T HR CI 12021 ST

Standard

Bridge Impact Protection

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Important message

For queries regarding this document, please email the ASA at
standards@transport.nsw.gov.au or visit www.transport.nsw.gov.au

Standard governance

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Document history

Version	Summary of changes
1.0	First issue.

Preface

The Asset Standards Authority (ASA) is a key strategic branch of Transport for NSW (TfNSW). As the network design and standards authority for NSW Transport Assets, as specified in the *ASA Charter*, the ASA identifies, selects, develops, publishes, maintains and controls a suite of requirements documents on behalf of TfNSW, the asset owner.

The ASA deploys TfNSW requirements for asset and safety assurance by creating and managing TfNSW's governance models, documents and processes. To achieve this, the ASA focuses on four primary tasks:

- publishing and managing TfNSW's process and requirements documents including TfNSW plans, standards, manuals and guides
- deploying TfNSW's Authorised Engineering Organisation (AEO) framework
- continuously improving TfNSW's Asset Management Framework
- collaborating with the Transport cluster and industry through open engagement

The AEO framework authorises engineering organisations to supply and provide asset related products and services to TfNSW. It works to assure the safety, quality and fitness for purpose of those products and services over the asset's whole-of-life. AEOs are expected to demonstrate how they have applied the requirements of ASA documents, including TfNSW plans, standards and guides, when delivering assets and related services for TfNSW.

Compliance with ASA requirements by itself is not sufficient to ensure satisfactory outcomes for NSW Transport Assets. The ASA expects that professional judgement be used by competent personnel when using ASA requirements to produce those outcomes.

About this document

This standard details the design requirements for bridge impact protection from road vehicles in the metropolitan heavy rail network.

This document supersedes RailCorp manual TMC 312 *Underbridge Impact Protection*, version 1.1.

This standard is a first issue.

The changes from the previous content include the following:

- conversion from a manual to a standard
- updates to referenced documents
- addition of durability requirements
- updates to collision protection requirements
- updates to environmental and sustainability requirements

- updates to decommissioning and disposal requirements
- rearrangement of the order of requirements

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1. Introduction

Spans for new bridges over roadways are designed for vertical clearances specified in AS 5100 *Bridge design*, except where the relevant authorities have granted approval for reduced vertical clearance.

Some existing bridges have a vertical clearance less than that specified in the standard. Bridge spans with substandard vertical clearance over roadways are more at risk of impact from road vehicles than bridges with standard clearances; in the past many existing bridges have been affected.

Bridges with a high risk of impact collision require protection against structural damage that results in reduction in load carrying capacity. In the instance of rail underbridges, an associated objective is to mitigate against the risk of a train derailment resulting from the lateral displacement of the track after a bridge strike from a road vehicle.

Options for mitigating the damage potential of at-risk bridges due to vehicular strikes include:

- increasing the vertical clearance under the bridge by either raising the soffit level of the bridge, lowering the road level beneath the bridge, or a combination of both
- providing a heavy collision resistant bridge superstructure
- providing bridge collision warning and protection system

These options are often impractical and cost prohibitive for existing bridges and difficult bridge sites, and a feasible option is to protect the bridge by installing a collision protection system, determined by risk assessment. For rail underbridges, the most common form of protection system used is a collision protection beam (CPB), referred as a crash beam, in the past. A CPB is intended to either slow or stop a vehicle that is over-height for the clearance at a particular bridge site to prevent impact with the bridge superstructure.

2. Purpose

This standard specifies the requirements for bridge CPBs in the metropolitan heavy rail area.

This standard provides requirements for:

- risk assessment
- determining vertical clearances beneath bridge spans over a roadway
- the design of CPBs
- prioritising existing underbridges over roadways for impact protection

2.1. Scope

This standard covers the requirements for the whole-of-life of collision protection systems for bridges, from design through to decommissioning, in the metropolitan heavy rail area.

Only CPBs are covered in this standard in this version. Passive forms of collision risk reduction or protection, such as electronic and infrared detection systems, height clearance gauges and the like are planned for future versions.

This standard does not cover the design of bridges to resist vehicular collision impact and the decision to install a bridge collision protection system.

2.2. Application

This standard applies to all organisations and individuals involved in all design aspects of bridge impact protection for bridges in the metropolitan heavy rail area.

In addition to the requirements of this standard, asset decisions take into account the life cycle cost considerations specified in T MU AM 01001 ST *Life Cycle Costing*.

If when using this standard, it is considered that the intent of stated requirements is unclear, a clarification should be sought from the Asset Standards Authority (ASA).

3. Reference documents

The following documents are cited in the text. For dated references, only the cited edition applies. For undated references, the latest edition of the referenced document applies.

Australian standards

AS 1742.2 Manual of uniform traffic control devices – Part 2: Traffic control devices for general use

AS 1743 Road signs - Specifications

AS 2700 Colour standards for general purposes

AS 5100 Bridge design (all parts)

AS 5100.2: 2017 Bridge design – Part 2: Design loads

AS 5100.2 Supplement 1 – 2007 (obsolescent) Bridge Design – Design loads- Commentary (Supplement to AS 5100.2-2004)

Transport for NSW standards

ESC 300 Structures System

ESC 302 Structures Defect Limits

MN A 00100 Civil and Track Technical Maintenance (extracted from formerly ESC 100)

