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Level 2

Track Bed Investigation, Design and Installation

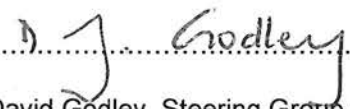
Endorsement and Authorisation

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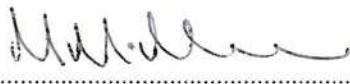
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User information

This Network Rail standard contains colour-coding according to the following Red–Amber–Green classification.

Red requirements – no variations permitted

- Red requirements are to be complied with and achieved at all times.
- Red requirements are presented in a red box.
- Red requirements are monitored for compliance.
- Non-compliances will be investigated and corrective actions enforced.

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- Amber requirements are to be complied with unless an approved variation is in place.
- Amber requirements are presented with an amber sidebar.
- Amber requirements are monitored for compliance.
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Green guidance – to be used unless alternative solutions are followed

- Guidance should be followed unless an alternative solution produces a better result.
- Guidance is presented with a dotted green sidebar.
- Guidance is not monitored for compliance.
- Alternative solutions should be documented to demonstrate effective control.

Amendment marks

- First document amendments are presented with a single black line to the right of the affected text.
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Issue record

Issue	Date	Comments
1	5 th Dec 2015	This standard replaces Formation Treatments NR/SP/TRK/9039

Compliance

This Network Rail standard is mandatory and shall be complied with by Network Rail and its contractors if applicable from 05/03/2016.

When this standard is implemented, it is permissible for all projects that have formally completed GRIP Stage 3 (Option Selection) to continue to comply with the issue of any relevant Network Rail standards current when GRIP Stage 3 was completed and not to comply with requirements contained herein, unless stipulated otherwise in the scope of this standard.

Reference documentation

British Standards/EN

BS 812	Testing aggregates
BS 1377	Methods of test for Soils for civil engineering purposes
BS 5930	Code of Practice for Site Investigations(Amended to take into account the following: BSEN 14688 – 1:2002 – Identification and Description of Soil – 2:2004 – Principles for Classification of Soil BSEN 14689 – 1:2003 – Description of Rock
Amendment 1	
BS EN 13250	Geotextiles and geotextile-related products – Characteristics required for the use in construction of railways.

Network Rail Company Standards

NR/L2/TRK/8100	Track Ballast and Stoneblower Aggregate
RT/CE/S/033	Track Blanketing Sand
NR/L2/TRK/2102	Design & Construction of Track
NR/L3/CIV/005	Railway Drainage Systems Manual
NR/L3/ENV/044	Track Maintenance, Renewal or Alteration – Used Ballast Handling
NR/L2/TRK/2500	Engineering Assurance Arrangements for Track Engineering Projects
NR/L2/AIF/1020	Buried Services Data Provision (formerly NR/L2/AMG/1020)
NR/L2/INI/CP1030	Working safely in the vicinity of buried services (formerly NR/L2/AMG/1030)

Other

Network Rail Contaminated Land Manual
Network Rail Track Ballast Replacement – Work Site Risk Assessment Protocol

Disclaimer

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1 Purpose

The document sets out a consistent technical approach to track bed diagnosis, investigation and design. This is to reduce the risk of premature track bed failures and high frequency of maintenance interventions following track renewals work.

2 Scope

This Business Process Document details the requirements and guidance for those engaged in site investigation scoping, site investigations, design, specifying track renewals and the installation of the track bed. Background information is provided to facilitate further understanding of track bed failure mechanisms and the rationale in support of the design solutions.

This document applies to all ballasted track and provides details on the process to be undertaken to ensure the required level of desk study and site investigation is undertaken to support a robust track bed design. It applies to routine track renewals, enhancements and remodelling schemes.

It does not apply to high speed lines above 125 mph.

3 Introduction

The quality of a track, i.e. its ability to retain good geometry and its response to mechanical maintenance (tamping, stone blowing) is directly related to the design and condition of the track bed and the earthworks.

The track bed is considered to consist of two elements:

- The ballast which deteriorates under traffic and with track maintenance activities and therefore requires periodic replacement.
- The formation, consisting of a sand blanket or other fine grained materials (where present) over the subgrade, upon which the required depth of ballast is placed. This shall be permanent, and not require replacement or maintenance.

On a well-built formation the only track bed treatment required shall be ballast replacement. However, in the UK there are many locations where formations do not provide the ideal support conditions, and can therefore lead to a considerable reduction in the useful life of the track bed and high levels of maintenance intervention.

