Narrow (0.1-0.3 mm)	Med-Wide (> 0.3 mm)
Miscellaneous	Stratification, Segregation, Cold Joints, Abrasion, Wear, Slippery, Active Wet Area			Wet+Cracks

Good	Fair	Poor

Table B 8.2 – Defect Summary for Asphalt

ASPHALT	Light	Medium	Severe
Cracks	1-5 mm wide	6-10 mm	> 11 mm
Edge Cracks (inwards)	600 mm	600-900 mm	> 900 mm
Pot Holes	< 10 mm depth	10 -20 mm	> 20 mm
Local Protrusions	< 10 mm depth	10 -20 mm	> 20 mm
Wheel Track Rutting	< 10 mm depth	10 -20 mm	> 20 mm
Rippling	Few Bumps	Rough Ride	Very Rough Ride
Loss of bond	150 mm long	150-300 mm	> 300 mm
Ravelling	Noticeable Loss	Shallow Disintegration	Shallow /Deep+ Potholes
Flushing	Visible Colour	Distinct Colour	Wet+Tire Marks
DECK TOP (WS)			
Top Down Defects	Light/Medium isolated crack, Wheel Track Rutting, Rippling, Bond Loss, Ravelling, Flushing, Slippery		
Bottom Up	Protrusion, Wide Isolated crack		Potholes, Cracks (Map, Alligator, Radial, Edge)

Good	Fair	Poor

PART 3 – ADDITIONAL INVESTIGATIONS

3.1 INTRODUCTION

Part 3 of this manual describes some of the additional investigations that can be done.

The presence of material defects usually triggers further, more detailed investigations. The most common types of investigations are material condition surveys for concrete elements (e.g., Bridge Deck Condition Survey, Substructure Condition Survey, etc.). Investigations can also be done for other materials such as steel, wood, aluminum etc. Additional investigations are usually triggered when a pre-determined percentage of an element is exceeded in the "poor" Condition State. Sections 2.5.4 to 2.5.20 describe these triggers. In some cases, the first sign of a material defect would trigger a more detailed investigation. (Examples: a fatigue crack in a steel girder - may trigger Fatigue Investigation, severe soffit deterioration – may trigger a Bridge Deck Investigation, severe scour of a shallow foundation – may trigger an urgent Underwater Inspection".

In addition, material defects often lead to performance deficiencies, which would trigger other follow-up actions, such as a strength evaluation. Performance deficiencies and corresponding follow-up actions are described in Part 2, Section 2.6.

During an inspection, the inspector may determine that additional information is required to properly assess the structure. The presence of severe material defects or performance deficiencies may necessitate additional investigations. When requesting an additional investigation, the inspector shall indicate the required timeframe for its completion, as outlined in Part 2, Section 2.8.42.8.

3.2 MATERIAL CONDITION SURVEYS

Condition surveys involve the detailed measurement and documentation of areas of defects and deterioration that exist on a structure. Procedures more precise than visual inspection techniques are usually employed. Examples of these procedures are: material testing of samples, half-cell surveys, etc. For additional information on condition surveys for concrete elements, refer to the Structure Rehabilitation Manual. Additional information on detailed assessment of structures affected by alkali-aggregate reaction can be found in CSA A864-00, Guide to the Evaluation and Management of Concrete Structures Affected by Alkali-Aggregate Reaction. Material condition surveys for wood, called detailed timber investigations, are described in Part 4, Section 4.2. Material condition surveys for steel include crack detection, which is usually part of a fatigue investigation and described in Part 3, Section 3.4 and Part 4, Section 4, or a detailed corrosion investigation which is normally carried out as part of a strength evaluation and described in Part 3, Section 3.6.

Material defects that meet the proportions listed in Table 3.2.1 may warrant a detailed condition survey. Condition Surveys are also conducted on structures scheduled for rehabilitation and, in some cases, when a structural evaluation is required.

