Oberon Tarana Heritage Railway

Engineering Standard

Structures

OTCS 310

UNDERBRIDGES

Version 1.0

Issued August, 2018

Approved by:

Document control

Revision	Date of Approval	Summary of change
1.0	August, 2018	First Issue. Includes content from the following former RIC standards: TS 30 000 3 01, TS 31 000 3 01, TS 31 200 1 01, TS 31 400 1 01, C 4005, C 4009, C 4010, CTN 01/14, CTN 04 22. And CRN CS 310 Ver 1.0

Summary of changes from previous version

Section	Summary of change

Contents

1 Purpose, scope and application

This document specifies the design requirements for underbridges

This Standard does not cover the load rating of underbridges, which is documented in OTCS 301 "Load Rating of Underbridges".

Underbridges are defined as bridges supporting the track and passing over waterways, roadways, pathways and flood plains etc. They include viaduct, subway and culvert structures.

The term „culvert" is used to refer to minor ballast-top openings comprising metal pipes, concrete pipes, concrete boxes, concrete arches, brick and masonry arches.

2 References

2.1 Australian and international standards

AS 1085.1: 2002 - Railway Track Material Part 1: Steel Rails

AS 1111.1: 2000- ISO metric hexagon bolts and screws - Product grade C - Part 1: Bolts

AS 1597.2: 1996 - Precast reinforced concrete box culverts

AS 1657: 1992 - Fixed platforms, walkways, stairways and ladders – Design, construction and installation

AS 1720.1: 2010 - Timber structures – Design methods

AS 1742.2: 2009 - Manual of uniform traffic control devices – Traffic control devices for general use

AS 1743: 2001 - Road signs – Specifications

AS/NZS 2041: 1998 - Buried corrugated metal structures

AS/NZS 2041.2: 2011 - Buried corrugated metal structures - Installation

AS 3600: 2009 - Concrete structures

AS 3818.1: 2003 - Timber – Heavy structural products - visually graded, Part 1: General requirements

AS 3818.2: 2003 "Timber – Heavy structural products - visually graded, Part 2 Railway track timbers

AS 4100: 1998 - Steel structures

AS 5100: 2004 - Bridge design

2.2 BBRC documents

OTCS 100 - Civil Technical Maintenance Plan

OTCS 200 - Track System

OTCS 215 - Transit Space

OTCS 220 - Rail and Rail Joints

OTCS 230 - Sleepers and Track Support

OTCS 301 - Load Rating of Underbridges

OTCS 302 - Structures Defect Limits

OTCS 410 - Earthworks and Formation

OTCS 420 - Track Drainage

2.3 Other references

CRN CP 213 – Trackside Signs

CRN CP 301 - Structures Construction

CRN CP 411 - Earthworks Materials Specification

Standard Drawing Numbers 785-568, 785-569, 785-570 and 785-571

CV 0041442 Standard Steel Walkway (With Refuge) to suit 9m to 15m Fabricated Steel Girder Spans

CV 0042333 Standard 1500 Wide Steel Walkway (Without Refuge) to suit 9m to 15m Fabricated Steel Girder Spans

CV 0115011 Standard Ballast Retaining Wall

CV 0162590 Standard Intermediate Rail Support at Bridge Ballast Walls

Australian Rainfall and Runoff - Institution of Engineers Australia 1987

Waterway Design - Austroads 1994

Bridge Waterway Manual - RTA September 2000

3 Engineering authority

Design and selection of infrastructure detailed in this standard may only be undertaken by persons who have been granted appropriate Engineering Authority by the Engineering Manager.

4 General requirements

4.1 Design standards

All underbridges shall be designed to Australian Standard AS 5100 “Bridge design” and the requirements specified in this document.

4.2 Existing structures

When renewing the substructure or superstructure on an existing underbridge, the design shall comply with Section 4.1 and shall provide for the current and proposed future line usage and business requirements.

This includes widening or extending existing bridges.

When replacing the superstructure only, the structural capacity of the substructure shall be assessed. The assessment shall be based on the actual loading from rail traffic. In determining the actual loading, any increased loading due to proposed future line usage and business requirements shall be included. The substructure shall be strengthened to meet the actual loading if the assessment determines the capacity is not adequate.

4.3 Integrated designs

The design of each underbridge shall be integrated taking into account all associated requirements such as service routes, signalling infrastructure, drainage, bonding and architectural treatments. Where appropriate, aesthetics shall be taken into account including proportions, details and finishes.

In locations that are vulnerable to vandalism and graffiti, appropriate measures shall be taken to discourage access to the bridge. Anti-graffiti paints should be specified in areas where there is a high risk of graffiti.

4.4 Approved materials

Approved construction materials for main structural elements are steel and concrete. With the exception of transoms, timber materials shall not be used as structural elements in the design of underbridges.

Masonry is approved for existing structures and as facing material for new structures where this is required in special circumstances such as for heritage reasons.

4.5 Clearances for rail, road and pedestrian traffic

Where an underbridge passes over a road, pedestrian access, cattle access, navigable waterway or other rail line, horizontal and vertical clearances beneath the structure shall be provided in accordance with AS 5100 or Engineering Standard OTCS 215 "Transit Space", as applicable. For navigable waterways clearances shall be agreed with the relevant authority.

Clearances to bridge members above rail level (e.g. through girders or trusses) shall also conform to BCS 215.

4.6 Clearances to electrical services and equipment

Electrical services within the rail corridor may include aerial lines and exposed low voltage equipment.

Bridges shall be designed and constructed to ensure that minimum clearances are observed to all electrical power lines and equipment, in accordance with Australian Standards and the regulations of the relevant electrical authorities.

Where high voltage aerial lines are located above the bridge, measures shall be taken to ensure that the risk of transferred potential associated with fallen conductors is mitigated.

4.7 Earthworks

Earthworks associated with underbridges shall be designed in accordance with Engineering Standard OTCS 410 "Earthworks and Formation", Engineering Specification CRN CP 411 "Earthworks Materials" and the specification for engineered backfill in Section 16.3.1.

4.8 Provision for services

Provision may need to be made for services managed by OTHR (e.g. low voltage, signalling, communications), or for services owned by other authorities and utilities (e.g. telephone, water supply, power and gas).

The designer shall consider requests that may be received from other authorities for new services to be attached to a bridge. Special ducts shall be provided for both current and future services, where appropriate. Services shall be segregated where necessary, e.g. power and signalling.

The location and fixing of the service ducts shall be designed so that future access to the underbridge structure for inspection and maintenance is not impeded. The service ducts shall also be designed and located so that the future inspection and maintenance of the services is not impeded.

Service ducts shall be located to comply with OTCS 215.

Where service ducts are attached to a bridge walkway, they shall be positioned so that they do not encroach on the safe working area or create a trip or other safety hazard.

4.9 Safety

The design of underbridges including the design of substructure or superstructure renewals shall include safety considerations for construction and maintenance personnel, and any other parties including operations personnel who may be required to use the structure.

Designs for underbridges and culverts shall provide safe access for inspection and maintenance. This may include access steps, ladders, cages, inspection gantries, walkways and fixing points.

4.10 Protection of the environment

The design of underbridges including the replacement of components in existing structures shall take into account environmental impacts during construction and maintenance activities, with a view to minimising any impacts.

Where appropriate, relevant external authorities shall be consulted and environmental reviews undertaken to ensure that all legislation and regulations applicable to the protection of the environment are taken into account.

4.11 Heritage

Heritage considerations and classifications shall be observed in all underbridge designs. This may have particular application in circumstances where an existing structure is being replaced or modified, or where a new structure is being proposed in the vicinity of existing heritage items.

Both indigenous and European heritage aspects shall be addressed where appropriate, with due consideration of current legislation and procedures

4.12 Protection of the public

Suitable protection shall be installed on bridges to prevent spillages from wagons conveying mineral products, ballast or spoil from falling through the bridge or off the side of the bridge onto road vehicles or pedestrians underneath. This may be achieved by the use of steel mesh or similar material, laid between transoms or fitted to the sides of safety walkways.

4.13 Design procedure – new or infrequently used products

If any products specified in the design documentation can reasonably be deemed to be new or infrequently used, these must be identified by the designer and referred to the General Manager for approval. The designer must be satisfied that the manufacturer/constructor/maintainer understands any special requirements/practices relating to the product prior to release of the design documentation.

4.14 Warning plaques

On ballast top bridges, plaques or stencilling shall be installed in a visible location on the top of the kerbs, providing a warning that excess ballast and lifting of the track above design level are not permitted over the bridge

4.15 Drawings

Construction drawings shall comply with standard procedures and formats, and shall detail the design criteria and any other information that is relevant to ensuring that the new structure is constructed and maintained in accordance with the design.

4.16 Construction

Design documentation shall identify standards for construction, including construction methods, processes and materials.

The owner has a suite of technical specifications for construction of structures. The specifications are detailed in Engineering Specification CRN CP 301 "Structures Construction" and shall be incorporated in the design and construction documentation of underbridges.

Design documentation shall include relevant references for material testing and testing of welds. The

design of new underbridges and the design of superstructure or substructure renewals shall take into account construction constraints, particularly under live operating conditions and track possession constraints.

Designers shall consider clearances from the track to the piling equipment when designing substructures. Clearances shall take account of transit space, safeworking and construction requirements, and the availability/ duration of track possession to avoid both construction constraints and excessive length of abutments and piers.

The minimum clearance under normal operating conditions is the kinematic envelope (out-of-gauge load) plus 200mm.

4.17 Maintenance

The design of underbridges, including the design of superstructure or substructure renewals, shall take into account the ability to access components for inspection and maintenance purposes. On steel underbridges, sufficient clearance shall be provided between end cross girders and ballast walls for this purpose.

Components, materials and finishes should be chosen to minimise future maintenance. Maintenance

requirements shall be specified in the design documentation for structures. Requirements shall include examination tasks and frequencies, damage limits, and repair standards. In most cases, OTCS 100 "Civil Technical Maintenance Plan" and OTCS 302 "Structures Defect Limits" will apply. However site specific maintenance requirements may need to be provided.

4.18 Advertising Signs

Design loadings for advertising signs shall be in accordance with relevant Australian Standards.

The underbridge shall be assessed for the structural capacity to withstand the advertising sign design loadings.

Fixing details shall be in accordance with design codes and practices. They shall not impact on the structural integrity of the bridge. They shall not create an obstruction that causes water to pond or debris to accumulate on the bridge structure. They shall only be made into existing structural members with the approval of the Engineering Manager.

Fixings and ladders for the sign shall not impinge on the clear walking space of walkways and the clear space of refuges.

Signs and fixings shall not prevent access for inspection and maintenance of the bridge, including the structure immediately behind the sign.

5 Design loads

5.1 New underbridges

New underbridges shall be designed to accommodate axle configurations in accordance with AS 5100 for the various Track Classes as detailed in Table 1.

