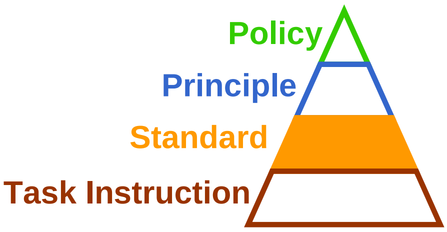

Structures Standard

Rail Bridge Design (Waka Kotahi Bridge Manual Annex)

Purpose

This document is for the design of rail bridges. It supersedes B-ST-DE-3036 Issue 1.0 2023.

Document Control

Document No.	B-ST-DE-3036	Issue No.	Issue 2.0
Date Effective	1/07/2024		
Prepared (P) Reviewed (R) Amended (A)	V1 - G Brown V1 - R Wessel V2 – L Coleman	Checked and Approved By	Professional Head – Structures Engineering
		Authorised for Release By	Professional Head – Structures Engineering

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1. Revision Procedure and History

This is a 'living' document, that will be updated every five years or whenever KiwiRail determines that changes to it and processing requirements documented herein are appropriate.

If changes arise from the review, this document will be reissued, however, if no changes arise from the review, the current version of this document will remain in force.

Refer to the **Briefing Note(s) for B-ST-DE-3036 Rail Bridge Design (Waka Kotahi Bridge Manual Annex)**

and **Document History** (at the end of this document) for full document changes.

Issue No	Prepared (P) Reviewed (R) Amended (A)	Authorised for Release By	Date Effective
01	G Brown (P) R Wessel (R)	Liam Coleman Professional Head Structures Engineering	01 May 2023
02	L Coleman	Liam Coleman Professional Head Structures Engineering	01 July 2024

1.1 Changes in this issue

Issue No	Section	Description	Page(s)
2	6.2	Clearances for curved and cant track	7
	6.8	Walkways	8
	7.3	Vertical superimposed dead load	9
	7.14	Snow	11
	7.22	Fatigue loads	13
	7.23	Deflection of superstructures	13
	8.12.5	Date and loading panels	19
	8.12.6	Asset Identification signage	19

2. Associated Documents

Level	Number	Title	Relationship

Signed by Liam Coleman on: 5/07/2024 3:42:53 PM 4112

Table of Contents

Signed by Liam Coleman on: 5/07/2024 3:42:53 PM 4112

Signed by Liam Coleman on: 5/07/2024 3:42:53 PM 4112

List of Figures

List of Tables

Signed by Liam Coleman on: 5/07/2024 3:42:53 PM 4112

3. Acronyms and Definitions

Acronyms	Definition
kN	Kilonewton
m	Metre
m^3	Cubic metre
MPa	Megapascal
AEP	Annual exceedance probability
DCLS	Damage control limit state
CALS	Collapse avoidance limit state
AADT	Annual average daily traffic
FoS	Factor of safety
km/h	Kilometres per hour

3.1 Notes, caution and warnings

Icon	**Definition**
	Note(s) to point out something of special importance
	Caution or warning – drawing special attention to anything of important reminder or a safety message

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4. Scope

This document is for the design of rail bridges and replaces W201 Railway Bridge Design Brief Issue 6 dated 2011.

5. Introduction

5.1 Introduction

Rail bridge design shall be undertaken in accordance with the Waka Kotahi Bridge Manual, except as outlined in this document. Rail specific requirements are provided based on the previous W201 requirements or the Australian Standard AS 5100 Bridge Design, where appropriate. Bridge Manual Third Edition Amendment 4 published in May 2022 is applicable.

This document addresses the parts of the Bridge Manual that are relevant to the design of rail bridges and provides specific alternative requirements where the Bridge Manual is not applicable.

Sections of the Bridge Manual that are not referenced in this document shall not be used for the design of rail bridges. This includes section 7.0, section 8.0, Appendix A, Appendix B, Appendix C, Appendix D, Appendix E and Appendix F, in addition to specific clauses within other sections which are referenced below.

All references to standards shall be taken to mean the latest version unless stated otherwise.

Where references to other documents are provided in this document, the name of the other document prefixes the reference section. Where there is no document name provided, the reference is to a section of this annex.

5.2 Definitions

A rail bridge is defined as a bridge or large culvert that carries one or more live rail tracks.

A large culvert is defined as a culvert with a waterway cross section greater than $3.4m^2$.

6. Design – General requirements

6.1 Design philosophy

The design philosophy for rail bridges shall be in accordance with section 2.1 of the Bridge Manual.

Rail bridges shall be Importance Level 3.

6.2 Geometric requirements

The geometric requirements in Bridge Manual section 2.2 are not applicable to rail bridges except for vertical clearances for rail bridges over highways and local roads.

Geometric requirements for rail bridges are provided in the following standards:

KiwiRail Standard T-ST-DE-5212 - Track Clearance Standard
KiwiRail Standard E-SP-AE-61317 - AEA Traction Clearances.

Signed by Liam Coleman on: 5/07/2024 3:42:53 PM 4112

6.2.1 Clearances for curved track

The minimum allowable horizontal curve across a new bridge is 150m. For curved track between 150 to 450m radius, speeds in excess of 80km/h are not possible and reduced dynamic load allowance shall be considered in accordance with AS5100.2 section 9.5 and AS 5100.7 section 11.4.3 to reflect the reduced operating speed.

For half-through bridges on >450m radius track, which does not exceed the vertical and horizontal clearances of the Auckland Metro Area ("Lower Sector Gauge" – Fixed Structure Gauge Line 9 in T-ST-DE-5212) will not be affected by vehicle end or centre throws and no additional deck width clearances need to be considered. For track on a 150 to 450m radius the deck width based on straight/tangent track will increase by the amount calculated from the following formula:

$$1487 + \left(\frac{28350}{R}\right)$$

(Units m)

If the bridge exceeds the Auckland Metro Area clearances ("Upper Sector Gauge" – Fixed Structure Gauge Line 9) the requirements of T-ST-DE-5212 need to be applied.

6.2.2 Clearances for track on a cant

The maximum allowable cant across a new bridge is 70mm. On curved track a cant allowance needs to be considered. For half-through bridges which do not exceed the vertical and horizontal clearances of the Auckland Metro Area the cant allowance can be calculated as follows:

$$\frac{Cant\ x\ Height}{Gauge}$$

(Units mm)

If the bridge exceeds the Auckland Metro Area clearances ("Upper Sector Gauge" – Fixed Structure Gauge Line 9) the requirements of T-ST-DE-5212 need to be applied.

6.3 Waterway design

Waterway design for rail bridges shall be in accordance with section 2.3 of the Bridge Manual.

For additional requirements for the design of river protection works, refer to KiwiRail Civil Engineering Standard – River Protection C-ST-RP-4106.

6.4 Site investigations

Site investigations for rail bridges shall be in accordance with section 2.4 of the Bridge Manual.

For additional requirements for site investigations, refer to KiwiRail Civil Task Instruction – Geotechnical Investigations C-TI-GE-4201.

6.5 Influence of approaches

The influence of approach embankments for rail bridges shall be in accordance with section 2.5 of the Bridge Manual.

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6.6 Urban design

The urban design requirements of section 2.6 of the Bridge Manual shall not generally apply to rail bridges, except for special circumstances to be defined by the rail authority. Such circumstances might include rail bridges located in urban areas or other locations specified by the rail authority.

6.7 Special studies

Special studies for rail bridges shall be in accordance with section 2.7 of the Bridge Manual.

6.8 Walkways

Walkways shall be provided on new rail bridges to provide access for inspection and maintenance staff, unless sufficient clearance is provided on a ballasted shoulder outside of the rail clearance envelope.

Inspection and maintenance walkways shall comply with the geometric requirements of section 6.2 for clearance requirements and to AS 1657 for walkway widths and loading.

The minimum height of the handrail, measured from walkway deck level is 1.1m

6.9 Culverts

Large culverts with a waterway cross sectional area greater than $3.4m^2$ shall comply with the requirements of this document.

6.10 Bridge transitions

KiwiRail are currently developing a “ballast box” precast solution. Before a detailed design is carried our seek approval from PH structures on what transition is to be applied.