PART 3 – ADDITIONAL INVESTIGATIONS

PART 3 – ADDITIONAL INVESTIGATIONS

Table 3.2.1 Material Condition Survey Triggers

Condition Survey Type	Description	Condition Survey Trigger	References
Concrete Deck (Asphalt or Concrete Surface)	Involves the testing of various core samples, sawn samples and the delineation of delaminated areas and areas of high corrosion potential (using half-cell survey)	10% of deck top or soffit element in “Poor” Condition State	Structure Rehabilitation Manual
Non-destructive Delamination Survey of Asphalt Covered Decks	Involves the delineation of delaminated areas using non-destructive testing techniques such as Ground Penetrating Radar, Impact Echo testing, etc.	5% of element in “Poor” Condition State	Structure Rehabilitation Manual
Concrete Substructure	Involves the testing of various core samples, etc., and the delineation of delaminated areas and areas of high corrosion potential (using half-cell survey)	10% of element in “Poor” Condition State	Structure Rehabilitation Manual
Structural Steel Coating	A detailed survey of the condition of the coating to confirm the feasibility of over-coating. The survey involves testing coating adhesion, dry film thickness, etc. If deterioration is still in the early stages (Combined area of Fair and Poor greater than 25%, and Poor is less than 10% at the visual inspection stage), “over-coating” of the steel may be a viable rehabilitation option. This involves cleaning the surface with a wire brush and “over-coating” the entire surface. If deterioration exceeds the above thresholds, traditional coating techniques (sandblasting the surface, priming, etc.,) would probably have to be used.	25% of combined area in “Fair” and “Poor” Condition States and the percentage in Poor is less than 10%.	Structural Steel Coating Manual
Timber Structure Investigation	A detailed investigation of the wood elements using techniques such as probing, drilling, coring, etc.	10% of element in “Poor” Condition State	Part 4 of this manual
Post-Tensioned Strand Investigation	Involves exposing areas of post-tensioning strands to determine possible corrosion and extent of duct grouting.	50% of “Deck End” element in “Poor” Condition State	Structure Rehabilitation Manual

3.3 UNDERWATER INVESTIGATIONS

Underwater inspection shall be considered for elements under water where the depth or clarity of water does not permit a satisfactory visual inspection. They are also carried out when there is evidence of scour or undermining of the structure foundations. For scour prone structures, underwater inspections should normally be carried out at five-year intervals, unless information is available to justify either reducing or increasing this interval. Underwater inspections should only be carried out by qualified divers familiar with the following CSA Standard: "Occupational Safety Code for Diving Operations". Additional information on Underwater Inspections is contained in Part 5 of this manual.

3.4 FATIGUE INVESTIGATIONS

Some jurisdictions operate dedicated fatigue inspection programs for their bridges with fatigue-prone details. These programs involve regular close-up inspections of steel elements and the use of Non-Destructive Testing techniques, when necessary (see Part 4 of this manual).

Bridges requiring fatigue-type inspections are prioritized through a review of the steel bridge inventory, including details such as construction practices, materials, and structural configurations. For fatigue-prone structures, detailed fatigue investigations should typically be conducted at five-year intervals unless available information supports adjusting this interval. The prioritization of bridges may be expressed through a fatigue index, as described in MTO's Fatigue Inspection Guidelines for Steel Bridges.

Fatigue investigations may also be triggered if fatigue cracks are identified during a biennial inspection.

3.5 SEISMIC INVESTIGATIONS

During the course of a detailed visual inspection, the inspector may observe situations that may place structures at risk if they are in a high seismic zone. The inspector may notice:

- Rocker bearings that are severely inclined and may be in danger of collapse during a seismic event.
- The superstructure may be close to the edge of its bearing seats. The bearing seat lengths may be inadequate during a seismic event.

If some of the above observations are made, the inspector can request that a detailed seismic investigation be done.

