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Preface

This standard was prepared by the Ballastless track systems Development Group, overseen by the RISSB Infrastructure Standing Committee.

Objective

The objective of this Standard is to provide technical requirements to enable a rail infrastructure manager (RIM) to design, supply, install and maintain ballastless track systems. The Standard outlines minimum requirements for ballastless track systems. RIM's may accept alternative independently certified products, materials, construction procedures or testing regimes which meet or exceed these requirements. Responsibility for ensuring the minimum requirements are met remains with the parties undertaking the works.

This Standard is intended to be used by rail authority's, RIM, projects, and specifiers of ballastless track systems and for reference and development by suppliers and construction contractors.

Compliance

There are four types of provisions contained within Australian Standards developed by RISSB:

(a) Requirements.

(b) Recommendations.

(c) Permissions.

(d) Constraints.

Requirements – it is mandatory to follow all requirements to claim full compliance with the Standard. Requirements are identified within the text by the term 'shall'.

Recommendations – do not mention or exclude other possibilities but do offer the one that is preferred. Recommendations are identified within the text by the term 'should'.

Recommendations recognize that there could be limitations to the universal application of the control, i.e. the identified control is not able to be applied or other controls are more appropriate or better.

Permissions – conveys consent by providing an allowable option. Permissions are identified within the text by the term 'may'.

Constraints – provided by an external source such as legislation. Constraints are identified within the text by the term 'must'.

For compliance purposes, where a recommended control is not applied as written in the standard it could be incumbent on the adopter of the standard to demonstrate their actual method of controlling the risk as part of their WHS or Rail Safety National Law obligations. Similarly, it could also be incumbent on an adopter of the standard to demonstrate their method of controlling the risk to contracting entities or interfacing organisations where the risk may be shared.

RISSB Standards address known hazards within the railway industry. Hazards, and clauses within this Standard that address those hazards, are listed in Appendix D.

Appendices in RISSB Standards may be designated either "normative" or "informative". A "normative" appendix is an integral part of a Standard and compliance with it is a requirement, whereas an "informative" appendix is only for information and guidance.

Commentary

Commentary *C Preface*

This Standard includes a commentary on some of the clauses. The commentary directly follows the relevant clause, is designated by ‘C’ preceding the clause number and is printed in italics in a box. The commentary is for information and guidance and does not form part of the Standard.

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Section 1 Scope and general

1.1 Scope

The scope of the Standard includes:

(a) defining a minimum set of technical requirements for ballastless track systems (BTSs), track structure and ballastless track specific fastenings; and

(b) provides guiding principles for the design, supply, construction and maintenance of BTSs.

This Standard does not specifically cover crane rail systems, cane rail systems, and rail (as defined in AS 1085.1), but items from this Standard may be applied to such systems as deemed appropriate.

Further details for higher speed rail, light rail and heavy rail applications may be included in future developed Codes of Practice for BTSs.

1.2 Normative references

The following documents are referred to in the text in such a way that *some* or all of their content constitutes requirements of this document:

- AS 1085.19, *Railway Track Material: Resilient Fastening Assemblies*
- AS 1530.1, *Methods for fire tests on building materials, components and structures, Part 1: Combustibility test for materials*
- AS 3600, *Concrete Structures*
- AS 5100.2, *Bridge Design – Part 2: Design Loads*
- AS 5100.4, *Bridge Design – Part 4: Bearings and deck Joints*
- AS 7513, *Railway Rolling Stock Interior Environment*
- AS 7635, *Railway Infrastructure - Track Geometry*
- AS 7636, *Railway Structures*
- AS 7638, *Railway Earthworks*
- AS 7643, *Track Stability*
- AS 7702, *Rail Equipment Type Approval*
- AS 7722, *EMC Management*
- ISO 3381, *Railway applications – Acoustics – Noise measurement inside railbound vehicles*
- ISO 14837-1, *Mechanical vibration – Ground-borne noise and vibration arising from rail systems – Part 1: General guidance*
- EN 13146-9, *Railway applications – Track – Test methods for fastening systems – Part 9: Determination of stiffness*
- EN 13231-2, *Railway applications – Track – Acceptance of works – Part 2: Acceptance of reprofiling rails in plain line, switches, crossings and expansion devices*
- EN 13481-5, *Railway applications – Track – Performance requirements for fastening systems - Part 5: Fastening systems for ballastless tracks*
- EN 15461, *Railway applications – Noise emission – Characterisation of the dynamic properties of track sections for pass by noise measurements*

- EN 15610, *Railway applications – Acoustics – Rail and wheel roughness measurement related to noise generation*
- AGPT02, *Guide to Pavement Technology – Part 2: Pavement Structural Design*
- HB 198, *Guide to the specification and testing of slip resistance of pedestrian surfaces*

NOTE: Documents for informative purposes are listed in a Bibliography at the back of the Standard.

1.3 Defined terms and abbreviations

For the purposes of this document, the following terms and definitions apply:

1.3.1

ARO
accredited rail organisation

1.3.2
automatic train control
used to describe on-board automation that contributes to or replaces the driver's judgement as to how to control the train

1.3.3
axle counters
equipment used to detect the presence of rail vehicles by counting the number of axles entering or leaving a location. They can be used to operate signalling or other infrastructure equipment

1.3.4
balise
a track mounted spot transmission unit that uses transponder technology. Its function is to transmit/receive messages to/from the rolling stock passing overhead

1.3.5
BOEF
beam on continuous elastic foundation

1.3.6
BTS
ballastless track system

1.3.7
California bearing ratio (CBR)
California bearing ratio is the ratio of the bearing load that penetrates a material to a specific depth compared with the load giving the same penetration into crushed stone. The test measures neither stiffness modulus nor shear strength directly but gives a combined measure of both

1.3.8
check rails
rails placed in track inside the running rail at particular locations which comes into contact with the back of the wheel flange to guide wheels through points and crossings, on curves and through flangeway gaps in streets

1.3.9
close containment device
devices designed to retain derailed rolling stock in close proximity to the running rails and forming part of the trackform. Examples include guard rails in ballasted trackform and integrated concrete upstands in ballastless trackform

1.3.10
CWR
continuous welded rail

1.3.11
EMC
electromagnetic compatibility

1.3.12
exceptional load
infrequent load which exceeds the limit for the relevant operational conditions

1.3.13
fatigue
fatigue of a material that is the weakening of material subjected to stress

1.3.14
FEM
finite element method

1.3.15
friction modifiers
used to control friction between the wheel tread and rail crown (or rail head), to reduce curving forces and associated wear, damage and noise

1.3.16
guard rail
a rail (inside or outside the running rail) used to restrain lateral movement of a derailed wheelset. Used to protect structures or control the lateral movement of the wheelset on bridges or in other higher risk situations