Track Class	Design Load configuration
Main Lines	
Heavy Haul Coal Operations	350-LA plus DLA
Class 1 and 2 lines	300-LA plus DLA
Class 3 and 5 lines	280-LA plus DLA
Sidings	
General Yard	300-LA plus 50% DLA
Sidings (includes unloading bins)	330-LA plus 0% DLA
Passenger operations/ or maintenance	180-LA plus 0% DLA

Table 1 – Design loading for underbridges

NB. The „Reference Load" is 300-LA. For the other loadings, all axles shall be proportioned by the ratio of the nominated LA load divided by 300.

Track classes are defined in OTCS 200 "Track System".

For loadings less than 300 LA, future loading requirements need to be considered. Final approval of the design loads shall be obtained from the Engineering Manager.

When designing through girders or truss bridges, secondary structural elements shall be incorporated in the structure to accommodate potential collision loading from a derailed vehicle, in accordance with AS 5100. These are required in order to protect the main structural elements of the bridge from damage.

Where underbridges are designed for installation beneath infrastructure and will extend beyond the existing tracks, they shall be designed for the above loadings for the full extent of the rail corridor.

5.2 Refurbished underbridges

Design loads for major work on existing bridges, including superstructure renewal, ballast top conversion and substructure renewals shall be as above, unless waivers have been approved by the Engineering Manager.

5.3 Seismic loading

The class of bridge for seismic loading in accordance with AS 5100.2 Table 14.3.1 Bridge Earthquake Design Category is:

- bridges on main lines are Type III i.e. essential to post-earthquake recovery.
- bridges on sidings are Type I, except for bridges over roadways or railways which are Type II.

Non-compliance may be approved if the Engineering Manager considers the bridge to be on a route that is a non-essential post-earthquake recovery corridor.

5.4 Culverts

5.4.1 Loading

New culverts shall be designed to accommodate axle configurations as nominated for new underbridges above.

AS 5100 shall be used to determine the vertical live load pressure at the required depth below sleeper. Minimum and maximum ballast depths shall be considered as well as wheel configurations to determine the critical case.

AS 1597.2 shall be used to determine the horizontal component of live load (i.e. 0.5 times the vertical live load at the given depth). Loadings shall be determined at the top and bottom of the culvert leg and pressures distributed as a trapezoid.

The dynamic load allowance (DLA) shall be determined as follows:

- Box culverts: in accordance with AS 1597.2
- Suspended slab (deck slab supported as simply supported beam on legs): in accordance with AS 5100. Note that AS 5100 has no specific culvert option for determining $L\alpha$. If the span length is taken as $L\alpha$ it gives a DLA of 100%, which is too conservative.

Adopt other loads, load factors and load combinations from AS 5100.

Where culverts are to be extended across the rail corridor to accommodate additional tracks or access roads, the following design loading shall be applied:

- Access road only: R20 (See Appendix 1 for details of R loading configuration)
- Rail loading: in accordance with Table 1.

5.4.2 Structural design

Structural design shall be in accordance with AS 5100 except for shear design, which may be in accordance with AS 1597.

When locating new concrete box culverts in expansive soils an appropriate bedding design shall be undertaken by an authorised Geotechnical Engineer.

Fatigue design shall be in accordance with AS 5100.

6 Bearings and deck joints

Bearings and deck joints shall be designed in accordance with AS 5100.4 “Bridge design, Part 4: Bearings and deck joints”.

The design loads shall be in accordance with AS 5100.2 “Bridge design, Part 2: Design loads”.

Bearings and joints shall be designed to provide sufficient access for the inspection, maintenance and replacement of the bearings and joints.

The minimum vertical distance between the underside of the main beams and the bearing shelf shall be 500mm.

Jacking points shall be provided on the bearing shelf.

7 Track structure requirements

7.1 General

Transom top, ballast top and direct fixation are approved track structures for underbridges.

Track structure shall be selected to minimise the “Whole of Life” cost of the asset.

Ballast top underbridges are preferred to transom top due to ease in maintaining the track. Ballast top underbridges provide for a significant reduction in track degradation adjacent to bridge ends.

Direct fixation of the track to bridge decks may be considered where constraints such as limited vertical clearances exist below or above the track.

Mechanical rail joints are not permitted on bridges. Anchoring of track and provision for expansion switches shall be in accordance with BCS 220 ”Rail and Rail Joints”.

7.2 Ballast top

Specific component configuration requirements exist for guardrails, walkways, handrails and refuges and bridge ends, as detailed in this standard.

The distance between the inside face of the ballast kerb and centre line of track on straight track shall be 1950mm. This distance may need to be increased where the track is on a curve to ensure that ballast is fully retained on the bridge.

The standard height of the ballast kerb shall be 600mm. This may need to be reduced in special situations where hydraulic or other conditions demand, or increased where the track is on a grade or superelevated over the structure.

In all cases the structure shall be designed so that the top of the ballast is no higher than the top of the kerb.

7.3 Transom top

Specific component configuration requirements exist for guardrails, walkways, handrails and refuges and bridge ends, as detailed in this standard.

The design of transoms shall be in accordance with the details provided in Section 17 of this standard.

7.4 Direct fixation

Not Applicable

8 Drainage and waterproofing

New underbridges, except transom-top bridges, shall be designed to prevent rainwater runoff discharging to the watercourse or roadway below. The runoff should be captured and drained away from the track structure at the bridge end.

For the replacement of existing underbridges or renewal of bridge superstructures, decks shall have positive drainage systems where possible. Waterproofing of the bridge deck may be achieved where appropriate by the use of membranes approved by the Engineering Manager. Where used, membranes shall be protected from mechanical damage from the track ballast by the installation of shock mats or similar materials.

On all new concrete ballast-top bridges, shock or ballast matting shall be laid as a minimum between the ballast and concrete surface, to reduce abrasion and breakdown of the ballast and to prevent the ballast working into any gaps in adjoining concrete members.

Where piped drainage is used, the system shall be cleanable and generally comply with the requirements of Engineering Standard BCS 420 “Track Drainage”. The minimum pipe size shall be 225mm diameter.

9 Culverts and small openings

Small span structures such as reinforced concrete pipes, precast culvert units and corrugated pipes etc. are basically “under formation” crossings. These products are generally commercially available and are designed in accordance with the requirements of AS 5100.

Corrugated steel pipes and pipe-arches shall be designed in accordance with the requirements of Section 18 of this standard.

10 Waterway requirements

To design and size underbridge structures to satisfy waterway requirements, the following steps are required:

- Determine the hydrological and hydraulic requirements for the opening.
- Establish the requirements of other authorities and government departments.

The procedures to be followed shall conform with the requirements of AS 5100 and shall generally be in accordance with the RTA “Bridge Waterway Manual”, the Austroads “Waterway Design Manual” and “Australian Rainfall and Runoff“.

Where existing culverts require extension, the cross sectional area and the hydraulic performance of the extension shall be checked for the above criteria for new culverts. The hydraulic performance of the extension shall also be not less than that of the existing culvert.

The determination of design flood and bridge waterway area shall be carried out by authorised engineers, and shall be independently checked. The methods shall be recognised and widely accepted, and appropriate to the locality.

10.1 Hydrology and hydraulic requirements

Flood discharges shall generally be determined for average return intervals (ARI) of 10 year, 20 year, 50 year, 100 year, 2000 year and Probable Maximum Flood (PMF) events.

Bridge structures shall be designed for ultimate limit states (ULS) and serviceability limit states (SLS), in accordance with AS 5100.

Small culvert structures and minor openings may be designed for an ultimate limit state as follows:

- Discharge < 50 m^3/sec: ARI of 50 years
- Discharge > 50 m^3/sec: ARI of 100 years

Assessment of the hydrological and hydraulic requirements shall, typically, be carried out in three stages as follows:

- Field investigation: The study should include a sketch, levels of the upstream and downstream watercourse including shape, slope and condition, land use, records of previous floods, approximate kilometrage of catchment, details of other openings affecting the subject stream, evidence/ extent of any scouring, ponding, blockage and debris, photographs and recommendations. For the replacement of underbridges other than minor openings, this work will normally be undertaken by a qualified surveyor.
- Calculation for recommended waterway area: Relevant catchment characteristics should be determined using the procedures as set out in "Australian Rainfall and Runoff" together with extensive hydrological experience. The report should include the maximum discharges for the average return intervals listed above, the kilometrage of catchment divides, kilometrage, size and type of all openings within the catchment, and the distance from existing rail level to existing natural surface at the subject opening.
- Interpretation of calculations: The resulting flood height, velocities, freeboard and afflux etc. associated with various structural options and sizes shall then be determined and a final selection made.

10.2 Requirements of other authorities and government departments

Other authorities and government departments have a statutory role concerning streams and rivers. It is essential that they be contacted at an early stage in the development of the underbridge design to ensure that their requirements are addressed.

Preliminary plans shall be referred to the appropriate authority where the following circumstances apply:

- Tidal streams and rivers
- Non-tidal streams and rivers
- Navigable waterways
- Marine life
- Flood prone land and flood plains

11 Scour protection

11.1 General requirements

Scour protection shall be designed generally in accordance with the RTA “Bridge Waterway Manual” September 2000 and Austroads “Waterway Design” 1994.

11.2 Culverts

To protect against erosion and undermining, all precast concrete box culverts and wingwalls shall be installed with concrete aprons and cut-off walls extending a minimum of 900mm on both the upstream and downstream sides.

Scour protection will not normally be required when any one of the following criteria apply:

- The calculated velocity of flow through the culvert opening at design flow is < 1.5 m/s.
- The bed and banks consist of sound rock or are protected by sound rock bars, and the toe of the embankment is protected.
- The gradient of the channel downstream is flatter than 1%.
- The calculated velocity of flow through the culvert opening at design flow is < 2.5 m/s and the streambed consists of gravel or stones with 50 % by weight exceeding 150mm.

Geometric considerations may require slope protection where scour protection of the bed is unnecessary.

If scour protection is required downstream of the culvert, it shall extend for a distance not less than 1.5 times the opening height from the end of the culvert. It shall also incorporate a cut-off extending 500mm below the bottom of the protection or to rock, whichever is the lesser, and shall be carried to the wing walls or up the sides of the channel to at least the serviceability limit states level. Negotiations will be required with adjoining landowners if this requirement results in the scour protection extending outside the railway boundary.

Scour protection shall be specially designed for channels with a grading steeper than 1%.

11.3 Underbridges

Scour protection shall be provided to footings and pile caps where there is a potential for undermining resulting from scouring of the watercourse under the bridge.

The railway formation around the abutments and wings of a bridge shall be provided with appropriate scour protection where there is a history of scouring and washaways, or where hydrological and hydraulic assessments indicate a potential future problem. Similar protection of the railway embankment adjoining the bridge may also be necessary.