3.6 STRENGTH EVALUATION – LOAD CARRYING CAPACITY

To determine the load carrying capacity of a structure, a strength evaluation should be performed. It is extremely difficult to determine a load limit with only visual inspection information. Bridge plans should be reviewed, and a structural analysis should be performed. If bridge plans do not exist, measurements should be taken, similar bridge plans can be reviewed, assumptions can be made, and some calculations should be done. In addition, for steel structures, it is often necessary to accurately measure the thickness of critical members and determine the actual section loss as it varies across the element. This information should be used in the evaluation. For concrete structures, section loss in reinforcing steel should also be measured and accounted for in the evaluation.

3.7 MONITORING OF DEFORMATIONS, SETTLEMENTS, MOVEMENTS, AND CRACKS

During a detailed visual inspection, the inspector may have identified elements that have settled, deflected, rotated, or tilted. If the movement has stabilized, immediate action is probably not required. To determine if movements have stabilized, a monitoring program should be implemented, whereby various measurements are recorded over a period of time and compared to previous measurements.

The propagation of cracks in various materials can also be monitored over a period of time.

The anticipated maximum lateral construction movement of RSS/MSE wall is:

- In the order of H/250 for rigid reinforcement and H/75 for flexible reinforcement.
- Tilting due to differential lateral movement from the bottom to the top of the wall would be anticipated to be less than 4 mm per m (¼-inch per 5 ft) of wall height for either system.
- Post construction horizontal movements are anticipated to be very small.
- Post construction vertical movements should be estimated from foundation settlement analysis and measurements of actual foundation settlement during and after construction should be made.

The instruments for monitoring of RSS/MSE walls are suggested as follows:

Table 3.7.1 Suggested instruments for monitoring of RSS

RSS/MSE MONITORING PARAMETERS	SUGGESTED INSTRUMENTS
Horizontal movements of face	Visual observation, Surveying methods, Horizontal control stations, Tiltmeters
Vertical movements of overall structure	Visual observation, Surveying methods, Benchmarks, Tiltmeters
Local movements or deterioration of facing elements	Visual observation, Crack gauges
Horizontal movements within overall structure	Surveying methods (e.g., transit), Horizontal control, stations, Probe extensometers, Fixed embankment extensometers, Inclinometers, Tiltmeters
Vertical movements within overall structure	Surveying methods, Benchmarks, Probe extensometers, Horizontal inclinometers, Liquid level gauges

Lateral earth pressure at the back of facing elements	Earth pressure cells, Strain gauges at connections, Load cells at connections

3.8 WATER TESTING

In CHBDC Section 2.3.2.2, several site-specific parameters must be tested to classify the environmental exposure experienced by a structure in submerged conditions, water-level fluctuation zones subject to regular flooding, or areas exposed to cyclic wetting and drying from the waterbody. The values obtained from these parameters are used to determine the appropriate exposure class, which in turn establishes the applicable deterioration mechanisms for the structure.

3.8.1 Testing and Test Methods for MTO Sites

During MTO OSIM inspections, inspectors shall complete a water test which will include the testing of proximate water bodies or watercourses for the following:

a) pH, using test strips or pH test meter;

b) resistivity (Ohm-cm), using test meter;

c) chlorides (ppm), using test strips or test meter;

d) water-soluble sulphates (ppm), using test strips or test meter;

e) hardness (ppm), using test strips or test meter;

f) water velocity (m/s), using a flowmeter, timing a float over a known distance, or estimation.

For bridges, culverts, and retaining walls, a minimum of one (1) water test shall be conducted per site when the structure has a foundational element that could come into contact with the water (flood conditions must be considered). On large structures an additional test may be conducted upon the MTO's Regional Engineer's discretion. The results of the tests shall be reported by sample location and shall list the values obtained for each parameter in their units specified in the MTO's Bridge Management System.

