Division / Business Unit:	Corporate Services & Safety
Function:	Track & Civil
Document Type:	Procedure

Load Rating of Underbridges

ETE-09-05

Applicability

ARTC Network Wide

SMS

Publication Requirement

Internal / External

Primary Source

Document Status

Version #	Date Reviewed	Prepared by	Reviewed by	Endorsed	Approved
1.1	01 Jun 20	Standards	Stakeholders	Manager Standards	General Manager Technical Standards 15/06/2020

Amendment Record

Amendment Version #	Date Reviewed	Clause	Description of Amendment
1.0	18 Jul 19		First issue of procedure.
1.1	01 Jun 20		Added complete typical ARTC load diagrams (App. A) to comply with ARTC ETE-09-02. Added definition of notations of the form ETE0905F-01 (App. B). Added ARTC structural modelling requirements (App. C) for load ratings to standardise submittals. Applied minor changes in some sentences.

Table of Contents

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) technical 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:

- AS 5100: 2017 & 2004 Bridge Design Standard
- AS 7636: 2013 RISSB Railway Structures

1.6 Acronyms

The following terms and acronyms are used within this document:

Term or acronym	Description
ARTC	Australian Rail Track Corporation
AS	Australian standard
DLA	Dynamic Load Allowance
FEA	Finite Element Analysis
FLS	Fatigue Limit State
LR	Load Rating
MTF	Multiple Track Factor
NRV	Nominated Rating Vehicle
RF	Load Rating Factor
RISSB	Rail Industry Safety and Standards Board
SHM	Structural Health Monitoring
SLS	Serviceability Limit State
ULS	Ultimate Limit State

1.7 Definitions

The following definitions are used within this document:

Term or acronym	Description
Bridge Inspection	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.
Fatigue Assessment	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.
Load Rating (LR)	A 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.

Load Rating Factor (RF)	A ratio of the available bridge capacity for traffic load effects to the traffic load effects of a nominated rating vehicle.
Nominated rating vehicle (NRV)	A design traffic load, a specific road vehicle, or a specific train rolling stock configuration designated for the particular rail line
Structural Health Monitoring (SHM)	The use of various sensing devices and ancillary systems to monitor in situ behaviour of a structure to assess the performance of the structure and assess its condition.

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 required 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 or a deflected or distressed component, cracking, deformations, or abnormal vibrations.

2.3 Fatigue Limit State (FLS)

Refer to Cl.5.

3 Loads and Load Factors

Prior to undertaking load rating of bridges, all matters listed in AS5100.7:2017, Cl.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. AS5100.2:2017, Tables 6.1(A) and 6.1(B) shall be taken as the minimum material weights considered for the calculation of dead and superimposed dead load, unless stated otherwise on the related drawings.

- **Live Load**

In addition to the 300LA traffic load,, the load ratings are required for RAS vehicles and current trains operating over the structure as nominated by ARTC. Refer to Appendix A for some ARTC typical load diagrams.

- **Horizontal Forces**

  - Centrifugal and nosing loads shall be taken as per AS5100.2:2017, Cl.9.7
  - Braking and Traction forces

The following characteristics of coal and freight trains (300LA) may be used to determine braking and traction forces when using the Rational method in AS5100:2017, Cl.9.7.2. 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

ARTC will confirm critical rail vehicle specifications, if the rational method in lines other than heavy haul is required.

- **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 the 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 AS5100.2 and 5100.7: 2017.

- DLA may be adjusted in accordance with AS5100.7:2017, Cl.11.4.3 for the train and nominated rail line speed.
- DLA shall not be increased for any existing bridges where there is no transition slab at abutments.

- **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 factor for 300LA shall be taken as 1.6.

Load factors for other effects shall be taken as per AS5100.7:2017, section 12.

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 AS5100:2017- Bridge Design standard or other relevant Australian or international standards. Substructure components may also require to be assessed for stability (including sliding or overturning) to specify the maximum critical bridge capacity or to further investigate foundation strength under loads. Substructure components shall be assessed, where there are concerns about progressive cracks, movement, rotation, or settlement or where piles or abutments ultimate capacity under heavier loads are unknown.