SPC 301 Structures Construction

T HR CI 12002 ST Durability Requirements for Civil Infrastructure

T HR CI 12008 ST Capacity Assessment of Underbridges

T HR CI 12020 ST Underbridges

T HR EL 12004 ST Low Voltage Distribution and Installations Earthing

T MU AM 01001 ST Life Cycle Costing

T MU AM 01003 ST Development of Technical Maintenance Plans

T MU EN 00005 ST Ambient Environmental Conditions

T MU EN 00007 GU Integrating Green Infrastructure

T MU EN 00008 ST Sustainability Assurance Requirements

T MU MD 00006 ST Engineering Drawings and CAD Requirements

T MU MD 20001 ST System Safety Standard for New or Altered Assets

T MU MD 20002 ST Risk Criteria for Use by Organisations Providing Engineering Services

T MU SY 20001 ST Surface Transport Fixed Infrastructure Physical Security Standard

TN 016: 2015 Overbridges and footbridges – Earthing and bonding requirements

Legislation

Heritage Act 1977

Roads Act 1993

Work Health and Safety Act 2011

Other reference documents

Austroads 2010, Guide to Road Design (All parts)

Bridge Policy Circular BPC 2007/07 Vertical Clearance on Bridges

Highways England, 2020, Design Manual for Roads and Bridges: Highway Structures & Bridges Design, CD 366 Design criteria for collision protection beams (formerly BD 65/14), Revision 0

Office of Environment and Heritage, State Heritage Register

Office of Environment and Heritage 2005, State Agency Heritage Guide – Management of Heritage Assets by NSW Government Agencies

RailCorp Section 170 Heritage and Conservation Register

RailCorp Section 170 Heritage and Conservation Register - Movable heritage

Roads and Maritime Services Bridge Technical Direction (BTD) Manual

Roads and Maritime Services Technical Direction, Bridge, BTD 2011/05 Rev 1 Minimum Restraint Requirements for Superstructures

SafeWork NSW 2019, Code of Practice, Safe Design of Structures

4. Terms and definitions

The following terms and definitions apply in this document:

AADT annual average daily traffic volume; the total yearly traffic volume in both directions divided by 365

AEO Authorised Engineering Organisation

ASA Asset Standards Authority

basic height clearance vertical clearance at a bridge or CPB between the structure soffit and the road surface (before corrections for road geometry); the minimum basic height clearance is the smallest value for the road carriageway

BFB broad flange beam

bridge strike a vehicular collision on the bridge or CPB caused by a vehicle or load that is carried by a road vehicle

carriageway part of the road surface that includes all traffic lanes and road shoulders extending to a physical barrier limiting where road traffic can travel; separate carriageways exist for each traffic direction and can also exist for multiple carriageway roads

chord line in relation to this standard is a theoretical (16 m minimum length) straight line placed on the roadway vertical alignment, including to any part of the carriageway width; it represents the baseline of a long rigid vehicle body passing under the bridge

CPB collision protection beam (formerly known as crash beam)

designer AEO organisation responsible for the design

gauge strip sacrificial element placed at the underside of the protection beam to absorb the vehicle impact collision without causing significant damage to the protection beam

measured clearance (headroom) effective clearance at a bridge or CPB

metropolitan heavy rail area the rail freight network and the rail passenger network within the metropolitan heavy rail area bounded by Newcastle (in the north), Richmond (in the northwest), Bowenfels (in the west), Macarthur (in the southwest) and Bomaderry (in the south), and all connection lines and sidings within these areas, but excluding private sidings. The TfNSW metropolitan rail area in this standard excludes light rail, Sydney Metro, Country Regional Network (CRN) and Australian Rail Track Corporation (ARTC) networks.

RIM rail infrastructure manager; in relation to rail infrastructure of a railway, means the person who has effective control and management of the rail infrastructure, whether or not the person -

(a) owns the rail infrastructure; or

(b) has a statutory or contractual right to use the rail infrastructure or to control, or provide, access to it

(RIM approval or acceptance within this standard refers to written agreement by the Head of civil discipline or equivalent position within the RIM's organisation)

sign posted clearance clearance value that appears on the signs at, or in advance of, bridges with substandard clearance

substandard clearance roadway clearance less than the clearance standard as defined by the road authority

TfNSW Transport for NSW

TMP technical maintenance plan

> *Note: In addition the definitions in CD 366 Design criteria for collision protection beams (formerly BD 65/14), Revision 0 apply in this document.*

5. Risk and safety

Vulnerable bridges over roadways with a high risk of a strike from over-height vehicles shall be provided with an appropriate form of protection against damage. The protection configuration shall be determined by risk assessment. Protection configurations options include the following:

- collision protection beam (CPB)
- electronic vehicle height sensing system
- height clearance gauges

Safe design is mandated in the *Work Health and Safety Act 2011* and shall be incorporated into the design of collision protection beams. Guidance on the safe design of structures can be found in the NSW Government 2019 Code of Practice, *Safe Design of Structures*. See AS 5100 *Bridge Design* (all parts) for additional information.

The design of collision impact protection for bridges shall take into account safety considerations for construction, operational, maintenance and decommissioning workers as well as the users of the bridge and roadways beneath.

The designer shall establish and implement a process that manages safety assurance across the full life cycle of the structure. The design process system shall be developed in accordance with T MU MD 20001 ST *System Safety Standard for New or Altered Assets*.

The design of CPBs shall ensure that safe access is provided for inspection and maintenance of the CPB and the bridge span that is being protected.

The CPB shall not be used as a walkway.

Services shall not be supported by CPBs.

5.1. Risk assessment

Where the vertical clearance of bridge span(s) over a public road is less than the minimum requirement specified in AS 5100, or the requirement nominated by the road authority, a risk assessment shall be undertaken to determine the level of risk mitigation required.

The risk assessment shall assess the likelihood of the bridge being struck by road traffic and determine whether collision protection is needed. The most appropriate form of protection shall be determined by the risk assessment.