The transitions between rail bridges and approaches shall comply with the requirements of KiwiRail Standard Details CE–100912:

Bridge Transition Repair Standard Details: Formation Excavation – Sheet 1
Bridge Transition Formation Reinstatement – Sheet 2
Bridge Transition Formation Reinstatement – Sheet 3.

6.11 Superstructure drainage

The superstructures of new rail bridges shall be provided with a suitable drainage system for stormwater run-off. For ballast decks, this shall include provision for stormwater to be positively drained from the deck to prevent stormwater being retained within the ballast. For open superstructures, stormwater can be allowed to run-off directly from the deck.

All discharges of stormwater from rail bridges shall comply with resource consent requirements.

6.12 Substructure drainage

The substructures of new rail bridges shall be provided with a suitable drainage system for groundwater within backfill to abutments or retaining walls, unless the structures are designed for the effects of groundwater.

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All discharges of stormwater from rail bridges shall comply with resource consent requirements.

6.13 Topographic survey

For the requirements of topographic survey refer to KiwiRail Track Standard – Topographic Survey T-ST-DE-5213.

7. Loading

7.1 Introduction

All rail structures shall be designed for the following loads which shall be considered to act in various combinations as set out in section 7.23.

7.2 Vertical dead load

Vertical dead loads shall comply with the requirements of section 3.4.1 of the Bridge Manual.

Dead loads may be based on the following unit weights:

Structural concrete 25kN/m^3
Structural steel 77kN/m^3.

7.3 Vertical superimposed dead load

Vertical superimposed dead loads shall consist of all permanent loads added after the structural system becomes complete. It shall include track ballast, railway track sets, fill, handrails, barriers, kerbs and services.

Superimposed dead loads may be based on the following unit weights:

Ballast 19kN/m^3
Complete rail track sets 5kN/m
Fill 17kN/m^3.

The unit weight of rail track sets includes for the weight of the rails, rail seatings, rail fastenings and sleepers.

Ballast depths of 500mm shall be designed for which allows for 300mm under the sleepers and 200mm for ballast shoulders and infill between the sleepers. The 500mm will need to be factored as per tables 7.1 & 7.2

An allowance for services and future services shall be made in accordance with Bridge Manual section 3.4.2.

7.4 Vertical train loads

Vertical train loads shall consist of the weight of trains, a dynamic load allowance, and loads from derailed trains.

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7.4.1 Vertical train load

For spans up to 50 m in length, vertical train loads shall be 210LA modified rail traffic loads to AS 5100.2 section 9.2 as shown in Figure 7.1 below. This applies to both simply supported and continuous spans.

Figure 7.1 shows the loads and spacing for a single axle group. Additional axle groups should be considered. Refer to AS 5100.2 section 9.2 for spacing between axle groups. Spacing of axle groups vary from 12.0m to 20.0m to give the maximum effect in the member under consideration.

For spans greater than 50m in length, vertical loading shall be agreed with KiwiRail on a project specific basis.

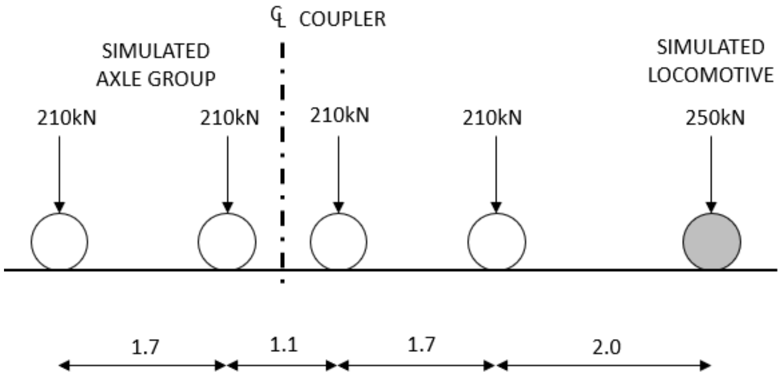

Figure 7.1 – 210LA Train Loading (only single axle group shown)

For rail bridges with more than one track, multiple track factors shall be in accordance with AS 5100.2 section 9.4.

The distribution of train axle loads shall be in accordance with AS 5100.2 section 9.6.

7.4.2 Dynamic load allowance

The dynamic load allowance shall be in accordance with AS 5100.2 section 9.5.

7.4.3 Vertical loads from derailed trains

Vertical loads from derailed trains shall be in accordance with AS 5100.2 section 11.5. Vertical train loading shall be taken as 210LA loading.

Load factors shall be in accordance with section 7.23 below.

7.5 Horizontal train loads

7.5.1 Centrifugal loads

For rail bridges on curves the centrifugal force shall be in accordance with AS 5100.2 section 9.7.1

7.5.2 Braking and traction train loads

The braking and traction longitudinal train load shall be in accordance with AS 5100.2 section 9.7.2 except as below.

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Braking and traction loads derived shall be factored by 0.70 to allow for the reduced vertical train load in New Zealand.

For bridges supporting ballasted track, up to one third of the longitudinal loads may be assumed to be transmitted by the track to resistance outside of the bridge structure, provided that no expansion switches or similar rail discontinuities are located on, or within, 18m of either end of the bridge.

7.5.3 Nosing loads

The nosing loads shall be in accordance with AS 5100.2 section 9.7.3.

7.5.4 Loads on ballast kerbs

Loads on ballast kerbs shall be in accordance with AS 5100.2 section 9.7.4.

7.6 Earthquake load

Earthquake loads on rail bridges shall be in accordance with Bridge Manual section 3.4.3.

7.7 Shrinkage, creep and prestressing effects

The effects of shrinkage, creep and shortening due to prestressing shall be in accordance with Bridge Manual section 3.4.4.

7.8 Wind

Wind loads shall be in accordance with Bridge Manual section 3.4.5.

7.9 Temperature effects

Temperature effects shall be in accordance with Bridge Manual section 3.4.6.

7.10 Construction and maintenance load

Construction and maintenance loads shall be in accordance with Bridge Manual section 3.4.7.

7.11 Water pressure

Loads due to water pressure shall be in accordance with Bridge Manual section 3.4.8.

7.12 Groundwater on buried surfaces

Groundwater pressures shall be in accordance with Bridge Manual section 3.4.9.

7.13 Water ponding

Water ponding loads shall be in accordance with Bridge Manual section 3.4.10.

7.14 Snow

Snow loads shall be considered for bridges located in the Central Plateau and the Southern Alps and shall be in accordance with Bridge Manual section 3.4.11. For rail bridges snow loading would only be applied to walkways which are not perforated.

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7.15 Earth loads including rail surcharge loads

Earth loads shall be in accordance with Bridge Manual section 3.4.12, except that surcharge loads due to train loads shall be derived in accordance with AS 5100.2 section 14.3.

7.16 Load on handrails

Loads on handrails for inspection and maintenance walkways shall be in accordance with AS 1657.

7.17 Load on walkways

Loads on walkways shall be in accordance with AS 1657. Loading for inspection and maintenance shall be 2.5kPa. This may be increased where heavy equipment is likely to be required on the walkway with the agreement of the Professional Head, Structures.

7.18 Vibration

The vibration criteria of Bridge Manual section 3.4.15 do not apply to rail bridges.

7.19 Settlement, subsidence and ground deformation

Loads due to settlement, subsidence and ground deformation shall be in accordance with Bridge Manual section 3.4.16.

7.20 Forces locked-in by erection sequence

Forces locked in by the erection sequence shall be in accordance with Bridge Manual section 3.4.17.

7.21 Collision loads

7.21.1 General

Collision loads shall be in accordance with AS 5100.2 section 11 except as below.

Collision loads shall be applied using load combinations to section 7.23.

7.21.2 Collision load from road traffic

Collision loads from road traffic shall be in accordance with Bridge Manual section 3.4.18.b

7.21.3 Collision loads from rail traffic

Collision loads from rail traffic shall be in accordance with AS 5100.2 section 11.4 except as below.

Collision loads on support elements from AS 5100.2 shall be factored by 0.70 to allow for the reduced vertical train loads in New Zealand.

7.21.4 Collision loads on through-girder type rail bridge superstructures

Collision loads on through-girder type rail bridges shall be in accordance with AS 5100.2 section 11.4.4.

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7.21.5 Platforms

Where a platform is deemed to provide protection from derailed vehicles within station areas, the construction of the platform shall comprise reinforced concrete facings and a compacted fill material with a density of not less than 1500kg per cubic metre.