11.4 Alternative construction materials

Alternative forms of scour protection approved for use around culverts and bridges include:

- Grassing of embankment faces
- Hand placed loose rock (rip rap)
- Sand bags filled with lean grout (e.g. 1 cement to 19 loam)
- Revetment mattresses (concrete filled)
- Gabion baskets or Reno mattresses (rock filled)
- Mortared spall
- Precast concrete headwalls

- Cast in situ concrete headwalls
- Cast in situ concrete aprons and cut-off walls

12 Protection of bridges over roadways

Not Applicable.

13 Collision protection

Not Applicable.

14 Walkways, refuges and handrails

14.1 Functional purpose

Walkways serve the following purposes:

- protect authorised personnel from falling when crossing a bridge;
- provide a safe pathway for train crew in the event of a train having stopped or failed on a bridge;
- facilitate track inspection;
- facilitate the replacement of transoms, sleepers and other track components.

Refuges serve the following purpose:

- provide a safe area on a bridge for authorised personnel to stand clear of a passing train.

  Note: Standard width walkways do not provide a safe area or refuge.

Handrails serve the following purpose:

- protect authorised personnel and train crew from falling off the side of the bridge and approaches.

14.2 Walkways

14.2.1 General

Walkways shall be installed on underbridges where the height from bridge deck to the lowest invert level is greater than 2 metres.

When designing the location of walkways, consideration shall be given to particular site characteristics such as flood issues (e.g. afflux and debris), track curvature, sighting distances and train lengths.

On single track where walkways are required, they should be installed in the following order of preference:

- downstream side of a bridge over water where flood levels are high;
- on the „outside" of a bridge on a curve;
- on the same side of the track on adjacent bridges spaced less than one train length apart, with the „worst" safety access bridge governing the side selected for the walkway.

One walkway shall be provided on single track bridges and on double track bridges less than 15m long. Two or more walkways are required on double track bridges longer than 15m. Refer to the typical configurations for walkways, refuges and handrails as shown in Appendix 2.

Where provided, walkways shall be extended with suitable detailing at each end of the bridge to provide a safe transition to the approaches and adjoining rail embankments. Particular attention shall be given to the detail where the last walkway panel abuts the face of the abutment, to ensure that adequate support is provided to the walking surface.

14.2.2 Design requirements

The following design criteria shall apply to walkways on underbridges:

- normal loading is to be self-weight plus 5kPa live load, i.e. when no special storage bays are provided;
- on major bridges where special storage bays, designated by signage, are provided, general walkway loading may be reduced to 3kPa live load. The reduced walkway loading shall also be designated by signage;
- on transom top bridges, there should generally be no gap between the end of the transoms and the walkway deck;
- where a grating is required in the 4-foot or on the transom ends, a proprietary material is to be used that will not lift or deform. Products such as expanded metal are not to be used where they are prone to deformation and lifting at the ends, thereby creating a trip hazard or the risk of being picked up by a passing train;
- on excessively wide ballast top deck bridges, i.e. 3 metres and greater from centreline of track to edge of bridge, no discrete walkway will be required. In this case a handrail will be provided , irrespective of deck to invert height;
- minimum clear walking space shall be 600mm;
- for transom top bridges, the surface of the walkway shall be at or below underside of transom level and ≤ 300mm below top of transom level;
- on ballast top bridges, the normal standard is to set the walking surface of the walkway level with the top of the kerb;
- walkway components shall comply with AS 3600, AS 4100 and AS 1657.

14.2.3 Walkway storage

No walkway shall be loaded beyond the design value. If storage requirements exceed this value, storage bays shall be provided and designated by signage. 5kPa live load equates to 300 kg loading per metre length of 600mm wide walkway.

14.3 Refuges

The design requirement for the placement of refuges is that no person shall be more than 10m from a safe place. Based on this requirement:

- Refuges shall be provided on underbridges over 20 metres in length.
- Refuges may be required on bridges less than 20 metres where site conditions warrant their installation.
- The distance between refuges shall not exceed 20 metres over the length of the bridge. The spacing at each location shall be determined by a risk assessment, taking account of factors such as train speed, available sighting distances and the existence of warning light systems.

Refuges shall have a minimum clear space of 700mm depth and 1500mm width.

To establish the need for refuges and/or signage, the default clearances from the centreline of the nearest track to the front of a refuge are:

- 2230mm on straight track
- 2500mm on curved track

Where circumstances prevent the installation of refuges and the clearance from the track centreline to the back of a walkway is less than the kinematic envelope (out-of-gauge load) plus 600mm, warning signs shall be installed as detailed in 13.7.3 below.

Walkways may be used to provide a „continuous refuge" where the particular circumstances (e.g. sighting distances, traffic volumes, bridge length) warrant such provision.

Where a walkway is to provide a „continuous refuge", configuration details shall be:

- yellow safety line at kinematic envelope plus 200mm from track centreline
- clear walking space of 600mm behind the yellow line for the length of the walkway.

14.4 Handrails

Handrails shall be provided on the outside of walkways and refuges and also on the opposite side of a ballast top underbridge where the height from deck to invert exceeds 2 metres.

Handrails shall consist of vertical posts together with a top rail and intermediate rail. Specific layouts shall be in accordance with the proprietary specifications of approved suppliers. The height of the top rail shall be not less than 950mm above the deck surface.

14.5 Configurations

Typical configurations for walkways, refuges and handrails are shown in Appendix 2.

In most situations, walkways will be cantilevered on the outside of both transom top and ballast top structures. In addition, a walking area by way of a grating may also be required on transom top bridges in the 4-foot and on the transom ends.

14.6 Services

Services and utilities for shall be located so as not to infringe on the walking or standing areas.

They are to be located to the outside of the walkway and extra width of walkway shall be provided to achieve the minimum walking space specified above.

14.7 Safety marking and signage

14.7.1 Safety marking

Delineation of the safe areas to walk and stand on a walkway/ refuge shall be provided by a line 75mm wide and painted in Safety Yellow colour.

14.7.2 Restrictions on use

Each walkway shall display a sign at each access end showing „Authorised Persons Only". An „Authorised person" is a person authorised by BBRC or its agents to enter onto and cross rail bridges.

The sign shall also incorporate a warning regarding the restriction on loading (See Figure 2).

The sign shall be manufactured in accordance with Engineering Specification CRN CP 213 "Trackside Signs".

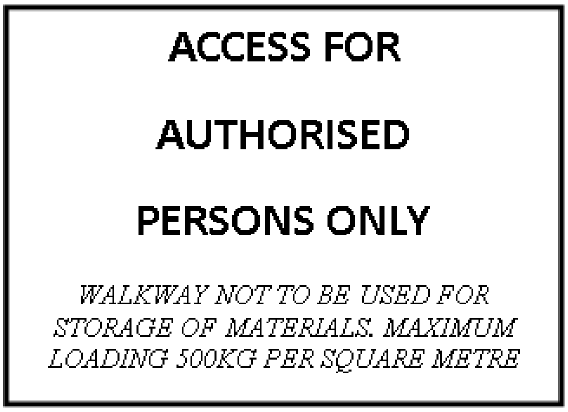

Figure 2 – Authorised persons sign

14.7.3 Limited clearances

An additional sign, as shown in Figure 3, shall be attached to all underbridges with walkways where the clearance from track centreline to the walkway handrail is less than the kinematic envelope plus 600mm.

The sign shall be manufactured in accordance with CRN CP 213. Where similar signs have previously been provided, they should be replaced with the new sign when due for replacement.

Figure 3 – Limited clearance sign

15 Guard rails

15.1 Functional purpose

The prime purpose of guard rails on underbridges is to keep derailed or derailing bogies/wheels tracked parallel to and in close proximity to the running rails. This action prevents a derailed train from striking adjoining infrastructure or falling over the side of the bridge.

In the case of through girder and through truss type underbridges, the guard rails prevent impact with key structural supporting elements.

For through girder, through truss and direct fix bridges concrete upstands may be provided in lieu of guard rails. The upstands shall be designed for a 80kN lateral load. The design shall take account of cross drainage requirements. The upstand shall comply with the relevant configuration requirements for guard rails.

In addition, the guard rails, by way of a baulking effect, provide additional support to the track at the bridge ends.

15.2 General requirements

Guard rails shall be installed on the following underbridges:

- Through span bridges and their approach spans.
- Transom top bridges on Class 1 and 2 lines > 3m long.
- Transom top bridges on Class 3, 3G and 5 lines > 3m long and on a curve or within 100 metres of the trailing end of a curve.
- Ballast top bridges > 20m long.

For other ballast top bridges on Class 1 and 2 lines, a risk assessment shall be undertaken to determine whether guard rails are required. The risk assessment should consider the following criteria:

- Height of bridge
- Bridge span
- Probability and consequence of a derailment
- Track alignment and configuration
- Train speed, density and type of traffic

15.3 Guard rail details

15.3.1 Configuration

Guard rail installations shall comply with the following requirements:

- Guard rail shall be new rail or recycled rail Category 1 (White rail) in accordance with BCS 220 “Rail and Rail Joints”.
- Guard rail section shall be the same as the running rail or one section size less than the running rail
- Top of guard rail shall be no higher than the adjacent running rail and no more than 50mm below the running rail.
- Each guard rail shall be fastened on both sides to every transom/sleeper
- On timber ties, guard rails may be directly fixed to the timber with no plates
- Tapered nose section (“vee”) shall extend for a minimum of 3.6 metres beyond the abutment on the train approach side of the bridge. The design of the vee shall be in accordance with Drawing Number 785-570. The nose of the vee shall be bolted.
- Rails shall extend parallel for a minimum of 3 metres beyond the abutment on the train departure side of the bridge
- Where traffic is bi-directional, the tapered guard rail section shall be installed at both ends of the bridge
- Clearance between gauge face of running rail and adjacent face of guard rail shall be a minimum of 200mm and a maximum of 380mm

  The maximum clearance is preferred. The Engineering Manager may approve a reduction to a minimum of 200mm based on an assessment of

  ~ requirements for tamping ballast top bridges,

  ~ requirements for tamping bridge ends,

  ~ the potential for derailed wheels to strike holding down bolts on transom top bridges

  ~ and the use of resilient baseplates for mitigating noise and vibration

  and the implementation of an effective maintenance regime for bridge ends
- Block-out holes for guard rail fastenings in concrete sleepers shall be grouted with an approved high strength grout

For fixing details, dimensional set-out and componentry detail and sizes, the following standard guard rail drawings are available:

785-568	Bridge guard rails Ballast top bridge Arrangement for concrete sleepered track
785-569	Bridge guard rails Details of concrete guard rail sleepers Concrete sleepered track
785-570	Bridge guard rails Ballast / Transom top bridge Arrangement for timber sleepered track
785-571	Bridge guard rails Timber sleepered track Details of special plating for tapered nose

15.4 Joints in guard rails

Whilst no joint is permitted in running rails on bridges, guard rails may have minimal joints with at least two bolts on each side.

If standard fishplates are used, six bolts are required.