Risk assessments shall be conducted in accordance with T MU MD 20002 ST *Risk Criteria for Use by Organisations Providing Engineering Services*. Risk assessments shall be site-specific. The risk analysis shall include the following risk factors:

- history of the bridge strikes and damage severity
- material used in bridge construction such as concrete, steel, wrought and cast iron, masonry
- material behaviour, such as fracture toughness and ductility, when subjected to bridge strike
- structural configuration of the bridge and supports and associated structural redundancy, lateral and vertical restraint system
- likely damage of critical components
- practicality for retrofitting strengthening and lateral and vertical restraint systems to existing bridges
- road classification and permitted vehicles (general access, restricted access, and so on)
- vertical clearance and road geometric profile
- angle of skew between the bridge and the road; see Section 8.9 for comment
- type of road traffic and volume, including percentage of heavy vehicles, bus rigid body truck, semi-trailer, B-double, and so on
- alternative traffic routes
- potential injury to road users and pedestrians
- potential maximum probable vehicle energy level (mass and speed at impact)

- existing controls such as signage, load limits, speed limits
- effectiveness of potential collision detection and prevention systems, for example low height clearance gauges, infrared detection, and CPBs

The key factors that determine the maximum probable collision impact force from a potential bridge strike at the site are as follows:

- vehicle speed, may be assumed to be the maximum road speed limit
- vehicle mass, may be assumed to the maximum vehicle mass for the road classification
- vehicle stiffness, based on assumptions regarding vehicle crashworthiness
- structure stiffness such as rigidity

The information for the potential colliding vehicle can be validated from site traffic survey data.

A risk assessment methodology (informative) for prioritising underbridge sites is provided in Appendix A. The aim of this assessment methodology is to identify and prioritise underbridges for protection from motor vehicle collisions.

Risk assessments shall be submitted for acceptance by the rail infrastructure manager (RIM).

5.2. Broad flange beams

Underbridges with broad flange beams (BFBs) have a history of brittle fracture at points of impact. Slab decks with encased BFBs are less problematic.

BFB underbridges that suffer major strikes from motor vehicles should be investigated and replaced or protected where replacement is not feasible.

BFB underbridges with minor strikes shall be protected or replaced.

All other BFB underbridges over roadways without a history of strikes should be included in a risk assessment.

5.3. Security

Requirements for security and crime prevention strategies relating to CPBs shall be determined in consultation with the RIM, and shall be in accordance with T MU SY 20001 ST *Surface Transport Fixed Infrastructure Physical Security Standard*.

6. Environment and sustainability

Section 6.1 to Section 6.3 provide the environment and sustainability requirements for bridge protection systems.

6.1. Green infrastructure

For guidance on integrating green infrastructure within bridge protection systems, refer to T MU EN 00007 GU *Integrating Green Infrastructure*.

6.2. Sustainability assurance requirements

For integrating sustainability within bridge protection systems, refer to T MU EN 00008 ST *Sustainability Assurance Requirements.*

Additional information on sustainability and climate change considerations is set out in AS 5100.

6.3. Ambient environmental conditions

Environmental conditions defined in T MU EN 00005 ST *Ambient Environmental Conditions* shall be taken into account for the design of collision protection systems.

7. Heritage

TfNSW is responsible for maintaining and appropriately managing heritage items under its stewardship and control. The *Heritage Act 1977* was enacted to protect, conserve and manage environmental heritage, including items of archaeological significance. The provisions of the *Heritage Act 1977* shall be met when changes are proposed for items listed on the Office of Environment and Heritage *State Heritage Register*.

The principles and relevant guidelines contained in the NSW Office of Environment and Heritage *State Agency Heritage Guide – Management of Heritage Assets by NSW Government Agencies* shall be followed for heritage items listed on the *RailCorp Section 170 Heritage and Conservation Register.*

Maintenance and design changes to heritage-listed bridges shall result in minimal adverse visual and physical heritage impacts, and shall keep their setting and broader landscape context in order to respect and maintain their heritage significance.

8. Design of collision protection beams

Section 8.1 to Section 8.13 provide the requirements for various design aspects of collision protection beams.

8.1. Design standards

The design of collision protection beams (CPBs) shall be in accordance with Highways England *Design Manual for Roads and Bridges: Highway Structures & Bridges Design CD 366 Design Criteria for Collision Protection Beams,* Revision 0 (referred as CD 366, Revision 0 in this standard) and AS *5100 Bridge Design*. All sections in CD 366, Revision 0 shall apply, except where they are customised in this standard to suit TfNSW requirements. Some specific section references to CD 366, Revision 0 have been added for ease of navigation and alignment between the two documents.

Section 6 of CD 366, Revision 0 contains normative references to Eurocodes, British Standards, and UK road authority standards and specifications, codes of practice legislation and regulations. These key references shall be replaced by equivalent Australian and TfNSW documents listed in Table 1.

Legislation and regulations cited in CD 366, Revision 0 do not apply and shall be replaced by the applicable Australian commonwealth and state equivalents. Not all documents cited in CD 366, Revision 0 may have equivalent local counterparts.