Figure 1 details the components of a typical UK track bed

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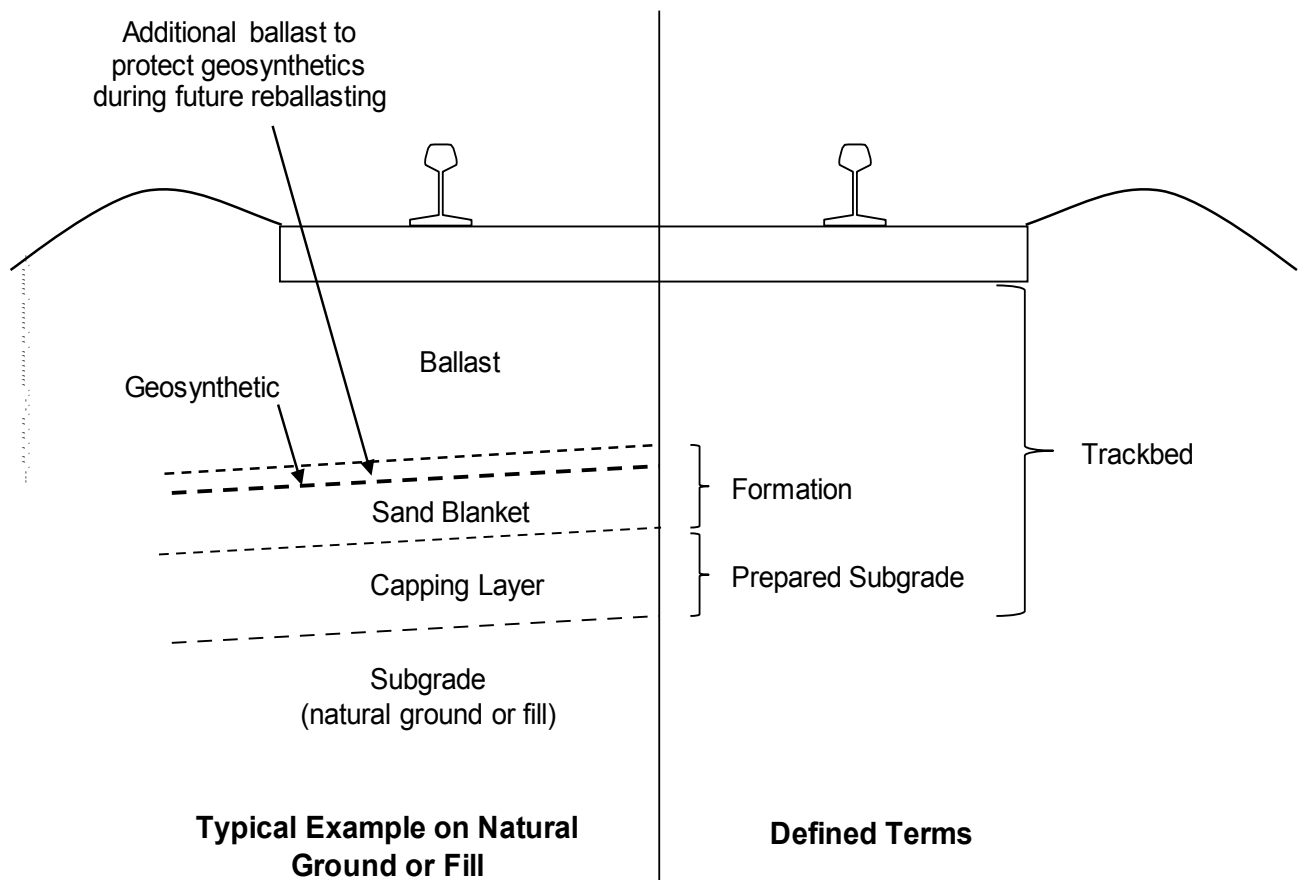


Figure 1 - Components of a typical Track Bed

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4 Definitions

Anti-pumping Geocomposite

Can be used as an alternative to a sand blanket dependent on existing drainage and formation / sub-grade condition. The application of these is subject to a detailed review of the existing track performance through desk study and site investigation.

Ballast

Nominally single-sized granular material of specified properties, placed on the formation to provide vertical and lateral support to the sleepers or bearers.

Ballast Polyurethane

A technique used to limit ballast deformation, formed by surface application of polyurethane, mixed in situ, to form a flexible reinforcement.

Blanket

A layer, or several layers, laid over the subgrade to give the formation its desired properties. The layers can include granular material (to act as a filter or modulus improver) or synthetic layers.

Buildability

Factors that may affect installation of a particular treatment other than the physical condition of the track bed layers, e.g. clearances to drains, structural foundations and chemical contamination.

Capping Layer (Prepared Subgrade)

An imported material whose purpose is to enhance the properties of a poor subgrade prior to placing the blanket (formation layer).

Critical Velocity (Surface Wave / Rayleigh Wave Velocity)

The natural velocity of wave propagation along a track bed due to a load pulse on a sleeper which is representative in magnitude and duration of the passage of a heavy axle load at high speed.

Dynamic Sleeper Support Stiffness

The peak load divided by the peak deflection of the underside of a rail seat area of an unclipped sleeper subjected to an approximately sinusoidal pulse load at each rail seat; the pulse load being representative in magnitude and duration of the passage of a heavy axle load at high speed.