Capacity assessment under vertical and horizontal forces is required for an underbridge substructure constructed of steel and / or wrought iron. .

Note: In determining ultimate structural capacities, AS5100.7:2017 shall be fully considered. ARTC needs to be consulted where the Engineer seeks a clarification about requirements for application of specific load effect that is not stipulated in this procedure.

The acceptable assessment methods of ultimate capacity may be categorised as follows:

- Semi-empirical or hand calculation methods
- 3D structural or a Finite Element Analysis (FEA)

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 Cl.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_u shall be reported for each underbridge component and registered in form ETE0905F-01. Appendix B includes definition of notations used in this form.

Note: Load rating summary Tables for section line Engineering inspection which are separate to the form ETE0905F-01 shall be reported as directed by Business Units.

4.2 Software Requirements

ARTC shall be provided with the output files of SpaceGass software for review, where bridge components are structurally modelled. Appendix C includes minimum requirements for structural modelling of ARTC underbridges.

4.3 Load Rating Factor

The Load Rating Factor (RF) shall be calculated against R_u as per AS5100.7:2017, section 14 for all the load effects specified, but not limited to the Cl.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 Cl.1.7 for the definition of bridge inspection. As Is RFs shall consider accurate or rational levels of deterioration in the existing structural components. For each underbridge, the component that has the lowest RF value shall be identified.

RF reports submitted to ARTC shall clearly include, but not be 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 Cl.6.

Refer to form ETE0905F-01 which needs to be separately registered on the ARTC Enterprise 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. AS5100.6:2004 shall be used for fatigue assessment.

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, field tests or SHM may be requested by ARTC. For supplementing the desktop fatigue assessment, a more refined FEA including elements such as gussets, stiffeners, welded and bolted connections or additional girder plates under various load cases may also need to be created to better address the stress-strain 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 monitor the actual strain or vibration 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.

Theoretical fatigue assessments submitted to ARTC shall clearly include, but not be 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 Enterprise Asset Management System, Ellipse for each underbridge.

6 Underbridge Management

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

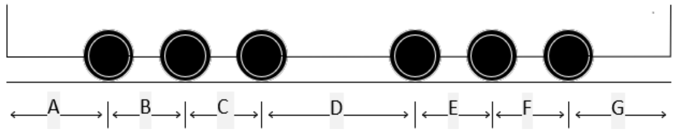
- What speed reduction is required to increase the rating to 1, that is, the reduction to DLA with respect to a reduced speed.
- The critical component limiting RF shall be identified in the form ETE0905F-01. ARTC may require the Engineer to further explore modification and strengthening of that component 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 Enterprise Asset Management System, Ellipse.

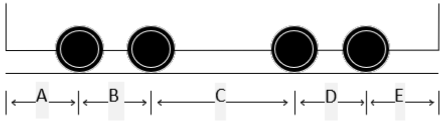
Appendix A- Some Typical Load Diagrams

This appendix includes some ARTC typical load diagrams. The Engineer shall use a string of at least 3 locomotives hauling 10 wagons where load rating is required for loading traffic rather than 300LA.

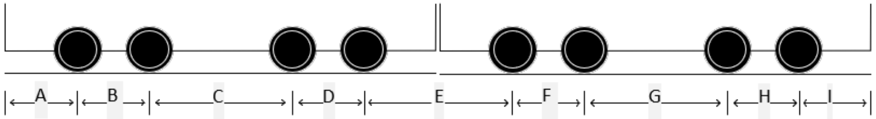
Locomotive Configuration **LOCOMOTIVE**	**LOCOMOTIVE MAXIMUM INDIVIDUAL AXLE LOAD (TONNES)**	**LOCOMOTIVE MAXIMUM OVERALL MASS (TONNES)**	**LOCOMOTIVE CONFIGURATION - DISTANCE BETWEEN AXLES (MM)** 							**OVERALL LENGTH OF LOCOMOTIVE**
			A	**B**	**C**	**D**	**E**	**F**	**G**	
RAS 270	29.5	177	1800	1800	1800	8200	1800	1800	1800	19000
RAS 210	23.0	138	1800	1800	1800	8000	1800	1800	1800	18800
QR5000	29.33	176	2410	2006	2006	9393	2006	2006	2173	22000
90 Class	27.5	165	1859	2022	2127	9984	2127	2022	1859	22000
L Class	22.83	137	1955	1905	1905	8690	1905	1905	1955	20220

