Rail Baltica

RBDG-MAN-014-0107

Design guidelines

Railway Superstructure - Track

13-05-2024

Co-funded by
the European Union

The sole responsibility of this publication lies with the author.
The European Union is not responsible for any use that may be made of the information contained therein.

Table of Contents

1. Applicable standards

The following regulations and standards shall be used for the design.

1.1. European standards

The relevant European standards used for high speed lines and conventional lines are listed below:

Standard	Title
EN 13146-1	Railway applications - track - test methods for fastening systems - part 1: determination of longitudinal rail restraint
EN 13146-2	Railway applications - track -test methods for fastening systems - part 2: determination of torsional resistance
EN 13146-3	Railway applications - track - test methods for fastening systems - part 3: determination of attenuation of impact loads
EN 13146-4	Railway applications - track railway applications - track - test methods for fastening systems - part 4: effect of repeated loading
EN 13146-5	Railway applications - track railway applications - track - test methods for fastening systems - part 5: determination of electrical resistance
EN 13146-6	Railway applications - track - test methods for fastening systems - part 6: effect of severe environmental conditions
EN 13146-7	Railway applications - track - test methods for fastening systems - part 7: determination of clamping force
EN 13146-8	Railway applications - track test methods for fastening systems part 8: service testing
EN 13146-9	Railway applications - track - test methods for fastening systems - part 9: determination of stiffness
EN 13230-1	Railway applications - track - concrete sleepers and bearers - part 1: general requirements
EN 13230-2	Railway applications - track - concrete sleepers and bearers - part 2: prestressed monobloc sleepers
EN 13230-4	Railway applications - track - concrete sleepers and bearers - part 4: prestressed bearers for switches and crossings
EN 13230-5	Railway applications - track - concrete sleepers and bearers - part 5: special elements
EN 13231-1	Railway applications - track - acceptance of works - part 1: works on ballasted tracks - plain line
EN 13231-2	Railway applications - track - acceptance of works - part 2: works on ballasted track - switches and crossings
EN 13231-3	Railway applications - track - acceptance of works - part 3: acceptance of rail grinding, milling and planning work in track
EN 13232-1	Railway applications - track switching and crossings - part 1 definitions
EN 13232-2	Railway applications- track switching and crossings - part 2 requirements for geometric design
EN 13232-3	Railway applications- track switching and crossings - part 3 requirements for wheel/rail interaction
EN 13232-4	Railway applications - track switching and crossings - part 4 actuation, locking and detection
EN 13232-5	Railway applications - track switching and crossings - part 5 switches
EN 13232-6	Railway applications - track switching and crossings - part 6 fixed common and obtuse crossings
EN 13232-7	Railway applications - track switching and crossings - part 7 crossing with moveable parts

EN 13232-8	Railway applications - track switching and crossings - part 8 expansion devices
EN 13232-9	Railway applications - track switching and crossings - part 9 layouts
EN 13450	Aggregates for railway ballast
EN 13481-1	Railway applications - track- performance requirements for fastening systems - part 1: definitions
EN 13481-2	Railway applications - track - performance requirements for fastening systems - part 2: fastening systems for concrete sleepers
EN 13481-5	Railway applications - track - performance requirements for fastening systems - part 5: fastening systems for slab track
EN 13481-6	Railway applications - track - performance requirements for fastening systems - part 6: special fastening systems for attenuation of vibration
EN 13481-7	Railway applications - track- performance requirements for fastening systems - part 7: special fastening systems for switches and crossing and check rails
EN 13674-1	Railway applications - track - rail - part 1: Vignole railway rails 46 kg/m and above
EN 13674-2	Railway applications - track - rail - part 2: switch and crossing rails used in conjunction with Vignole railway rails 46 kg/m and above
EN 13674-3	Railway applications - track - rail - part 3: check rails
EN 13803-1	Railway applications - track - track alignment design parameters - track gauges 1435 mm and wider - part 1: plain line
EN 13803-2	Railway applications - track - track alignment design parameters - track gauges 1435 mm and wider - part 2: switches and crossings and comparable alignment design situations with abrupt changes of curvature
EN 13848-1	Railway applications – track - track geometry quality - part 1: characterisation of track geometry
EN 13848-2	Railway applications - track - track geometry quality - part 2: measuring systems - track recording vehicles
EN 13848-3	Railway applications - track - track geometry quality - part 3: measuring systems - track construction and maintenance machines
EN 13848-5	Railway applications - track - track geometry quality - part 5: geometric quality levels - plain line
EN 14587-1	Railway applications - track - flash butt welding of rails - part 1: new r220, r260, r260mn and r350ht grade rails in a fixed plant
EN 14587-2	Railway applications - track - flash butt welding of rails - part 2: new r220, r260, r260mn and r350ht grade rails by mobile welding machines at sites other than a fixed plant
EN 14587-3	Railway applications - track- flash butt welding of rails - part 3: welding in association with crossing construction
EN 16273	Railway applications - track - forged rail transitions
EN 14730-1	Railway applications - track - aluminothermic welding of rails - part 1: approval of welding processes
EN 14730-2	Railway applications - track - aluminothermic welding of rails - part 2: qualification of aluminothermic welders, approval of contractors and acceptance of welds
EN 14969	Railway applications - track - qualification system for railway trackwork contractors
EN 15689	Railway applications - track - switches and crossings - crossing components made of cast austenitic manganese steel
EN 13231-4	Acceptance of works - part 4: acceptance of reprofiling rails in switches and crossings
EN 13848-4	Railway applications - track- track geometry quality - part 4: measuring systems - manual and lightweight devices
EN 16028	Railway applications - wheel/rail friction management - lubricants for trainborne and trackside applications

