Abstract: Part 2 Design loads of Australian Standard AS 5100 Bridge design sets out the parameters for loads on all bridges in Australia. There have been numerous enhancements to improve the scope, clarity and intent. Design loads for road traffic barriers have been increased. Other road traffic loads are largely unchanged. Conversely, the loading section for rail bridges has been comprehensively updated. Changes include:

- Braking loads for both short bridges and long bridges have been addressed.
- The distribution loads for open deck and ballasted deck steel bridges and concrete deck bridges have been clarified.
- Different collision loads have been specified for objects at varying distances from the track.
- Loads due to derailed trains have been better defined.
- Protection of piers, vertical abutments and deflection walls have been expanded and clarified.
- Light rail has been included for the first time to reflect the re-emergence of this type of public transport.

The force method for earthquake design remains in the main body of the part. An alternative displacement method has been included in the appendix.

Other new inclusions in this part of the standard include urban debris loads during flooding, design loads for errant road or rail vehicles for air space developments in close proximity road or rail corridors. These additional loads reflect changed usage in the urban landscape as well as incorporating learnings from natural disasters.

Ship impact loads for navigable waterways and fire loads have been included for the first time.

Keywords: Loads, bridge, rail, light rail, pedestrian, collision loads, fire, earthquake

1. Introduction

There have been significant changes to AS 5100 Part 2 Design Loads (1). A simplistic measure of the magnitude of the changes is the 72 page 2004 version (1) has been increased to 135 pages in the latest revision of AS 5100.2 (2).

Significant differences between this Standard (2) and AS 5100.2—2004 (1) are the following:

- Changes and clarifications to the provision for collision loads from rail traffic.
- Changes to dynamic load allowance for rail traffic load effects.
- Addition to provisions for bridge collision from waterway traffic.
- Updated bridge traffic barrier loads to more closely reflect vehicles currently using the road network. Barrier test levels and minimum effect heights were adopted from the AASHTO Manual for Assessing Safety Hardware (MASH) (3) which replaced NCHRP Report 350 (4).
- Earthquake design procedures for bridges rewritten to align with the current earthquake loading Standard AS 1170.4—2007, Structural design actions, Part 4: Earthquake actions in Australia (5). New displacement-based earthquake design procedures were included as an informative appendix.
- Improvement to serviceability and fatigue limit states for road signs and lighting structures.
- Expansion of water flow forces to include impact from large moving urban objects during flood events.
- Addition of light rail loading.
2 Significant changes to the standard

The details of the significant changes in this Part (2) are discussed below.

2.1 Collision loads from rail traffic

Rail collision loads apply to all structures above and within 20 m adjacent to rail tracks, such as—

- rail bridges;
- road bridges;
- pedestrian, cyclist path and maintenance bridges;
- deflection walls and crash walls;
- air space developments;
- external developments; and
- similar structures in underground railways.

When supports are within 10 metres of the track, rail collision loads have been increased from 3000kN to 4000kN parallel to the track and 1500kN normal to the track. The load decrease to 1500kN in any direction for supports between 10 and 20 metres of the track. No collision loads is applicable for supports over 20m from the track.

Collision loads of 500kN now include members within 10 metres horizontally and 5 metres vertically above the track. Collision loads also apply to through girders and through arches because of the close proximity of the superstructure to the track.

Bridges also are to be designed collision loads of a derailed train unless the primarily structural elements provide a smooth, solid surface with no chance of snagging. The end of through-girder are to be designed for a head on collision.

For underground rail and air space developments, these loads are applied both vertically and horizontally.

2.2 Dynamic load allowance for rail traffic load effects

The definition of characteristic length $L_o$ has been changed for piers is the sum of lengths of adjacent loaded spans. Previously, it was the sum of adjacent span lengths.

The dynamic factor is a constant formula for all span length and the special value for spans less than 3.6m in the 2004 version (1) has been deleted. The distinction in dynamic load allowance between ballasted deck spans, open deck spans or spans with direct rail fixation has been removed and a single factor adopted for all types in the latest revision of AS 5100.2 (2).

2.3 Bridge collision from waterway traffic

Collision loads from waterway traffic have been included for the first time. Bridges shall be designed for collision from waterway traffic. Design inputs include:

- Pier locations that are to be designed for impact. This includes the channel and adjacent pier locations.
- The upper bound loads shall consider all vessels currently operating in the waterway or likely to operate in the waterway for the next 100 years.
- The minimum velocity of impact shall be the larger of the maximum flood velocity or the maximum speed of the vessel under power.