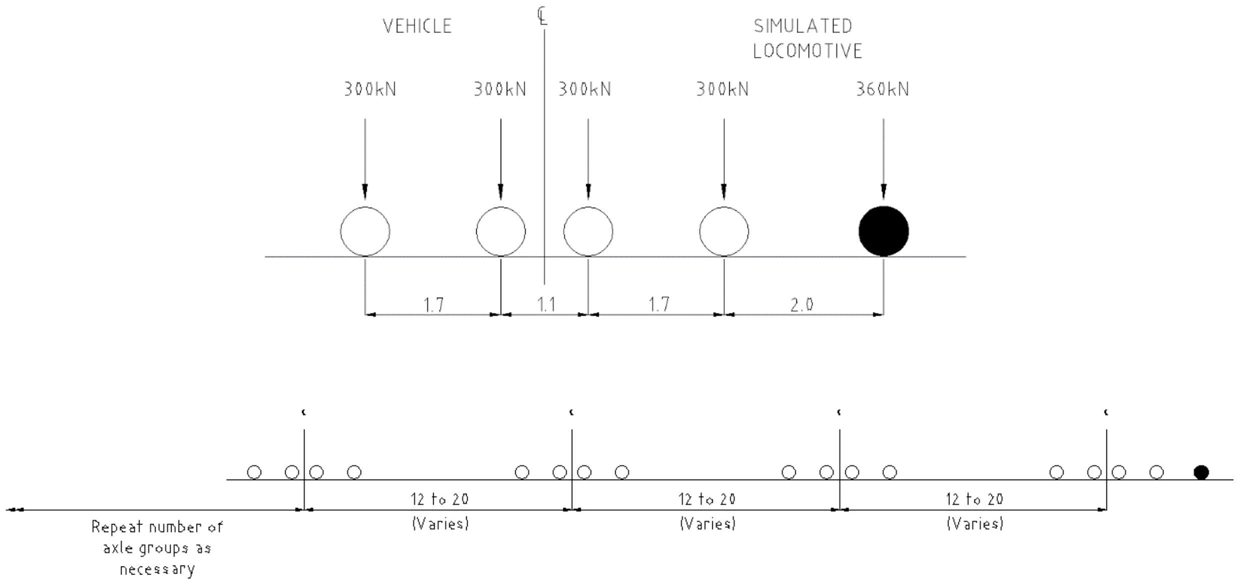
Wagon Configuration

WAGON	WAGON MAXIMUM INDIVIDUAL AXLE LOAD (TONNES)	WAGON MAXIMUM OVERALL MASS (TONNES)	WAGON CONFIGURATION - DISTANCE BETWEEN AXLES (MM)					OVERALL LENGTH OF WAGON
			A	B	C	D	E	
RAS 270	30	120	825	1780	10490	1780	825	15700
RAS 210	25	100	1050	1720	8400	1720	1050	13940
RAS 210	23	92	980	1720	6150	1720	980	11550
General Freight	25	100	1070	1780	11170	1780	1070	16870
Steel	23	92	1250	1750	5000	1750	1250	11000



WAGON	WAGON MAXIMUM INDIVIDUAL AXLE LOAD (TONNES)	WAGON MAXIMUM OVERALL MASS (TONNES)	WAGON CONFIGURATION - DISTANCE BETWEEN AXLES (MM)									OVERALL LENGTH OF WAGON
			A	B	C	D	E	F	G	H	I	
NHEH Coal	30	240	825	1800	10060	1800	1650	1800	10060	1800	825	30620
QR QHCH Coal	30	240	945	1779	10025	1779	1740	1779	10025	1779	945	30796





300LA Traffic Load (AS5100.2:2017)

Appendix B- Notations (Form ETE0905F-01F)

This appendix lists the definition of notations used in the form ETE0905F-01.