1.2.UIC recommendations

The relevant UIC recommandations used for high speed lines and conventional lines are listed below:

Standard	Title
UIC 717-2	Laying of track on a reinforced concrete deck
UIC-719	Earthworks and track-bed layers for railways lines
UIC 720	Laying and maintenance of tracks made up of continuous welded rails
UIC 721	Recommendations for the use of hard quality and extra hard quality rails
UIC 774	Track-Bridge interaction
UIC 779-9	Safety in railway tunnels
UIC 864-1	Technical specification for the supply of sleeper screws
UIC 864-2	Technical specification for the supply of steel track bolts
UIC 864-3	Technical specification for the supply of spring steel washers for use in the permanent way
UIC 864-4	Technical specification for the supply of fishplates or sections for fishplates made of rolled steel
UIC 864-5	Technical specification for the supply of rail seat pads
UIC 864-6	Technical specification for the supply of baseplates made of rolled steel
UIC 864-7	Rolled profiles for base-plates for UIC rails
UIC 864-8	Rolled profiles for fishplates for 54kg/m and 60kg/m rails.
UIC 864-9	Rolled profile for fishplates for UIC 71 rails.
UIC 866	Technical specification for the supply of cast manganese steel crossings for switch and crossing work.

2. Functional & performance requirements

2.1. Overall objective

The trackwork design is to be formulated with the objective of producing a safe and efficient system. Minimizing maintenance costs and maximising operating efficiency are key requirements. The track shall also be fully integrated and compatible with the other interfacing systems.

The main goals for the track technical definition shall be the:

- Ride smoothness and safety of the transport system,
- Support of the vertical and longitudinal loads (static loads, braking forces, expansion forces),
- Capability to interface with civil works structures and other systems as rolling stock, power system and signalling,
- Use of classical and proven components able to be easily dismantled,
- Equipment longevity,
- Equipment reliability,
- Reduction of constraints and maintenance costs,
- Reduction of environment impact (noise and vibrations),
- Electrical insulation towards earth and electrical continuity for track return current and signalling track circuits.

Note. For interfaces issues, chapter 4.2.6 of the INF TSI shall be respected.
Note. Customer requirements for superstructure elements (sleepers, fastenings, ballast, turnouts etc.) will be set later.

2.2. Equipment longevity

The trackworks shall provide equipment longevity and reliability. The track components shall be designed in order to resist against weathering and mechanical influence as defined for design life in RBDG-MAN-012 general requirements. In particular, all the exposed steel parts from the track shall be protected against corrosion except for the running rails.

2.3. Maintainability

The trackworks shall minimize maintenance constraints and maintenance costs. Maintenance shall be performed with as few special pieces of equipment and tools as possible and equipment shall be easily dismantled. Each component is manufactured from one source supplier and has dimensional tolerances to ensure that each component is interchangeable.

The track shall be designed with provisions for lateral and vertical adjustments range in order to compensate rail wear and potential differential settlements of the structures.

