Load Rating of Underbridges
ETE-09-05

Applicability

ARTC Network Wide
SMS

Publication Requirement

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Primary Source

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1 Introduction

This procedure is intended to ensure load limits on ARTC underbridges are efficiently and effectively managed by adopting acceptable Load Rating Factors (RF)s to underbridges at any time considering structural capacity of underbridge, vehicle loads, axle spacings, speed, structural condition and fatigue assessment.

1.1 Purpose

This procedure:

- provides the technical requirements to facilitate RFs and fatigue assessments to be performed for underbridges on the ARTC rail network.
- standardises Load Rating (LR) report submittal and documentation requirements for the ARTC underbridges.

1.2 Scope

Railway structures subject to this procedure are underbridges only; under the ARTC tracks.

All existing underbridges shall be assigned “As New” and “As Is” load ratings in accordance with AS 7636.

The As New LR is based on bridge inspection and determination of capacity assessment based on the constituent components of the bridge being in new condition.

The As Is LR is based on an inspection and determination of capacity assessment based on the existing condition of the components of the bridge.

All LRs and RFs in As New and As Is conditions shall be registered on the ARTC Asset management system Ellipse.

ARTC may also require estimating the theoretical remaining life of an underbridge under various experienced axles.

Fatigue assessment reports shall be registered on the ARTC Asset management system Ellipse.

Earthquake loads, load testing, qualitative assessment, Structural Health Monitoring (SHM) and other test methods are excluded from this procedure.

Where a conflict is found to exist between the requirements of Australian Standards and this procedure, the requirements of this procedure shall take precedence.

1.3 Document Owner

The ARTC Manager Standards is the Document Owner and is the initial point of contact for all queries relating to this procedure.

1.4 Responsibilities

Business Unit management is responsible for implementing this procedure.

1.5 Reference Documents

The following documents support this procedure:
1.6 Acronyms

The following terms and acronyms are used within this document:

<table>
<thead>
<tr>
<th>Term or acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARTC</td>
<td>Australian Rail Track Corporation</td>
</tr>
<tr>
<td>AS</td>
<td>Australian standard</td>
</tr>
<tr>
<td>DLA</td>
<td>Dynamic Load Allowance</td>
</tr>
<tr>
<td>FEM</td>
<td>Finite Element Model</td>
</tr>
<tr>
<td>FLS</td>
<td>Fatigue Limit State</td>
</tr>
<tr>
<td>LR</td>
<td>Load Rating</td>
</tr>
<tr>
<td>NRV</td>
<td>Nominated Rating Vehicle</td>
</tr>
<tr>
<td>RF</td>
<td>Load Rating Factor</td>
</tr>
<tr>
<td>RISSB</td>
<td>Rail Industry Safety and Standards Board</td>
</tr>
<tr>
<td>SHM</td>
<td>Structural Health Monitoring</td>
</tr>
<tr>
<td>SLS</td>
<td>Serviceability Limit State</td>
</tr>
<tr>
<td>ULS</td>
<td>Ultimate Limit State</td>
</tr>
</tbody>
</table>

1.7 Definitions

The following definitions are used within this document:

<table>
<thead>
<tr>
<th>Term or acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>Bridge Inspection</td>
<td>An Engineering inspection level which is undertaken as prescribed by ETE-09-01. This bridge inspection level assesses: (a) physical condition and performance (structural behaviour) (b) integrity assessment of structural components (c) corrective and preventative management requirements and includes close photographs, engineering considerations and technical recommendations.</td>
</tr>
<tr>
<td>Fatigue Assessment</td>
<td>An estimation of the cumulative damage in a bridge component under repeated loading for the purpose of assessing its theoretical remaining serviceable fatigue life. The cumulative fatigue damage shall consist sum of the damage due to historical loading.</td>
</tr>
<tr>
<td>Load Rating (LR)</td>
<td>An calculation of the load carrying capacity of a structure within the stress limits of design code requirements, assessed against a specific reference load or against design load.</td>
</tr>
<tr>
<td>Load Rating Factor (RF)</td>
<td>A ratio of the available bridge capacity for traffic load effects to the traffic load effects of a nominated rating vehicle.</td>
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</table>
2 Load Rating - Limit States

2.1 Ultimate Limit State (ULS)

As a minimum requirement for LR, Ultimate Limit State (ULS) shall be used in calculation of a RF for the ARTC underbridges.

2.2 Serviceability Limit State (SLS)

Serviceability Limit State (SLS) may be requested by ARTC to provide further investigations into a known defect in a specific underbridge. These defects may include signs of stiffness reduction, an evident cross-sectional loss, component cracking, deformations, or abnormal vibrations.

2.3 Fatigue Limit State (FLS)

Refer to clause 5.

3 Loads and Load Factors

Prior to undertaking load rating of bridges, all matters listed in AS 5100.7: 2017, clause 5 shall be resolved, unless otherwise already clarified in the ARTC structures standards.

For LR, the following loads and load factors shall be applied to the underbridge and its components.