If modified fishplates are used, the four bolts shall all have the nuts on the inside. Fishplates shall be modified by machining, not by oxy-acetylene cutting.

No joints are permitted in the vee.

16 Bridge ends

16.1 General

The design of new underbridges and the major refurbishment of existing underbridges shall provide for the stability and compaction of the bridge ends.

This applies to ballast top, direct fix and transom top bridges.

16.2 Functional requirements

Bridge ends shall be designed to:

- provide a transition between solid and flexible track support systems;
- maintain the integrity of the ballast profile at the end of the bridge;
- maintain the integrity of the ballast condition;
- maintain the tie support across the interface.

16.3 Approved configurations

There are a number of approved structural configurations for improving the performance of bridge ends. Selection of the most appropriate configuration for each location will be influenced by the following factors:

- traffic density, tonnage and speed;
- feasibility of implementation;
- whether the improvement is part of a construction, upgrading or maintenance activity.

Typical details and drawings of approved configurations are provided in Appendix 3. These configurations include:

- engineered backfill
- resilient pads and resilient baseplates
- approach slabs
- ballast retention walls

- intermediate rail support on ballast walls.

16.3.1 Engineered backfill

The formation immediately behind the abutments may be constructed in layers of selected compacted fill reinforced with geogrid. Provision shall be made for drainage below the compacted fill.

A typical layout of engineered backfill is shown in Appendix 3.

16.3.2 Resilient pads and resilient baseplates

On transom top and direct fixation structures, resilient pads or resilient baseplates may be installed on concrete sleepers on the bridge approaches and on the bridge.

Resilient pads and resilient baseplates are not approved for use on steel sleepers.

Resilient baseplates may be installed on concrete sleepers on the bridge approaches and on the bridge. Where used they shall meet the following installation requirements:

- Resilient baseplates shall be installed on 8 sleepers on the approach side of the bridge
- Resilient baseplates shall be installed on 8 sleepers on the departure side of the bridge
- Resilient baseplates shall be installed on eight transoms on each end of the bridge, or if there are < 32 transoms in the bridge place resilient baseplates on all transoms.

Timber transoms may be installed instead of sleepers on the bridge approaches to increase the stability of the bridge ends. Where used they shall meet the following installation requirements

- Five (5) sleepers shall be replaced with transoms with resilient pads on the approach side of the bridge
- Eight (8) sleepers shall be replaced with transoms with resilient pads on the departure side of the bridge
- Install resilient pads on eight transoms on each end of the bridge, or if there are < 32 transoms in the bridge place resilient pads on all transoms.

The use of concrete sleepers just at bridge ends in timber sleepered areas is not recommended unless resilient baseplates are used on the sleepers and on the bridge transoms.

Steel sleepers are not approved for use as the last 5 sleepers at bridge ends, except in the following situations:

- When renewing the sleepers on an existing ballast top bridge or installing a new ballast top bridge, steel sleepers may be used on a face over the bridge and shall also be installed for a minimum of 5 metres past each end of the bridge.

16.3.3 Approach slabs

A transitional stiffness can be provided between the bridge approaches and the bridge deck itself by the installation of concrete approach slabs.

Where bridges are located on a skew, the end of the approach slab shall be shaped to be perpendicular to the track, to avoid rocking of the sleepers.

Approach slabs may be used in conjunction with track slab and ballast top, transom top and direct fixation bridges. When installed on a ballast top bridge, they should be provided with kerbs lining up with the kerbs on the deck of the bridge.

16.3.4 Ballast retention walls

Ballast retention walls may need to be installed at bridge ends to prevent loss of ballast from the track. Retaining the ballast profile will reduce the rate of deterioration in the track top and also assist track lateral stability.

Ballast retaining walls may be constructed from posts and guardrailing or precast concrete walls. Concrete walls are preferred.

Alternatively, structurally designed precast concrete trough units combining an integral deck and kerbs may be used under the track. This option may have particular advantages where the existing approach embankments are narrow.

Typical layout details for post and guard-railing are shown in Appendix 3.

16.3.5 Intermediate rail support on ballast walls

The maximum spacing between the centre of the last sleeper and the centre of the first transom on a bridge should be limited to 600mm in accordance with OTCS 230 “Sleepers and Track Support”.

In situations where centres in excess of 600mm cannot be avoided, a specially designed support shall be installed at the ballast wall, enabling the tie spacing to be restored to normal and reducing the forces at the bridge end.

This configuration includes the use of a resilient rubber pad on top of the ballast wall, which provides support to the rail when deflecting under load.

A typical layout is shown in Appendix 3.

17 Transoms

17.1 General

Transoms are primary load carrying elements of a railway underbridge. They have been traditionally cut from hardwood timber, although alternative materials (e.g. laminated timber or other composite materials) may be developed in the future.

Timber transoms shall conform to the requirements of AS 3818.1-2003 “Timber – Heavy structural products - visually graded, Part 1: General requirements”, AS 3818.2-2003 “Timber – Heavy structural products – visually graded, Part 2: Railway track timbers” and AS 1720.1 – 1997 “Timber structures – Design methods”.

17.2 Design requirements

Timber transoms shall be 250mm wide and have a minimum length of 2800mm. The spacing should not exceed 600mm.

Table 2 below gives the minimum thickness of transoms (measured at any point along the length of the transom), based on:

- Design loading of 300LA + DLA
- Timber stress grade of F22 (Strength Group 2) in accordance with AS 3818.2
- Timber joint strength of J2
- Holding down bolt size M22

Girder centres spacing (mm)	**Transom spacing** (mm)	**Max Speed** (km/h)	**Track Curvature** (Radius m)	**Minimum transom thickness** (mm)
2000	500 - 600	115	> 800	150
			≤ 800	150 [Note 2]/160[Note 3]
		80	> 800	150
			≤ 800	150[Note 2]/150[Note 3]

Table 2 – Transom thickness requirements

Note 1. Maximum super-elevation on curved track = 125mm
2. Maximum track offset in relation to span centreline = 30 mm
3. Maximum track offset in relation to span centreline = 70mm

Adjustments to the above minimum thicknesses shall be made if different stress grades and joint strengths of timber are used.

Use of thinner transoms may be approved where restricted clearances exist. This approval may impose additional inspection and maintenance requirements.

Track offsets from span centreline > 70mm are not permitted without approval of the General Manager.

17.3 Fixing of Transoms

Approved fastenings for fixing transoms include swage bolts and galvanised bolts with conical springs and nylon lock nuts, and Galvanised bolt with round washer at head and square washer together with normal flat spring washer at nut. Standard galvanised MS bolts are generally preferred on timber girder bridges, as swage bolts tend to rotate the girders. Swage bolts are generally preferred on steel girder bridges.

For new bridges, bolts shall be a minimum size of M24 and grade 8.8.

For re-transomming of existing bridges, bolt size shall be determined by compliance with edge distance requirements. Bolts should be a minimum size of M22 and grade 8.8. M24 bolts are commonly used as M22 bolts are not readily available

Bolts shall be manufactured to meet the requirements of AS 1111.1.

17.4 Notching of transoms

Square cut notching of timber transoms is not permitted.

Any localised reduction in thickness of a transom must be achieved by a maximum 1 in 8 beveling and rounded change of direction away from the reduced section. (See Figure 5.)

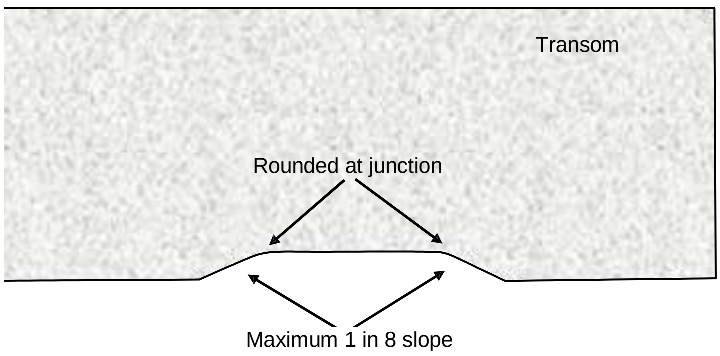

Figure 5 – Notching of transoms

18 Buried corrugated metal structures

Buried corrugated metal structures include helical lock-seam corrugated metal pipes, annular bolted seam corrugated steel pipes, pipe-arches and arches complying with Australian Standards AS/NZS 2041.

18.1 Configuration

This section details the allowable uses of Buried Corrugated Metal Structures, restrictions on locations and limitations on pipe designs.

18.1.1 Locations

Buried corrugated metal structures may be used under or over all classes of lines. .

18.1.2 Limitations

The following limitations are placed on use of standard corrugated steel pipes with galvanised coating. Design solutions may be available utilising different base materials and coatings. .

18.1.2.1 General

- Corrugated metal pipes shall not be used where anticipated stream velocity > 5.0 m/s.
- Pipes should not be laid in permanent water.
- Pipes should not be used to carry corrosive liquids such as industrial wastes or brackish water.
- Corrugated metal pipes shall not be used within five kilometres of the coast.
- Where pipes are to be laid skew to the centreline of track, the following shall apply :
  - Up to 1200mm dia. the ends of pipes shall be square.
  - For pipes > 1200mm dia. the ends may be skew cut or skew and bevel cut. The preference is for bevels, for efficiency and less likelihood of blocking.

18.1.2.2 Helical lock-seam pipes

Helical Lock-Seam corrugated metal pipes of hot dip galvanised steel finish shall not be used where salt water flow occurs or where water flows with pH < 5 occur.

18.1.2.3 Other corrugated metal pipes

Overbridges shall not be constructed from full periphery structures using plates beneath the ballasted track section.

Nestable corrugated metal pipes complying with AS/NZS2041-1998 shall not be used.

18.2 Design

This section details design requirements for designs to be undertaken by authorised design personnel.

Pipe selection and site design based on preselected pipe designs for use with full circle helical lock-seam corrugated metal pipes between 300mm and 1800mm diameter may be undertaken by authorised field staff. Procedures for Field Design are provided in Appendix 4.

18.2.1 Design philosophy

Buried corrugated metal structures are flexible buried members that rely on soil-structure interaction. Because of this interaction, installation needs to be in accordance with specified standards for the structure to achieve the required design behaviour. The design philosophy takes into account structural failure; bearing failure of the surrounding soil; handling stresses; and durability.