Completing the water test may require the use of more than one type of test device or kit to ensure all required data is collected accurately. The following lists the testers currently available and what parameters they measure:

Table 3.8.1: Different water testing devices/kits and parameters they are able to test

Test Device or Kit	Test Parameters
Multimeters	PH
	Resistivity
	Chlorides
	Hardness
Test Strips	PH
	Chlorides
	Water Soluble Sulphates
	Hardness
Photometric Testing	PH
	Hardness

TABLE OF CONTENTS

PART 4 – MATERIAL CONDITION SURVEYS

4.1 STRUCTURAL STEEL

4.1.1 Non-Destructive Testing Methods For Detection Of Defects In Steel Components

A comprehensive non-destructive testing program of steel bridge components should be carried out whenever the members are cleaned to bare metal for any reason. At this time, a thorough visual examination of all exposed surfaces and connections can be implemented along with an examination of critical areas and components. This can be performed by the use of non-destructive techniques described herein.

Non-destructive testing is a term used to describe a process which allows materials and structures to be examined for defects without changing or destroying their usefulness. A wide variety of techniques have been devised among which the most commonly used, in addition to visual inspection, are:

- Liquid penetrant or dye penetrant (LP)
- Magnetic particle (MP)
- Ultrasonic Testing (UT)
- Eddy Current testing (ET)
- Radiographic (RT)

Of the five methods presented, none can satisfactorily identify all defects, each has its limitations and the accuracy that can be achieved with all the equipment under laboratory conditions can seldom be obtained in the field due to normally unfavourable site conditions.

A large variety of defects can be identified using non-destructive testing procedures and these are classified in three categories;

- Primary Inherent Defects
- Secondary Fabrication Defects
- In-Service Defects

Primary inherent defects in the materials used in the manufacturing of steel structures (plates, forgings, castings structural shapes, etc.) conform to the applicable standards. The standards permit minor surface discontinuities and non-significant internal defects which are smaller than the minimum allowable size. These defects, which remain in the finished product and are smaller than the maximum allowable defect size, usually have little effect on the strength of the member.

Secondary fabrication defects can be introduced into the material during fabrication. Processes used to produce the final product may introduce different defects or discontinuities to the structure. These are usually, but not always, identified through quality control procedures and are rectified by the fabricator. However, these defects are sometimes missed and should always be considered in subsequent inspections.

In-service defects arise from cyclic stresses or excessive loading which result in metal fatigue. This fatigue leads to the initiation of cracks which propagate and cause component failure. General corrosion of a component results in section loss reducing the ability of the component to support the design load. Pitting Corrosion combined with cyclic stresses causes stress corrosion cracking. This results in the reduction of a components strength and ability to carry design loads.

Defects remaining in the finished structure may, due to their shape, location, and service environment, become stress raisers. These stress raisers compromise structural integrity.

All of the various non-destructive techniques can be applied in the field to identify and evaluate defects although some techniques are more suitable than others. The following sections describe each of the procedures, along with advantages and disadvantages in field applications.

4.1.1.1 Liquid Penetrant Testing

The liquid penetrant method is commonly used in both shop and field to reveal defects that are open to the surface. It is simple to carry out, involves little time, is inexpensive and is easily interpreted. The process consists of the following:

- The surface of the metal is carefully cleaned with a wire brush or by water blasting to remove all loose scale, rust, etc. followed by solvent cleaning to remove any surface contaminants. Grinding or sanding of the surface may burr over or otherwise obscure defects.
- A liquid penetrant, a brilliantly coloured penetrating oil, is applied to the cleaned surface and allowed to seep into the surface defects for thirty minutes or more.
- Excess penetrant is then removed, and a developer agent is sprayed onto the surface.
- The developer dries to a white chalky coating and remains unchanged in the absence of any defects. Where surface defects do exist, the penetrant is drawn to the surface by capillary action and stains the developer.

The surface can then be visually examined for cracks or other surface defects which will be revealed by brightly coloured stains on the white surface.

The dwell time of the penetrant can be varied to detect cracks of different widths, the finer the crack the longer the dwell time. Fluorescent penetrants can be used with ultraviolet light to detect cracks wider than about 3 microns. The sequence for liquid penetrant application and typical images are shown in Figure 4.1.1.1 to Figure 4.1.1.3.