7.22 Fatigue Loads

Fatigue loads shall be in accordance with AS 5100.2 section 9.8, except that the base number of cycles shall be for the main freight line network unless instructed otherwise by KiwiRail. The base number of cycles can be taken as Branch line freight if the gross tonnage is less than 500,000 and agreed by the PH Structures. This requirement replaces AS 5100.2 section 9.8.4.

The design traffic load shall be in accordance with section 7.4 above and shall use half of the design dynamic load allowance.

The axle group spacing for fatigue **assessment** shall be the same as the critical spacing for the live load analysis **for SLS and ULS demands**.

If a spare span is refurbished and used to build a new bridge, allowance is to be made for the past-history of the spare span when calculating the total number of load cycles.

7.23 Deflection of superstructure

Deflection limits of rail bridges under traffic shall be in accordance with AS 5100.2 section 9.10

7.24 Load factors and combination of load effects

7.24.1 General

The load factors and load combinations to be adopted at the ultimate limit state and serviceability limit state shall be as below.

The effects of the loads described in the above sections shall be combined by summating each load effect multiplied by the relevant load factors shown below.

In any combination, if a worse effect is obtained by omitting one or more of the transient loads, this case shall be considered. Similarly, the case of any of any ‘permanent’ load that is not always present (e.g. superimposed dead load, shrinkage and creep or settlement that are not initially present) shall be considered if a worse effect is obtained.

The load combinations specified cover general conditions. Provision shall also be made for other loads (e.g. snow and fire) where these might be critical. Combinations for such loads shall be agreed with the KiwiRail on a project specific basis, or shall be detailed in the project principal’s (or minimum) requirements for design and construct type projects.

Locked-in effects due to erection sequence shall be included under dead load and prestressing as appropriate (see Bridge Manual section 3.4.17).

For specific load effects for the design of completed structures refer to Bridge Manual section 3.5.2.

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7.24.2 Serviceability limit state load factors and combinations

The load factors and combinations in Table 7.1 shall be applied at the serviceability limit state.

7.24.3 Ultimate limit state load factors and combinations

The load factors and combinations in Table 7.2 shall be applied at the ultimate limit state.

7.24.4 Construction Load combinations

Construction load factors and combinations shall be in accordance with Bridge Manual Tables 3.4 to 3.7.

For specific load effects for structures under construction refer to Bridge Manual section 3.5.3.

7.24.5 Fatigue load factor

A load factor of 1.0 shall be used for fatigue due to train loading.

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Table 7.1 - Load combinations and load factors for the serviceability limit state for the design of completed structures

			Dead		Other permanent							Traffic				Environment						
		Combination	Self-weight (Conc/Steel)	Superimposed (Ballast / Direct Fix)	Bearing friction	Creep/shrinkage	Prestressing	Earth pressure	Settlement	Groundwater pressure (ordinary)	Ordinary water flow and buoyancy [d]	Train live loading	Horizontal effects braking & traction	Transverse effects nosing & centrifugal (not simultaneously)	Pedestrian/cycle	Groundwater pressure (elevated) [a]	Floodwater flow and buoyancy, with scour [a]	Water ponding [a]	Wind [a]	Uniform temperature	Differential temperature
	Load symbol		DL	SD	BF	SG	PS	EP	ST	GW_O	OW	LL	HE	TE	FP	GW_E	FW	PW	WD	TP	DT
Permanent effects only		T0	1.00	1.30/1.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	0.50	0.50
Primary traffic (train+ pedestrian) with environmental	Trains with temperature	T1A	1.00	1.30/1.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	0.70	0.70
	Trains with wind	T1B	1.00	1.30/1.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	0.70	-	-
	Trains with flood	T1C	1.00	1.30/1.20	1.00	1.00	1.00	1.00	1.00	-	-	1.00	1.00	1.00	1.00	0.70 [c]	0.70 [b]	0.70	-	-	-
Environmental with traffic (trains and pedestrians)	Temperature with trains	T2A	1.00	1.30/1.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.70	0.70	0.70	-	-	-	-	1.00	1.00
	Wind with trains	T2B	1.00	1.30/1.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.70	0.70	0.70	-	-	-	1.00	-	-
	Flood with trains	T2C	1.00	1.30/1.20	1.00	1.00	1.00	1.00	1.00	-	-	1.00	0.70	0.70	0.70	1.00	1.00	1.00	-	-	-
Environmental combinations	Flood with wind	T3A1	1.00	1.30/1.20	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	1.00	1.00	1.00	0.70	-	-
	Wind with flood	T3A2	1.00	1.30/1.20	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	0.70 [c]	0.70 [b]	0.70	1.00	-	-
	Temperature with wind	T3A3	1.00	1.30/1.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	0.70	1.00	1.00
	Wind with temperature	T3A4	1.00	1.30/1.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	1.00	0.70	0.70

Notes:

a) Load factor applied to serviceability limit state level flood, groundwater and wind actions

b) If 0.70xFW results in a lower load than 1.00xOW, it shall be replaced by 1.00xOW

c) If 0.70xGWE results in a lower load than 1.00xGWO, it shall be replaced by 1.00xGWO

d) Ordinary water flow and buoyancy to be taken as due to the flow with an AEP of 1 (i.e. 1 year event)

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Table 7.2 - Load Combinations and load factors for the ultimate limit state combinations for the design of completed structures [a]

			Dead [d]		Other permanent [d]							Traffic				Environment						Extreme		
		Combination	Self-weight (Conc / Steel)	Superimposed (Ballast / Direct Fix)	Bearing friction	Creep/shrinkage	Prestressing	Earth pressure	Settlement	Groundwater pressure (ordinary)	Ordinary water flow and buoyancy [c]	Train live loading	Horizontal effects braking & traction	Transverse effects nosing & centrifugal (not simultaneously)	Pedestrian/cycle	Groundwater pressure (elevated)	Floodwater flow and buoyancy, with scour	Water ponding	Wind	Uniform temperature	Differential temperature	Earthquake	Tsunami	Collision loads/derailed train loads[e]
Load symbol Load	Load symbol		DL	SD	BF	SG	PS	EP	ST	GW_O	OW	LL	HE	TE	FP	GW_E	FW	PW	WD	TP	DT	EQ	TS	CO
Permanent effects only		TO	1.2/1.1	1.7/1.4	1.35	1.35	1.00	1.35	1.35	1.00	1.35	-	-	-	-	-	-	-	-	0.50	0.50	-	-	-
Trains with temperature & pedestrians		T1A	1.2/1.1	1.7/1.4	1.30	1.35	1.00	1.50	1.35	1.00	1.35	1.60	1.60	1.60	1.50	-	-	-	-	1.00	1.00	-	-	-
Trains with wind and temperature		T1B	1.2/1.1	1.7/1.4	1.30	1.35	1.00	1.50	1.35	1.00	1.35	1.40	1.40	1.40	1.20	-	-	-	1.00 [b]	0.75	0.75	-	-	-
Environmental with trains	Primary temperature with traffic	T2A	1.2/1.1	1.7/1.4	1.30	1.35	1.00	1.50	1.35	1.00	1.35	1.20	-	-	1.00	-	-	-	-	1.70	1.25	-	-	-
	Primary flood with traffic	T2C	1.2/1.1	1.7/1.4	1.30	1.35	1.00	1.50	1.35	-	-	1.20	-	-	1.00	1.00	1.30	1.00	-	-	-	-	-	-
Environmental combinations	Primary wind with flood and temperature	T3A	1.2/1.1	1.7/1.4	1.30	1.35	1.00	1.50	1.35	-	-	-	-	-	-	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-
Blank to align with Waka Kotahi Bridge Manual		T4A																						
Extreme	Seismic	T5A	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	0.50	0.50	1.00	-	-
	Tsunami	T5B	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	0.50	0.50	-	1.00	-
	Collision / derailed train	T5C	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.20/ 1.00 [e]	-	-	1.20/ 1.00 [e]	-	-	-	-	0.50	0.50	-	-	1.00/ 1.20 [e]

Notes:

a) Also load combinations and load factors for damage control limit state (DCLS) and collapse avoidance limit state in accordance with Bridge Manual sections 5 and 6. Load combinations due to fatigue, construction forces, prestress at transfer are not included in this table.

b) See Bridge Manual section 3.4.5(b) for wind speed to be considered in conjunction with train loading

c) Ordinary water pressure and buoyancy to be taken as due to the flow with an AEP of 1 (i.e. 1 year return event other than for extreme load combinations 5A (seismic), 5C (collision) and 5D (derailed train) where it shall be taken as due to mean daily flow conditions

d) Where the effect of possible reduction in any permanent load is critical at ultimate limit state, a factor of 1.00 shall be used for that load. See also Bridge Manual section 3.5.1(a)

e) For derailed train load use 1.20 for Case A and 1.0 for Case B and kerbs – refer to AS 5100.2 section 11.5

8. Analysis and design criteria

8.1 General

8.1.1 Analysis

Structural analysis shall be undertaken in accordance with Bridge Manual section 4.1.