The proposed design vessel and speed shall be reviewed and approved by the relevant authority. The ultimate equivalent static vessel impact force may be determined in accordance with AASHTO’s Load and Resistance Factor Design (LRFD) Bridge Design Specification (6). The resulting minimum equivalent static ship impact force shall be applied to piers in navigable waterways.
Piers in the waterway shall be designed for an equivalent static vessel impact force in the direction of the channel centreline. Additionally, the piers shall be designed to resist a load of 50% of the equivalent static vessel impact force applied separately in a direction perpendicular to the channel centre-line. These forces shall be applied anywhere between 1.0 m above mean low water spring (MLWS) and 1.0 m above mean high water spring (MHWS).

The superstructure shall be designed to resist a horizontal force equal to 20% of the equivalent static vessel impact force applied independently of impact loads to the piers.

### 2.4 Updated bridge road traffic barrier loads

Road traffic barriers design philosophy has been updated from NCHRP 350 (4) to MASH (5) to reflect the latest international design methodology. Design articulated vehicles considered include both tanker and flatbed trailers with significantly different heights for their centre of gravity. The consequence of this change is an increase in loads and an increase in minimum effective heights. The differences between the 2004 version (1) and current revision (2) are tabulated in Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>AS 5100.2 – 2004 (1)</th>
<th>AS 5100.2 - New version (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate outward load (kN)</td>
<td>250</td>
<td>300</td>
</tr>
<tr>
<td>Ultimate longitudinal load (kN)</td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td>Vehicle contact length for outward loads (m)</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td>Effective height (mm)</td>
<td>800</td>
<td>900</td>
</tr>
</tbody>
</table>

Loads have increase by some 20 to 25 percent. There has also been an increase in effective height of barriers.

### 2.5 Earthquake design procedures for bridges

The earthquake section of this revision has been had a major rewrite. The force based method is still the preferred method in the main body of this part. However, an informative displacement based method is included as Appendix B (2). It is considered that the force based method is applicable for typical bridges in Australia and this version aligns with current AS 1170.4 earthquake code (5). The displacement method was included as an informative section because there is a school of thought that this is a more theoretically correct approach. It has been included for information to the user and may be applicable to more seismic sensitive structures or in seismic active areas such as New Zealand. The displacement method has a maximum pier height of 40 metres whilst the force method has a maximum height of 30 metres.

One of the critical changes in this revision is the applicability of this section. The requirements for a maximum span of 100 metres and conventional superstructure, for example, beam, slab or box-girder is unchanged from the 2004 version (1). However, there are additional requirements in the revision (2):

- maximum change in angular deviation in abutments of 90 degrees
- skews less than 35 degrees
- maximum pier height of 30 metres, and
- maximum concrete compressive strength of 65 MPa
In response to events in Christchurch, soil liquefaction has been defined as sandy and silty soils with a Standard Penetration Test value of less than 10 within the top 10 metres of fill.

The analysis principles of the force based method have been extensively expanded. The superstructure shall be subdivided into bridge frames between expansion joints. The bridge frames become critical elements for the basis of earthquake designs. The relative stiffness of adjacent frames shall be considered. Reinforced concrete shall be based on cracked section properties whilst prestressed members are designed on full section properties. The requirements for weight distribution of tall (greater than 20 metres) and spans greater than 40 metres have been defined for the first time.

2.6 **Serviceability and fatigue limit states for road signs and lighting structures**

The 2004 version of AS 5100.2 (1) addressed serviceability by excessive vibration due to vortex shedding but provided no guidance design. Minor signs were designed for a wind speed of 20m/s whilst larger signs and signs above the carriageway were designed for wind in accordance with AS 1170.2 (7).

The revision of AS 5100.2 (2) has introduced significant changes including:

- zero downward deflection of horizontal members in portal frames and cantilevers,
- limits on upwards deflection of horizontal members,
- consideration of rotation of foundation for cantilever posts,
- fatigue limit state in accordance with AASHTO Standard Specification for Structural Supports for Highway Signs, Luminaires and Traffic Signals (8) for Category 1. (The Australian wind speed shall be used in the calculation.).

2.7 **Expansion of water flow forces to include impact from large moving objects during flood events**

Previous versions of this only considered rural forces due to log impact. In this revision it has been extended to urban debris items such as pontoons, pleasure craft, shipping containers and other similar items.