2.4.Safety

The main general requirements for safety that are relevant to the permanent way subsystem are the following:

- The design, construction or assembly, maintenance and monitoring of safety-critical components, and more particularly of the components involved in train movements shall be such as to guarantee safety at the level corresponding to the aims laid down for the network, including those for specific degraded situations.
- The parameters involved in the wheel/rail contact shall meet the stability requirements needed in order to guarantee safe movement at the maximum authorised speed.
- The trains shall run without the risk of derailment or collisions between them or with other vehicles or fixed obstacles, and avoid unacceptable risks associated with the proximity of the electric traction supply,
- The components used shall withstand any specified normal or exceptional loading throughout their period in service. The safety repercussions of any accidental failures shall be limited by appropriate means.
- The permanent way shall withstand without failure the vertical, lateral and longitudinal loads, whether static or dynamic, exerted by the trainsets, in the specified track environment and while achieving the required performance,
- The permanent way shall permit the monitoring and maintenance of the installations necessary to keep the critical components in safe condition.

2.5.Environmental requirements

The general requirements pertaining to environmental protection that are relevant to the superstructure subsystem are the following:

- The repercussions on the environment of the establishment and operation of the high-speed rail system shall be assessed and taken into account at the design stage of the system,
- The materials used in the infrastructure shall prevent the emission of fumes or gases which are harmful and dangerous to the environment, particularly in the event of fire,
- The noise and vibration generated by the rail-wheel contact shall be sufficiently low to fulfil the environmental requirements.

3. Description of the Interfaces

3.1.Generalities

The trackworks shall be designed in order to interface properly with other physical and functional systems that include civil works, power supply, rolling stock, line side signalling subsystems.

3.2.Interfaces with civil works

The permanent way superstructure along the Rail Baltica line project lays over 4 different types of substructures:

- Embankment,
- Cutting,
- Bridges/viaducts,
- Tunnels.

Approach slabs (other methods of transition zones) shall be provided at all positions between track beds of significantly different modulus.

3.2.1. Embankments

A large majority of the track layout is built above an embankment structure.

The dynamic loads applied by the rolling stock on the track will be transferred to the sub-structures.

The foundation works shall be design in order to:

- Provide a homogeneous support and stiffness to the track super-structure.

3.2.2. Cutting

Part of the track layout is built on cutting structure.

The dynamic loads applied by the rolling stock on the track will be transferred to the sub-structures.

The foundation works shall be designed in order to:

- Provide a homogeneous support and stiffness to the track super-structure.

3.2.3. Bridges/Viaducts

The design of Rail Baltica line comprises civil engineering bridges/ viaducts.

Rail structure interaction studies shall be carried out for every type of elevated structure in order to define the basis of design loads and to verify that rail stresses arising from the interactive behaviour of rail and structures are acceptable. If not, some constructive arrangements will be defined, such as:

- Rail Expansion Joints
- Fasteners with reduced longitudinal restraint.

3.2.4. Tunnels

The design of Rail Baltica line comprises civil engineering Tunnels.

Rail structure interaction studies shall be carried out for every type of tunnel structure in order to define the basis of design loads and to verify that rail stresses arising from the interactive behaviour of rail and tunnels are acceptable.

3.2.5. Track Drainage

The drainage is designed in order to prevent the track or other equipment from being submerged and water to be accumulated in puddles.

3.3.Interface with Power Supply

The interfaces with the energy subsystem concerns:

- The structure gauge set for the overhead line masts,
- The electrical clearance for the overhead lines and the pantograph and its incidence on structures,
- The transmission of traction currents by the track.

3.3.1. Electrical insulation

The track works shall provide necessary electrical insulation as per the requirements of signalling.

The power supply and signalling subsystems shall define the positions of the rail insulated joints where necessary.

The permanent way sub-system shall provide electrical insulation towards earth.

3.3.2. Electrical continuity

The track works shall ensure return current for power supply.

Power Supply shall provide rail to rail and track to track connections for equipotential connections.

The permanent way sub-system shall provide rail characteristics to Power supply sub-system in order to perform traction simulation studies.

3.3.3. Interference with crossing cables

The power supply and signalling sub-systems shall define the positions of cable crossings through the track when interfering with track superstructure.

3.4.Interface with Rolling Stock

The track shall be designed to provide a smooth and safe guidance for the transport system.