Table 1 - Reference documents

CD 366, Revision 0 reference	Replacement reference
CD 127 *Cross Sections and Headroom*	Austroads 2010, *Guide to Road Design* (All parts) Specific requirements of the road authority
BSI. BS EN 1991-1-7: *UK National Annex to Eurocode 1 – Actions on structures – Part 1-7 General actions – accidental actions*	AS 5100.2:2017 *Bridge design - Part 2: Design loads*
BSI. BS 7430: *Code of practice for earthing*	TN 016: 2015 *Overbridges and footbridges – Earthing and bonding requirements*
BSI. BS 7671: *Requirements for electrical installations. IET wiring regulations*	T HR EL 12004 ST *Low Voltage Distribution and Installations Earthing*
BS EN 62305 *Protection against lightning*	AS/NZS 1768 *Lightning protection*
The Stationery Office. TSRGD 2016, *The Traffic Signs Regulations and General Directions 2016*	AS 1742.2 *Manual of uniform traffic control devices - Part 2: Traffic control devices for general use*
The Stationery Office. TSM Chapter 4, *Traffic Signals Manual Chapter 4 – Warning Signs*	AS 1743 *Road signs – Specifications* Road authority requirements
Legislation	*Heritage Act 1977* *Work Health and Safety Act 2011* *Roads Act 1993*
GG300	Not applicable
CG101 *Introduction to the Design Manual for Roads and Bridges*	AS 5100, RMS BTD and BCP documents T HR CI 12030 ST *Overbridges and Footbridges*
CS 450 Highways England. CS 450, *'Inspection of highway structures'*	Relevant RMS and TfNSW bridge inspection manuals and standards

Note: The term 'headroom' that is used in CD 366, Revision 0 is referred as 'clearance' in this standard and Austroads Guide to Road Design.

Where a conflict exists between CD 366, Revision 0 and this standard, the requirements in this standard shall take precedence and a clarification sought from the Lead Civil Engineer, ASA.

Design requirements for underbridges over roadways are provided in T HR CI 12020 ST *Underbridges*. These requirements shall be applied to existing bridges with substandard clearance where practical. The adequacy of an existing bridge's structural capacity, stability, vertical and lateral restraint systems, shall be reviewed, and upgraded where necessary; refer to T HR CI 12008 ST *Capacity Assessment of Underbridges*. Upgrading the lateral and vertical restraint of a bridge should be undertaken, irrespective of whether a CPB is provided to protect the bridge.

8.1.1. TfNSW standard CPB designs

TfNSW has developed standard drawings for CPBs (referred to as crash beams in standard drawings). The standard designs are listed in Table 2 and CPBs consist of the following components:

- the CPB itself – replaceable after major impact damage
- the end support frame, mounted to the bridge substructure, intended to restrain the CPB and survive an impact on the CPB

Table 2- Standard drawings for CPBs

EDMS no.	Drawing title
CV0094405	STANDARD BEARING UNIT FOR CRASH BEAM SPANS 13m TO 17m
CV0235132	STANDARD CRASH BEAM MAXIMUM SPAN 17m MINIMUM SPAN 13m
CV0235186	STANDARD CRASH BEAM DSETAILS FOR 7.7m SPAN
CV0254437	STANDARD BEARING UNIT FOR CRASH BEAM SPAN 17m TO 26m
CV0254702	STANDARD CRASH BEAM MAXIMUM SPAN 12m
CV0254703	STANDARD CRASH BEAM MAXIMUM SPAN 24m
CV0254704	STANDARD CRASH BEAM MAXIMUM SPAN 18m
CV0254714	STANDARD CRASH BEAM MAXIMUM SPAN 27m

The standard drawings were based on collision loads less than specified in AS 5100. However AS 5100.2 Supplement 1 – 2007 (obsolescent*) Bridge Design – Design loads- Commentary (Supplement to AS 5100.2-2004)* states that the infrastructure owner (TfNSW) may specify reduced loadings on collision protection beams consistent with the design of previous protection beams that demonstrate satisfactory performance.

CPBs based on standard designs are proven to perform satisfactorily over a number of decades for the majority of bridge strikes. Standard details can be used as a basis for customised application at each particular bridge site. A CPB for a long span length may be used in a shorter length for increased capacity.

The use of standard details where applicable is recommended; however not mandatory unless required in this or another TfNSW standard, or by the RIM.

CPB designs based on standard details for similar span lengths are deemed to satisfy the intent of protection beam design in AS 5100, for the protection of robust rigid bridge structures with inherent redundancy, for example, multi-beam and slab decks, solid slab decks; however where the designer proposes to adopt a standard CPB design or detail for a non-robust bridge structure such as steel truss or through deck, the designer shall assess the suitability of the standard CPB design for applicability to the type of bridge being protected. An assessment of the probable maximum collision force shall be undertaken to ensure a standard CPB can resist this force. See Section 5.1.

For fracture critical structures with low inherent redundancy such as, steel girder decks, steel trusses, the designer shall assess the suitability of standard designs before use.

Where a standard design is found to not provide a sufficient level of protection to the bridge, the CPB shall be designed for the loads specified in AS 5100. An energy absorbing CPB restraint system similar to the standard CPB design shall be adopted.

8.1.2. RMS Bridge Technical Direction Manual and bridge policy circulars

The design of bridge impact protection shall comply with the requirements in the relevant technical directions in the *RMS Bridge Technical Direction Manual* and bridge policy circulars (BPC).

Specific RMS documents applicable to bridge impact protection and the design of bridges over roadways are as follows:

- Bridge Policy Circular BPC 2007/07 *Vertical Clearance on Bridges*
- BTD 2011/05 Rev 1 *Minimum Restraint Requirements for Superstructures* (applies to design of new bridges and major bridge upgrades, not applicable to the design of CPBs)

Where a conflict exists between the requirements of this standard and an RMS bridge technical direction (BTD) or policy (BPC), the requirements of this standard shall take precedence.

The designer shall establish the currency of the list of BTDs and determine whether new bridge technical directions are relevant to the design of CPBs.

RMS standard details and arrangements for associated CPB items (for example, traffic barriers protecting crash beam supports) for bridges and roads shall be used.

8.2. Approved materials

For approved materials that can be used for CPBs, refer to section 4.12 and section 4.13 of CD 366, Revision 0.