2.8 **Light rail traffic design load**

Live loading has been expanded to include light rail loads in response to resurgence in this form of public transport. Light rail design loads have been included for the first time. The light rail traffic design load shall be based on 150LA, derived by multiplying the 300LA rail traffic loads by a factor of 0.5, with nine (9) axles. The nine axles are comprised of the simulated locomotive axle plus two groups of four trailing axles. For bridges where queuing of light rail vehicles is possible, additional trailing axle groups may be included, as specified by the relevant authority.

3. **Other changes to the standard**

Other differences between this revision of the Standard (2) and AS 5100.2—2004 (1) are the following:

3.1 **Improved pedestrian and cycleway barrier loads**

The 2004 (1) standard provided design loads and deflection limits for pedestrian barriers what included normal and panic loads for crowd events. Deflection limits were imposed for posts and longitudinal rails. However, no guidance was provided on the strength requirements for infills, typically balusters, for example.

This revision has recognized that the infill may be balusters, mesh or solid. A 1.5kPa loading acting over the entire infill area can be applied as a means of determining the structural capacity of the infill area.
Additionally, a load of 1.0kN acting over an area of 0.1m x 0.1m acting transversely away from the footpath is also required to be applied. This loading is a robust load case representing vandalism.

### 3.2 Expanded dynamic loads for pedestrian and cycleway bridges

Ensuring that a pedestrian or cycleway bridge is does not have large acceleration or deflection due to the passage of a pedestrian or cyclist is a critical design case. A new requirement for maximum vertical acceleration has been introduced. The maximum vertical acceleration \( a \), in m/s\(^2\) (Equation 1), may be taken as:

\[
a = 4\pi f^2 y \psi \text{ (m/s}^2)\tag{1}
\]

where:

- \( y \) = static displacement due to design pedestrian load of 700 N, in metres
- \( \psi \) = dynamic response factor (Figure 1)

**NOTE:** Values of \( \delta \) for different types of construction are given in Table 13.4.1.

![Figure 1. Dynamic response factor (\( \psi \))]
3.3 **New table for unfactored vertical pressure due to design rail traffic loads**

Surcharge loads from rail loads have been included in previous version of this standard (1). Three load cases were considered with a wordy description of the load distribution. As a means of simplicity of understanding the interpretation of the clause a new table has been included in this revision (2). This should also provide consistency in application by all users.

3.4 **Inclusion of super-t girders in the calculation of bridge thermal effects**

Super T girders were introduced in the 1992 Austroads Bridge Design Code (9). This revision has, for the first time, included a temperature gradient for super T girders based on that for concrete box girders. It provides completeness of AS 5100.2 (2) for this common girder type.

3.5 **Clarification of loads and load factors for construction loads**

During construction of a bridge, the structure is often more vulnerable than after construction is completed. Hence, the most critical time for bridge stability is during construction. This revision has included specific loads that provide guidance for the designer and a statement for contractors to understand what a bridge is capable of supporting during construction. Loads and load factors considered are for dead load, launching phase of concrete incrementally launched girders and all other structures.

3.6 **Addition of protective screen, design of protective screen and noise barrier for wind load and robustness**

Bridges may have protective screens to stop the throwing of objects onto road or rail below. Protective screen structural design have been included for the first time. Wind loads are in accordance with AS-1170.2 (7). The return frequency for wind is specified as:

- 200 years for noise barriers and protection screens that are located on road or rail authority property and cannot fall onto or slide down a slope onto other property, roadway, walkway or onto traffic areas.
- 1000 years for noise barriers that can fall onto railways and onto roadways.
- 500 years for all other noise barriers.

Robustness has been introduced for both noise barriers and protective screens. The criteria are specified below in 3.6.1 and 3.6.2:

3.6.1 **Protection screens**

A protection screen shall be designed to withstand an ultimate limit state load of 2 kN applied over an area of 50 mm × 50 mm on the screen, at any point, which produces the most adverse effect.

3.6.2 **Noise barriers**

Unless approved otherwise by the relevant authority, noise barriers shall be capable of withstanding the impact of a 4 kg steel ball dropped from a height of 3 m when the panel is supported horizontally above the ground.

The test panel shall be set up such that its ends are supported with a similar edge distance to that used in service. The test panel shall be set up for the worst case of span and width to be used in service.