1.3.17
quasi-static loading
quasi-static loading refers to loading where inertial effects are negligible (time and inertial force are irrelevant) allowing the use of simple static force models of that instant

1.3.18
rail creep
the permanent or progressive longitudinal movement of rails in track caused by expansion or contraction of the rail or the action of traffic

1.3.19
resilient rail fastenings
a fastening that provides a degree of elasticity between the sleeper and rail with the aim of avoiding the loosening of the fastening due to vibration, as well as enhancing the ability of the fastening system to resist longitudinal creep forces and buckling forces associated with continuously welded rail

1.3.20
RIM
rail infrastructure manager

1.3.21
RSNL
rail safety national law

1.3.22
SFAIRP
so far as is reasonably practicable

1.3.23
slab track
track fixed with fixation assemblies to a concrete slab under the rails

1.3.24
toe load
the force exerted by a resilient fastening system onto the rail to control longitudinal, vertical and rotational rail movement

1.3.25
track circuit
an electric circuit where current is carried through the rails and used to detect the presence of trains. Track-circuits are used in the operation and control of points and signalling equipment

1.3.26
track magnet
permanent or electro-magnet which, under certain conditions, operates by indication induction an on apparatus on a vehicle passing by

1.3.27
track-structure interaction
a complex phenomenon that occurs between the rail and the structure when continuous welded rail (CWR) is used on a railway bridge

1.3.28
train stop
a system (also known as trip gear) involving a trip cock on the vehicle and a trip arm located track side which, when engaged, directly initiates an emergency brake application. The train stop is employed at signals in conjunction with a red aspect and also in areas where train speed is required to be externally controlled

General rail industry terms and definitions are maintained in the RISSB Glossary. Refer to: https://www.rissb.com.au/products/glossary/

Section 2 System requirements

2.1 General requirements

The BTS shall be specified to align with the RIM track classifications or ARO track classification standards.

The selection of a BTS type should be based around the required system criteria in which it will be placed. Appendix A gives guidance on different BTS types.

The design of the BTS shall ensure that deformations of the track structure do not adversely affect the integrity of interfacing infrastructure.

Any ends or changes in type of BTSs shall occur perpendicular to the track to avoid uneven axle support.

Transitions from BTSs to other track support systems shall occur perpendicular to track to avoid uneven support.

The running rails shall be continuous with no mechanical joints within the length of the BTS, unless otherwise approved by the RIM.

Non-embedded rail BTSs shall use a resilient fastening system for running rails that is approved in accordance with either AS 1085.19, EN 13481-5 or as specified by the RIM.

Embedded rail BTSs shall use a fastening system for running rails that is approved in accordance with EN 13481-5 or as specified by the RIM.

2.2 Design life

BTS components (e.g., fastenings, rail, etc.) shall have a design life in accordance with the relevant railway track material standard (e.g., AS 1085) subject to periodic maintenance but without renewal or structural repairs unless otherwise specified by the RIM.

Design life for BTS structural components on viaduct/bridges and in tunnels shall be as per the primary/main structure or 100 years. Elsewhere, design life shall be a minimum of 50 years or as specified by the RIM.

BTS sub-structures shall have a design life greater than or equal to the BTS they support.

BTS bearings for floating BTSs shall have a design life of 50 years unless otherwise specified by the RIM.

Subsystems and components which are subject to a shorter design life than the overall BTS due to wear or fatigue (e.g., rails), shall include provision for replacement.

2.3 Track design geometry

The track geometry where the BTS is to be used shall be compliant with AS 7635 or as specified by the RIM.

The BTS shall support and retain rails to the required track geometry parameters within the agreed rail operator tolerances for the specified rail sizes.

The design of the BTS shall ensure that deformations of the track structure are within the track geometry tolerances defined by the RIM.

Construction and maintenance tolerances should be specified for BTSs that meet the following RIM or project specified criteria:

(a) Passenger comfort.
(b) Ride quality.
(c) Maintenance intervals.
(d) Track availability.
(e) Noise and vibration.
(f) Integration with surrounding environment.
(g) RAMS targets.

2.4 Track stability

BTS stability shall be compliant with AS 7643 or as specified by the RIM.

The BTS shall be designed to provide track stability when subject to loads and effects including:

(a) thermal stresses;
(b) rail creep;
(c) track-structure interaction;
(d) vertical wheel loads;
(e) lateral wheel loads;
(f) traction and braking forces;
(g) changes in support conditions; and
(h) differential settlements.

The BTS shall ensure that any structural movement, concrete shrinkage or thermal effects do not adversely affect rail stress or other operational infrastructure. Construction, expansion and contraction joints shall be provided for as per design requirements.

Embedded BTSs shall assess vertical buckling as well as lateral buckling, particularly when the system relies on poured polymer resins and infill blocks for retention.

The BTS design shall assess the track gradients to determine if additional longitudinal rail restraint, such as increased toe loads or decreased fastening spacing, is required.

Track stability in the longitudinal, lateral and vertical directions should be demonstrated by:

(i) analysis of moment of inertia or;
(j) fixations introduced at the interfaces between subsystems and components to handle longitudinal, horizontal and vertical forces.

2.5 Structure gauge

The design of any derailment/close containment device integrated into the BTS shall ensure that the structure gauge requirements are met.

The BTS profile shall accommodate items of infrastructure that have a physical or operational interface.

Commentary *C2.5*

Items with potential structure gauge implications for the design of the BTS profile include:

- train stops in the trip position;
- rolling stock warning/control equipment;
- drainage systems;
- points operating equipment and rodding;
- maintenance and emergency egress walkways;
- rolling stock detection equipment (such as detector loops, balises, axle counters);
- local cable connections for signalling or bonding;
- wayside condition monitoring equipment and associated connections to track;
- rail lubricator actuators;
- platforms;
- overhead support structures;
- signals and indicators;
- automatic wagon door openers in the active position; and
- other lineside equipment such as signal trunking.

2.6 Maintainability

The BTS shall provide for all track maintenance activities as required.

Commentary *C2.6*

The design considerations of a BTS should include maintainability across the asset lifecycle. This includes methodology, scheduling, spares management, plant and tools required.

Track maintenance activities that can be considered in the design of the BTS include:

- inspection and detection systems (e.g., ultrasonic rail inspections);
- bearing inspection and replacement;
- testing of earthing and bonding points;
- repair/replacement of pavement surfacing;
- jacking of structure for bearing replacement;
- replacement of components and subsystems (e.g., fastening system components);
- repair of rail defects and broken rails;
- rail milling/rail grinding;
- rail replacement;
- replacement of special trackwork (e.g., turnouts, diamonds, points, crossings);
- track geometry measurement and adjustment;
- CWR stressing and in-situ rail welding;
- emergency rail clamping; and
- installation/adjustment/replacement of rail lubrication systems.