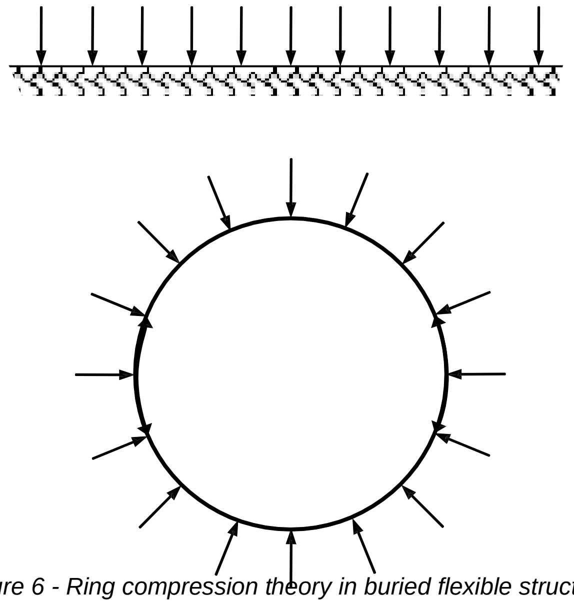

Figure 6 - Ring compression theory in buried flexible structures

The design of metal pipes and arches is based on the ring compression theory. The ring compression in the structure is calculated on the equivalent vertical pressure at the crown on the metal structure.

This theory is only valid if the metal structure has a minimum cover of correctly installed fill and adequate side support so that arching of the surrounding material can occur. Failure of a metal structure designed by ring compression is assumed to occur on the horizontal axis.

18.2.2 Design requirements

Buried Corrugated Metal Structures shall be designed in accordance with the requirements of Australian standard AS/NZS 2041.

18.2.3 Design loading

Design loading shall be in accordance with Section 5.1 for the appropriate class of line.

– Span divided by 4, whichever is greater

In no case shall the top of the pipe to be < 300mm below formation level.

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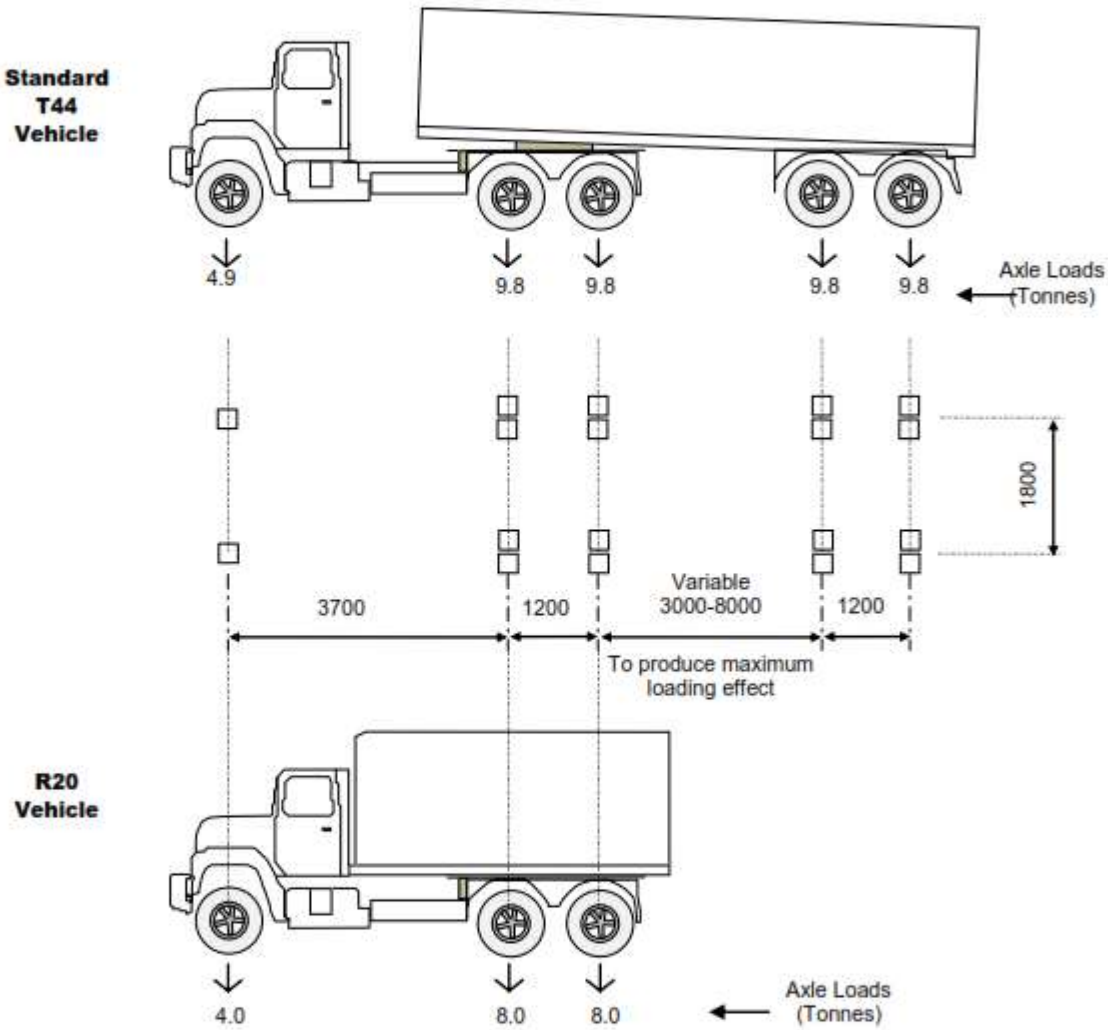
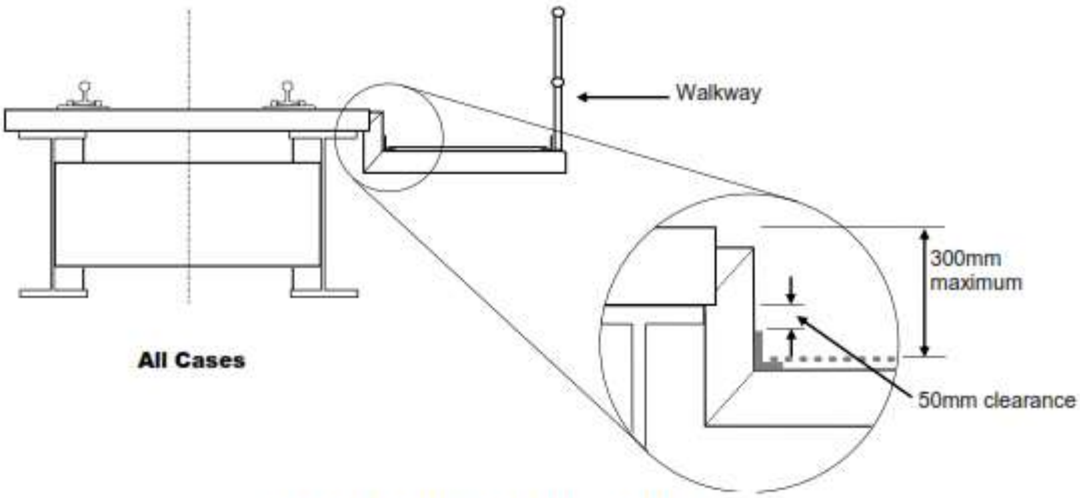
Appendix 1 R Loading Configuration

The 'R' vehicle is a rigid truck with the same configuration as the prime mover portion (first 3 axles) of the 'T' vehicle and the numerical portion is the vehicle's weight in tonnes.



