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Structures

Section 9

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ARTC Network Wide SMS

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Amendment Record

Amendment Version #	Date Reviewed	Clause	Description of Amendment
3.0	24 Nov 09		Updated to reference use of existing NSW Standards for Walkways and Guard Rail requirements
3.1	27 Apr 10	9.2.1, 9.2.2, 9.2.4; 9.4.4; Various	Specific positions within ARTC structure added; Clause on maintenance work added; Word bridge(s) replaced with structures and minor reformatting
3.2	18 Jun 10	9.4.2; 9.4.4; 9.4.5; 9.5.2	Title changed to Temporary Work for Construction; Maintenance Work requirements updated; Requirements for As-Built Drawings updated; Nosing load requirements updated. Banner added regarding mandatory requirements in other documents and alternative interpretations.
3.3	24 Oct 11	9.3.3; 9.3.5; 9.3.11; 9.3.12; 9.3.13; 9.4.4; 9.5.2	Certification – third party verification added; Design Loads – Hunter heavy haulage design load 350LA added; Transom Design – Timber properties added; Walkways/Refuges/Handrails – Introduction of new Walkway policy in NSW; Guard Rails – Introduction of new Guard Rails policy in NSW; Maintenance Work – reference number updated; Loads

			and Loading Factors – Wind Load – further clarified. Minor editorial change to remove CRN applicability box.
3.4	10 Feb 14	Various	Updates and clarifications on competency levels for structures staff, culvert design reference, EGP-03-01 reference to certification of drawings, use of bridge approach slab as transition approach, walkway/refuge/handrail requirements, re-badged BSS 01 made obsolete, guard rail maintenance, road traffic barrier requirements, service duct location, nosing load deleted as covered in AS 5100, clarification on when an inspection is 'compliance', inspection and maintenance of third party structures and redundant structures. Other minor editorial updates throughout. Further updates to Clause 9.3.2 Competency Requirements and Clause 9.7.5 Redundant Structures following OSERG review 8/09/2014.
3.5	03 Jul 17	Various	Minor editorial changes. Communication towers added to structures discipline. The roles of structures personnel removed. "Safety in Design" added. Transom design section revised completely to include Australian Standards and transom thickness for steel spans with 4 girders. Load rating for road bridges revised to include new load limit signage.
3.6	22 Sept 17	9.5.2	LL factor specified as 1.4
3.7	15 Jan 19	Various	Responsibilities removed as they are covered under SMS and position description Small and large culverts replaced with culvert Weighbridge removed Minimum depth from rail level to top of pipe defined Maximum ballast depth below sleepers defined Bridge bearing requirements added Flood immunity defined Transom pad, packer and installation details added 'No Safe Place' requirements for bridges and tunnels alignment with RISSB Guideline Editorial changes

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Mandatory requirements also exist in other documents.

Where alternative interpretations occur, the Manager Standards shall be informed so the ambiguity can be removed. Pending removal of the ambiguity the interpretation with the safest outcome shall be adopted.

9 Structures

9.1 General

Structures generally include bridges, culverts, tunnels and miscellaneous structures, as shown in Table 9.1 below:

Asset Class	Structure Type
Bridge	Underbridge Overbridge Footbridge
Culvert	Culvert
Tunnel	Tunnel
Miscellaneous Structures	Access (i.e. stairs, walkways) Buffer stop Culvert non-track Communication Towers Flood structure Lighting Gantry Lighting Tower Disused Loading Structures (now acting as retaining walls next to tracks) Overhead Service crossing Retaining wall Signal gantry (including cantilever structure) Sound barrier Turntable Water Structures

Table 9.1 – Asset Class and Structure Type

9.2 Design

The Code of Practice sets out the requirements for the design of new railway, road and pedestrian bridges, culverts and other significant structures. It defines requirements specifically or by reference to relevant Australian Standards.

"Safety in Design" is mandated by statutory requirements and shall be incorporated into the design.