Note. For rail/wheel interfaces issues, chapter 4.2.4.5 of the INF TSI shall be respected.

3.4.1. Gauge

The distance between the two rails, as well as the shapes of the wheels and rails coming into mutual contact, is defined in great detail in order to ensure compatibility of the infrastructure with the rolling stock subsystem. Furthermore, this compatibility takes into account existing lines, which form a large part of the interoperable network.

The standard nominal track gauge shall be 1435mm. Curves may have gauge widening to ease wheel/rail wear.

On straight: 1433mm ≤ gauge ≤1444mm
On curve with R>10 000m: 1434mm ≤ gauge ≤1440mm
On curve with R≤10 000m: 1434mm ≤ gauge ≤1443mm

3.4.2. Rail inclination

Inclination of rail shall be set with 1/40 inclination.

3.4.3. Rolling stock loads

The forces exerted by the vehicles on the track, which determine both the conditions relating to safety against vehicle derailment and the characteristics of the track's ability to withstand them, orginated from the contact between the wheels and the rails and from any associated braking equipment when this acts directly on the rail.

These forces include:

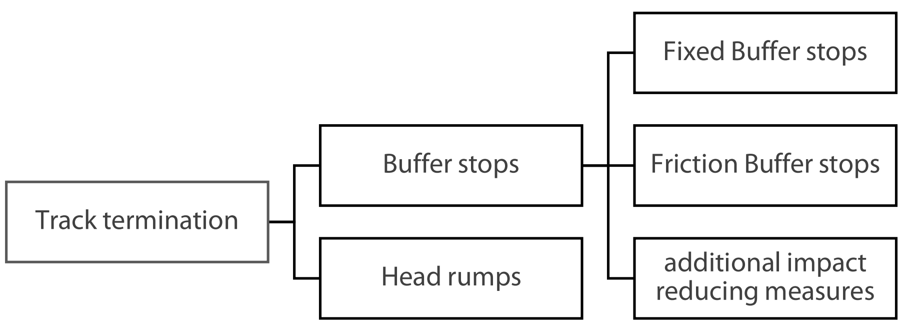
- Vertical forces - static, due to the weight of the vehicle spread over the wheelsets, quasi-static in curves, due to transfer of the vertical loads as a result of lateral accelerations not compensated by track cant, and dynamic, due to the track geometry and the vehicles' behaviour,
- Lateral forces, which are quasi-static in curves, due to lateral accelerations not compensated by track cant, and dynamic, due to the track geometry and the vehicles' behaviour,
- Longitudinal forces due to vehicle accelerations and decelerations when braking and accelerating.

The track system shall support the transfer of physical loads between the vehicle and the infrastructure.

3.4.4. Track termination

Track termination measures refer to the practices and components used to terminate a section of railway tracks safely and effectively. Track termination measures must be designed at dead end tracks to prevent rail vehicles from rolling out of the dead-end tracks, to prevent accidents, protect infrastructure, and facilitate the smooth operation of the railway network.

The following types of track termination can be installed or used in general (see figure below):



Buffer Stop: The purpose of the buffer stop is to absorb the kinetic energy of the train in case of collision caused by inaccurate braking and avoid or minimise (when the designed absorbing capacity of the buffer stop is exceeded) the damage to passengers, rolling stock and infrastructure.

- The Buffer stop can be designed as a **fixed Buffer stop**, absorbing the energy of the impacting vehicle without changing its position. This is rarely the case and reserved for very low speed or light trains or freight wagons.
- Most of the cases the Buffer stops must be designed as so-called **friction Buffer stop** . In this case the Main frame of Buffer stops is sliding along the rail and thereby absorbing more energy and effectively braking the

impacting vehicle down. In this case, the Buffer stop has a defined braking distance. This is currently the most common and cost-efficient way of designing track terminations.

- In cases no sufficient braking distance for friction Buffer stops is available or even higher energy need to be safely absorbed, **additional impact reducing measures** like hydraulic buffers can be installed on the main frame of the Buffer stop.

Head Ramps: Head ramps are loading ramps at the end of a dead-end track. They are used to load or unload wagons via the front side. Head ramps can only perform a very small amount of braking work if they are equipped with hydraulic dampers, for example. Head ramps will be designed to handle the energy released by the vehicle buffers. The speed of the approaching rolling stock must be limited to ~ 5 km/h.