The design of the BTS shall provide for safe access, inspection and maintenance of interfacing infrastructure, where applicable.

Commentary *C2.6*

The design considerations of a BTS SHOULD include maintainability of interfacing infrastructure across the asset lifecycle. This includes the safe access, maintenance methodology and renewal activities for interfacing infrastructure.

Interfacing infrastructure that can be considered includes:

- road pavements and furniture;
- signalling equipment and cabling (e.g., train stops, detector loops, axle counters, balises);
- wayside condition monitoring equipment ;
- drainage systems including pits, pipes, trenches;
- electrical systems, earthing and bonding cables, stray current testing points, overhead support structure;
- rail lubrication systems, hoses and actuators;
- combined services routes;
- platform structures;
- noise mitigation panelling; and
- walkways – emergency and maintenance access.

Any new method, equipment or plant required for maintenance of the ballasted track system shall be identified during the design phase and submitted to the RIM for review and acceptance.

Where applicable, the BTS shall provide for track cant adjustment, gauge adjustment, and adjustment of the rail position due to wear, faults and defect removal.

Where applicable, a minimum clearance as specified by the RIM should be provided between the rail foot and the top of the BTS surface to allow for welding and rail clamping.

The BTS surface shall provide for safe underfoot conditions for people walking along or across the ballastless track (e.g., pedestrians at designated level crossings, track workers or evacuating passengers).

Commentary *C2.6*

Guidance on the specification of slip resistance for surfaces is provided in Table 3B of handbook SA HB 198:2014.

Safe underfoot conditions will also require the design of the surfacing to avoid trip hazards in areas that will be walked on.

Where supported by a tunnel, the predicted values for differential movement between adjacent tunnel segment or sections shall be determined as input parameters for maintenance of the BTS during design. Consideration shall be given to differential movement due to temperature and shrinkage effects.

Commentary *C2.6*

Significant differential vertical movements do not generally occur as shear connectors are usually provided between adjacent tunnel segments.

2.7 Noise and vibration

BTSs shall be designed and constructed in such a way that noise and vibration from rolling stock operations shall comply with prescribed noise and vibration limits for the relevant state/territory noise policy, RIM and system specific requirements.

BTS noise and vibration compliance shall be achieved for all operational conditions, including the full range of operational loads and excitation frequencies, approved rolling stock, operational speeds, track and wheel conditions, asset conditions and environmental conditions across the respective maintenance cycles.

Where applicable, the design of BTSs should include assessment and mitigation of:

(a) ground-borne noise and vibration;

(b) structure-borne noise and vibration;

(c) airborne noise, including that radiated by an underlying structure such as on a bridge or viaduct;

(d) in-car noise; and

(e) noise levels at sensitive receivers.

Commentary *C2.7-1*

Sensitive receivers can include:

- Transient receivers such as patrons and pedestrians that temporarily pass by the rail corridor; and
- Permanent receivers such as the occupants of neighbouring adjacent residential, commercial, educational and industrial spaces.

Non-human sensitive receivers and sensitive equipment such as that used for medical imaging and in laboratories, audio-visual recording facilities, and animals should also be considered.

Where assessment and mitigation of ground-borne noise and vibration is required, methodologies shall be consistent with those defined in ISO 14837-1 or as specified by the RIM.

Where ground-borne or structure-borne noise is reduced through the incorporation of vibration isolation (e.g., floating ballastless track, booted bi blocks, booted sleepers, resilient fastenings etc.) into the design of the BTS as per ISO 14837-1, the RIM should allow for the potential resultant increase in airborne noise, including in-car noise, and tactile vibration emissions.

Commentary *C2.7-2*

Incorporating vibration isolation, such as floating slabs and resilient rail fasteners, into the BTS can increase airborne noise by reducing the track decay rates as defined in EN 15461 and can increase tactile vibration through the introduction of low-frequency resonances of the BTS. Track decay rates can be increased through the application of rail dampers and/or optimisation of component selection, while tactile vibration can be reduced through traditional vibration control methods.

Where in-car noise is to be considered and unless specified otherwise by the RIM, in-car noise should be assessed in accordance with ISO3381 and should comply with noise limits specified by the RIM.

Where airborne or in-car noise is to be considered, and unless specified otherwise by the RIM, track decay rates should be measured in accordance with EN 15461.

Where the dynamic stiffness of rail fastening systems is to be assessed, and unless specified otherwise by the RIM, the dynamic stiffness should be assessed in accordance with the dynamic high-frequency test for assemblies in EN 13146-9.

Unless specified otherwise by the RIM, the rail head condition following maintenance should be in accord with the longitudinal profile requirements specified in EN 13231-2.

Where acoustic rail roughness is to be considered, it should be measured in accordance with EN 15610 and maintained to the limits specified by the RIM.

The RIM should procure, or otherwise arrange access to, grinding or milling machines such that grinding and/or milling can be performed at regular intervals.

BTSs shall be designed to minimize the growth of rail corrugation.

Commentary *C2.7-3*

Measures to minimize the growth of rail corrugation can include, but are not limited to, ensuring compatible wheel and rail profiles, considering wavelength fixing mechanisms, using head hardened rail on curves and in braking and traction zones, and using friction modifiers to control friction levels at the wheel/rail interface.

Operational and maintenance activities that can influence noise and vibration from the BTS should be assessed, including but not limited to the following:

(a) track design features such as curves and crossovers, which increase the levels of ground-borne vibration generated at source;

(b) ongoing maintenance of rolling stock, particularly management of wheel defects;

(c) ongoing maintenance of track, particularly the management of rail running surface defects;

(d) transitions between track sections with differing support stiffness characteristics;

(e) wheel and rail interface issues such as corrugation development;

(f) access, inspection and maintenance of resilient components; and

(g) impacts of the adoption of Automatic Train Control or limited variability between rolling stock speed and acceleration profiles.

Commentary *C2.7-4*

To meet noise requirements, particular characteristics for noise control can be incorporated in the design of the BTS.

Vibration requirements can necessitate adjustment of structural properties of the track system to fulfil the performance specified. The track stiffness can therefore be governed by the vibration requirements.

2.8 Derailment

Derailment management provisions for the BTS, including the need for close containment devices, shall be determined through a risk assessment process carried out in accordance with RIM requirements and RSNL.

The BTS design should incorporate the following in the context of derailment events to improve passenger safety, limit damage to adjacent infrastructure and improve track availability:

(a) protection of critical above rail structural elements from derailed rolling stock;

(b) guidance of the derailed rolling stock and lateral displacement from track centreline;

(c) control of the rotation of the derailed rolling stock to reduce risk of overturning; and

(d) BTS layout, strength and stability for required loads and spatial footprint to enable re-railing of rolling stock following a derailment.