Approved construction materials for main structural elements of CPBs are steel and concrete in accordance with AS 5100 and SPC 301 *Structures Construction*. The chosen materials shall behave in a ductile non-brittle manner upon impact, with the exception of infill concrete inside a CPB.

Rubber is approved as an energy absorbing material.

8.2.1. New and infrequently used materials

Any products specified in the design documentation that can reasonably be deemed to be new or infrequently used shall be identified by the designer and referred to the Lead Civil Engineer, ASA, for approval.

The designer shall ensure that the manufacturer, constructor and maintainer of the product understand any special requirements or practices relating to the use of the product in the rail or road environment prior to release of the design documentation. The design documentation shall include these special requirements.

8.2.2. Use of dissimilar materials

Where dissimilar metals are used, the connections shall be designed in order to avoid the risk of galvanic corrosion. See also Section 8.4.

8.3. Durability and design life

The durability and design life requirements shall be in accordance with T HR CI 12002 ST *Durability Requirements for Civil Infrastructure*. These requirements replace those stated in CD 366, Revision 0.

The designer shall assess the requirements for stray current and electrolysis prevention in the CPB design.

Requirements for any ongoing monitoring shall be specified on the drawings or in the durability plan where applicable, and the technical maintenance plan (TMP).

8.4. Electrical earthing and bonding

Refer to section 4.13 of CD 366, Revision 0 for electrical earthing and bonding requirements. References to BS EN standards shall be replaced with the standards nominated in Table 1.

In addition, the design for earthing and bonding in the electrified area shall comply with the requirements in TN 016: 2015 *Overbridges and footbridges – Earthing and bonding requirements*.

8.5. CPB gauge strip

A gauge strip on a CPB is a sacrificial element attached to its underside, and designed to sustain the vehicle impact collision from a vehicle with minor clearance height infringement directly without causing significant damage to the CPB.

Gauge strips have been proven to be effective in service and shall be incorporated for all CPBs where practical.

Gauge strips shall have the following characteristics:

- Gauge strips shall be designed to be readily replaced without the need to replace the entire crash beam that could result in significantly reduced disruption to both road and rail traffic.
- Standard CPB details incorporate welded gauge strips. Bolted gauge strips are more practical as they are more easily replaced and shall be adopted.
- Gauge strips and connections to the CPB shall be designed for the loads specified in AS 5100.
- The gauge strip and CPB soffit shall be smooth and without bolt head projections or the like.
- The projection of the gauge strip below the CPB soffit shall be minimised. This projection should not be more than 20 mm.
- The soffit level of the CPB shall be in accordance with Section 8.6 of this standard. The soffit level of the gauge strip will, by necessity, be lower than the CPB soffit level. The design CPB soffit level shall not be adjusted to allow for the gauge strip vertical projection.
- The underside of the gauge strip and CPB should be constructed parallel to the road surface vertical alignment and crossfall where appropriate, that is, not necessarily horizontal. Refer to Figure 3.8 to Figure 3.11 of CD 366, Revision 0 unless otherwise specified by the road authority.

8.6. Vertical clearance to CPBs

Determination of the vertical clearance under the CPB shall take into account the gauge strip requirements included in Section 8.5.

8.6.1. Soffit level and measured clearance

The measured clearance is the shortest distance between the structure soffit and a chord line placed over the road surface. This shortest distance is typically normal to the road surface and chord line. The measured clearance equals the basic height clearance if no sag, hog, cross fall or gradient to the roadway vertical alignment is present. The minimum measured clearance is the smallest value for the road carriageway.

For soffit level and measure clearance, refer to section 3.4 to section 3.17.1 of CD 366, Revision 0.

The following customisation applies:

- the measured clearance from the soffit of the bridge or CPB where present, shall be measured normal to the road surface, or chord line
- the vehicle base line length shall be considered as the chord line
- the minimum chord length shall be 16 m, or longer where specified by the road authority

8.6.2. Sign posted clearance

The sign posted clearance shall be based on the measured minimum clearance of the CPB or gauge strip where installed, for each carriageway, or the bridge soffit where no CPB is present, less 100 mm safety margin.

The resulting clearance value shall be rounded down to the nearest 0.1 m and this value shall appear on the signs at, or in advance of, bridges with substandard clearance. For example, a minimum measured clearance of 4.765 m less 100 mm safety margin and rounded down would be signposted at 4.6 m.

Where the safety margin to the measured minimum clearance is less than 100 mm (for example at an existing bridge site that is subsequently re-surveyed), the RIM shall advise the road authority.

Refer to BTD 2007/07 for requirements for bridges over RMS roadways.

8.6.3. Clearance signs

Signage in accordance with AS 1742.2 shall be erected at bridges with substandard clearance.

'Low Clearance' signs shall be erected on the bridge where the vertical clearance is less than 4.6 m.

The clearance sign may also be erected where the vertical clearance is more than 4.6 m and less than 5.4 m.

The installation of a CPB may require the existing signed clearance to be amended. Any change shall be carried out in consultation with the road authority.

The road authority is responsible for placing signs along the road corridor.

8.6.4. Attachment of signs and equipment

Refer to section 5.4 of CD 366, Revision 0 for attachment of signs and equipment requirements.

8.6.5. Clearance documentation

The RIM shall record the following data for each road carriageway in the bridge examination reports and where appropriate in the TfNSW Bridge Management System:

- minimum basic height clearance, position and date measured
- minimum measured clearance, position and date measured
- sign posted clearance, position and date measured or inspected
- copy of RMS clearance certificate where applicable
- any other signage
- any protection measure, for example CPB, with minimum basic and measured clearances
- any bridge strike incident, and whether the strike was on the bridge or CPB
- permitted vehicles using the road, such as general access, restricted access, and so on

8.7. Clearance re-measurement

Refer to section 3.14 of CD 366, Revision 0 for re-measurement of clearance requirements.