The safety in design process shall identify potential hazards and the potential risks to persons during construction, future operation, maintenance and eventual decommissioning of an asset. During the design phase, risks shall be eliminated or minimised. Residual risks shall be documented in accordance with ARTC's risk management procedures.

9.2.1 Basis of Design

Bridge design shall be carried out in accordance with the Australian Bridge Design Standard AS (AS/NZS) 5100 and RISSB's Australian Railway Infrastructure Standard AS 7636 Railway Structures.

AS (AS/NZS) 5100 series sets out the requirements for the design, using limit states principles, of the following:

- Bridges that are required to support road traffic loads.
- Bridges that are required to support rail traffic.
- Bridges that are required to support light rail traffic.
- Pedestrian bridges, including bicycle and wheelchair access.
- Other structures that are required to support road and rail traffic, e.g. culvert and structural components related to tunnels, except those covered specifically by other Standards.
- Structures, other than bridges, that are required to support or resist road or rail traffic loads, e.g. retaining structures, deflection walls, signal gantries and sign gantries.
- Structures built over and/or adjacent to railways.

Culvert design shall be carried out in accordance with the Precast Reinforced Concrete Box Culverts Standard AS 1597, Design for Installation of Buried Concrete Pipes Standard AS 3725, Precast Concrete Pipes Standard AS 4058, Buried Corrugated Metal Structures Standard AS 2041, Long-span Corrugated Steel Structures AS 3703 and Buried Flexible Pipelines – Part 1 Structural Design AS/NZ 2566.1.

Top of drainage pipes under tracks shall not be less than 1.2m below top of rail level unless otherwise approved by ARTC.

Design of all other structures shall be carried out in accordance with relevant Australian Standards.

Design of any structures utilising materials not currently covered by any Australian Standards shall only be undertaken following "Type Approval" by ARTC.

9.2.2 Competency Requirements

The designs, design approvals and verification shall only be carried out by persons holding the appropriate competency level in accordance with ARTC competency certification.

ARTC shall select the designers, design checkers and independent verifiers based on their demonstrated skills and experience with the construction materials (concrete, steel, timber, masonry, composites) and structure type (including but not limited to bridges, tunnels, communication towers).

9.2.3 Acceptance by ARTC

"ARTC Acceptance" of Drawings:

- All drawings shall be accepted on behalf of ARTC by the applicable discipline competent project or maintenance engineer.
- The drawings shall be accepted as complying with the engineering requirements of the project.

9.2.4 Certification

All "Issued for Construction Drawings" shall be signed by the Design Engineer, and counter signed by the Design Check Engineer. Third party independent verification certificate for all construction drawings must be provided unless ARTC waives this requirement.

All design changes shall comply with the requirements of Rail Network Configuration Management Procedure EGP-03-01.

9.2.5 Design Loads

All structures shall be designed for the loading effects prescribed in AS (AS/NZS) 5100 and/or AS 7636 unless otherwise loading is specified by ARTC.

For rail traffic load other than 300LA design load, the load shall be taken as the proportion of the 300LA design load.

As a minimum, when loading is not specified:

- Rail bridges and culverts shall be designed to 300LA rail traffic design load with applicable dynamic load allowance.
- Rail bridges and culverts on the NSW Hunter heavy haulage lines shall be designed to 350LA rail traffic load with applicable dynamic load allowance.
- All ballast top rail bridges shall be designed for 600mm maximum ballast depth below sleepers. (Plaque(s) must be clearly displayed on top of ballast kerb in each span indicating maximum designed low-leg rail height above plaque).
- Road bridges shall be designed to SM1600 and W80 wheel design loads with applicable dynamic load allowance.
- Walkways and Footbridges shall be designed for 5kPa with applicable dynamic load allowance.

9.2.6 Bridge Bearing

The requirements for rail bridge bearings shall be as follows:

- For new steel spans, the bearings must be spherical bearings or bearings approved by ARTC.
- For new concrete spans, the bearings must be spherical bearings, elastomeric bearings or bearings approved by ARTC.