Rating Date

Day on which load rating calculations is carried out or submitted to ARTC.

Company / Rating Engineer

Company and Engineer(s) undertaking load rating calculations.

Load Rating-Limit State

ULS, SLS or FLS. Refer to Section 2.

Asset (Ellipse Equipment #)-Underbridge Name-Railway Line-Chainage

Ellipse equipment number of the underbridge which includes underbridge name, railway line and chainage (kilometrage) where the underbridge is located.

Underbridge Type-Year of Construction

Underbridge type e.g. steel truss bridge, super T girder or prestressed planks over concrete abutments, etc. Year of construction for underbridges may be assumed to be the same as year of design noted on drawings.

Overall Length-Number of Spans-Spans Configuration

Total length of underbridge, number of spans and span(s) configuration such as simply supported or continuous spans.

Latest Bridge Inspection Date and Report (Ellipse Equipment #)

Day on which latest Engineering inspection is performed including Ellipse equipment / original report number.

Underbridge overall Condition (when rating is undertaken)

Engineer shall rate overall bridge condition as per the following Table:

Condition State	Rating (n)	Description
Very Good	1	All components appear good
Good	2	The majority of the components appear good; No history of major defects; Occasional minor repairs.
Fair	3	1 or more P5 (less than 2 years Priority Code) defect present; Some historical defects which have been removed.
Poor	4	1 or more P3 (less than 6 months Priority Code) – P4 (less than a year Priority Code) defects present.
Very Poor	5	1 or more P1 (less than 7 days Priority Code) - P2 (less than 28 days Priority Code) present.

Technical documents including site investigations calculations, tests, fatigue assessment, SHM, computer models, etc. (Ellipse Equipment #)

Ellipse equipment / original report number for documents related to this load rating shall be noted.

Nominated Rating Vehicle

Load rating form shall be filled for 300LA only, unless 300LA cannot be taken by the underbridge. In any case, one nominated rating vehicle only is required.

Underbridge component

Refer to Cl.4.1 for the underbridge components to be rated. Each rated component shall be listed in a separate row.

Design action / Combined actions

Each component shall be rated in different design actions such as bending, shear, axial or torsion. Other combined actions such as combined bending and axial effect or similar shall also be noted.

L

Effective span or Length of member per meter.

L_α

Characteristic length of member per meter. Refer to AS5100.2:2017, Cl.9.5.2.

φ **(As New)**

Capacity reduction factor of member in As New condition.

φ **(As Is)**

Capacity reduction factor of member in As Is condition. Refer to AS5100.7:2017, Cl.10.5.

R_u

Calculated ultimate capacity of member in moment, shear, torsion or axial per kN.m / kN in accordance with the AS5100:2017.

γ_g

Load factor for dead load. Refer to AS5100.7:2017, Section 12.

γ_{gs}

Load factor for superimposed dead load. Refer to AS5100.7:2017, Section 12.

γ_Q

Traffic (live) load factor. Refer to section 3 of this procedure. For horizontal forces, refer to AS5100.7:2017, Section 12.

S_g^*

Load effects due to dead load per kN.m / kN.

S_{gs}^*

Load effects due to superimposed dead load per kN.m / kN.

S_p^*

Load effects due to secondary effects of prestress per kN.m / kN.

S_s^*

Load effects due to shrinkage, creep, differential settlement and bearing friction per kN.m / kN. In most cases, these load effects can be taken as nil in ULS rating, unless there are obvious signs of member distress, relative settlement or deformation due to such effects.

S_t^*

Load effects due to temperature per kN.m / kN.