The available clearance shall be measured immediately after the CPB installation, and clearance sign adjusted, where necessary to suit, and appropriate signs erected before the road is opened to traffic.

8.8. Adaptability for replacement

The CPB shall be designed for ease of replacement following impact damage. Particular attention shall be paid to the design of the supports to allow transmission of forces to the substructure without damage. See Section 8.5 of this standard.

8.9. Layout and position

Refer to section 3.1 to section 3.3.2 and section 3.18 to section 3.19.1of CD 366, Revision 0 for layout and position requirements.

In addition, the horizontal deflection of the CPB shall take into account the following:

- elastic-plastic deformation of the CPB
- elastic deformation of energy absorbing buffers at the supports

The preferred horizontal arrangement for CPB is parallel to bridge. This may not necessarily be the correct approach for all bridges. Where a bridge is highly skewed to the roadway, after colliding with the CPB, the vehicle may deflect and tip over if the CPB is parallel to the bridge. A risk assessment shall be undertaken to determine the orientation of the CPB for highly skewed bridges.

8.10. Protection for road users

The design of the CPB shall provide sufficient structural integrity so that on impact, the CPB remains whole and does not collapse and become a hazard to road users.

Safety chains shall be installed at each end of the CPB. Safety chains shall be capable of supporting the CPB’s dynamic weight in the event of dislodgement from its supports with a minimum factor of safety of 2.0.

The length of chain shall be specified such that the vertical drop of the CPB is no greater than 0.3 m from the CPB’s bearing level.

8.11. Painting and hazard markings

CPBs shall be painted in the colour ‘Y15 Sunflower’ in accordance with AS 2700 *Colour standards for general purpose*.

Hazard markings shall be painted on the full front face surface areas of a CPB that are visible to the driver of an oncoming vehicle. The markings, unless otherwise specified by the road authority, shall be stripes of 150 mm minimum to 250 mm maximum width and of 300 mm minimum height. The stripes shall be of alternating yellow and black (Y15 Sunflower and N61 Black in accordance with AS 2700) colour and sloping at 45 degrees to the vertical. The direction of slope, as viewed by oncoming traffic, shall be down to the right for the protection beam face from the left side to the right until the road centre line and down to the left for the remaining section of protection beam face. The strip markings shall be over the traffic lanes.

Hazard markings shall be submitted to the road authority for agreement.

Refer to section 5 of CD 366, Revision 0 for general requirements and Appendix A of CD 366, Revision 0 for photograph examples.

8.12. Substructure and supports for CPBs

The condition of the existing substructure to which the CPB support structure is attached shall be assessed for condition and capacity. Weak areas shall be strengthened. Capacity assessment of the existing substructure shall be undertaken in accordance with AS 5100.7 and T HR CI 12008 ST for rail underbridges.

Refer to section 3 of CD 366, Revision 0.

The supports of a CPB shall form an integral part of the main bridge structure. The CPB shall not be attached to a separate free-standing structure without the approval of the Lead Civil Engineer, ASA.

Refer to section 4.8 of CD 366, Revision 0.

In addition, the design of components such as holding down bolts, anchorages, plinths, bases and structural aspects of foundations shall be designed to resist loads not less than specified in AS 5100. The load factor shall be taken as 1.75 for the ultimate limit state and 1.30 for any serviceability limit state. The purpose of the enhanced load factors is to ensure that in the event of a severe strike, the components listed should be in an undamaged state, and only the gauge strip (see Section 8.5 and Section 8.8) section of the CPB may need replacement after a moderate bridge strike. In the event of a severe bridge strike, only the CPB may need replacement.

8.13. Collision protection of CPB supports

Where approval is granted to construct the CPB support independent of the bridge structure, the requirements for collision protection for support elements adjacent to roads shall be determined by risk assessment in conjunction with the relevant road authority and the RIM.

9. Documentation

The design of all new collision protection systems shall be documented and relevant information retained by the RIM.

9.1. Investigation report

Where an investigation is carried out for a bridge collision protection system, the investigation report shall include the following:

- bridge location and description including track and kilometrage and asset ID
- photos and existing drawings
- condition inspections and assessment for an existing bridge
- history of previous bridge strikes for an existing bridge
- bridge capacity assessment for an existing bridge
- description of the road approaches to the bridge
- road classification and permitted vehicles, such as general access, restricted access
- clearance dimensions, copy of current clearance certificate from road authority (see Section 8.6.5)
- signage and existing controls
- road and bridge survey, services searches
- site geotechnical investigation where required

- heritage impact assessment where applicable
- bridge protection options, including arrangement drawings where appropriate
- cost estimates and options evaluation including life cycle costing assessment
- safety in design and hazard log
- recommendations for preferred option

9.2. Detailed design report

A detailed design report shall be prepared for all new bridge collision protection systems. The detailed design reports shall include the following:

- bridge, track (line and kilometrage) and location description
- design standards
- design inputs and assumptions
- design life, material and section properties
- design methodology and analysis methods and software used
- summary of design loads, member design actions and member design capacities
- horizontal, vertical and measured clearances to bridge soffits and CPB soffits, where used
- clearance dimensions, see Section 8.6.5
- heritage and environmental and sustainability issues
- constructability issues
- durability plan
- TMPs
- safety in design, risk and hazard logs
- 'for construction' drawings
- technical specifications

9.3. Construction drawings

Drawings for construction shall comply with T MU MD 00006 ST *Engineering Drawings and CAD Requirements*.