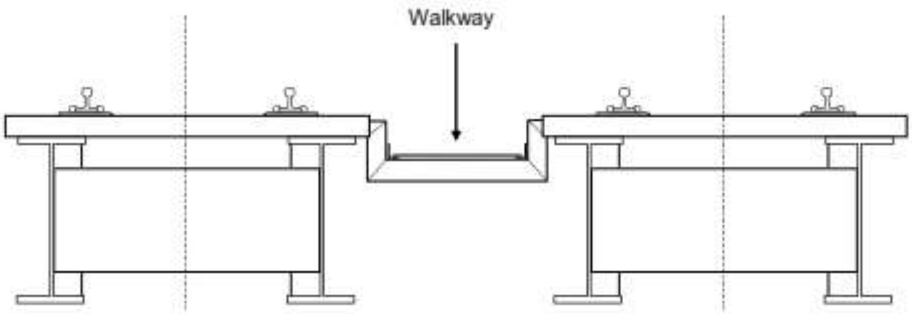
Design Vehicle Configurations

Appendix 2 Typical Walkway, Refuge and Handrail Configurations



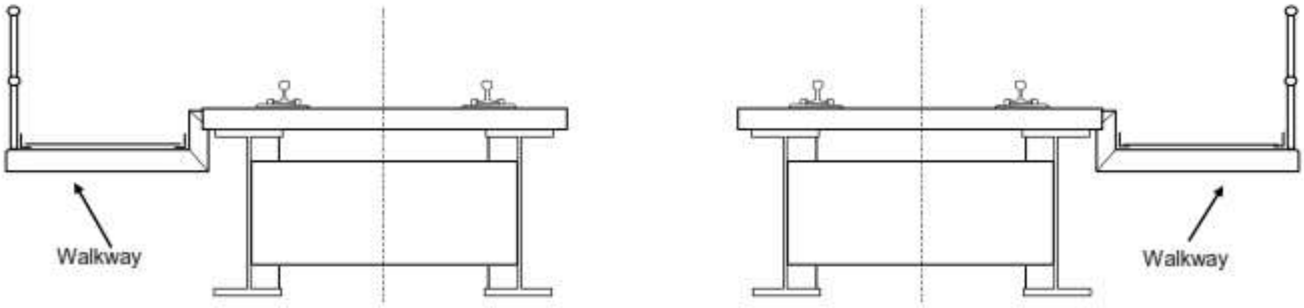
All Cases

SINGLE TRACK – TRANSOM TOP

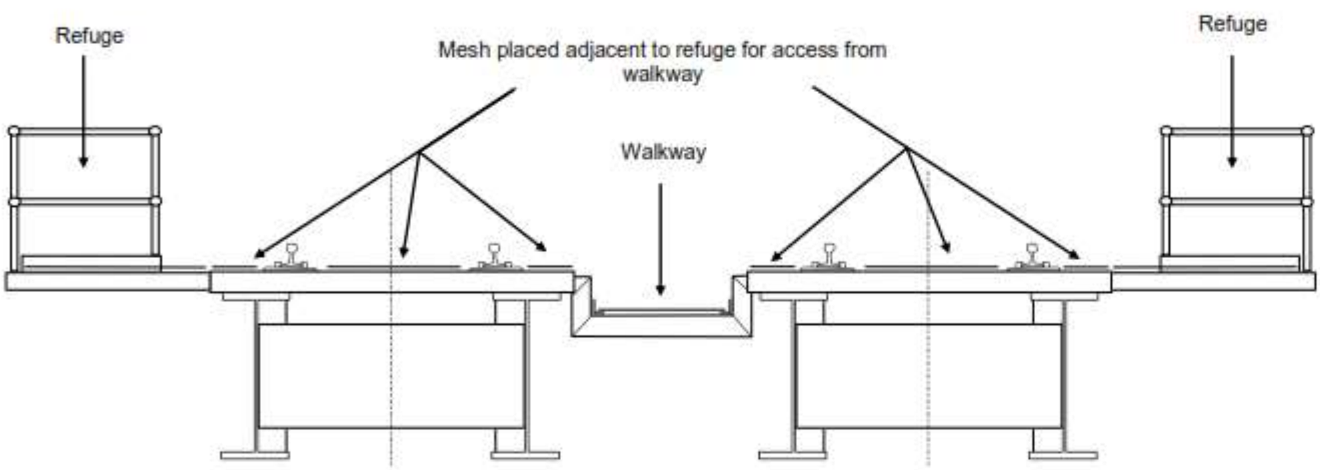


DOUBLE TRACK – TRANSOM TOP

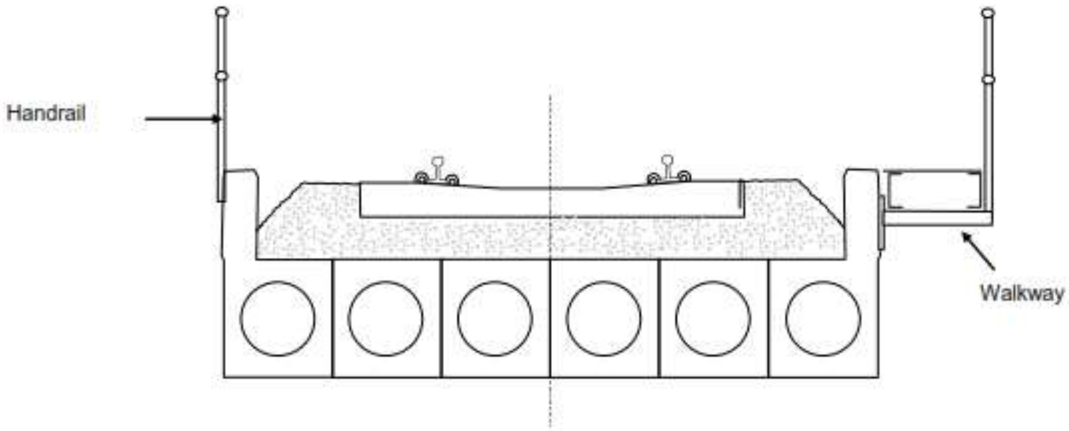
Less than 15m length



DOUBLE TRACK – TRANSOM TOP
Greater than 15m length - use where sighting is restricted