S_Q^*

Load effects due to traffic (live) load per kN.m / kN.

α

DLA for full speed (full speed may be taken as 80km/hr or above). Refer to AS5100.2:2017, Cl.9.5.

W

Multiple Track Factor (MTF). Refer to AS5100.2:2017, Cl.9.4.

RF

Load Rating Factor as calculated below. Refer to AS5100.7:2017, section 14.

$$RF = \frac{Available\ bridge\ capacity\ for\ traffic\ (live)\ load\ effects}{Traffic\ (live)\ load\ effects\ of\ nominated\ rating\ vehicle}$$

$$= \frac{\varphi R_u - (\gamma_g S_g^* + \gamma_{gs} S_{gs}^* + S_p^* + S_s^* + S_t^*)}{\gamma_Q (1+\alpha) W (S_Q^*)}$$

LR

Load Rating which is represented as LA.

Underbridge Management

Refer to section 6. Reduced speed and amended LR shall be noted in this column, if resulted RF is less than unity. Other action including a proposal summary for member strengthening method may be noted in this column, provided that such an investigation has been undertaken by Engineer.

Underbridge component limiting LR

Lowest LR related to the critical assessed member shall be noted.

Remaining Fatigue Life Estimation (Yrs)

Refer to Section 5. Members with different fatigue lives (in year) shall be listed in this section. This section is usually requested for steel / wrought Iron components only,

Appendix C- Minimum Requirements for Structural Modelling

The following Table defines structures to be modelled:

Structure type	Required?	
	Yes	No
Concrete ballasted deck		×
Transom top bridge	√ (see Note a)	
U-frame / through girder bridge	√ (see Note a)	
Through truss bridge	√	
Steel trestles and bracings	√ (see Note b)	
Prestressed / posttensioned deck or planks		×
Super T girder		×
Precast culvert		×
Concrete / masonry arch	√ (see Note 1-5)	
Rail deck culvert		×
Steel box girder		×
Composite / non-composite ballasted bridge		×

Note a: Modelling may only be required, where the assessed structure is too complex r hand calculations. Some transom top or through girder bridges which consists two similar girders connected to only one type of cross beam and / or wind bracing may not necessarily require to be modelled. Only in these cases, modelling will be optional as recognised by the Engineer. It should be noted however that modelling of all the assessed underbridges are preferable. ARTC shall be consulted, in cases there are uncertainties about modelling, analysis types or other requirements.

Note b: Steel trestles and bracings shall be modelled together with its superstructure (including elastic bearings, if any) as one integrated SpaceGass model.

Some Modelling Considerations

1- Creating Structural Model:

ARTC requires that only an Engineer with appropriate level of competency, structural knowledge and experience in bridge modelling, design or load rating creates an underbridge model. The created bridge models shall be as close as possible to the actual members in the real bridge. In models, all the structural members shall be created precisely as far as applicable in SpaceGass, so that the total calculated mass of the structural model indicates the total approximate mass of the real bridge. ARTC may use created models for other purposes such as modal, or other types of analysis, structural rectifications or a SHM in the future.

Note 1-1-Any deterioration in structural members shall be modelled based on actual field measurements and after comparing these measurements with available design drawings and undamaged sections. The Engineer needs to allocate deterioration to the damaged member only by means of; reducing its section thickness, changing its section or member stiffnesses or amending its member fixities after sound Engineering judgment about such damage. For modelling corrosion in steel or wrought iron members, section loss may be allocated only where member has an actual thickness loss rather than where they appear to have surface rusting or flaking paint. Deformed or deflected members may be modelled as a tension-only or a bending stiffness-reduced member. It is essential that member fixities are modelled as close as possible to the As Is condition to ensure load distribution and boundary conditions are properly considered in the model, which may even be different from the As New or designed condition.

Note 1-2-Material design properties such as Young’s modulus, yield and ultimate strength of each member shall correctly be filled in the section design form of SpaceGass, even if the model is only used for an analysis rather than an assessment.