The construction drawings shall detail the following:

- bridge arrangement and component identification and numbering in accordance with ESC 300 *Structures System*

- the design loadings on CPBs
- horizontal and signposted clearances to bridge soffits and CPB soffits (see Section 8.6.5)
- any other information that is relevant to ensure that the new structure is constructed and maintained in accordance with the design
- the details of granted concessions
- the construction hazards and risks on the general arrangement drawing in the form of safety notes
- construction sequence, as applicable

9.3.1. As-built construction drawings

As-built construction drawings shall be prepared and submitted to the TfNSW Virtual Planroom at the completion of the construction works.

An as-built CPB clearance survey shall be carried out immediately after CPB installation.

9.4. Technical specification

The designer shall prepare a complete technical specification for the bridge collision protection system and associated works.

The technical specification for overbridge or footbridge construction shall be in accordance with SPC 301.

RMS QA specifications are referenced in SPC 301. The designer shall supply all the relevant design information required as input into the relevant appendices within the RMS specifications, including any customisation required to specific clauses or sections.

The design documentation shall reflect this requirement and shall include all project specific requirements necessary for completeness of the technical specifications.

10. Construction

The design shall take into account construction constraints, particularly construction activities during live road and rail operating conditions, as well as any restrictions associated with construction during track possession.

Particular requirements include the following:

- Refer to section 3.6 of CD 366, Revision 0 and Section 8.7 in this document.
- Clearances shall take into account transit space requirements, safe working and construction plant and equipment.

- Adequate clearance shall be provided to allow for inspection and maintenance under normal train operations.
- Access shall be provided to all parts of the collision protection system for inspections and maintenance activities such as re-painting, in accordance with specific requirements stated in the durability plan.

11. Maintenance

The CPB design and installation maintenance requirements are as follows:

- The collision protection system design shall provide ease of access to, and sufficient clearance around components for inspection and maintenance activities.
- Maintenance requirements shall be specified in the TMP for the structure. The requirements shall include examination tasks and frequencies, damage limits and repair standards. MN A 00100 *Civil and Track Technical Maintenance* and ESC 302 *Structures Defect Limits* applies to most bridges. However, additional site-specific maintenance requirements shall be documented in a specific TMP. The requirements and high-level processes for the development of TMPs are in T MU AM 01003 ST *Development of Technical Maintenance Plans*.
- Design features such as spikes shall be installed to prevent birds nesting on CPBs.
- Clearance and CPB data incorporating documentation requirements in Section 8.6.5 and the requirements of the road authority shall be specified in the TMP for the structure.

The following information for each bridge strike event shall be recorded:

- date and time of the event
- which CPB has been struck (Up side of the track, Down side of the track)
- location along the CPB
- extent of damage to the CPB and the bridge

12. Decommissioning or disposal

Decommissioning is the final process of withdrawing an asset from active service on the network.

Disposal is the process of removing an asset from the network, for example, demolition of a CPB followed by removal and recycling.

The decommissioning or disposal of a bridge is the final stage of the asset life cycle. Proper planning of this part of the life cycle is an integral part of the strategic life cycle process.

The process to be undertaken for the disposal of an asset shall be as follows:

- justification in the investigation report (safety, financial and so on) for disposal of the asset
- confirmation of stakeholder engagement regarding the proposed action - such engagement shall include all relevant authorities, but not be limited to heritage, local, state and federal government, the RIM and environmental body consultation
- agreement from all stakeholders to the decommissioning or disposal of the existing asset

After decommissioning and disposal, the asset database shall be updated by the RIM to reflect network changes.

At least 95% per cent of construction and demolition waste by weight of the decommissioned asset should be diverted from landfill.

Appendix A Impact protection risk analysis for rail underbridges (informative)

There are many underbridges over roadways with inadequate vertical clearance and they face a risk of impact from motor vehicles. It is not feasible to protect all existing underbridges over roadways. A risk analysis is required to prioritise existing vulnerable bridge sites and determine the requirements for protection. AS 5100 provides no guidelines on the method of risk analysis.

The risk analysis should include the following criteria:

- material of bridge construction
- vertical clearance and road profile
- structural configuration (redundancy)
- traffic volume (including high vehicles)
- vehicle energy level (mass and speed)

The risk analysis shall consider all at-risk underbridges, with or without previous vehicular bridge strikes located over roadways. In addition, the method shall determine comparative vulnerability of sites to determine priority locations.

A semi-quantitative risk analysis method is outlined in Appendix A.1. This method is suitable for ranking existing at-risk sites, with or without a history of bridge strikes, in a priority order based on the risk criteria developed.

To mitigate the risk for at-risk bridges within TfNSW boundaries, several measures were proposed and implemented; however the preferred option is the installation of collision protection beams located directly in front of the bridge deck.

To protect at-risk bridges mostly in the electrified area, CityRail in the 1980s and early 1990s undertook the following:

- the installation of protection beams on the 30 most at-risk underbridges
- the renewal of many broad flange beam (BFBs) underbridges over roadways

A.1. Introduction

The main vehicles responsible for bridge strikes with underbridges are trucks, plant, cranes and cherry pickers. In NSW, the approximate number of bridge strikes per annum (current at 2009) is set out in Table 3.

Table 3 - Bridge strike data

Severity of bridge strike	Structural damage	Description	Number per year
Minor	Nil	Damage is trivial. Only scrapes superstructure.	5000
Major	Moderate	Introduces local cracks or minor dents or both in superstructure at point of impact.	50
Potentially critical	Protection beam protection	Impact energy absorbed by protection beam. Severe damage to protection beam.	12
Critical	Severe	Bridge crippled or grossly displaced with severe track misalignment. Almost certain derailment condition.	1-2

A.1.1 Methodology

The objective is to provide a risk analysis methodology that determines the need for protection and prioritises at-risk sites of existing underbridges over roadways.