8.2 Reinforced concrete and prestressed concrete design

8.2.1 General

Design of reinforced and prestressed concrete shall be undertaken in accordance with Bridge Manual section 4.2, except as below.

8.2.2 Crack widths

For Bridge Manual section 4.2.1 (a), Load combination 0 shall be replaced by load combination T0 in Bridge Manual table 4.1.

8.2.3 Design for fatigue

For Bridge Manual section 4.2.1 (j), in the application of NZS 3101 clause 2.5.2.2 the stress range due to repetitive loading to be considered in flexural reinforcing bars shall be that due to train loading at the serviceability limit state (LL x 0.5 dynamic load allowance).

For Bridge Manual section 4.2.1 (j), in the application of NZS3101 clause 19.3.3.6.2 the stress range due to frequently repetative loading to be considered in prestressed and non-prestressed reinforecement shall be that due to train loading at the serviceability limit state (LL x dynamic load allowance). No infrequent train loading shall be considered.

8.3 Structural steel and composite construction design

8.3.1 General

Design of structural steel and composite construction shall be undertaken in accordance with Bridge Manual section 4.3.

8.3.2 Fatigue of steel bridges

Design of steel bridges for fatigue shall be undertaken in accordance with AS 5100.6 section 13.

8.4 Timber design

Design of timber shall be in accordance with Bridge Manual section 4.4.

Signed by Liam Coleman on: 5/07/2024 3:42:53 PM 4112

8.5 Aluminium

The design of aluminium shall be in accordance with Bridge Manual section 4.5.

8.6 Other materials

The criteria applying to the use of other materials not mentioned in this document will be subject to the approval of KiwiRail.

8.7 Bearings

The design of bearings shall be in accordance with Bridge Manual section 4.7.

8.8 Integral and semi-integral abutments

Integral and semi-integral abutments shall be designed in accordance with Bridge Manual section 4.8.

8.9 Network and tied arch bridges

Network and tied arch bridges shall be designed in accordance with Bridge Manual section 4.9 upon approval from the Professional Head, Structures.

8.10 Buried structures

Buried structures shall be designed in accordance with Bridge Manual section 4.10.

8.11 Bridges subject to inundation by flooding

Bridges subject to inundation by flooding shall be designed in accordance with Bridge Manual section 4.11.

8.12 Miscellaneous design requirements

8.12.1 Deck drainage

Deck drainage to ballast top and solid deck rail bridges shall achieve the requirements of Bridge Manual section 4.12.3 where possible. Where this is not possible, the agreement of the Professional Head, Structures shall be obtained.

8.12.2 Services

Where services are carried by a rail bridge, they shall be designed in accordance with Bridge Manual section 4.12.5.

8.12.3 Confinement of embedded fixings

Embedded fixings shall be designed in accordance with Bridge Manual section 4.12.8.

8.12.4 Anti-graffiti coatings

Where to be provided, anti-graffiti coatings shall be designed in accordance with Bridge Manual section 4.12.19.

Signed by Liam Coleman on: 5/07/2024 3:42:53 PM 4112

8.12.5 Date and loading panels

All structures subjected to direct fix loading shall have displayed details of the date of construction and the design live loading, cast into the superstructure. Sizing and fixing of the plates shall be in accordance with the Bridge Manual and Figure 4.5.

Structures designed to 210LA-BT or 210LA-DT shall have this information displayed on two panels in locations visible for inspection.

BT indicates the structure is designed for ballasted track while DT indicates direct fix track.

8.12.6 Asset Identification Signage

Asset identification signs help inform people what the asset number is and location of the asset on the network. Assets will be given a Bridge number for the line in question. The signs are to be mounted at each end of the asset on the left-hand side.

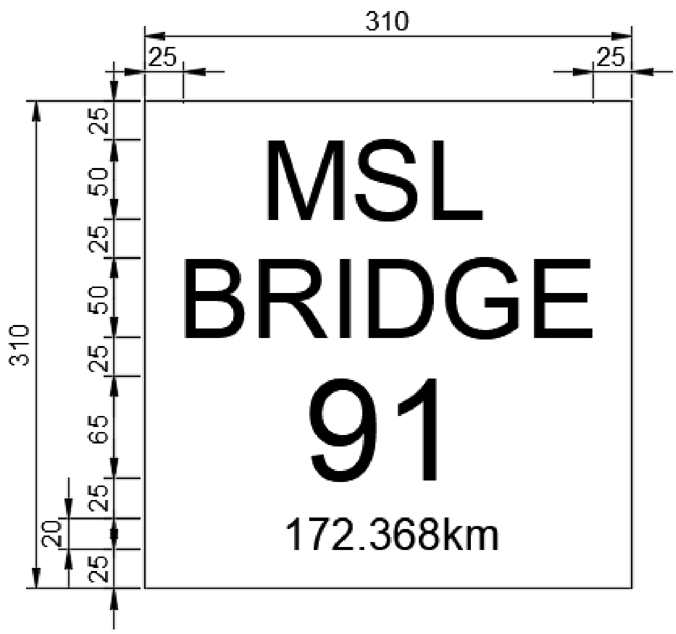

Figure 8.1 – Example of an asset identification sign (dimensions in mm)

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9. Earthquake resistant design of structures

Earthquake resistant design of rail bridges shall be undertaken in accordance with the requirements of Bridge Manual section 5.0, except as below.

In Table 5.1 note 2 of the Bridge Manual, the definitions of emergency traffic for rail bridges shall be as follows:

- Hi Rail vehicles up to 7 tonnes within 3 days for DCLS or after temporary repair for CALS. A load factor of 1.6 and a dynamic load factor for a speed of 50km/h may be used for both DCLS and CALS.
- Work trains within 1 month for DCLS where work trains shall be 210LA loading. Work trains for CALS shall be 210LA if permanent repair is possible although reduced load capacity may be necessary. A load factor of 1.2 and a dynamic load factor for a speed of 30km/h may be used for both DCLS and CALS.

Horizontal linkage systems, as described in Bridge Manual section 5.7.2, are generally not provided for rail bridges.

Seismic restraint, in both the longitudinal and transverse directions, is normally provided for non-integral rail bridges in the form of shear keys or dowels. Seismic restraint shall be designed in accordance with the Bridge Manual.

10. Site stability, foundations, earthworks and retaining walls

Design for site stability, foundations, earthworks and retaining walls shall be in accordance with Bridge Manual section 6, except as below.

Bridge Manual table 6.1 settlement limits for soil structures apply. For rigid walls and flexible walls or slopes capable of displacing without structural damage, settlement limits for rail bridges shall be taken to be the same as supporting a road carriageway with AADT >2500.

Bridge Manual table 6.2 shall apply, except that post-earthquake function – short term, shall be for a bridge to be repairable to carry normal rail traffic within 1 month with a slope stability FoS > 1.3 under static strength conditions, although speed restrictions may be acceptable until long term reinstatement is completed.

Bridge Manual section 6.7 is not applicable to rail bridges unless agreed with the rail authority.

For additional requirements for retaining walls refer to Civil Engineering Standard – Retaining Walls C-ST-RW-4104.

Signed by Liam Coleman on: 5/07/2024 3:42:53 PM 4112

11. Reporting

11.1 Highway structures design guide requirements

The highways structures design guide requirements for reporting are generally applicable to the design of rail bridges and shall be adopted where applicable.

11.2 Additional rail specific requirements

Specific rail requirements for reporting are as below.

11.2.1 Design assessment report

When design options are being assessed these shall be reported to KiwiRail in a design assessment report.