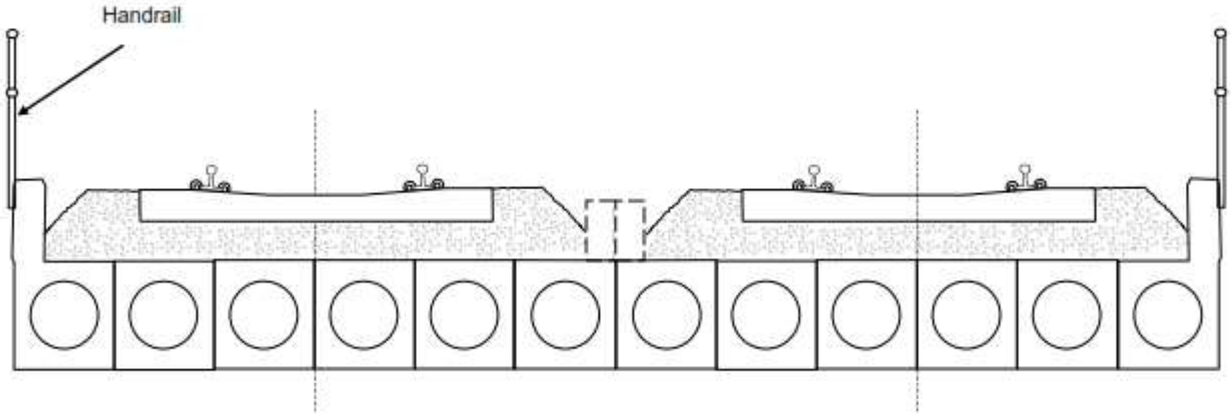


DOUBLE TRACK – TRANSOM TOP
Greater than 15m length - use on straight track only

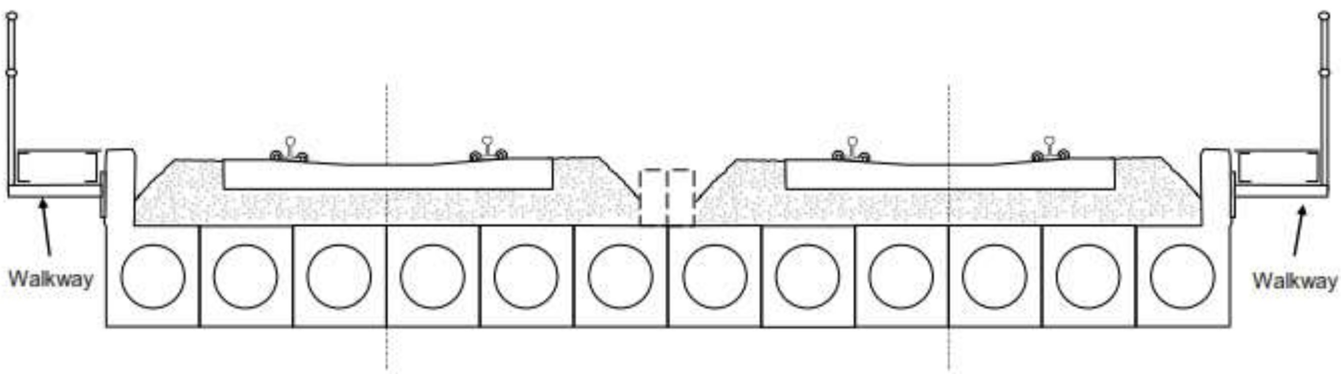


All Cases

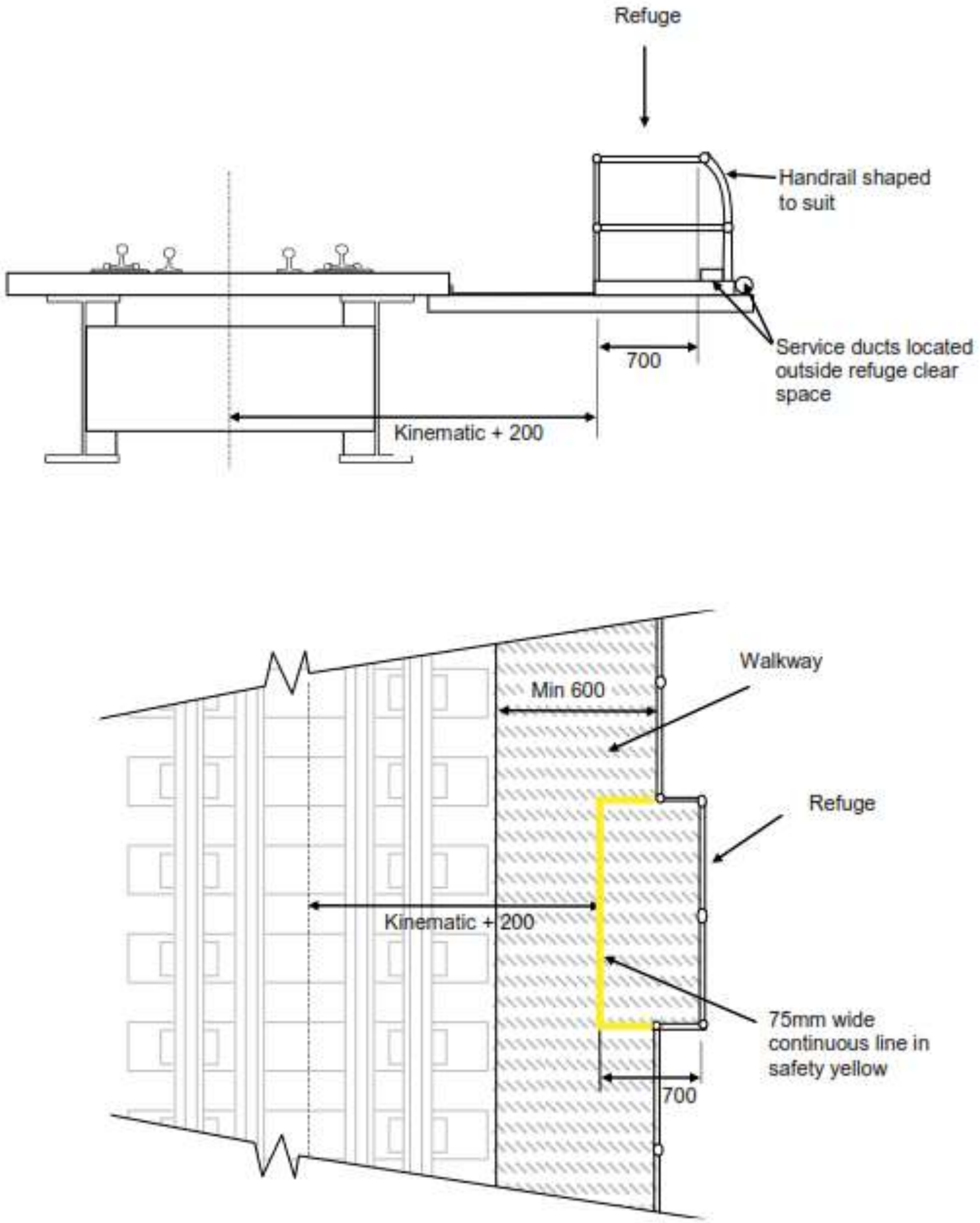
SINGLE TRACK – BALLAST TOP



DOUBLE TRACK – BALLAST TOP
Less than 15m length

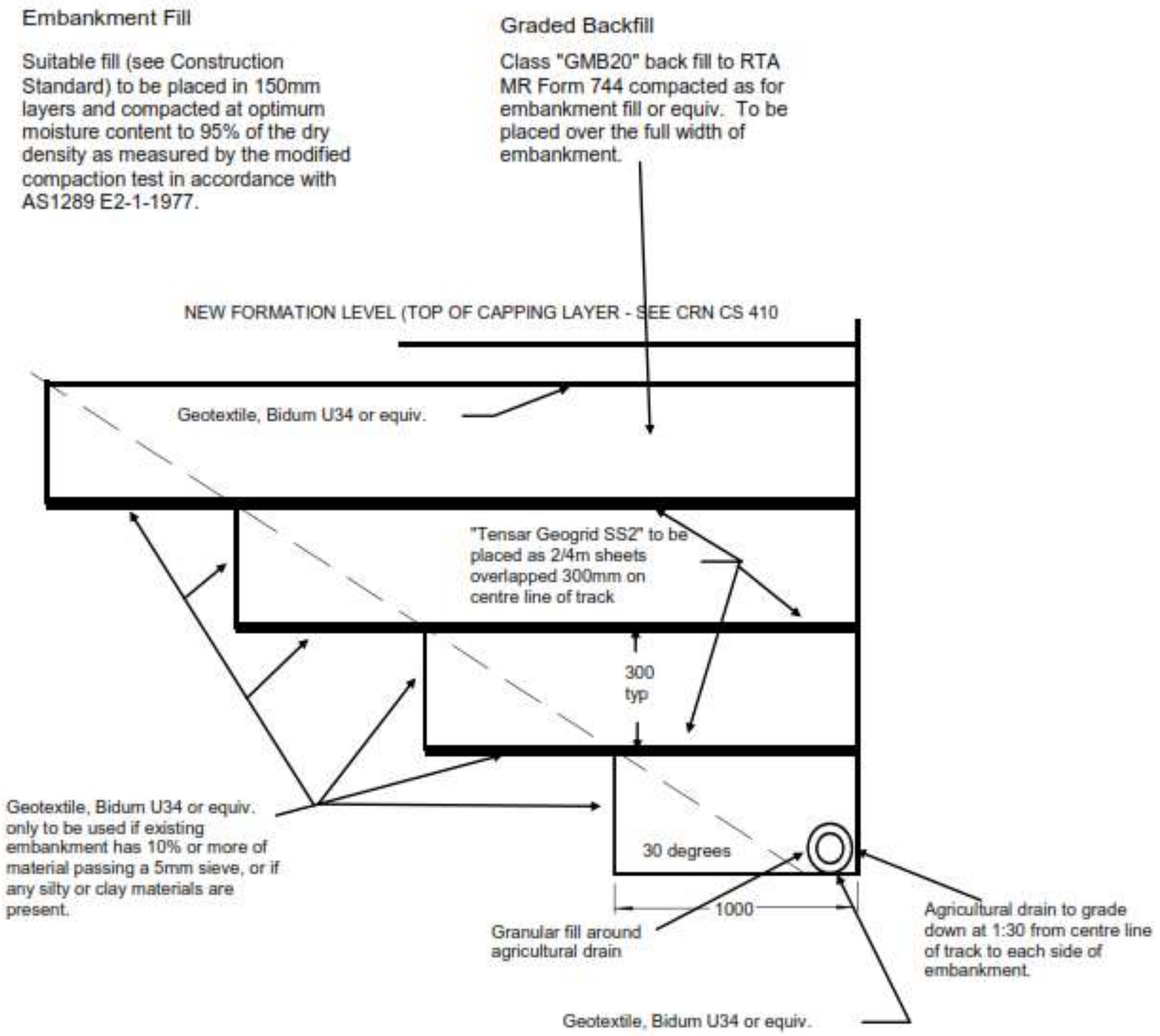


DOUBLE TRACK – BALLAST TOP
Greater than 15m length

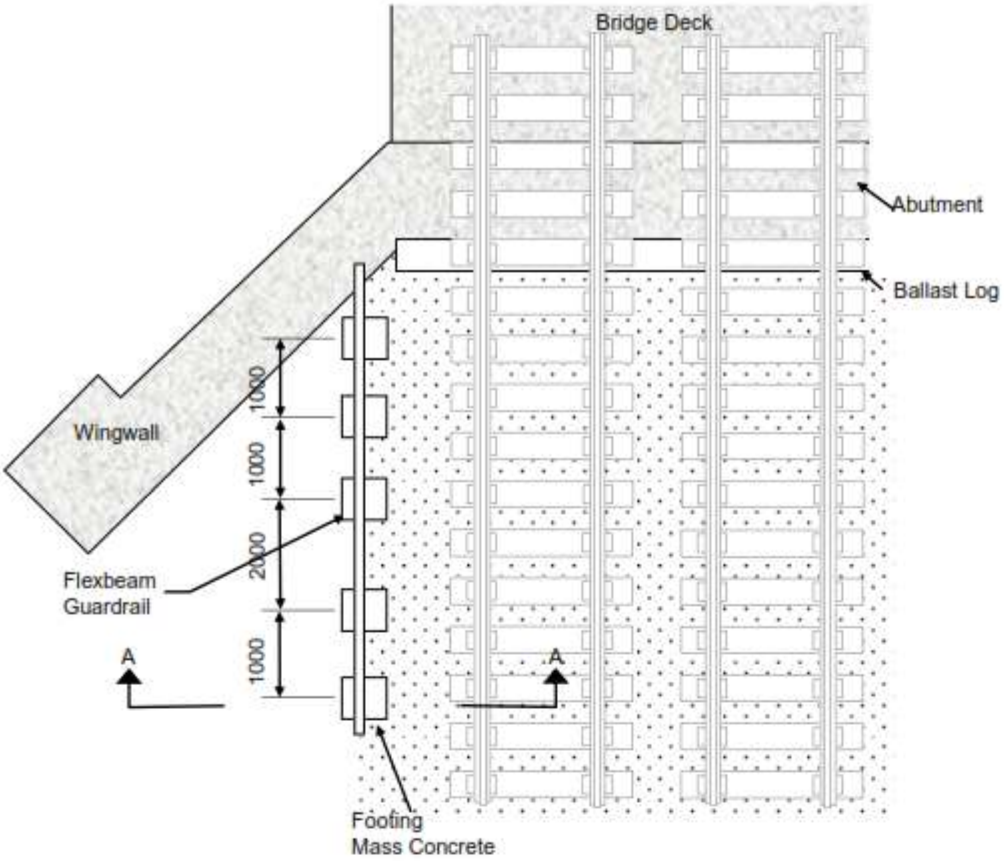


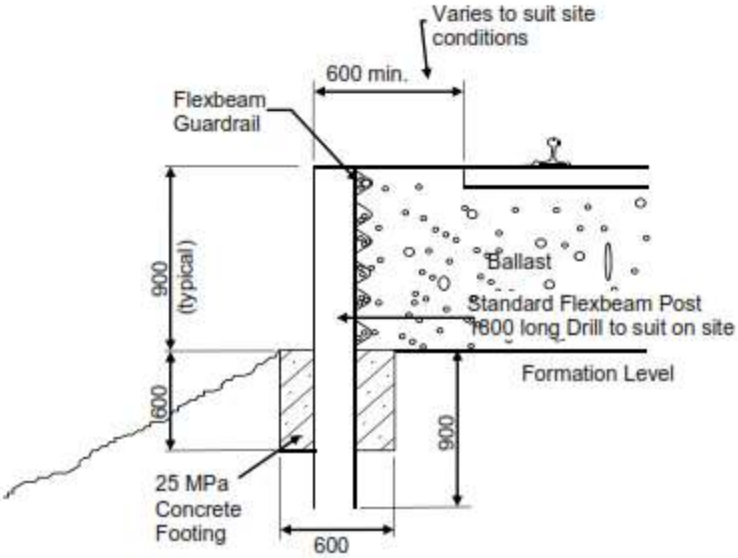
Refuge/ Walkway Combination

Appendix 3 Approved Bridge End Configurations



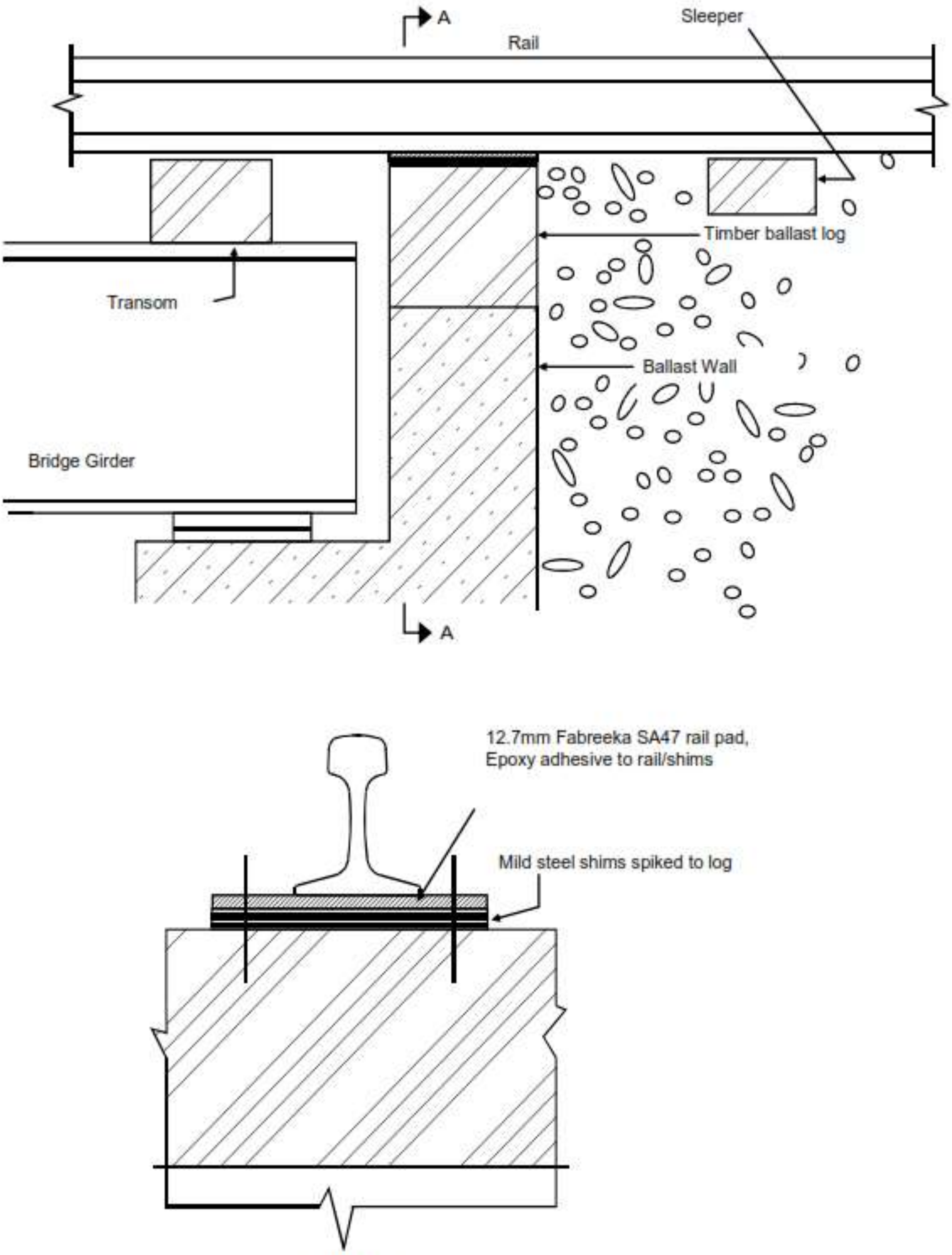
Engineered Backfill





Section A-A

Ballast Retention Walls



Ballast Retention Walls

Appendix 4 Buried corrugated Metal Structures – Field Design Process

Full circle helical lock-seam corrugated steel pipes have been pre-selected by JHR CRN in a combination of pipe diameters and wall thicknesses to suit the majority of general installations. By following the Field Design processes in Figure 8, authorised field personnel can determine whether the pre-determined designs will work, in which case design and ordering can be completed in the field, or that the structure design should be referred to an authorised structural engineer for design.