- All spherical bearings must be designed with 100year design life.
- All other bearing types must be designed with 50year minimum design life.
- All bearings must be designed for rail traffic loading specified in Clause 9.2.5 Design Loads.

Only Spherical Bearings comprising Ultra High Mechanical Polyethylene (UHMPE) as the sliding material shall be used and must comply with European Technical Approval ETA-08/115.

Where use of pot bearings cannot be avoided, only pot bearings that use Polyoxymethylene (POM) or Carbon Filled Polytetrafluoroethylene (PTFE) as internal sealing elements complying with current version of CEN-EN1337-5 Structural Bearings – Part 5: Pot Bearings shall be used.

For all other bridge types, the design of the bearings must comply with AS (AS/NZ) 5100.

9.2.7 Clearances

Horizontal and vertical clearances for structures (adjacent to and over the track) shall comply with Section 7 of this Code of Practice (or as approved by ARTC).

All structures over road traffic access with less than the regulated vertical clearance shall have overhead road clearance signs posted on them.

9.2.8 Waterways

ARTC can set the annual exceedance probability (AEP) for a particular waterway or drainage system. As a minimum, when the AEP is not specified by the ARTC, the flood openings shall be designed to accommodate the following:

- Major under track structures (discharge equal to or greater than $50m^3$/sec): 1% AEP (as defined in Australian Rainfall & Runoff guideline, previously defined as 100year precipitation event).
- Minor under track structures (discharge less than $50m^3$/sec): 2% AEP (previously defined as 50year precipitation event).
- Structures not under railway track: 2% AEP (previously defined as 50year precipitation event).

For rail bridges, the flood immunity and serviceability limit state Average Recurrence Interval shall be 100years as set out in AS (AS/NZ) 5100 unless otherwise specified by ARTC.

9.2.9 Abutment Slabs

1. Approach Slab

The approach slab designed as an integral structural component for the stability of the abutment or to square off a skewed abutment shall not to be used for a transition approach. The approach slab seated on an abutment must be adequately piled at the opposite end. The design of slab must ensure that there is no uplift on the abutment that could cause track misalignment due to any differential settlements at the piled end of the slab. Adequate drainage must be provided to ensure there is no entrapment of water on the approach slab or that any water drains off the slab structure onto the formation under the track.

2. Transition Slab

The transition slab shall be provided for all rail bridges. The slab must not be seated on the abutment. The length of slab across the rail track must suit the width of the bridge approach embankment and the slab must be at least 5m wide in direction parallel to running rails or as

approved by ARTC. Adequate drainage must be provided to ensure there is no entrapment of water on the slab or that any water drains off the transition structure onto the formation under the track.

9.2.10 Ballast Mat

Ballast mat may be considered for installation in the following circumstances:

- Concrete deck rail bridge.
- Rigid foundation.
- Tunnel.
- Where there is insufficient ballast depth (a waiver will be required for noncompliant ballast depth).
- Where required for noise and vibration attenuation.

As a minimum the ballast mat shall meet the following requirements:

- The requirements of DIN 45673-5 *Mechanical vibration – Resilient elements used in railway tracks – Part 5: Laboratory procedure for under-ballast mats.*
- Mat shall provide elastomeric, consistent modulus that may be further augmented by fibre reinforcement.
- As a guide, mat static bedding modulus (C_{stat}) to be 0.12-0.15 N/mm^3 for ballast depth equal to or greater than 300mm and 0.06-0.10 N/mm^3 for ballast depth less than 300mm.
- Mat shall not be constructed from reconstituted or re-cycled materials unless otherwise approved by ARTC.

9.2.11 Transom Design

9.2.11.1 Transom Material

Transoms are now available in a variety of materials. ARTC still uses hardwood timber transoms.