11.2.2 Approval in Principal statement

At the commencement of the detailed design stage, the design intent shall be reported to KiwiRail in an approval in principal statement.

11.2.3 Design features report

At the completion of detailed design stage, the final design shall be reported to KiwiRail in a design features report.

12. Technical approval

12.1 Highway Structures Design Guide requirements

Technical approval for rail bridges shall follow the requirements of the Highway Structures Design Guide, where applicable.

Technical approval for KiwiRail structures shall be obtained from KiwiRail Professional Head, Structures.

12.2 Departures from standards

Where the design standards set out in this document are not achievable and/or practicable, a departure from standards shall be obtained from the rail authority.

Departures for KiwiRail structures shall be obtained from KiwiRail Professional Head, Structures.

13. References

Waka Kotahi NZ Transport Agency (2022) Bridge Manual SP/M/022 Third Edition amendment 4

Standards Australia AS 5100.2 Bridge Design, Part 2 Design loads

AS 1657 Fixed Platforms, Walkways, Stairways and Ladders

American Railway Engineering and Maintenance-of-Way Association (AREMA), 2015, Manual for Railway Engineering

Signed by Liam Coleman on: 5/07/2024 3:42:53 PM 4112

KiwiRail Network Engineering Railway Design Brief W201, Issue 6, 2011
KiwiRail Network Engineering Track Engineering Handbook T:200, January 2015
KiwiRail Network Engineering Standard T-ST-DE-5212, Track Clearance Standard
KiwiRail Network Engineering Standard E-SP-AE-61317, AEA Traction Clearances
KiwiRail Network Engineering Civil Standard Formation C-ST-FO-4110 dated March 2019
KiwiRail Network Engineering Bridge Transition Formation Reinstatement Drawings CE 100912 Sheets 1 to 3, Revision A
KiwiRail Civil Engineering Standard C-ST-GE-4105, Ground Engineering and Earthworks
KiwiRail Civil Engineering Standard C-ST-RP-4106, River Protection
KiwiRail Civil Engineering Standard C-ST-RW-4104, Retaining Walls
KiwiRail Civil Track Instruction C-TI-GE-4201, Geotechnical Investigations
KiwiRail Track Standard T-ST-DE-5213, Topographic Survey

Signed by Liam Coleman on: 5/07/2024 3:42:53 PM 4112

Appendix 1 Commentary

C5 Introduction

C5.1 Introduction

This document provides background and commentary on the new KiwiRail Rail Bridge Design Standard and the rationale for the changes made from the previous Railway Bridge Design Brief W201.

KiwiRail requested Beca Ltd to prepare a new KiwiRail Rail Bridge Design Standard to be used for the design of rail bridges in New Zealand.

The overarching philosophy of the Standard as determined by KiwiRail is to align the design of rail bridges in New Zealand with the design of road bridges by adopting where possible the Waka Kotahi NZTA Bridge Manual (Bridge Manual) and a limit state approach to the design of rail bridges in New Zealand. Where the Bridge Manual is not applicable or does not cover the specific requirements for rail bridges, the Standard adopts AS 5100 requirements particularly for loading and design of specific elements.

Previously, W201 adopted a mixture of design standards including AREMA, the Bridge Manual and specific KiwiRail requirements.

It is KiwiRail's intention that the Standard should have a similar format to the Bridge Manual and that it may ultimately become a section of the Bridge Manual. Similarly, this commentary may eventually be added to the Bridge Manual commentary.

This document covers the following:

- Design – general requirements
- Loading
- Analysis and design criteria
- Earthquake resistant design of structures
- Site stability, foundations, earthworks and retaining walls
- Reporting
- Technical approval.

C5.2 Definitions

Definitions are provided for a rail bridge to be designed to the KiwiRail Rail Bridge Design Standard as being a bridge or large culvert that carries one or more live rail tracks. A large culvert is also defined as being a culvert with a waterway cross section greater than $3.4m^2$ which is in line with the Bridge Manual definition.

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C6 Design – General requirements

C6.1 Design philosophy

The design philosophy for bridges set out in the Bridge Manual is adopted and rail bridges are categorised as Importance Level 3.

Reduced importance levels for bridges located on less trafficked lines may be adopted in future.

C6.2 Geometric requirements

Clarification is provided of Bridge Manual geometric requirements which are not applicable to rail bridges except for vertical clearances over highways and local roads which adopt the Bridge Manual requirements.

Reference is made to the geometric requirements for rail bridges as provided in relevant KiwiRail standard drawings.

C6.2.1 Clearances for curved track

For half-through bridges that do not exceed the maximum vertical and horizontal clearances of the Auckland Metro Area (sometimes referred to the Lower Sector Gauge) the structural members are positioned low down on the structural gauge and do not cause clash conflicts. If there is curved track across the bridge with a radius >450m the effects of vehicle end and centre throws do not need to be considered as the body of the vehicle in located in the upper sector gauge above the structural members.

For track on a 150 to 450m radius the deck width based on straight/tangent track will increase by the amount calculated from the following formula:

$$1487 + \left(\frac{28350}{R}\right)$$

(Units m)

This formula has been calculated based on a concept “pocket” ISO container wagon (drawing 15023590 to 15023592) which has 15,046mm bogie centres and a wagon width of 2,602mm for the Lower Sector Gauge.

C6.2.2 Clearances for track on a cant

For half-through bridges that do not exceed the maximum vertical and horizontal clearances of the Auckland Metro Area (sometimes referred to the Lower Sector Gauge) the structural members are positioned low down on the structural gauge and do not cause a clash conflict. The rotational effects of the vehicle body due to cant are minimal in the lower sector gauge and as such only a small allowance for cant needs to be considered as per the formula in section 6.2.2.

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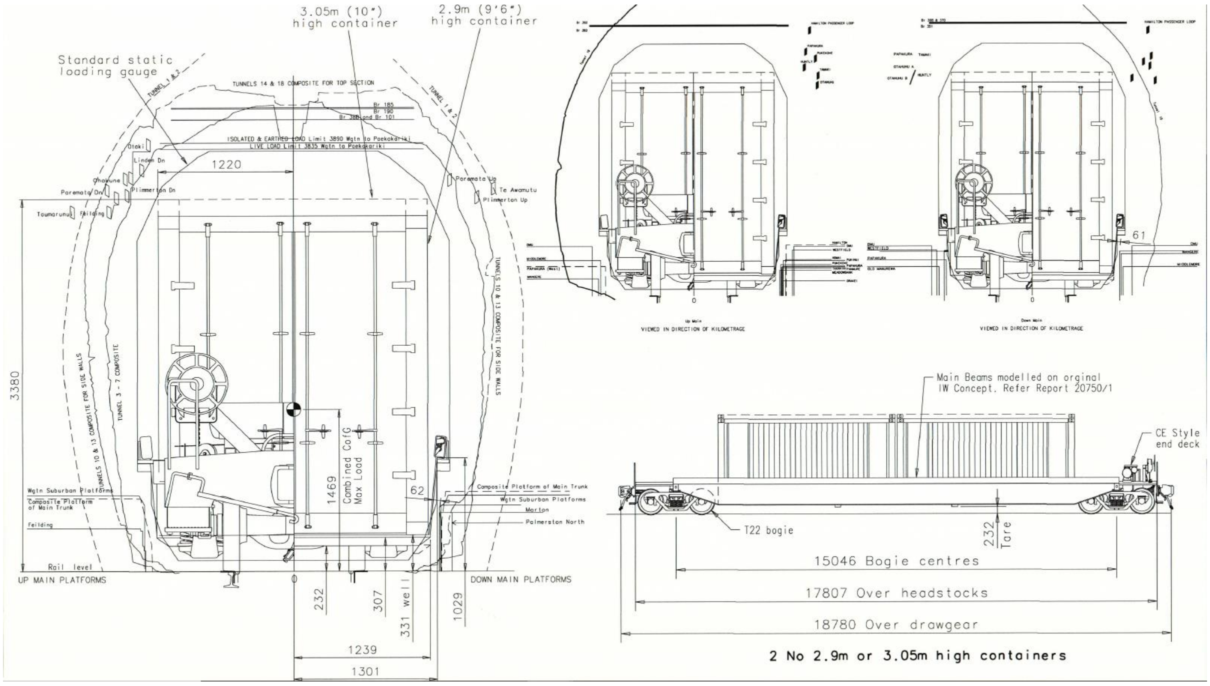

Figure C6.1 – Concept "pocket" ISO container wagon.