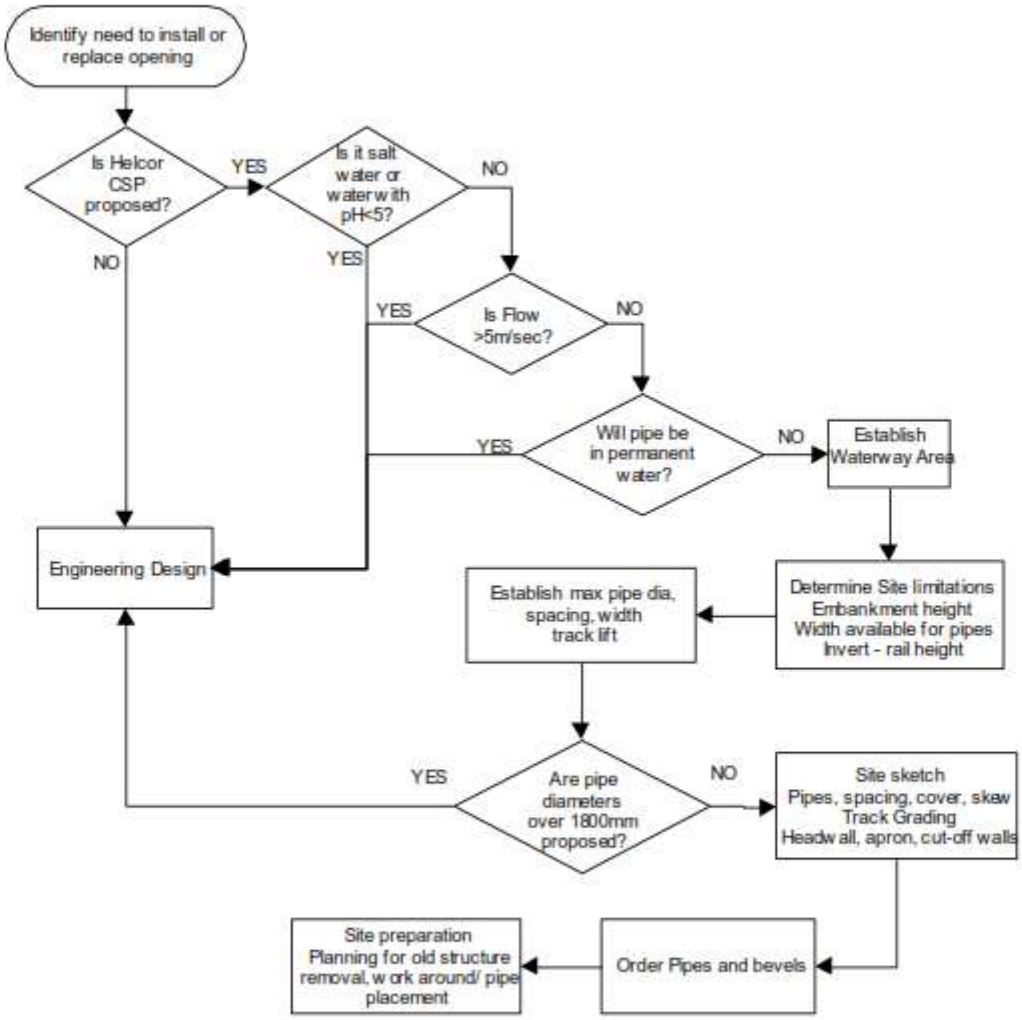


Figure 8 - Field Design Process

How to calculate the size and length

To calculate the correct pipe diameter and length you must know;

1. required waterway area
2. the formation width.
3. the angle of slope (batter) of the embankments.
4. the height from the rails (or lowest rail on a curve) to the waterway floor on both sides of the track.

ALWAYS MEASURE THESE FACTORS AND DRAW A SKETCH.

The golden rule for choosing size (diameter) is select the largest diameter pipe available which suits and will give adequate cover from top of pipe to rail level. Pipe cover requirements are detailed in Section 18.3.

The manufacturers offer a service to determine pipe segment lengths (where the joints occur in a pipe length). It is recommended that, unless there is a specific requirement regarding length, this should only be nominated after consultation with the manufacturer. Economies are maximised by optimising pipe segment lengths in respect to coupling, transport and on-site installation.

If you wish to determine the length of pipe segments, you also need to know;

- what lengths the pipes are manufactured in, and
- how long a bevelled end is for the diameter you have selected.

The recommended minimum bevel obvert length is 1.5 times the diameter or 1.0m whichever is greater. This is necessary to safely absorb handling loads in transit and to minimize out of round risk for fitting of coupling bands.

The MINIMUM square ended barrel length prior to bevel cutting is 3.7m.

The MAXIMUM barrel length prior to bevel cutting is 12m.

Figure 9 and Table 5 provide information on standard bevel lengths.

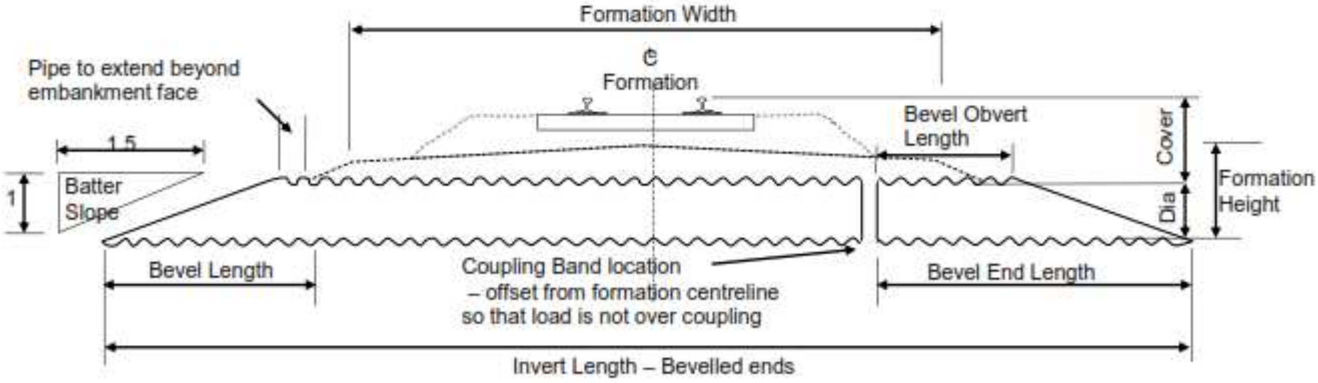


Figure 9 - Pipe terminology

Diameter (mm)	Bevel Length (mm) (based on 1.5:1 Batter)	Preferred dimensions*	
		Bevel Obvert Length (mm)	Bevel End Length (mm)
300	450	1550	2000
450	675	1325	2000
600	900	1100	2000
750	1125	1875	3000
900	1350	1650	3000
1050	1575	1575	3150
1200	1800	1800	3600
1350	2025	2025	4050
1500	2250	2250	4500
1650	2475	2475	4950
1800	2700	2700	5400

Table 5 - Bevel lengths

The dimensions shown above are STANDARD. They may be varied for particular situations, in which case the required dimensions should be determined in consultation with the manufacturer.

How to order

Design engineers and purchasers should provide the following information when purchasing.

- How many pipes (cells)?
- Pipe diameter (thickness is predetermined).
- Invert length of each pipe (cell)
- Are ends square or bevel cut?
- Skew number, if any. Where pipes are required to be cut with ends skewed, you need to submit details to the manufacturer using the Skew sketch in Figure 7. Nomination of the skew 'angle' is inadequate and prone to misinterpretation.
- Delivery location (what kilometrage and nearest town)
- Pipe segment lengths or handling limitations

Additional information

When seeking assistance from the manufacturer either at design or purchasing stages the following additional information is of assistance:

- Formation width
- Formation height
- Embankment protection intended

Appendix 5 Approved products

Approved Swage Fastenings			
ITEM NAME	**DESCRIPTION**	**HUCK PART No**	**APPLICATION**
WASHER, SQUARE	75MM X 75MM; 23MM ID; 6MM THK; GALVANIZED TO AS 1214		USED WITH TRANSOM BOLTS
LOCK COLLAR	7/8" LOCK COLLAR	LC-2R28G	USED WITH TRANSOM BOLTS
LOCK COLLAR	1 " LOCK COLLAR	LC-2R32G	ALL 1" (32) PINS and HEAL BLOCK
LOCK COLLAR	1-1/8" LOCK COLLAR	LC-2R36G	ALL 1-1/8" (36) PINS
BOLT, TRANSOM	HUCK 7/8" DIA PIN; 11" LG; ROUND HEAD; REQUIRES LOCK COLLAR S/C 1537711, ROUND WASHER S/C 1729672, CONICAL WASHER S/C 1690072 & SQUARE WASHER S/C 1454701	C50LRTB-BR28-11	
WASHER, CONICAL	SPRING, VOLUTE; 316 S/STEEL; 85MM OD; 8MM THK; 34MM FREE LG; CONICAL TYPE	TBST 20/24	USED WITH TRANSOM BOLTS
WASHER ROUND	7/8" ROUND WASHER; GALVANIZED TO AS1214	TBWPT22H	USED WITH TRANSOM BOLTS
BOLT, TRANSOM	HUCK 7/8" DIA PIN; 12" LG; ROUND HEAD; REQUIRES LOCK COLLAR S/C 1537711, ROUND WASHER S/C 1729672, CONICAL WASHER S/C 1690072 & SQUARE WASHER S/C 1454701	C50LRTB-BR28-12	
BOLT, TRANSOM	HUCK 7/8" DIA PIN; 13" LG; ROUND HEAD; REQUIRES LOCK COLLAR S/C 1537711, ROUND WASHER S/C 1729672, CONICAL WASHER S/C 1690072 & SQUARE WASHER S/C 1454701	C50LRTB-BR28-13	
BOLT, TRANSOM	HUCK 7/8" DIA PIN; 14" LG; ROUND HEAD; REQUIRES LOCK COLLAR S/C 1537711, ROUND WASHER S/C 1729672, CONICAL WASHER S/C 1690072 & SQUARE WASHER S/C 1454701	C50LRTB-BR28-14	
BOLT, TRANSOM	HUCK 7/8" DIA PIN; 15" LG; ROUND HEAD; REQUIRES LOCK COLLAR S/C 1537711, ROUND WASHER S/C 1729672, CONICAL WASHER S/C 1690072 & SQUARE WASHER S/C 1454701	C50LRTB-BR28-15	

Notes:
1. BR indicates High Tensile Steel
2. LR & LH indicate Round Head & Thread Head
3. 32 & 36 indicate 1" or 1-1/8" (in 1/32")
4. XZ indicates Extended Locking Grooves
5. 56 & 64 indicate Grip No (See Table)
6. Washer Hardness: Rc 35-45.