Transoms manufactured from fibre composite materials or any other materials shall only be utilised following “Type Approval” by ARTC.

Specific requirements for timber transoms are as follows:

- Timber stress grade shall be F22 or higher.
- Structural grade and timber species shall comply with the requirements of Table 9.2 below.
- Timber must be free of loose knots, unsound knots and knot holes.
- Want, wane and sapwood, individually or in aggregate, shall not exceed one seventh of the cross-section nor two fifths of the wide face on which it occurs.

All other requirements for transom timber must comply with the following standards:

- AS 1720.1 – “Timber structures – Design methods”.
- AS 2082 – “Timber Hardwood - Visually Stress - graded for structural purposes”.
- AS 2878 – “Timber classification into strength groups”.
- AS 3818.1 – “Timber – Heavy structural products – Visually graded, Part 1: General requirements”.

- AS 3818.2 - “Timber – Heavy structural products – Visually graded, Part 2: Railway track timbers”.

Groups	Common Name	Visual Stress-grade		Botanical Name(s)
		Structural Grade No 1	**Structural Grade No 2**	
Group 1	Grey Ironbark	F27	F22	E. siderophloia E. drepanophylla E. paniculata
	Red Ironbark	F22	N/A	E. fibrosa E. crebra E. sideroxylon
	Grey Gum	F27	F22	E. punctata E. propinqua
	Tallowwood	F22	N/A	E. microcorys
	White Mahogany	F22	N/A	E. acmenoides
Group 2	Spotted Gum	F22	N/A	C. maculate C. citriodora C. henryi

Table 9.2 – Transom Timber

9.2.11.2 Transom Size

Transom dimensions and tolerances shall be as stated in Table 9.3 below.

	Dimensions (mm)	Tolerance (mm)
Length	2800, 3000, 3200	+50, -0
Width	250 nominal	+25, -0
Thickness	As per Tables 9.4 and 9.5 below	+6, -0

Table 9.3 – Transom Dimensions and Tolerances

9.2.11.3 Transom Thickness and Holding Down Bolt

Some of the transom top steel span rail bridges in Victoria have 4 girders, compared to 2 girders in NSW. It is also relevant to note that some transom top bridges in Victoria were originally designed for Broad Gauge track whereas they are now standardised to Standard Gauge track.

Transoms for steel spans with 2 girders or timber spans with 3 girders

For transom top steel and timber rail bridges with span main girders at 2m centres maximum, the transom thickness shall be provided in accordance with Table 9.4 below:

AXLE LOAD & SPACING	TRANSOM SPACING (mm)	MAX SPEED (km/h)	JOINT STRENGTH GROUP[3]	HD BOLT SIZE (min)[4]	TRACK HORIZ. ALIGNMENT	MIN. TRANSOM THICKNESS (mm)[5]
30t axles as per AS5100.2 - 300LA rail traffic loading	600	115	J1	M30	Straight	190
					Curved	210[2]
		80	J1	M30	Straight	185
					Curved	205[2]
	500 - 550	115	J1	M30	Straight	170
					Curved	185[1]/200[2]
		80	J1	M30	Straight	165
					Curved	180[1]/190[2]
30t axles at ≥1500 centres (120t coal wagons)	500 - 600	115	J1	M24	Straight	150
					Curved	165[1]/170[2]
		80	J1	M24	Straight	150
					Curved	160[1]/165[2]
25t axles at ≥1500 centres (100t general freight wagons)	500 - 600	115	J2	M22	Straight	150
					Curved	150[1]/160[2]
		80	J2	M22	Straight	150
					Curved	150[2]

Table 9.4 - Minimum Timber Transom thickness and Holding down Bolt for 2 girder spans

Transoms for steel spans with 4 girders

For transom top steel rail bridges with span main girders at 610, 910 and 610mm centres maximum, the transom thickness shall be provided in accordance with Table 9.5 below:

AXLE LOAD & SPACING	TRANSOM SPACING (mm)	MAX SPEED (km/h)	JOINT STRENGTH GROUP[3]	HD BOLT SIZE (min)[4]	TRACK HORIZ. ALIGNMENT	MIN. TRANSOM THICKNESS (mm)[5]
25t axles at ≥1500 centres	400 - 600	115	J1 or JD2	M22	Straight	110
					Curved	120[2]
		80	J1 or or JD2	M22	Straight	110
					Curved	120[2]

Table 9.5 - Minimum Timber Transom thickness and Holding down Bolt for 4 girder spans

Notes on Tables 9.4 and 9.5:

Maximum superelevation on curved track = 125 mm

1. *Max. track offset in relation to span centreline = 30 mm*
2. *Max. track offset in relation to span centreline = 70mm*
3. *J groups as specified in Table C1 of AS 3818.1*
4. *Swage Bolts shall be grade 8.8S bolts with reduced tension to suit timber application. All other bolts shall be commercial Grade 4.6.*
5. *Any localised reduction in thickness of a transom must be achieved by a maximum 1 in 8 bevelling and rounded change of direction away from the reduced section.*

9.2.11.4 Transom Pad and Packer

All transoms on steel girder spans shall be seated on rubber pads to reduce impact loading on steel superstructure and if required packers shall be used to achieve required rail level.

Specific requirements for pads under timber transoms are as follows:

- Pad shall be SA47 rubber pad or equivalent.
- Desirable thickness of pad to be 12mm.
- Total thickness of pad(s) shall not be greater than 32mm.
- No steel plate to be inserted between layers of rubber pads.

Specific requirements for packers under timber transoms are as follows:

- Packer(s) shall be installed below pad (excludes girders with riveted cover plate(s)).
- Packers to be steel plates, High Density Polyethylene (HDPE) sheets or equivalent to suit required thicknesses.
- Packer thickness shall not be greater than 50mm in total unless otherwise approved by ARTC.

Typical timber transom installation is shown in sketch below.

- Conical spring with washers can be installed either under collar or head of bolt (spring expands as timber shrinks).

- No more than 2 flat washers shall be used under bolt head and 1 either side of spring washer without prior approval by ARTC.

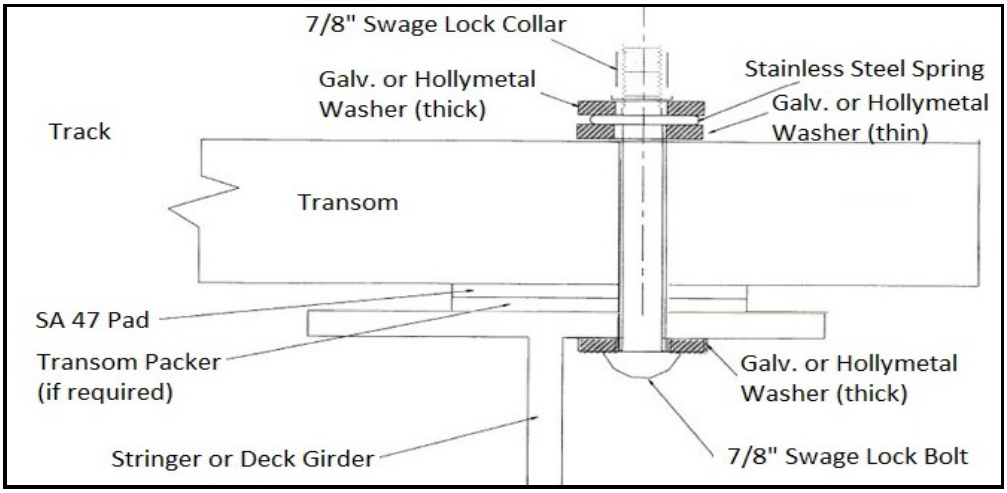

Diagram 1 - Timber Transom insulation details (typical)

9.2.12 Walkways / Refuges / Handrails

All new walkways / refuges / handrails on rail bridges, culverts or in tunnels or on any other structures shall comply with the requirements of AS (AS/NZS) 5100 and AS 1657.