Commentary *C2.8*

Where the system requires a derailment event assessment, collision simulation can be used to evaluate the effectiveness of a derailment containment device to ensure impact to adjacent infrastructure and impact to passenger safety is minimized.

The following risks and hazards should be included in a SFAIRP risk assessment process to determine the need for a derailment containment device:

(e) the rolling stock rotating from an upright position in the event of derailment;

(f) lateral displacement of the rolling stock outside of the track section during a derailment;

(g) derailed wheel-sets tracking non-parallel and not in close proximity to their running rails;

(h) damage to the track and supporting structure;

(i) position of a derailed rolling stock obstructing passenger evacuation routes;

(j) consequential harm to persons and damage to rolling stock and infrastructure; and

(k) derailed rolling stock striking critical structural elements of adjacent interfacing infrastructure.

BTSs and derailment containment devices shall be designed for the derailment load cases and design traffic loads as specified by the RIM.

Derailment containment devices shall eliminate snagging points on a derailed wheelset. Where gaps between derailment containment devices are unavoidable, a risk assessment shall be undertaken to manage risks associated with snagging points SFAIRP.

2.9 Electrical interfaces

2.9.1 General

In electrified areas, the design of BTSs shall implement earthing and bonding strategies as specified by the RIM such as isolation, testing and collection points etc.

The BTS shall ensure that safe touch potential voltages are not exceeded during operations in the case of a short-circuit and/or earth fault.

The BTS track fastenings shall provide the appropriate electrical resistance between the rail and trackform structure and between both running rails in all possible environmental conditions as agreed with the RIM.

2.9.2 Rail-to-earth electrical insulation

The BTS shall provide an electrical resistance to earth as specified by the RIM.

Commentary *C2.9.2*

Where the BTS design incorporates the use of resilient boots, care should be taken to ensure electrical insulation is maintained during construction through the continuous welding of the boot as well as inspection and testing activities to mitigate the likelihood of holes in the finished product.

2.9.3 Electrical interfaces with traction supply systems

The design of structural and electrical properties of the BTS shall be coordinated with the requirements for electrical safety, earthing, bonding and the return current.

Where the rails act as a return current path for the traction power system, the longitudinal resistance of the running rails in the BTS shall be as low as reasonably practicable as agreed with the RIM.

At level crossings, or other locations where the rails are embedded in the pavement, the BTS shall ensure the longitudinal resistance of the running rails and the rail-to-earth electrical insulation are unchanged from the surrounding system.

2.9.4 Electrical interfaces with signalling systems

The BTS design shall address the constraints of the signalling system e.g., electrical separation of the rails for track circuits, physical space needed for insulated rail joints, the clearance around the rail for axle counters or bonding connections.

2.9.5 Electromagnetic compatibility (EMC) with signalling systems

EMC compatibility of the BTS with different equipment shall be assessed and managed in accordance with AS 7722.

Requirements for loop-free zones and requirements for zones with restricted content of metal shall be distinguished and agreed between signalling and track designers.

The attenuation of the electromagnetic field of discrete electrical components (e.g., balise, wheel sensor, axle counting heads, track magnets etc) shall be limited as specified by the RIM.

2.9.6 Fixing of equipment

The design of the BTS shall make provision for all infrastructure equipment required to be installed (e.g., loops, balise's, axle counters, track circuits, noise absorbing panels, level crossings, guard rails, check rails, etc), and their connections to the track.

The BTS design shall assess and provide for all loading, including structural or electrical loads, arising from the fixing of electrical equipment, including signalling assets, to the BTS.

2.10 Type approval

As required by the RIM, products and/or components used in the BTS shall be type approved in accordance with the RIM's requirements and AS 7702 as applicable.

Section 3 Ballastless track system design

3.1 System integration

The design shall include system integration to ensure compatibility between the track components/subsystems and external interfaces.

System integration shall include assessment of failure/deterioration modes of the BTS, subsystems, and components.

The design shall ensure all components are accounted for and the interactions, internal loads and load distribution effects are dealt with.

The design of the BTS shall incorporate the interaction with adjacent infrastructure such as road pavements, station platforms, overhead support structures, rail signals and traffic signals.

3.2 Structural design

3.2.1 General

The BTS shall be able to resist all quasi-static, vertical, lateral, longitudinal and dynamic load combinations with no assembly or track system failures. The design of the BTS shall not cause component failure, excessive deterioration of track materials or rolling stock assemblies.

The design of the BTS shall ensure that deformations of the track structure do not adversely affect the integrity of interfacing infrastructure.

Design of any bearings, pads, strip pads, and joints in BTSs shall be in accordance with the requirements of AS 5100.4.

3.2.2 Loading

3.2.2.1 Load distribution

The distribution of load for the BTS shall be calculated using a rigorous analysis that accounts for the relative stiffness of the rail, the slab and supporting substrate.

> Commentary *C3.2.2.1*
>
> For guidance on load distribution models, refer to:
>
> - EN 16432-1, *Railway Applications – Ballastless track systems – Part 1: General requirements; and*
> - EN 16432-2, *Railway Applications – Ballastless track systems – Part 2: System design, subsystems and components.*

The following load distribution models may be used to determine design actions in the slab pavement:

(a) slab and beam on continuous elastic foundation (BOEF); and

(b) slab on elastic supports using finite element method (FEM).

Where FEM is used, results should be calibrated and verified against traditional design methods.

Where the BTS is constructed and integrated within a trafficable road, the pavement shall be designed in accordance with to Austroads Guide to Pavement Technology Part 2: Pavement Structural Design and expected axle loads as determined by the RIM or relevant road authority.

The design of BTSs shall incorporate the interaction with the track, the vertical and horizontal stiffness and the effects of the following components:

(c) Rail.

(d) Rail baseplate and fastening assemblies.

(e) Ballast, where present.

(f) Prefabricated elements (such as monoblocks, sleepers, slabs, resilient boots etc.).

(g) Top or infill slab.

(h) Bearing pads, where present.

(i) Base slab (pavement).

(j) Support system or substrate earthworks (subbase and subgrade).

(k) Movement joints in both the rail and slab.

(l) Transition arrangements.

3.2.2.2 Rail traffic loading

The rail traffic loads for BTS shall be in accordance with the requirements of AS 5100.2 unless otherwise specified by the RIM.

The rail traffic loading shall account for all current approved rail vehicles and any known future rail vehicles as defined by the RIM.

Load factors and load combination shall be in accordance with AS 5100 unless otherwise specified by the RIM.

Braking and traction forces shall be determined in accordance with AS 5100 unless otherwise specified by the RIM.

BTSs shall be designed for exceptional loads, incorporating the low likelihood of occurrence.

For BTSs on gradients and or curved horizontal alignment, the designer shall determine the requirements for anchoring and restraining the BTS to the foundation. Such systems can include shear keys and dowel bars.