The buffer stop shall be designed/sized (number of friction elements, buffer head position and shape, distance to the track end) according to operational requirements and consider location, specific train type, load, possible extent of damage and its probability for application of risk management process according to CSM-RA as well as requirements defined in chapter 5.9.

3.5.Interface with signalling

3.5.1. Switch motors

The permanent way sub-system is responsible for the supply of all mechanical parts of the switches and crossings including stretcher bars and switch blade mechanical locks.

The signalling sub-system is responsible for the supply of the switch machine and switch blade controllers.

The signalling sub-system shall provide all the necessary information to the permanent way sub-system in order to perform installation of the switch machine.

4. Description of Track cross section

The proposed track superstructure consists of:

- European gauge 1435mm,
- Rail inclination 1/40,
- Continuously welded rails profile EN 60 E2,
- Turnouts fitted with flexible switches, swing or fixe noses and concrete sleepers,
- Elastic fasteners fitted on concrete sleepers,
- Mono-block pre-stressed concrete sleepers with a sleeper spacing of 600mm (from axe to axe) with a tolerance of ±10mm. This spacing leads to 1666 sleepers per km.
- Buffer stops at the end of tracks.
- Ballast.

The thickness of ballast layer under sleeper bottom shall be minimum 30cm on embankment and 35cm on structures.

The breadth of a ballast section shoulder shall be minimum 50cm.

Note: On very small radius - less then 600m - technical solutions to improve track stability (widening of ballast shoulder breadth, reducing sleepers spacing, heavier sleepers, sleeper anchors, etc.) shall be considered and specific CWR studies shall be undertaken for each case.

The gradient of ballast section slopes shall not be more than 1:1,5.

Wherever the distance between adjacent tracks centrelines is up to 5 200 mm, inter-track spaces are filled with ballast.

The height of the ballast walls on bridges must be sufficient to retain the ballast. On bridges with open deck the minimum height shall be no less than 50 cm measured from the bridge deck. On bridges with trough deck sleeper bottom shall be submerged in ballast no less than 15 cm below the top of ballast tank sides.
For designs done before 2023 February, previous version may be used – Sleeper bottom on bridges shall be submerged in ballast 15cm below the top of ballast tank sides.

5. Technical specifications of components

5.1.Rail

For technical specification of rails, please see RBDG-MAN-014A

5.2.Continuous welded rail (CWR)

CWR shall be supplied in strings of the maximum feasible length due to transportation constraints.

CWR rails are then joined together by flash butt welding process in order to form long welded rails for the complete length of the mainlines (except at the location of expansion joints).

The process for rail welding shall be flash butt welding process wherever it is feasible (except in switches and crossings) and shall be performed according to EN13674.

All welding shall be carried out on a flash butt welding machine (FBWM) using an automatic, programmed welding sequence in accordance to EN 14587.

Procedure approval shall be carried out on the rail profile and grade by testing weld samples produced in accordance to EN 14587. Profile and grade shall follow requirements contained in EN 13674.

The welding hardness is tested, and the minimum and maximum hardness values shall be according to EN 14587-1 point 5.4.8

Weld production and testing shall be carried out according to EN 14587.

Weld straightness and flatness shall be carried out according to Class 5 of the standard 14587.

CWR shall:

- Guarantee lifelong traffic safety
- respect the climatic conditions
- Not depend on track plan and profile
- Length of CWR shall match the length of the section, block section or length of the loop track

The neutral temperature of CWR is 20+/-3 ºC.

5.3. Expansion rail joints

For technical specification of expansion rail joints, please see RBDG-MAN-014D

5.4. Guard rails

Guard rails are used to limit transverse movements of rolling stock, in case of derailment, as well as other protective solution such as guide wall or derailment kerb.

Guard rails shall be laid when the impact of a derailed train in a specific location is aggravated by local conditions and in the following cases:

- Fixed equipment in vicinity of the track (less than 3,05 meters from track centreline),
- Crossing of a significant river, railway or road,
- Bridges or viaducts longer than 30 meters.
- If expansion joints are required, the full length shall be fitted with guard rails.

Guard rails shall be installed in these locations and 40 meters after each end.

Guard rails are placed inside the track, near the right or left rail depending on the layout of the line.