C6.3 Waterway design

The requirements for waterway design in the Bridge Manual are adopted including freeboard requirements. This requires freeboard to be 0.6m unless there is a possibility that large trees may be carried down the waterway in which case the freeboard should be 1.2m. This replaces the W201 requirement for freeboard to be 0.6m.

A significant change to waterway design at bridges using the Bridge Manual is that the bridge is to be designed for both SLS2 and ULS limit states. At SLS2, the bridge is to be designed for a 1:100 AEP flood and at ULS for a 1:1000 AEP flood for an importance level 3 structure. W201 only required design for a 1:100-year event.

The performance criteria vary between limit states, with design at SLS2 requiring the waterway below the bridge to cater for a 1:100-year flood and meet freeboard requirements, and limit damage to the structure, approaches and any river protection works. At ULS the waterway is required to cater for a 1:1000-year flood but the bridge is allowed to be overtopped. River protection works may well be damaged and approaches may fail under this limit state, but the bridge must not collapse. It should be noted that the performance criteria for waterway design at each limit state are quite different to other design cases such as earthquakes.

Additional requirements for river protection works as per KiwiRail standards are referenced in the Standard.

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C6.4 Site investigations

The requirements for site investigations in the Bridge Manual are adopted.

Additional KiwiRail requirements for site investigations are referenced.

C6.5 to C6.13 Other general requirements

Other general requirements are included covering both the specific requirements in the Bridge Manual and specific KiwiRail requirements. These include requirements for approaches, urban design, special studies, walkways, culverts, bridge transitions, superstructure and substructure drainage and topographic surveys.

Requirements for walkways are included requiring them to be provided on new rail bridges together with reference to AS 1657 for walkway widths and loading.

Bridge transition and topographic survey requirements are added which reference KiwiRail standard details.

Requirements to provide suitable drainage systems to the superstructures of all rail bridges, and in particular ballast decks are included, together with requirements for substructure drainage to backfill at abutments.

C7 Loading

C7.1 Introduction

The loading is based on a combination of Bridge Manual and AS 5100.2 requirements with some requirements also taken from W201.

C7.2 Vertical dead load

Vertical dead loads to the Bridge Manual have been adopted and suggested material densities are provided for concrete and steel which are taken from W201.

C7.3 Vertical superimposed dead load

Superimposed dead loads are defined and unit weights are provided for rail specific components taken from W201.

C7.4 Vertical train loads

C7.4.1 Vertical train loads

General

The vertical train live loading has been revised with a new load model adopted to replace the W201 real vehicle load model. The previous W201 train arrangement was based on a real train configuration, where all axles were 25t to cater for future aspirations. The capacity of the network is currently 18t.

The approach taken for the new train loading was to use an international load model. Noting a load model is a fictional rail vehicle used to apply appropriate loading to bridges which envelopes the current fleet of vehicles and future

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requirements. For KiwiRail the long-term aspiration is for 25t axles but a staged approach of 20t to 22.5t to 25t will be taken. Achieving 25t will take substantial time and investment to achieve and will impact not only bridges but civil, track and rolling stock assets.

Beca Ltd were commissioned to carry out a review of the previous W201, European LM071 and AS 5100 load models to see what was most appropriate for the new Standard. WSP were commissioned to peer review the document. The work identified that the previous W201 real train loading was very conservative compared to the Australian and European networks/models which run 36t and 25t networks.

The review established that the most appropriate load model would be the AS 5100.2 load model. Bridge design in New Zealand is influenced by Australian standards and many bridge designers in New Zealand are familiar with Australian Standards. It was considered that by adopting an AS/NZ model and method of design it would lead to harmonisation and consistency in design and maximise the resources within New Zealand for rail bridge design, whereas in the past the AREMA and working stress methods of design were very niche with limited expertise in their use in New Zealand.

The live loading adopted is 70% of 300LA loading to AS 5100.2. This is now described as 210LA.

The 210LA was selected by comparing the load curves for flexure and shear to W201 (25t axles),W201 (18t axles), LM071 and 300LA loading, over a range of span lengths from 2m to 50m for both single simply supported spans and continuous two span bridges, with equal spans. The 210LA load model gives a step change in demands above a W201 18t, by adopting a single 25 tonne axle and a sequence of 21 tonne axles. The single 25t axle will cater for localised demands and still incorporate the future aspiration of 25t from the previous W201 model. With the factored loads applied in the new annex future axles of 20-25t can be catered for. The adoption of 210 LA loading will reduce the flexural and shear demands on bridges and should lead to more realistic and economical design outcomes than the previous W201 loading with 25 tonne axles.

It should be noted that AS 5100.2 requires the spacing of axle groups in the 210LA loading model to vary between 12.0m and 20.0m and the spacing should be selected to give the critical looad effect in the member being designed. Generally 12.0m will be critical for single span bridges but there may be configuarations of continuous bridges where larger axle spacings are critical.

Live load model

Only single and two span continuous bridges with equal spans were considered as these represent the worst case for demands at midspan and at piers, with a single span giving the critical sag demands and the two-span arrangement giving the critical hog and shear demands. Three span continuous bridges and greater are less onerous than two spans.

Signed by Liam Coleman on: 5/07/2024 3:42:53 PM 4112

Dynamic load factors and load factors were excluded from the analysis, as it was intended to compare the nominal train loads only. These are addressed separately.

Live load bending, shear and reactions

Bending moments, shear forces and pier reactions for 210LA loading for a range of simply supported single spans from 2m to 50m are provided in Table C7.1 below.

The load effects are unfactored and exclude DLA.

The pier reactions are for the central pier with two equal simply supported spans.

Signed by Liam Coleman on: 5/07/2024 3:42:53 PM 4112

Table C7.1 – Bending moments, shear forces and pier reactions for simply supported spans between 2m and 50m

Span Length (m)	Max. Bending Moment (kNm)	Max. Shear Force (kN)	Max. Reaction at Pier (kN)
2	126	305	336
3	210	357	448
4	337	426	565
5	495	477	671
6	683	544	741
7	893	592	791
8	1138	651	828
9	1408	700	858
10	1681	739	881
11	1954	771	914
12	2226	798	961
13	2499	821	1031
14	2772	840	1095
15	3044	868	1151
16	3317	900	1200
17	3590	938	1284
18	3863	981	1367
19	4136	1026	1441
20	4409	1071	1507
22	5077	1149	1622
24	5930	1215	1741
26	6871	1270	1882
28	7814	1335	2006
30	8761	1411	2164
32	9710	1492	2307
34	10933	1568	2433
36	12319	1635	2560
38	13704	1695	2702
40	15089	1761	2832
45	18568	1951	3168
50	22791	2117	3503

C7.4.2 Dynamic load allowance

The dynamic load allowance (DLA) has been revised to adopt the AS 5100.2 requirements. This change is consistent with adopting 210LA live loading. For some span lengths the DLA will increase compared to W201 requirements. For steel bridges it is expected to reduce. A high-level review of the AS 5100 DLA identified that it takes a similar approach to the European approach which was established in the 1970's and is still deemed appropriate today.

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An important aspect of the AS 5100 DLA is that it is selected to give the worst effect in the particular member under consideration and so may use several different values with the design of a bridge, whereas W201 DLA adopted a single value for all members.

C7.4.3 Vertical loads from derailed trains

The vertical derailment loading has been revised to adopt AS 5100.2 requirements but with the vertical load requirements taken as 210LA loading. This replaced the previous W201 derailment loading.

C7.5 Horizontal train loads

C7.5.1 Centrifugal loads

Transverse loads due to centrifugal effects are revised by adopting AS 5100.2 values.

C7.5.2 Braking and traction loads

The horizontal live load effects due to trains for longitudinal braking and traction loads, have been revised by adopting AS 5100.2 values except that braking and traction loads are factored by 0.70 to reflect the use of the 210LA live loading model.

The distribution of longitudinal braking and traction loads in AS 5100.2 has been amended to allow the distribution of up to 30% of longitudinal loads to resistances outside the bridge structures, in accordance with an earlier version of AS 5100.2 (2014), provided there are no discontinuities in the rail. This has been amended to reflect the likely distribution that will occur and we understand it will be in line with current Australian practice. It is expected that seismic demands will generally be in excess of these requirements and drive design outcomes.