Where embedded sleeper or monoblock items are used in the BTS, the structural depth of the BTS shall incorporate the degree to which the embedded item is bonded to the slab.

Where embedded sleepers or monoblocks are supported on resilient pads or by resilient boots, the structural depth shall be measured from the top of the slab at the underside of the resilient pad or boot.

3.2.2.3 Rail traffic fatigue loading

Design for rail traffic fatigue loading shall be in accordance with AS 3600 unless otherwise specified by the RIM.

Fatigue design loads shall be in accordance with AS 5100 unless otherwise specified by the RIM.

The base number of load cycles as defined in AS 5100.2 as CT shall be estimated as the number of current timetabled daily services operating on the line. This shall be assumed as constant over the design life, then multiplied by an appropriate factor for assumed growth in the number of services over the design life (minimum 20% growth factor) unless otherwise specified by the RIM.

The number of equivalent stress cycles (defined in AS 5100.2 as nT) for a passage of a single fatigue design traffic load shall be determined from a stress-time spectrum analysis of the incremental movement of the fatigue design load as defined by the RIM. The incremental movement parameters shall be sufficiently refined to capture the maximum peak stress spectrum.

The effective number of stress cycles (defined in AS 5100.2 as (n)) shall be determined using Equation 9.8.3 in AS 5100.2:2017 by substituting the calculated values for base number of load cycles and the number of equivalent stress cycles defined by the RIM. The designer shall compare the effective number of stress cycles determined using Table 9.8.4 in AS 5100.2:2017 for each component against values determined in accordance with this section and adopt the higher cycle values for design. Where any clause in AS 5100.2 references the design (effective) number of stress cycles (n), determined from AS 5100.2, the higher value of (n) shall be used.

3.2.2.4 Road traffic loading

The design road traffic loads for BTSs shall be determined in accordance with the requirements of AGPT02 Austroads Guide to Pavement Technology Part 2 – Pavement Structural Design unless otherwise specified by the RIM and relevant road authority.

In a shared running environment, the BTS design shall adopt static, dynamic, fatigue and impact loading from road traffic as well as rail traffic. The design shall incorporate the positional variance of the road traffic loading.

Where the BTSs is subject to perpendicular or skew angle road traffic movements, lateral impact loads on the system edges and the rail heads and fatigue analysis to account for the combination of rail and transverse road fatigue loading shall be incorporated in the design.

Where the BTS can act as an access route for emergency vehicles or heavy vehicles (such as buses, road freight, waste collection vehicles etc.), the design of the BTS shall incorporate the effects of such loading including positional variance across the BTS.

Where the BTS can be subject to longitudinal road vehicle loading, e.g., shared running tram systems, the fatigue analysis of the BTS shall incorporate road vehicle fatigue loading in combination with rail traffic fatigue loading.

3.2.2.5 Other loading

The BTS shall include seismic loading cases in accordance with AS 5100.2 or as specified by the RIM.

Environmental load cases (e.g., thermal and wind loading) shall be incorporated in the design of the BTS as needed.

The design of the BTS shall also incorporate loading effects from the following sources:

(a) Jacking forces for the installation and replacement of bearings.

(b) Construction traffic loading, including fatigue damage.

(c) Self-weight loading during construction (e.g., crane lifting of precast units).

(d) Dead load from non-structural finishes and equipment.

The design of the BTSs shall be able to accommodate the re-railing of rolling stock and other track vehicles to avoid placing undue stresses on the in-situ concrete BTS.

Jacking for re-railing of vehicles should use suitable pads to spread the load within the design limits of the concrete BTS, or alternative lifting arrangements should be deployed to avoid damaging the concrete BTS.

3.2.3 Pavement design

BTSs shall be designed using rigid pavement beam on elastic foundation design methodology or FEM.

All layered structures/pavements, including prefabricated slabs, distributing the loading by applying flexural resistance, shall be designed for the maximum flexural tensile stresses acting in the layer(s).

Calibrated and verified FEM should be used to optimize the design of individual layer thicknesses and widths.

The combination of loads which provides the greatest effects shall be used to determine the maximum bending moment acting in the pavement structure.

The maximum tensile flexural stresses or bending tensile stresses of all layers of a multi-layered system shall be calculated within the design process. Stresses shall not exceed the tensile flexural fatigue strength of the material within the layer.

The Austroads Guide to Pavement Technology provides guidance on the material properties and design methods that shall be used for the BTS pavement design unless otherwise specified by the RIM.

Commentary *C3.2.3*

The design methodologies for BTS pavements from EN 16432-2 provides useful guidance, however the *Austroads Guide to Pavement Technology* better reflects the local material properties and should therefore be used in preference to EN 16432-2.

3.3 Support systems

3.3.1 General

Commentary *C3.3.1*

This section specifies general requirements for the BTS according to the support system characteristics.

The required support system characteristics are separately specified in this clause for earthworks (cuttings, embankments, or at-grade situations), bridge structures and tunnels. It also covers transitions between these different substructure types.

BTSs shall make allowance for any site-specific risk that can impact the overall performance of the BTSs. These can include:

(a) geotechnical properties (including predicted settlement) of any track subgrade or formation under the BTS; and

(b) structural properties (including movement settlement or flexure) of any tunnel lining, bridge or viaduct structure supporting the BTS.

3.3.2 Earthworks

The earthworks formation (e.g., cuttings, embankments, at-grade, culverts etc.) supporting the BTS shall be able to transfer the vertical and horizontal loads from the BTS into the subgrade that can result in excessive deformations, out of tolerance track geometry or failure of the BTS.

The design of the BTS shall be compatible with the characteristics and performance of earthworks as specified in AS 7638 unless otherwise specified by the RIM.

For a BTS it is necessary to limit permanent deformations (settlement or heave) as well as elastic deformations due to variable loading. Design limits for these parameters shall be determined for both the design of the BTS and to establish the requirements for the design and construction of the supporting earthworks.

The stiffness of the formation shall be defined in order to design the BTS. If deformation modulus Ev2 on formation level is used, it should be at least [80 MPa/8% CBR].

The limiting stress to be applied by the BTS to the subgrade shall be specified.

BTSs do not normally tolerate significant permanent deformation of the substructure after construction. The earthworks design and construction staging shall be specified to ensure settlement/deformation of the formation is nearly completed before installation of BTS commences.

3.3.3 Bridges

Bridges (including shallow culverts/pedestrian underpasses) and BTSs have an influence on each other. Therefore, the interaction between them shall be incorporated in the integrated design.

NOTE: Guidance on the combined response of structure and track to variable actions is provided in EN 1991–2 and UIC 773-4.

The design of the BTSs on bridges shall comply with the requirements of AS 7636 unless otherwise specified by the RIM.