- Dead load and superimposed dead load

  Dead load and superimposed dead load shall include the weight of all structural / non-structural components of the bridge such as rail, fill, ballast, barriers, utilities, and other materials.

  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 Load

  In addition to the 300LA traffic load for freight lines, 350LA traffic load for heavy haulage coal lines and RAS vehicles, the load ratings will be required in terms of current trains operating over the structure as nominated by ARTC. Refer to Appendix A for some typical load diagrams.

- Horizontal forces

  - Centrifugal and nosing loads shall be taken as per AS 5100.2: 2017
  - Braking and Traction forces

  The following freight and heavy haulage coal train characteristics shall be used to determine braking and traction forces when using Rational method in AS 5100.2: 2017, clause 9.7.2.3.

    - Train length: 1800m
- CoG above rail: 2.1m
- Traction acceleration: 0.5m/s²
- Traction Length: 130m
- Braking deceleration: 1.2m/s²
- Braking length: 1800m

- **Wind load**
  ARTC will specify, if wind load calculations need to be considered for the capacity assessment of an underbridge. In general, for underbridges such as steel trusses, where wind and sway bracings are critical when train passes over the underbridge, wind on train and underbridge shall be included. For this case, the design wind speed of 20m/s is to be used for ULS live loads with load factor of 1.0, due to the short-term nature of the train loading on the structure.

  If SLS is required, the design wind speed shall be taken as 37m/s.

- **Dynamic Load Allowance**
  Dynamic Load Allowance (DLA) shall be taken as per AS 5100.2 and 5100.7: 2017.
  DLA may be adjusted in accordance with clause 11.4.3 of AS 5100.7:2017 for the train speed and nominated rail line speed.

- **Load Factors**
  The value for traffic load factor shall be taken as 1.4 for current and RAS train consists, unless otherwise nominated by the ARTC. The load factors for 300LA and 350LA shall be taken as 1.6.

**4 Load Rating Procedure**

**4.1 Capacity Assessment**

The ultimate structural capacities (R_u in kN.m / kN) of main super-structure components including, but not limited to the main girders, trusses, cross girders, stringers, bracings, deck slabs, connections and bearings shall be calculated in accordance with AS 5100:2017– Bridge Design standard or other relevant Australian or international standards.

Sub-structure components may also be assessed for stability (including sliding or overturning) to specify the maximum critical bridge capacity or to further investigate foundation strength under loads. Sub-structure components shall be assessed, where there are concerns about progressive cracks, movement, rotation, or settlement or where piles ultimate capacity under heavier loads are unknown.

Capacity assessment is required for an underbridge sub-structure constructed of steel and / or timber.

Depending on the nature of bridge design and structure complexity, the acceptable assessment methods of ultimate capacity may be categorised as follows:

- Semi-empirical or hand calculation methods
- Simplified 2D / 3D or a finite element analysis

Calculation reports submitted to ARTC shall clearly include, but not limited to the following results:
• Capacity assessment purpose
• Design standards and material strength assumptions
• Loading summary
• Load cases and combinations summary
• Calculated section, member and connection capacities (including moment, shear, torsion, axial, interactions and combinations, etc.) and further checks
• Analysis / modelling considerations
• As Is structural modelling for damaged sections
• Structural modelling outputs (Refer to clause 4.2)
• Bridge drawings, other technical notes and site investigation reports
• Conclusion and Recommendations identifying issues and deficiencies of the underbridge, and short term and long-term actions required to ensure safe operation of the bridge

R_f shall be summarised for each underbridge component and registered in form ETE0905F-01.

4.2 Software Requirements

ARTC shall be provided with the output files of SpaceGass software for review, where bridge components are structurally modelled.

4.3 Load Rating Factor

The Load Rating Factor (RF) shall be calculated against R_f as per AS 5100.7: 2017, section 14 for all the live load effects specified in clause 3 of this procedure for both As New and As Is conditions.

No RF shall be considered valid until a recent bridge inspection has been undertaken. Refer to clause 1.7 for the definition of bridge inspection.

For each underbridge, the component that controls (i.e. has the lowest RF value) the live loads shall be identified.

RF reports submitted to ARTC shall clearly include, but not limited to the following results:

• Schematic of nominated rating vehicles
• Summary of recent bridge inspection findings including condition assessment report, technical notes and photos (for As Is rating)
• Summary Table of reduction factors, load factors, load effects, dynamic load allowances, multiple track factors and remarks which clearly shows critical underbridge components or connections
• Summary Tables of RFs (As New and As Is)
• Conclusion and Recommendations- Refer to clause 6.

Refer to form ETE0905F-01 which needs to be separately registered on the ARTC Asset management system Ellipse for each underbridge.
5 Fatigue Assessment

ARTC may require estimating the theoretical remaining life of an underbridge under historical usage. Palmgren-Miner summation rule may be used to calculate the cumulative fatigue damage and estimation of structure’s remaining life based on the historical usage of the underbridge and amplitude nominal stress ranges. AS 5100.6: 2004 or 2017 shall be used for fatigue assessment. Detail Categories and fatigue strength curves shall be in accordance with the AS 5100.6: 2017.