C7.5.3 Nosing loads

Nosing loads have been revised by adopting AS 5100.2 values.

C7.5.4 Loads on ballast kerbs

Loads on ballast kerbs have been revised by adopting AS 5100.2 values.

C7.6 Earthquake loads

Earthquake loads from the Bridge Manual have been adopted.

C7.7 to C7.20 Other loads

Other loads due to shrinkage, creep, prestressing effects, wind, temperature effects, construction and maintenance, water pressure, groundwater, water ponding, snow, earth, vibration, settlement and forces locked-in by construction have adopted the Bridge Manual requirements.

Requirements for surcharge loads have been modified to include AS 5100.2 requirements for train surcharge loads.

Signed by Liam Coleman on: 5/07/2024 3:42:53 PM 4112

The requirements of AS 1657 have been adopted for handrails and walkways to reflect the specific requirements of these elements on rail bridges to cover maintenance access, rather than the Bridge Manual requirements which cover public pedestrian access for footways.

C7.21 Collision loads

C7.21.1 General

The collision loads combine the requirements from AS 5100.2 and the Bridge Manual. This replaces W201 requirements.

C7.21.2 Collision loads from road traffic

The collision load requirements of AS 5100.2 are adopted except for collision loads from road vehicles which will be in accordance the Bridge Manual requirements.

The AS 5100.2 approach to the use of redundancy and provision of alternative load paths and risk analysis is adopted.

C7.21.3 Collision loads from rail traffic

Collision loads on supports from rail traffic adopt the values in AS 5100.2 factored by 0.70 to reflect the lower vertical train loads in New Zealand.

C7.21.4 Collision loads on through-girder type rail bridge superstructures

The collision load requirements of AS 5100.2 are adopted for through-girder type rail supestructures.

C7.21.5 Platforms

The requirements for structures that are protected by platforms in W201 are retained.

C7.22 Fatigue loads

The fatigue load requirements of AS 5100.2 have been adopted except for the number of load cycles which is to be for the main freight line network unless instructed otherwise by KiwiRail.

The design traffic load for fatigue is the 210LA vertical train load but with half the dynamic load factor which is a requirement of AS 5100.2.

A requirement has been added for the axle spacing for fatigue loads to be the same as the critical axle spacing for the live load analysis. This has been added to provide consistency between the live load and fatigue load analysis.

The requirements from W201 for the use of refurbished spare spans are included.

C7.23 Load factors and load combinations

C7.23.1 General

The load factors and load combinations for the design of rail bridges have been revised to bring them into line with the Bridge Manual and AS 5100.2.

Signed by Liam Coleman on: 5/07/2024 3:42:53 PM 4112

The general philosophy is to adopt the Bridge Manual load factors and load combinations where possible and to modify these for the relevant AS 5100 load cases where the Bridge Manual factors are not appropriate or are not included.

It is noted that the Bridge Manual load factors and load combinations have been revised in 2022 to bring them closer to AS 5100.2 where appropriate and that the load combinations adopt a similar philosophy as used in AS 5100.2 considering the following broad categories of load combinations:

- Permanent effects only
- Primary traffic (trains and pedestrians) with environmental effects
- Environmental effects with traffic
- Environmental combinations without traffic
- Extreme loads covering seismic, tsunami and collision/derailed train at the ultimate limits state only

C7.23.2 and C7.23.3 Serviceability and ultimate limit state load factors and combinations

Load factors

The load factors adopted at the serviceability and ultimate limits states are the same as the Bridge Manual except as follows:

- Dead load adopts the AS 5100.2 load factors of 1.2 for concrete and 1.1 for steel for the ultimate limit state, except for the extreme load combination where the load factor is 1.0.
- Superimposed dead load adopts the AS 5100.2 load factors of 1.30 for ballast and 1.20 for direct fix for the serviceability limit state and 1.70 for ballast and 1.4 for direct fix for the ultimate limit state, except for the extreme load combination at ultimate limit state where the load factor is 1.0.
- Train live loads use the AS 5100.2 load factor of 1.0 at the serviceability limit state instead of 1.35 used in the Bridge Manual (1.35 is adopted in the Bridge Manual to offset deficiencies in the HN load model). At the ultimate limit state, the train load factors adopted are:
  - 1.60 when train loads are combined with temperature and pedestrian loads
  - 1.40 when train loads are combined with wind and temperature.
  - 1.20 when trains are combined with environmental effects
  - For the extreme load combination, the load factors for collision and derailment loads are 1.0/1.20 for derailment cases A and B as per AS 5100.2.

The adoption of AS 5100.2 load factors for dead, superimposed and train live loads will generally reduce the factored loads at the ultimate limit state which will lead to more realistic design outcomes. The reduction of the live load factor from 2.30 to 1.60 is the most significant change. The adoption of a load factor of 1.70 for ballast at ULS reflects the occurrence of ballast depths on bridges being increased over their life and will increase SDL demands on bridges. The use of

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1.20 and 1.10 for dead loads due to concrete and steel will better reflect the variation in loading with these materials.

Load combinations

The load combinations are the same as the Bridge Manual except as follows:

- Traffic loads are for trains which replace road vehicles
- There is no pedestrian only combination as the rail design annex does not apply to pedestrian only bridges.
- There are no special vehicle load combinations as they do not apply to rail bridges.

The use of similar load combinations for rail bridges as the Bridge Manual will make the design of road and rail bridges in New Zealand more consistent and will standardise the design approach across the industry. As noted above, the Bridge Manual load combination philosophy is similar to that used in AS 5100.2.

C7.23.4 Construction load combinations

The Bridge Manual construction load combinations have been adopted. The construction load combinations do not include any rail loads and so are the same as for road bridges.

C7.23.5 Fatigue load factor

A load factor of 1.0 is adopted for fatigue due to train loading as for AS 5100.2.

C8 Analysis and design criteria

C8.1 General

C8.1.1 Analysis

Structural analysis adopts the Bridge Manual requirements.

C8.2 Reinforced concrete and prestressed concrete design

C8.2.1 General

The design of concrete rail bridges has been amended to adopt the Bridge Manual requirements. This replaces the W201 requirement to design concrete bridges to NZS 3101 as modified by AREMA.

The Bridge Manual requires design of concrete bridges to NZS 3101 but without the AREMA modifications.

The main differences from this change in of concrete rail bridges are summarised below.

Signed by Liam Coleman on: 5/07/2024 3:42:53 PM 4112

C8.2.2 and C8.2.3 Crack widths and allowable stress range

For clerification the following Dynamic Load Allowances will be applied when calcuating crack widths:

- Fatigue – 0.5xDLA
- Deflection – 0.67xDLA
- LL Crack widths – 1.0DLA

Design of reinforced concrete

For reinforced concrete design W201 adopted NZ3101 but with the AREMA stress limits on serviceability flexural stresses in reinforcing. These stress limits are conservative and are intended to limit cracking widths to control cracking in the tension face to achieve the required durability outcomes for the bridge.

The change to using the Bridge Manual with NZS 3101 without AREMA modifications requires design to comply with crack widths at serviceability defined in the Bridge Manual as for road bridges but with load combination 0 replaced by load combination T0 in Bridge Manual table 4.1.

The Bridge Manual and NZS 3101 also specifies allowable stress ranges for the serviceability limit state to control fatigue in the non-stressed reinforcement. NZS 3101 clause 2.5.2.2 specifies the stress range due to repetitive loading to be considered in flexural reinforcing bars at the sercieability limit state. For this the repetative loading to be considered is train loading at the serviceability limit state (LL x dynamic load allowance).

Design of prestressed concrete

For prestressed concrete design W201 adopted NZS 3101 but with the AREMA requirement of zero tension at serviceability due to fluctuating flexural demands. This is a conservative approach to control cracking in the tension face to achieve the required durability outcomes for the bridge.

The change to using the Bridge Manual with NZS 3101 without AREMA modifications allows partial prestress design to be used for the design of concrete rail bridges and provides criteria for crack widths to satisfy durability requirements and stress ranges to control fatigue in prestressed and non-prestressed reinforcement.

This requires design to comply with crack widths at serviceability defined in the Bridge Manual as for road bridges but with load combination 0 replaced by load combination T0 in Bridge Manual table 4.1.