Note 1-3-It is recommended that structural members in complex models are categorised, so that they can be easier filtered by the top drawdown menu.

Note 1-4-To analyse members such as a pile, arch, abutment, prestressed / posttensioned girder, connection or a damage; an FEA or specific software may be used for modelling solid and shell elements or soil-structure interaction. In this case, ARTC shall be provided with the output file of that FEA package for read, review and registration of that analysis.

Note 1-5-Currently, SpaceGass is unable to model the solid or brick elements or to apply different Geotechnical modelling inputs. Thus, for analysing masonry underbridges or arches, an FEA software or a specific non-FEA package with the soil modelling capabilities can be used. If an FEA is used, it will be essential to consider modelling of crushing / cracking material, ring separations, soil-structure interaction, and if possible, the existing defects and repairs. Soil-structure interaction under dynamic load of trains in existing old masonry is a complex issue i.e. effect of the surrounding and underlying soil strength on the global stiffness, mass, damping of the system can be significant, however; most FEA packages have some soil selecting options such as Mohr-Coulomb material and soil continuum parameters. Soil may be modelled using trilinear springs; however, selecting correct boundary conditions for the overall system in this case is more important. In either modelling cases, care must be taken to ensure modelling represents the real bridge condition, reasonably. In most of the old underbridges, detail drawings are not available, so it may not be recognisable whether the masonry underbridge has an internal spandrel wall directly below the rail. These elements have been shown to have a significant effect on the overall bridge capacity.

Note 1-6-Modelling of an underbridge in other software than SpaceGass will not be acceptable by ARTC, if this can be carried out in SpaceGass.

2- Dead Load and Superimposed Dead Load

Dead loads or total structural mass of a model shall include exact members as measured in the field after members are checked with existing drawings. All built-up sections, wind and sway bracings, and recently replaced members shall be modelled accurately as they form the real bridge. Steel or timber decking in a truss or any ballasted bridge need not be modelled as finite plate elements in SpaceGass. Also, connections, stiffeners, gussets, barriers or kerbs need not be modelled, either in the global model. Such members can separately be analysed; however, their dead loads need to be applied as a separate dead load case in the model.

Note 2-1-Superimposed dead loads shall be applied to subjected members in model rather than in calculations. Existing drawings and field measurements shall be used to calculate dead and superimposed dead loads such as rails, sleepers, ballast, transoms, handrails and barriers, maintenance walkway or attached services.

Note 2-2-AS5100.2:2017, Tables 6.1(A) and 6.1(B) shall be taken as the minimum material weights considered for the calculated dead and superimposed dead loads, unless stated otherwise on the drawings. Before analysis, SpaceGass material library needs to be checked to ensure all the densities are properly adopted for the purpose of the load rating and bridge assessment.

3- Moving (Live) Load

ARTC requires separate SpaceGass outputs for different moving load scenarios i.e. 300LA or RAS models needs to be created in separate As New and As Is models. If SLS is considered, a separate model needs to be created as well. Where moving load is modelled for a bridge in SpaceGass, it is essential to model two wheels with a distance equal to the track gauge rather than a single axle in the middle of track. The narrow, standard and broad gauges shall be taken as 1067, 1435 and 1600mm, respectively. Moving loads shall be generated with the shortest possible increments. A good approximation is to adopt increments to maximum 1.5% of the shortest span to obtain the acceptable shear forces and reactions. It is also recommended that for underbridges the “Apply member loads to closest member only” option is always unticked to make sure maximum generated moving loads are applied to the structural members. Care should be taken to make sure loads are only applied to the appropriate superstructure members, not other secondary or the substructure members.

Note 3-1-RAS shall be modelled exactly as per what is stated in the Engineering inspection tender documents.

Note 3-2-The axles loads shall be determined adopting an acceleration due to gravity of $g=10m/s^2$ e.g. a 30t axle load will include two wheels; each with a 150kN vertical force.