Where required and after initial desktop assessment of historical load cases and number of applied cycles, if a main underbridge component is shown to have reached or be very close to the end of the theoretical fatigue life considering its corresponding detail category, further detailed desktop analysis or field tests may be undertaken. For supplementing the desktop fatigue assessment, a more refined Finite Element Model (FEM) including elements such as gussets, stiffeners or additional girder plates with refined meshes around high stress areas under various load cases may need to be created to better address the structural dynamic behaviour and stress levels. In addition to the desktop analysis, further field tests such as magnetic particle method, hammer or ultrasonic tests may need to be performed to verify the structural condition of components and to detect whether possible signs of fatigue cracks have appeared on any critical underbridge component. Other equipment such as sensors may temporarily or permanently be installed to specify the actual stress levels in the critical underbridge components under operational loads. In high cycle fatigue analysis, these stresses may then be used for reliability analysis of probabilistic fracture mechanics in a specific component. In this case, the FEM of underbridge may also need to be calibrated until the field stresses and FEM results become more consistent.

Theoretical fatigue assessments submitted to ARTC shall clearly include, but not limited to the following investigations:

- Fatigue assessment purpose and assumptions
- Design standards and assessment methodologies
- Source of data for load history analysis
- Load histories summary (year to year) including experienced vehicles and axles and speeds
- Effective number of cycles (year to year)
- Endurance limits (in cycles)
- DLA considered for desktop fatigue assessment or dynamic amplification factors obtained from field dynamic tests
- Detail categories and amplitude nominal stress ranges for all critical components
- Fatigue damages ratios
- Further tests summary (e.g. field tests such as magnetic particle method, hammer or ultrasonic tests, tensile strength test, core sampling, etc.)
- Conclusion which finally estimates the remaining life of the underbridge, assuming current operational usage of the underbridge or amended estimated future usage for the Business Unit as advised by ARTC
Form ETE0905F-01 needs to be registered on the ARTC Asset management system Ellipse for each underbridge.

6 Underbridge Management

Where the analyst calculates the RF < 1, the following additional information is required in the Engineering report to ARTC:

- What speed reduction is required to increase the rating to 1, that is, the reduction to DLA with respect to a reduced speed.
- The critical component limiting RF shall be identified. ARTC may require the analyst to further explore modification and strengthening of that component so that ARTC can consider implementation of other ways to increase the capacity of the component.

7 Report Registration

All RFs, structural calculations, output files of structural modelling, fatigue assessments and other test results shall be registered on the ARTC Asset management system Ellipse.
## Appendix A - Some Typical Load Diagrams

<table>
<thead>
<tr>
<th>Locomotive Configuration</th>
<th>INFRASTRUCTURE LIMITS EQUIVALENT TO METRIC COOPER M RATING DESIGN LOAD (REFER FIG 2.5.1)</th>
<th>LOCOMOTIVE MAXIMUM INDIVIDUAL AXLE LOAD (TONNES)</th>
<th>LOCOMOTIVE MAXIMUM OVERALL MASS (TONNES)</th>
<th>LOCOMOTIVE CONFIGURATION - DISTANCE BETWEEN AXLES (MM)</th>
<th>OVERALL LENGTH OF LOCOMOTIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAS 270 (M270)</td>
<td>29.5</td>
<td>177</td>
<td>1800</td>
<td>1800 1800 8200 1800 1800 1800 1800 19000</td>
<td>19000</td>
</tr>
<tr>
<td>RAS 210 (M210)</td>
<td>23.0</td>
<td>138</td>
<td>1800</td>
<td>1800 1800 8000 1800 1800 1800 1800 18800</td>
<td>18800</td>
</tr>
<tr>
<td>RAS 180 (M180)</td>
<td>20.3</td>
<td>123</td>
<td>2300</td>
<td>1700 1700 7240 1700 1700 2300 18640</td>
<td>18640</td>
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# Wagon Configuration

<table>
<thead>
<tr>
<th>INFRASTRUCTURE LIMITS EQUIVALENT TO METRIC COOPER M RATING DESIGN LOAD (REFER FIG 2.5.1)</th>
<th>WAGON MAXIMUM INDIVIDUAL AXLE LOAD (TONNES)</th>
<th>WAGON CONFIGURATION - DISTANCE BETWEEN AXLES (MM)</th>
<th>OVERALL LENGTH (SUM OF INDIVIDUAL SPACING)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>RAS 270 (M270)</td>
<td>30</td>
<td>825</td>
<td>1780</td>
</tr>
<tr>
<td>RAS 210 (M210)</td>
<td>25</td>
<td>1050</td>
<td>1720</td>
</tr>
<tr>
<td>RAS 210 (M210)</td>
<td>23</td>
<td>980</td>
<td>1720</td>
</tr>
<tr>
<td>RAS 180 (M180)</td>
<td>20</td>
<td>1040</td>
<td>1720</td>
</tr>
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</table>
300LA Traffic Load
350LA Traffic Load (For NSW Hunter heavy haulage lines only)