The processes involved in the identification and prioritisation of at-risk underbridges are outlined in Table 4.

Table 4 - Mitigation action

Has there been any bridge strike?	Type of hit	Action - Broad flange beams Note (a)	Action - Others Note (a)
Yes	Minor	Protect or replace BFBs (2)	Undertake risk analysis and prioritise (4)
Yes	Major	Replace BFBs (1)	Install protection beam (3)
Yes	Critical	Replace BFBs (1)	Install protection beam (3)
None yet Note (b)	Not available	Undertake risk analysis and prioritise (5)	Undertake risk analysis and prioritise (5)

Note (a): Numbers (1) through to (5) designate the relative order of risk.

Note (b): Risk analysis required to identify vulnerable underbridges that have not yet been struck. Factors that can lead to a change in the conditions at the bridge site include coastal or rural development, and the demands for faster and higher loads.

The steps in chronological order are as follows:

- identify sites where bridge strikes have occurred in the past
- identify other vulnerable sites with no history of bridge strikes
- undertake risk analysis at the sites if required by the Table
- prioritise sites following the risk order (1) through to (5) given in Table 5

The risk order (1) to (5) is a means of identifying and prioritising relative risks at sites with or without a bridge strike history.

A.1.2 Risk ranking

A level of risk of a bridge strike is present at every underbridge over roadways. The relative risk at vulnerable sites should be assessed on the basis of available data, the use of risk factors, or both and develop a list of bridge sites for priority protection works.

As shown in Table 5, a risk analysis is not required for bridge sites where major or critical strikes have occurred, as these require works to be undertaken.

To address the risk for other sites in a logical and consistent way, a risk analysis is undertaken in accordance with this Section.

A semi-quantitative risk approach is proposed. The analysis involves consideration of the sources of risk, their consequences and the likelihood that those consequences may occur.

Five risk factors, namely material of construction, vertical clearance, structural configuration, volume of road traffic, and vehicle energy levels, are identified as being of significance.

The risk factors are assigned ranking values between 1 (lowest risk) and 10 (highest risk) in accordance with Table 5. The numbers are merely for the purpose of ranking the sites. They have been derived from past experiences and relative level of perceived risks.

Table 5 - Risk ranking

Factor	Details	Ranking
Material of construction of deck (consequence)	Broad flange beam	10
Material of construction of deck (consequence)	Timber	8
Material of construction of deck (consequence)	Steel welded before 1965	7
Material of construction of deck (consequence)	Wrought iron, steel riveted, steel rolled sections	4
Material of construction of deck (consequence)	Steel welded after 1965, prestressed concrete	3

Factor	Details	Ranking
Material of construction of deck (consequence)	Reinforced concrete, jack arch, masonry viaducts	2
Vertical clearance, V (probability)	V < 4.2 m	10
Vertical clearance, V (probability)	4.2 m ≤ V ≤ 4.6 m	8
Vertical clearance, V (probability)	4.6 m < V ≤ 5.3 m	6
Vertical clearance, V (probability)	V > 5.3 m	2
Structural configuration (consequence)	Transom top single track, truss, through girder	10
Structural configuration (consequence)	Transom top double track, ballast top single track	5
Structural configuration (consequence)	Ballast top double track, slab track, multiple beams	4
Traffic volume (probability)	Change: developments, resorts, mines, power stations	7
Traffic volume (probability)	High: freeways, state highways	6
Traffic volume (probability)	Medium: local and regional roads	5
Traffic volume (probability)	Low: secondary roads	3
Vehicle energy level (consequence)	High energy: frequent vehicles over 10 t and high road speed possible (≥ 70 km/hr)	7
Vehicle energy level (consequence)	Low energy: Vehicles over 10t with only low speed possible (< 70 km/h)	3

The total ranking at each vulnerable bridge site is determined by adding the scores and then a list of priority sites is developed. The objective of a semi-quantitative approach is to produce a more detailed prioritisation than is achieved in qualitative analysis.

A.1.3 Protection of high-risk underbridges

A high-risk site can generally be brought to an acceptable level of risk by reducing the effects of one or both of the following:

- the likelihood of bridge strikes (vertical clearance or traffic volume)
- the consequence of bridge strike (deck material, structural configuration or vehicle energy impact)

For existing structures, the aforementioned measures of risk reduction may not be feasible. Some means of protection of the superstructure from a strike are required and they are outlined in Table 6.

Table 6 - Protection measures for existing underbridges

Description/ protection type	Efficiency	Installation cost/ /maintenance/ inspection	Issues
Protection beams Direct impact device	High	High costs of installation	Life of five years at frequent major collision sites Critical collisions eliminated
Clearance (gauge) frames Sound detection device	Moderate	Cheap installation cost	Major hazard to others if dragged down Noise could be muffled by traffic
Warning lights Sight device Light beam across road triggers light for driver's attention	Moderate	Regular inspection High tech servicing High installation for bidirectional traffic	Subject to equipment or power failure; vandalism Some drivers ignore lights
Impact detection device Impact force triggers railway signals to red	Moderate – fair	Regular inspection High tech servicing	Subject to equipment or power failure; vandalism Sensitivity problems Availability of signals
Increase vertical clearance by raising bridge or lowering road	Moderate	Very costly	Requires track to be lifted, road lowered or thinner deck construction May not be feasible at some sites

Note: The warning device will mitigate the risk of vehicle impact to some degree, however will not eliminate it.