The impact is permitted to cause only superficial scratches and marks on the panel. The depth of deformation considered to be acceptable is 4 mm within a circle of 20 mm diameter. Cracked or shattered glass panels are not acceptable.
3.7 **New fire effect load case**

Fire loading was not included in the 2004 version (1). The new revision (2) has considered:

- Hydrocarbon fires
- Cellulose fires
- User specified fires

Cellulose fires are designed in accordance with AS 1530.4 (10). Hydrocarbon fires are specified in accordance with:

- the Dutch Rijkswaterstaat (RWS) (11) RWS/HCinc fire curve for road traffic. This curve has modified the basic HC curve of Eurocode 2 Part 1-2 (12) by a factor of 1300/1000,
- the German National Rules and Regulations, RABT fire curve (13) for rail and bus traffic.

Details of design fire are defined in Table 2.

<table>
<thead>
<tr>
<th>Traffic type</th>
<th>Structural elements</th>
<th>Duration (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road</td>
<td>RWS / HCinc (11)</td>
<td></td>
</tr>
<tr>
<td>Rail</td>
<td>RABT-ZTV (13)</td>
<td>120</td>
</tr>
<tr>
<td>Bus</td>
<td>RABT-ZTV (13)</td>
<td></td>
</tr>
</tbody>
</table>

3.8 **Rail multiple track loads, braking loads, traction loads and nosing loads**

Multiple track load factors have been amended to make the intent clearer. The factor for each track is clearly defined. The 2004 version (1) could be interpreted that the value of the fourth track for example, applied to all tracks.

Horizontal braking and traction loads have been expanded to include options. The first option is an empirical method which is similar to the 2004 code (1). The new second method is the rational method using a more first principles design method based on the actual properties of the bridge and track elements.

Nosing loads have also been introduced for rail bridges. The design nosing loads of 100kN is applied at the top of rail in either direction and at any point along the structure.

4. **New or Revised Appendices**

A number of new or revised appendices have been added to this edition of the Standard (2), which provide additional information and guidance as follows:

4.1 **Update to special performance level bridge barrier loads**

This includes increasing the ultimate transverse load from 1000kN to 1200kN for 44 tonne articulated vehicle. The effective height has been increased from 1400mm in the 2004 standard (1) to 1500mm for a van and increase to1800mm for a tanker.

4.2 **New alternative displacement-based earthquake design procedures**

This section is informative. It caters for higher piers than the normative force based method. It does not align with the methodology of AS 1170.4 (5). However, the displacement based method is considered by some as a better method for tall piers or use in earthquake areas such as the south island of New Zealand. It has been included as a possible alternative method.
4.3 Bending moment and shear force for SM1600 and 300LA loads for simply supported spans up to 100m

This is considered a useful design aid. Similar information has been provided for T44 vehicles in previous codes and feedback from designers created the demand for its inclusion.

4.4 Summary of load factors and load combinations

Previous revision have had this information scattered throughout the text. It was considered that combining the information into a table would assist with clarity of intent for designers and assist in understanding by users.

5. Conclusions

AS 5100.2 Design Loads (2) has had a major revision. Train loads have been substantially revised with major changes to braking loads, collision loads on piers and superstructure, dynamic allowance, and surcharge loads from rail traffic. Additionally there has been clarification of multiple track loads, traction loads and braking loads. Light rail loads have been included for the first time. Road traffic barriers have been upgraded to align to the best international practice.

For all bridges, there has been update of force based earthquake provisions. A new informative displacement earthquake design section has been provided to provide guidance for high piers or high earthquake areas. Flood loads on bridges has been expanded to include urban flood loads such as pontoons, pleasure craft, and shipping containers.

Pedestrian and cycle barriers have been updated to consider the range of barriers used.

Fire loads have been defined for the first time. Protective screens and noise barriers wind loads have been defined. New robustness clauses have been included. Appendices have updated to include special performance barrier loads, an alternative displacement earthquake load and a summary of load factors and load combinations.

6. Acknowledgement

The revision of AS 5100 Part 2 was undertaken by Standards Australia Sub-Committee BD 090-2. The dedication and enthusiasm of this sub-committee is acknowledged. Their efforts in attending meetings, drafting clauses and debating content was appreciated. The efforts in extending the scope of AS 5100 Part 2 to be reflective of current loads is reflective of their commitment to develop the most relevant loading standard.

7. References

Standards Australia, AS 5100.2, “Bridge design – Design loads”, 2004, Sydney, Australia

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American Association of State Highway and Transportation Officials, “AASHTO Manual for Assessing Safety Hardware” (MASH), 2015, Washington, USA


Standards Australia, AS 1530.4, “Methods for the fire tests on building materials, components and structures – Fire resistance test of elements of construction”, 2005, Sydney, Australia

Rijkswaterstaat, RWS/Hcinc fire curve, Dutch Regulations, The Hague, The Netherlands