The walkways or suitable alternative access shall be provided along both sides of each track across structures where train crews regularly work on the ground for shunting, train inspections, etc.

In other cases, a risk assessment shall be performed to assess if walkways, refuges and/or handrails are required.

“No Safe Place” sign, as per Figure 1 below, must be posted at each end of structure where any walkway, refuge or wall is within 3m horizontally from nearest running rail. It must also be attached at locations along the wall where access is available to the track adjacent to the structure. Signage must be attached such that it is clearly visible to authorised staff.

The following requirements must apply to refuges that could be used in emergency situations:

- For bridges and culverts, refuges shall not infringe the Kinematic Envelope (KE) + 200mm from the centreline of the nearest track.
- For wall structures such as tunnels and retaining walls, refuges shall not infringe the KE + 500mm from the centreline of the nearest track.
- Refuges shall not exceed 20m intervals, one side for a single track and staggered for multiple tracks.
- Refuge is not required for structures less than 20m in length.
- Minimum dimensions of refuge shall be 2m in height, 1.5m wide and 0.7m in depth.
- Handrails on (or at) structures shall not infringe the KE + 200mm from the centreline of the nearest track.

Figure 1 below illustrates the general configuration of the 'No Safe Place' sign.

Figure 1 – 'No Safe Place' sign

The requirements for danger signage are set out in AS 1319.

9.2.13 Guard Rails

Guard rails are not required on rail bridges. All the existing guard rails, until removed, shall be safely maintained by Civil Team in accordance with Code of Practice Section 1: Rail.

9.2.14 Road Traffic Barrier

The road traffic barriers for all new road bridges over the ARTC network shall be designed to minimum standard of **Medium Performance Level** in accordance with AS (AS/NZS) 5100.

For bridge rehabilitation, the existing road barriers to be upgraded to performance level specified above or unless otherwise approved by ARTC.

9.2.15 Services

Services, utilities and service ducts shall be designed and fixed to structures so as to allow safe and unimpeded access to the structure for inspection and maintenance.

No services to be installed under bridges or through culverts or attached to structures without prior approval of ARTC.

Where service ducts are attached to bridge walkway, refuges or handrails they must be positioned so that they do not encroach on the safe working area or create a trip or other safety hazards.

9.3 Construction and Maintenance Work

9.3.1 General

All construction and contract maintenance shall be performed in accordance with individual contracts.

9.3.2 Maintenance Work

All maintenance work on existing structures shall be carried out in accordance with approved construction drawings or on a like-for-like basis or EHG-09-01 Structures Repair Guideline. Where the guideline is used the applicable repair methodology shall be subject to approval by structures representative or competent structures engineer. Any changes to as-designed structures configuration or structurally critical elements shall be approved by a competent structures engineer and accompanied by relevant risk assessment, any additional inspections and signed off by a competent structures representative. All work shall be carried out in accordance with EGP-03-01 Rail Network Configuration Management and EGN-03-01 Configuration Management Manual.

All emergency maintenance work must be adequately maintained and monitored until the structure is upgraded to safe operating condition.

9.4 Load Rating

9.4.1 Structure Load Rating

All existing bridges and culverts shall be assigned "As New" and “As Is” load ratings and fatigue assessment in accordance with AS 5100 Part 7 and AS 7636.

For road bridges, the vehicle mass and/or speed shall be reduced to attain a Rating Factor greater than unity (i.e. RF > 1.0). All deficient road bridges shall be sign posted with R6-17 sign in accordance with AS 1742.2 and AS 1743.

9.4.2 Loads and loading factors

The loads and factors are to be in accordance with AS (AS/NZS) 5100 except as modified/clarified below.

Dead Loads

The combined un-factored superimposed dead load such as running rails, any existing guard rails and transoms of the track together with/without steel walkway(s) can be taken as 5kN/m unless otherwise more refined analysis is required.