Note 3-3-If an FEA software is used for the analysis of an underbridge such as a masonry structure or arch, care must be taken when using transient dynamic / time-history response analysis to ensure that dynamic or amplification factors are not considered twice i.e. both in the model and the calculations. It is also noted that time steps are critical for such an analysis, so it should be avoided as much as possible unless there are some SHM devices installed on the underbridge to confirm natural frequencies of the structure with the transient analysis output. For an assessment, a nonlinear static moving load analysis may be used as a proper solution. DLA may also be applied in the model as an additional factor to the live load. The analyser for moving load influence line in some commercial FEA software can also calculate bending, shear or torsion on beam elements as well as stress and strain on shell and solid elements due to static moving load. This application solves the stiffness problem similar to the SpaceGass model; however, it benefits from different element types, meshing and stress distribution in the FEA software. For some FEA software; it may be necessary to predefine how loads should be applied to the elements in order that the train load distribution in AS5100:2017 is followed.

4- Horizontal Forces

When using the rational method; braking and traction loads may need to be analysed taking into account the requirements of both UIC 774-3 and AS5100.2:2017. In that case, a rigorous nonlinear FEA shall be created to assess rail-structure interactions, nonlinearly; including track stiffness, and vertical effects, braking, traction, thermal, shrinkage and creep loads using values stated in AS5100:2017 and this procedure. Precautions should be taken when using a combination of linear static and nonlinear transient analysis of different effects for obtaining maximum stresses in the rail or the structure. This method of assessment may only be required upon ARTC request; and where the structure does not theoretically pass the empirical forces as stated in AS5100.2:2017, Cl.9.7.2.2.

5- Wind Load

For trusses, trestles and bracings; models shall include applied wind load to structural members in the model, even if such a load case is not critical for the overall assessment. For load rating, wind load shall not be applied to train and members simultaneously unless advised by ARTC for a specific underbridge.

Note 5-1-SpaceGass has an application for wind load calculation only as per AS1170.2:2011. It should be noted that the definition of drag coefficient in AS5100.2:2017, section 17 is different to that provided in AS1170.2:2011. Wind load needs to be applied as per AS5100.2:2017 only using wind speeds and factors presented in this procedure.

6- Pedestrian / Maintenance Walkway Load

The minimum pedestrian / maintenance walkway load shall be taken as 5kPa, unless otherwise stated on design drawings.

7- DLA and MTF

DLA and MTF shall be applied in calculations and the model, respectively. As different members need to be assessed with their own DLAs, DLA shall not be applied as an overall dynamic factor to the entire model unless moving load is generated on each member, separately.

8- Load Factors and Load Case Combinations

Load factors and load case combinations shall be applied in the model rather than in the calculations.

ARTC shall be provided with models which include all load cases; including factored and unfactored, and the load combinations. Load combinations shall be taken as per AS5100.2:2017.

9- Other Load Cases

It should be noted that the mentioned load cases shall only be considered as the minimum required loads to be applied to a structure when load rating is undertaken. In any case, it is the Engineer’s responsibility to consider and apply other required loads as stated in AS5100:2017 considering structure geometry, material or application.

Examples that can be given are:

Structural analysis for the minimum restraint or stability where some obvious shortcomings exist about the structural stability in the lateral or longitudinal directions, assessment of thermal load, assessment of the damaged members from previous earthquakes or from an incident such as train derailment or a vehicle collision etc. Where modelling of these effects is deemed to be necessary, the Engineer shall consider rating of the members subjected to these effects in the model. ARTC shall be consulted, where there is an uncertainty about assessment of an underbridge for other loads than what is stated in this procedure.

10- Naming Model Outputs

Output files need to be named as referenced below:

Ellipse Equipment Number-Underbridge Name-Analysed Loading-Limit State-Rating State-Analysis Date

Example (Glennies Creek Bridge at Hunter Valley):

112873-Glennies Creek Bridge-300LA-ULS-As New-10-09-2020

Model Submittal

ARTC only requires unrun SpaceGass output files for review, as they can be readilytransferred by an email.