BTSs shall not fulfill any structural function in the design, other than the carriage of rolling stock and the effective transmission of railway forces into the support superstructure unless otherwise agreed with the RIM.

BTS design on underlying bridge/tunnel structures shall incorporate:

(a) long term deformation of the structure including settlement, seasonal temperature deflections, creep and shrinkage;

(b) structure deck stiffness including curvature of the deck, deformation and rotational angles at intermediate and end supports;

(c) interface requirements between BTSs and transitions to ballasted track; and

(d) differential deflections at structural expansion joints from temperature, rolling stock tractive and braking forces, and all live or dead loads.

Commentary *C3.3.3-1*

Certain types of BTS such as those using prefabricated elements on pavement (e.g., sleepers on asphalt) are more sensitive to bridge deformation. Deflection by traffic loading for these types of systems needs to be controlled to avoid pull out of the prefabricated elements from the underlying asphalt.

Deck rotation angles at bridge piers and abutments need particular attention as these generate uplift forces in the BTS.

The designer shall note the effects of interaction between the track and the bridge in the design, taking the rails, bridge deck and bearings, substructure and foundation into account.

Commentary *C3.3.3-2*

A typical track-bridge interaction model can include the following elements:

1. Rail stiffness
2. Bridge deck stiffness
3. Embankment stiffness and differential settlement between embankment and bridge
4. Rail expansion joints (if present) or use of reduced toe load fasteners
5. Track-bridge stiffness
6. Support stiffness

Guidance on track-bridge interaction can be found in the following references:

1. International Union of Railways UIC Code 776-2 R, *Design requirements for rail-bridges based on interaction phenomena between train, track and bridge*
2. International Union of Railways UIC Code 774-3 R, *Track/bridge Interaction Recommendations for calculations*
3. EN 16432-1, *Railway applications – Ballastless track systems – Part 1: General requirements*
4. EN 1991–2, *Eurocode 1 – Actions on Structures. Part 2: Traffic Loads on Bridges and other Civil Engineering works*

3.3.4 Tunnels

BTSs shall not fulfill any tunnel lining structural function in the design, other than the carriage of rolling stock and the effective transmission of railway forces into tunnel lining unless otherwise agreed with the RIM.

Where exposed to air, the materials for BTSs in tunnels shall be non–combustible to AS 1530.1 and shall comply with specific requirements for fire safety defined by the relevant authority or RIM.

3.3.5 Transitions

Transitions between earthworks, bridges and tunnels shall ensure a gradual transition with respect to track geometry and track stiffness.

The BTS shall be designed to take account of long-term variation in track geometry due to settlement and the variation in stiffness of the substructure. Capability for adjustment of the track geometry to minimize the resulting dynamic response of the vehicles shall be provided.

The length of the transition zone shall be designed based on the design speed for the line and the differences in the settlement and stiffness characteristics of the adjacent structures and substructures. The transition zone shall limit differential settlement at transitions between different support systems to a level that is compatible with the operational requirements.

The transition sections shall provide a progressive change in track stiffness and live load deflection over the greater length of either the length in metres covered by one second of travel at the maximum line speed or the longest approved vehicle bogey centres, unless otherwise specified by the RIM.

The transition trackform should be maintained and adjusted using the same plant, hand tools, procedures and practices as one of the adjoining trackforms.

The transition shall provide continuity of drainage between the adjacent trackform drainage systems.

The track alignment should remain consistent throughout the transition with no variable geometric features such as spiral transitions, cant transitions or vertical curves.

Where different trackforms (ballasted to ballastless or ballastless to BTSs) are used, the geometric tolerances at the wheel and rail interface shall be the same.

The number of interfaces between ballasted and BTS should be minimized.

Transition sections shall be provided at interfaces with ballasted track or any areas where a change in the underlying subgrade or structure results in a change in track stiffness.

3.4 Interdisciplinary requirements

BTSs shall allow for the provision, and spare capacity, of any required services and drainage systems.

3.4.1 Drainage

The drainage system shall incorporate the management of water at and below BTS foundation level to avoid upward water pressure forces on the BTS.

The surface of the BTS shall be graded to ensure that water is directed into the track drainage system and not pond on the surface of the BTS (including rail baseplates and fastenings).

The minimum gradient of the BTS surface shall be 0.333% (i.e. 1 in 300 slope) in any direction unless otherwise agreed with the RIM.

The design of the BTS shall provide for the waterproofing of the interface with the support system where applicable.

The drainage system shall ensure that water is not trapped and does not pond in the void beneath any floating BTS.

The drainage of any floating slab BTSs shall be designed to avoid a vibration path through the connection of the drainage to the floating slab.

The depth of run-off water on BTSs shall not interfere with signalling and electrical equipment.

The drainage system shall include drainage of the rail groove or flangeway in embedded rail type BTSs.

3.4.2 Provision for services

Provision shall be made in the design and construction of BTSs for services as required such as utilities (including 3rd party), signalling, electrical, earthing and bonding and telecommunications.

Services shall be positioned in accordance with the requirements defined by the RIM.

Position of services should:

(a) be clear of any walking or maintenance areas on the BTS where they can present a trip hazard;

(b) not interfere with, or obstruct, emergency walkways (if included) on the BTS;

(c) not obstruct access from the BTS to a safe place/position of safety

(d) not obstruct drainage;

(e) not be cast into the BTS (unless agreed with the RIM); and

(f) not obstruct track control marks for the BTS.

The location of any services shall ensure that future access for maintenance of the services is facilitated.

BTSs shall not be used as a method to reduce cover to buried services or other infrastructure over lengths where it is not possible to achieve an acceptable stiffness transition at the required design speed.

Any floating BTS shall ensure physical connection between the floating BTS and any services (such as earthing and bonding or signalling connections) are designed to avoid creating vibration paths between the BTS and base slab.

3.4.3 End of track protection systems

The design of the BTS shall incorporate the loading produced by the end of track protection system if required.

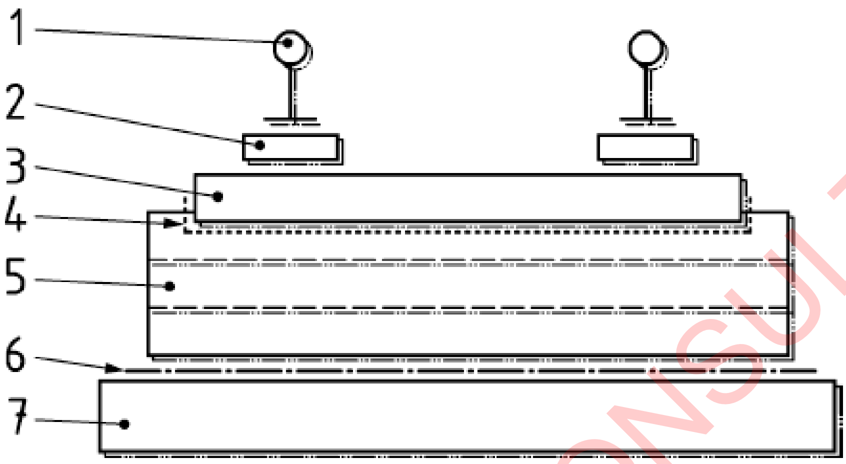
If retrofitted later, the end of track protection system should be designed to avoid loading the BTS.