Distance between head of the guard rail and head of the closest rail shall be maintained between 0.360 m and 0.370 m.

Top of guard rail level shall be aligned with top of rail level.

5.5. Sleepers

For technical specification of sleepers, please see RBDG-MAN-014B

5.6.Fastening system

For technical specification of fastenings, please see RBDG-MAN-014B

5.7.Ballast

For technical specification of ballast, please see RBDG-MAN-014C

5.8.Switches & Crossings

For technical specification of switches & crossings, please see RBDG-MAN-014D

5.9. Buffer stops

Buffer stops are elements at the end of the track. They signal the end of the track and are equipped with elements that can stop trains impacting at low speeds. Buffer stops prevent railway vehicles from going past the end of a physical section of track and derail. The purpose of the Buffer stop is to absorb the kinetic energy of the train in case of collision caused by inaccurate braking or violation of parking rules (for example, the train is not secured with brake shoes) and avoid or minimize (when the designed absorbing capacity of the Buffer stop is exceeded) the damage to personnel, passengers, rolling stock and infrastructure[1].

[1] See also RBDG-MAN-014E-0101_TS_Bufferstops (Railway Superstructure-Track) section 1)

On passing loops and exchange tracks, flank protection with derailing switches or derailers should be provided as shunt moves are expected and a local assessment of the risk should be realized to ensure the safety of the neighbouring area (risk of invading main track, roads or clashing with housing....).

The Buffer stop shall be designed/sized (number of friction elements, type of Buffer stop, distance to the track end) according to operational requirements.

Buffer stops are not intended to support the regular braking/stopping of trains, and their braking capabilities are limited for technical and economic reasons.

The Buffer stops shall[2]:

1. Prevent any structural damage of the train up to the maximum train collision speed (typically not more than 25 km/h of impact speed).
2. Prevent any structural damage of shunting movements (typically not more than 15 km/h of impact speed)
3. Consider typical maximum load of 850 tons for passenger trains and 1.500 tons as a typical weight for freight trains. Typical weight of standard freight trains should not be higher than 1.500 t. Still weight of special bulky freight trains can be up to 2.500 t. Therefore, contacting the Operations Department for expected trains weights is required.
4. Consider specific protection conditions to be applied for cases when:
    a) passenger train arrives at the dead-end track,
    b) residential area or other infrastructure is located behind the dead-end track,
5. Prevent the risk for rolling stock to climb onto the Buffer stop in case of collision with a Buffer stop,
    a) The Buffer stops shall prevent damage of electrical installations.

For each specific case risk assessment according to CSM-RA[3] shall be performed to assess the suitable Buffer stop type (both friction Buffer stops and fixed Buffer stops with or without hydraulic dampers as well as sand traps should be considered following a risk analysis). During local site investigations, special safety attention should be paid in case of people or certain infrastructure are located behind the Buffer stop or the sand trap (housing, roads etc).

Dead-end tracks (and therefore Buffer stops) should not be located on elevated structures. Nevertheless, if this particular case needs to be studied, sufficient load bearing structure should be provided after the Buffer stop.

The Buffer stop shall be compliant with the rolling stock TSI and standard EN 12663 regarding positioning of the train buffers and maximum force supported by the rolling stock. They need to be compliant with many different types of rolling stock – shape and height of buffer heads and anti-climber position of the rolling stock.

The Buffer stop design needs to be approved by RBR.

Additional objectives such as easy installation, cost effectiveness, easiness to put back into service following an impact, high degree of reliability, minimal maintenance, and space limitations (for example for friction Buffer stops) should be integrated into the design studies.

[2] See also RBDG-MAN-014E-0101_TS_Bufferstops (Railway Superstructure-Track) section 1.1)

[3] CSM-RA is a framework that describes a mandatory and common European risk management process for railway industry. Implementing Regulation (EU) No 402/2013 (Regulation on a common CSM safety method) for risk assessment and its evaluation (CSM-RA) is part of a comprehensive work program of the European Railway Agency and the European Commission.

6. Annexes

RBDG-MAN-014A	Technical Specification – Rails
RBDG-MAN-014B	Technical Specification – Sleepers, USPs and Fastenings
RBDG-MAN-014C	Technical Specification – Ballast
RBDG-MAN-014D	Technical Specification - Turnouts
RBDG-MAN-014E	Track Termination (Bufferstops, Head Ramps)