The Bridge Manual and NZS 3101 specifies allowable stress ranges for the serviceability limit state to control fatigue in prestressed and non-stressed reinforcement. NZS3101 clause 19.3.3.6.2 specifies the stress range due to frequently repetative loading at the serviceability limit state. For this the repetative loading to be considered is train loading at the serviceability limit state (LL x dynamic load allowance). No infrequent train loading is required to be considered since railway loading does not include an overweight train, unlike highway loading.

Signed by Liam Coleman on: 5/07/2024 3:42:53 PM 4112

C8.3 Structural steel and composite construction design

C8.3.1 General

The design of steel rail bridges including composite bridges has been amended to adopt the Bridge Manual requirements. This replaces W201 requirements.

The main differences of this change and the effects they have on design of steel rail bridges are summarised below.

For the design of steel components and fatigue W201 followed the requirements of AREMA 2006. This used a working stress approach.

The Bridge Manual adopts limit state design and follows the requirements of NZS 3404 for design of members expected to behave inelastically and AS 5100.6 for steel members expected to behave elastically.

The main effects of this change will be to design members and components using limit state approach in which most elements are designed at the ultimate limit state.

The Bridge Manual also refers to NZS 3101 for the design of composite deck slabs and composite columns.

C8.3.2 Fatigue of steel bridges

The design of steel rail bridges for fatigue has been amended to adopt the requirements of AS 5100.2.

For the design detailing of steelwork for fatigue W201 followed the requirements of AREMA 2006, Chapter 15 which provides specific requirements.

AS 5100.6 includes requirements for the design of steel railway bridges. It has specific requirements that relate to fatigue detailing and other requirements, in particular:

- Clause 3 provides general design requirements for bridges and sub-section 3.10 includes specific requirements for rail bridges
- Clause 3.10.2 provides slenderness limits for various steel members unless a rigorous fatigue assessment is carried out
- Clause 3.10.3 requires bracing for rail bridges that comply with clause 3.10.2 to be assessed for fatigue by allowing two times the calculated number of load cycles in the fatigue assessment
- Clause 3.10.4 requires rail truss bridge members and lattice girder members complying with clause 3.10.4 to be assessed for 1.4 times the calculated number of load cycles in the fatigue assessment
- Clause 3.10.5 provides requirements for end connections in floor members in rail bridges applying to stringers and cross girders and flexing legs of connection angles to achieve sufficient flexibility in the connections. Stringers are required to have end connection angles to ensure the necessary flexibility in the connection to cross girders. Cross girders and beams in solid floor

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construction are required to have connection angles where practicable. Welding is not permitted to connect flexing legs. Geometric requirements for flexing legs and stringers are also provided.

- Clause 3.10.6 provides requirements for the design of stringer and cross girder end connections and minimum moment on end connections in rail bridges
- Clause 3.10.7 provides requirements to achieve a satisfactory fatigue life for welded girders and cross girder to through girder connections. It requires that welded stiffeners, other than bearing stiffeners, are bolted to the tension flange of the girder and welding shall not be permitted, and that the end 40mm of the stiffener to web weld shall be fatigue life enhanced. It also requires that at cross girder to through girder connections, the cross girder bottom flange shall be bolted to the through girder bottom flange.
- Clause 3.10.8 has requirements for transom top spans to take account of the eccentricity of transom loading
- Clause 3.10.9 includes requirements for the minimum thickness of steel members.
- Clause 13 provides fatigue design requirements for steel bridges. This includes detail categories for different fatigue prone details and permitted stress ranges.

The adoption of the steel design and detailing requirements to AS 5100.6 is expected to result in similar outcomes to using AREMA since many of the requirements are similar. Both standards prohibit the welding of stiffeners to the tension flanges of steel girders in railway bridges. Both standards include requirements for stringer and cross girder connections and cross girder to through girder connections.

C8.4 Timber design

The Bridge Manual is adopted for the design of timber elements.

C8.5 Aluminium design

The Bridge Manual is adopted for the design of aluminium elements.

C8.6 Other materials

Design criteria for other materials are to be agreed with the KiwiRail Professional Head, Structures.

C8.7 Bearings

The Bridge Manual is adopted for the design of bearings.

C8.8 Integral and semi-integral abutments

The Bridge Manual requirements for integral and semi-integral abutments are adopted.

Signed by Liam Coleman on: 5/07/2024 3:42:53 PM 4112

C8.9 Network and tied arch bridges

The Bridge Manual requirements for network and tied arch bridge can be adopted subject to approval from KiwiRail Professional Head, Structures.

C8.10 Buried structures

The Bridge Manual requirements for buried structures are adopted.

C8.11 Bridges subject to inundation by flooding

The Bridge Manual requirements are adopted for bridges subject to inundation by flooding.

C8.12 Miscellaneous design requirements

Requirements have been added for deck drainage to ballast top bridges, services, confinement of embedded fixings and anti-graffiti coatings.

C9 Earthquake resistant design of structures

The design of rail bridges for earthquake resistant design fully adopts the Bridge Manual requirements.

W201 previously referenced the Bridge Manual but some specific KiwiRail requirements.

Clarification is provided in the Standard on the need for horizontal linkage systems for rail bridges and a definition is provided of emergency traffic that will use a rail bridge following an earthquake. This defines the post-earthquake response of the bridge.

Table 5.1 in the Bridge Manual defines the performance requirements of bridges at the various design earthquakes, but with emergency traffic defined as being able to carry Hi Rail vehicles of up to 7 tonnes within 3 days and work trains within 1 month. Work trains are to be taken as 210LA loading. It is noted that the track crossing over a bridge and the track on either side of a bridge may be damaged and require more extensive repairs than the bridge before it is useable by emergency traffic.

The effect of this change is expected to be minor as rail bridges in New Zealand are generally already designed to the Bridge Manual for earthquake resistance.

C10 Site stability, foundations, earthworks and retaining walls

Design for site stability, foundations, earthworks and retaining walls adopt the Bridge Manual requirements except for specific clarifications related to settlement limits, post-earthquake function the use of geofoam embankments.

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C11 Reporting

The Highway Structures Design Guide reporting requirements are referenced as being generally applicable to the design of rail bridges and are to be used where applicable.

Specific reporting requirements are provided for design assessment reports, bridge design statements and design features reports.

C12 Technical approval

The technical approval requirements in the Highways Structures Design Guide are to be adopted where applicable.

Technical approval is to be obtained from the Professional Head, Structures.

Requirements for departures from standards are included.

C13 References

Reference documents referred to in the annex are listed.

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Briefing Note(s) for B-ST-DE-3036 Rail Bridge Design (Waka Kotahi Bridge Manual Annex)

Date Effective	1/07/2024	Issue No.	Issue 2.0

Background

This document is for the design of rail bridges in New Zealand and it replaces W201 Railway Bridge Design Brief issue 6 dated 2011 published by KiwiRail.

Key changes / compliance

The design of rail bridges is to be in accordance with the NZTA Bridge Manual Third Edition Amendement 4 except for rail specific requirements which shall be in accordance with Australian Standard AS 5100 Bridge Design as modified by this document. Key changes include the adoption of limit state design principles for all design elements and a new loading model and load combinations that are generally in line with the Bridge Manual but with load factors and combinations to suit rail bridges.

Implementation

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Applicability (Select relevant boxes)	General	Civil	Signals	Structures	Track	Traction and Electrical	Control Systems	Mechanical
Zero Harm	☐							
Learning and Development	☐							
Project Management Office	☐							
Manager Property Revenue and Grants	☐							
National Train Control Centre	☐							
Engineering Services Manager	☐							
National Supply Chain and Distribution Manager	☐							
Professional Head		☐	☐	☐	☐	☐	☐	☐
Network Services Managers		☐	☐	☐	☐	☐	☐	☐
Region Operations Managers		☐	☐	☐	☐	☐	☐	☐
STTE Managers		☐	☐	☐	☐	☐	☐	☐
Production Managers		☐	☐	☐	☐	☐	☐	☐
Asset Engineers		☐	☐	☐	☐	☐	☐	☐
Others to inform list here								
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Document History

Note page numbers relate to the document at the time of amendment and may not match page numbers in current document.

Issue No.	Section	Description	Page(s)

Signed by Liam Coleman on: 5/07/2024 3:42:53 PM 4112