Where an end of track protection system is required to be retrofitted later and cannot be designed as an independent system, the BTS shall be checked for the additional loading resulting from the end of track protection system.

Appendix A Ballastless track system types (Informative)

A.1 General

BTSs may consist of, but are not limited to, the following levels of subsystems and components as shown in Appendix Figure A.1-1 and Appendix Table A.1-1 below:



Appendix Figure A.1-1 Ballastless track system - subsystems and components

Appendix Table A.1-1 Ballastless Track System - Subsystems and Components

Key	Item	Type
1	**Rail**	**Subsystem**
2	**Fastening system/system for embedded rail**	**Subsystem**
2.1	Clip, clamp, rail pad etc	Component
2.2	Adhesive	Component
3	**Prefabricated element**	**Subsystem**
3.1	Sleeper, block	Component
3.2	Slab, frame	Component
4	**Intermediate layer, boot, fixation**	**Subsystem**
4.1	Concrete filling layer	Component
5	**Pavement**	**Subsystem**
5.1	Single-, multi-layered pavement	Component
5.2	Base layer	Component
6	**Intermediate layer**	**Subsystem**
6.1	Foil, sheeting	Component
6.2	Compensation layer	Component
7	**Substructure**	**System**

NOTE 1:

The sequence of subsystems in vertical direction as well as the presence or absence of subsystems and components within the ballastless track is up to the individual design. Intermediate layers can be used at different subsystem interfaces (levels), hence intermediate layers are not explicitly shown.

NOTE 2:

A variety of BTSs are available and can be broadly defined as systems with discrete rail supports or continuous rail supports. Discrete rail supports can be further subdivided into BTSs with sleepers/blocks and BTSs without sleepers. Table A.1-2 below summarizes various BTSs.

A.2 Sleeper/block systems embedded in concrete

This BTS comprises of sleepers/blocks cast into a concrete trough or directly on top of a concrete roadbed. The integrated prefabricated elements (sleepers/blocks) form a BTS in combination with an in-situ component such as a filling layer, pavement, or hydraulic base layer. The BTS track rigidity and support stiffness performance are determined by the performance characteristics of the prefabricated elements (sleepers/blocks), in-situ components and connection properties.

When precast sleepers or blocks are used (not in the case of precast slabs) the surface of the filling layer forms the top of the BTS. The filling layer is used to create a monolithic structure connecting the precast sleepers/blocks to the track system and establishing a bond to the pavement. Typical sleeper/block systems embedded in concrete are shown in Appendix Figure A.-1 and Appendix Figure A.-2 below.

Appendix Figure A.2-1 Example of embedded sleeper type ballastless track system

Appendix Figure A.2-2 Example of embedded block type ballastless track system before (top) and after (bottom) concrete pour

A.3 Sleeper/block systems embedded on top of asphalt roadbed

This ballastless track system comprises of sleepers/blocks placed on top of an asphalt roadbed. Asphalt roadbed construction can reach a level of accuracy of ±2 mm and provides a stiff and level base for the sleepers/blocks. As asphalt does not require hardening and can be subjected to loading immediately after rolling, these BTSs can achieve high construction productivity. Advantages of asphalt roadbed BTSs include:

(a) Adapts to stresses from loading and temperature changes which cause yielding.

(b) Reduced noise and vibration transmission compared to concrete roadbed due to the internal damping properties of asphalt.

A.4 Precast concrete slabs

This BTS comprises of reinforced or pre-stressed concrete slabs. Advantages of precast concrete BTSs include:

(a) high quality of precast slab components;

(b) high level of mechanisation resulting in improved construction efficiency;

(c) reduce construction labour costs;

(d) direct adjustment and fixation of the rail;

(e) less immune to failing workmanship; and

(f) improved repairability and maintainability.

A typical precast concrete slab system is shown in Appendix Figure A.4-1 below.

Appendix Figure A.4-1 Example of precast slab type ballastless track system

A.5 Monolithic in-situ slabs

This BTS adopts direct rail fastenings bolted on civil structures (such as bridges, tunnels, or continuous monolithic slabs). Adopting direct rail fastenings on civil structures reduced the overall weight of the structure. The direct rail fastening system generally adopts a pad with high elasticity as a substitute for the elasticity of a ballast bed.

A BTS with a continuous stiff and rigid slab reacts like a continuous supported elastic beam under traffic loading which generally allows the BTS to be adopted on top of weak and soft layers as the rigid slab spreads the loads across a much wider and longer surface and across local defects.

Appendix Figure A.5-1 provides an example of an in-situ monolithic slab system.

Appendix Figure A.5-1 Example of in-situ monolithic slab system

A.6 Embedded rail systems

The modern embedded rail structure (ERS) is a continuous, elastically supported rail by means of a compound such as cork and polyurethane. The rail fixation is established by an elastic compound surrounding the whole rail profile except the rail head. Appendix Figure A.6 shows an example of an embedded rail system.

The characteristic principles of the rail fixation in embedded rail structures are:

(a) an elastic strip provides continuous support under the rail;

(b) the rail is guided in a groove by elastic fixation;

(c) top-down alignment of the rail;

(d) the rail profile is fixed by an elastic compound; and

(e) optimization of the elastic compounds, the groove dimensions, and strips.

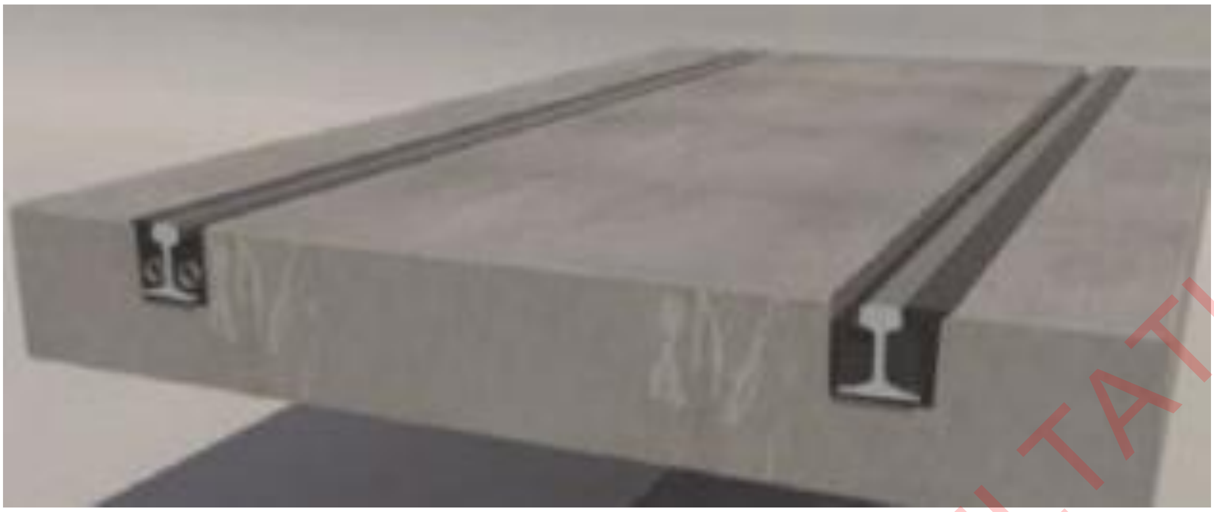
The advantages of embedded rail structures are as follows:

(f) Absence of dynamic forces due to secondary bending between single rail points.

(g) Increases rail life span.

(h) Overall reduction of maintenance.

(i) The embedded rail construction height can be reduced (e.g., in case of road crossing where a smooth obstacle free surface is needed).



Appendix Figure A.6-1 Typical embedded rail systems

Some embedded rail systems use a resilient boot which is wrapped around the rail foot and up the web to the head. The boot can be clipped or glued to the rail and are then usually cast into a concrete slab. Appendix Figure A.6 shows an example of a booted rail prior to embedment.

Appendix Figure A.6-2 Example of booted rail system prior to embedment pour

A.7 Floating slab track systems

Floating slab track (FST) systems are proven to provide the best vibration and ground-borne noise mitigation. FST systems consists of floating reinforced concrete slabs with rails mounted on top which forms a dynamically active mass that is isolated from the sub-structure by means of steel springs or rubber bearings. Appendix Figure A.7 shows an example of a of a floating slab track system.

FST systems typically consist of simple masses and springs that can isolate vibrations due to wheel-rail interactions. In an FST system, a continuous welded rail (CWR) is fixed to a concrete slab through rail pads with isolators under the concrete track. The rails are fixed to the slab modules using suitable (often also resilient) baseplates.

The slabs are (in turn) mounted on resilient rubber bearings tuned to the required resonance. Both baseplate and bearing systems can be modified along with the mass (i.e. thickness) of the slabs to "tune" the system to a desired resonance frequency. It is generally desirable to lower the resonance frequency to improve the vibration isolation performance of the system in the audible frequency range (i.e. at frequencies above the resonant frequency).

Appendix Figure A.7-1 Example of typical floating slab track system

Appendix B Information to be provided by the purchaser (Informative)

Appendix Table B-1 below is an example form to assist purchasers when ordering and/or seeking quotations for the supply of BTSs.

Appendix Table B-1 Request for Service – Supply of Ballastless Track Systems

Design Criteria	
Design life	MGT or Years
Maximum axle load	Tonnes
Annual gross tonnes	Mtpa
Main line speed	km/h
Track gauge	mm
Wheel Back-to-Back	mm
Track centres	m
Maximum cant	mm
Maximum cant ramp	1 in _
Allowable cant deficiency	mm
Maximum Rate of Cant Deficiency	mm/s
Minimum horizontal curve radius	m
Minimum vertical equivalent radius	m
Maximum gradient	%
Flangeway width	mm
Flangeway depth	mm
Bogie centres	mm
Vehicle length	mm
Unsprung vehicle mass	Tonnes
Rail size	kg
Preferred fastening type	
Rolling stock	
Derailment containment requirements	
Driveable surface profile for road vehicular loading	Yes/No
Walkway requirements for surface profile	Yes/No
Turnout & special trackwork requirements	

Appendix C Bibliography (Informative)

The following referenced documents are used by this Standard for informational purposes only:

- AS 1085.1, *Railway track material – Part 1: Steel rails*
- EN 1991–2, *Eurocode 1: Actions on structures – Part 2: Traffic loads on bridges and other civil engineering works*
- EN 16432-1, *Railway applications – Ballastless track systems – Part 1: General requirements*
- EN 16432-2, *Railway Applications – Ballastless track systems – Part 2: System design, subsystems and components*
- UIC Code 774-3 R, *Track/bridge interaction recommendations for calculations*
- UIC Code 776-2 R, *Design requirements for rail-bridges based on interaction phenomena between train, track and bridge*

APPENDIX D Hazard register (Informative)

Hazard Number	Hazard
6.1	Infrastructure - Harm to the environment - Derailment or Collision, Human Error, Track Failure, Track Obstructions, Design Failure, Health Failure and or Excessive Noise
6.2	Infrastructure - Excessive noise - Track Failure and or Design Failure
6.4	Infrastructure - Operational hazards - Derailment and or Collision, Human Error, Track Failure and or Design Failure
6.5	Infrastructure – Harm to persons – Derailment or Collision, Human Error, Track Failure, Design Failure, Organisational SMS Failure and or Environmental Impact
6.6	Infrastructure - Harm to track & civil infrastructure by rolling stock - Derailment or Collision, Human Error, Health Failure and or Design Failure
6.8	Infrastructure – Harm to Track & Civil infrastructure during construction - Human Error, Health Failure and or Organisational SMS Failure
6.9	Infrastructure – Harm to Track & Civil infrastructure during operation and maintenance - Human Error, Track Obstructions, Health Failure, Design Failure, Organisational SMS Failure, Security Breaches and or Environmental Impact
6.10	Infrastructure – Path infringement – Derailment or Collision, Human Error, Track Failure, Track Obstructions, Health Failure and or Design Failure
6.11	Infrastructure – Collision - Derailment, Human Error, Track Failure, Track Obstructions, Health and or Design Failure
6.14	Infrastructure – Derailment - Collision, Human Error, Track Failure, Track Obstructions, Health and or Design Failure
6.15	Infrastructure – Track failure - Derailment or Collision, Human Error, Track Obstructions, Health and or Design Failure
6.24	Infrastructure - Electric shock - Derailment and or Collision, Human Error, Track Failure, Threat, Design Failure, Organisational SMS Failure, Security Breach, Loads not Secure and or Vandalism
6.26	Infrastructure – Bodily impact - Derailment or Collision, Human Error, Track Failure, Track Obstructions, Health Failure, Design Failure, Security Breach, Loads not Secure and or Vandalism
6.27	Infrastructure – Excessive acceleration - Human Error, Health Failure, Design Failure, Organisational SMS Failure, Security Breach & Vandalism
6.28	Infrastructure - Track & civil infrastructure design failure - Human Error and or Organisational SMS Failure