Live Loads

In addition to the standard 300LA design vehicle and RAS vehicles (refer Structures Inspection Procedure, Train Consists) the load ratings will normally be required in terms of current trains operating over the structure as nominated by ARTC.

Braking and Traction Forces

The following characteristics of coal and freight trains shall be used to determine braking and traction forces when using Rational method in AS (AS/NZ) 5100 (2017) Clause 9.7.2.3:

- Rail traffic: 300LA for freight lines and 350LA for heavy haulage coal lines.
- Train length: 1800m
- CoG above rail: 2.1m
- Traction acceleration: 0.5m/s^2.
- Traction Length: 130m.
- Braking deceleration: 1.2m/s^2.
- Braking length: 1800m.

Load Factors

The value for Live Load factor shall be 1.4 for all current and RAS train consists unless otherwise nominated by ARTC. All other factors shall be as specified in AS 5100.7.

Wind load

The Serviceability Wind Speed in AS (AS/NZS) 5100 is 37m/sec. The lower 20m/sec is to be used on Ultimate Limit State live loads with load factor of 1.0 because of the short-term nature of the train loading on the structure.

9.4.3 Fatigue Rating

Where ARTC requires a fatigue analysis to be undertaken, the minimum theoretical remaining fatigue life across all structural elements shall be assessed in accordance with AS (AS/NZS) 5100. The Section 13 “Fatigue” in Part 6 of AS (AS/NZ) 5100 (2017) contains numerous discrepancies. Wherever applicable, the 2004 version of the bridge code should be used for fatigue assessment until the 2017 version is updated. Detail Categories shall be in accordance with the 2017 version of the Bridge Code.

9.5 Inspection and Assessment

9.5.1 Purpose

The purpose is to identify the requirements for systematic inspections so that:

- All structures are “fit for purpose” to meet operational needs.
- The responsibility and accountability for the structures management, inspection and maintenance is identified.
- The safety of all operators is ensured.
- The need for unplanned downgrading of service conditions is avoided for all structures.
- The inspections are carried out in accordance with the approved program, in the correct format and by competent inspectors.
- Data is provided for the development of structures management plans including strategic maintenance and replacement programs.
- Adequate structural integrity is maintained to an acceptable engineering Standard.
- Routine maintenance works are being effectively implemented.

9.5.2 Scope

ARTC shall establish a comprehensive, systematic, condition monitoring and load rating program for all nominated structures selected from Table 9.1. The program shall comprise the following inspection types:

- Engineering Inspection.
- Visual Inspection.
- Special Inspection.
- Track Patrol Inspection.

9.5.3 Third Party Structure

Inspection and maintenance of third party structures shall conform to the requirements of Road-Rail Interface Agreement and/or Infrastructure License Agreement between the parties.

9.5.4 Redundant Structures

Where possible and reasonable to do so, redundant structures and fittings shall be removed or isolated from the public and railway workers. Isolation actions can include filling in, entry barricading, fencing and signage. Some structures may be partially removed, leaving some residual elements in place. Until total removal or isolation, redundant structures, structural elements and fittings shall be subject to inspections and the minimum maintenance assessed as necessary to prevent an increased risk to the public and workers above that considered necessary SFAIRP during the structure's service life. Such inspection and maintenance actions of redundant structures and fittings shall be implemented until the structures are removed or isolated.

9.5.5 Operational Safety

All personnel involved with inspections shall not cause danger, delay, obstruction or stoppage to railway traffic and not interfere with the general business of the ARTC or its operators.

9.5.6 Work, Health and Safety

All inspection personnel shall comply with the ARTC's Work, Health and Safety procedures.

All inspection personnel shall be appropriately accredited for work on or within rail corridors in accordance with network operational and safe working requirements.

9.5.7 Environment

All inspection procedures shall comply with ARTC's environmental procedures.