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Earthwork

An embankment, cutting (soil or rock) or natural slope, or nailed or reinforced soil structure whose face angle is less than 70° to the horizontal.

Exploratory Hole

Any intrusive excavation, either hand or machine, undertaken for the purpose of examination, sampling or testing of ground (including track bed), or for determination of clearances to obstructions.

Formation

The ground on which the ballast is placed, consisting of a sand blanket / fine grained material and other protective layers to protect and enhance the properties of the sub-grade.

Formation Modulus

The formation material's internal resistance to deformation under the stress generated by train loading. Formation modulus can be measured using various techniques in-situ and in the laboratory. The Falling Weight Deflectometer (FWD) can be configured to measure the formation stiffness in-situ.

In the laboratory triaxle and biaxial loading tests can be used to measure the stiffness of the formation material (subject to sampling).

Geosynthetics

General term for synthetic layers included in the track bed either to enhance the properties of, or replace, a granular track bed layer. It includes geotextiles, geomembranes, geocomposites, geogrids and geo-cells.

Geotextile Separator

Separators are used to prevent intermixing between blanket materials and the ballast. They are suitable for new sand blankets and existing blankets that consist essentially of sand size particles. Separators are also used in drainage applications to prevent external fines from entering the drains.

Geogrids

Geogrid is a plastic mesh with high tensile stiffness and used as reinforcement at the base of a ballast layer or, within the ballast layer itself. Geogrids can also be used to reinforce granular layers in the lower track bed.

Geowebs

Cellular confinement system that is made of various polymers with different depths and sizes used to increase the track bed stiffness.

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Micro-pile

Is a small scale pile consisting of steel, concrete or granular material and is used to reinforce the underlying soils and reduce vertical track deflections in soft subgrades such as peat and softer clays.

Pitching Stones or Penning

A layer consisting of large, often flat, stones or boulders, historically placed over clay soils during the original construction of the railway to distribute load and protect the subgrade. Ash or sand was often used as infill between stones and as a blinding layer above and below. This method of construction does not feature in modern practice, but nevertheless usually facilitates good track geometry (Pitching Stones not disturbed unless absolutely necessary).

3D Polyurethane Ballast Reinforcement

3D Polyurethane Ballast Reinforcement can be used on new ballast to provide a stiffness transition, improvement in track bed stiffness or where it is necessary to stabilise track, either laterally or vertically. It is not suitable for use over soft ground. Specialist a.

Robust Separator

This product is a heavy duty geotextile / geocomposite and is used to separate ballast and a coarse grained formation materials. It can also be used when there is concern that the existing blanket is very thin and it is important to maintain its integrity.

Subgrade

The upper part of the earthworks or natural ground on which the blanket layer rests. The subgrade includes any capping layer (prepared subgrade) designed to improve the properties of a poor quality soil.

Subgrade Modulus

The subgrade material's internal resistance to deformation under the stress generated by train loadings. Subgrade modulus can be measured using various techniques in-situ and in the laboratory. The Falling Weight Deflectometer (FWD) can be configured to measure the sub-grade stiffness in-situ providing the sub-grade depth is known. The Light Weight Deflectometer (LWD) can be used directly on the sub-grade to measure its stiffness. The Dynamic Cone Penetrometer (DCP) can be used to estimate the California Bearing Ratio (CBR) of the sub-grade which can be converted into subgrade modulus using different empirical formula.

In the laboratory triaxial and biaxial loading tests can be used to measure the stiffness of the sub-grade material (subject to sampling).

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Track Bed Transition Zone

A short section of track bed specially designed to control track geometry at abrupt change in track support conditions (e.g. underbridge, culvert, ballasted to direct fastened track).

Track Bed

A general term including the ballast, blanket and capping layers.

Track Bed Layers

A general term referring to all layers placed between the subgrade and the underside of sleepers.

Track Category

The classification of a section of track by tonnage and speed, so that requirements relating to design, maintenance, renewal and inspection of the track may be specified and applied.

Track Geometry

The geometric properties of the track which affect the riding characteristics and safety of rail vehicles, namely short wavelength vertical and lateral alignment and twist measurements.

Under Ballast Mat

A compressible layer of resilient material which is used to reduce track bed stiffness over a structure or other hard subgrade and sometimes noise and vibration.

Under Sleeper Pads (USP)

Are elastic elements made from different synthetics materials such as polymers or EVA attached to the underside of the concrete sleeper / bearer to increase sleeper ballast contact area, reducing stresses within the ballast layer, extending the life of the ballast.

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5 Track Bed Evaluation and Investigation

5.1 General

Wherever track and/or associated lineside drainage are renewed the track quality and residual track bed life shall be assessed against the requirements of the track asset policy and the construction standard [NR/L2/TRK/2102](#). The assessment and any subsequent intrusive investigation shall be carried out in sufficient time to meet the timescales laid down for the renewal or enhancement planning process.

The first stage in any assessment shall be a desk study. The primary objective of the desk study is to gather all the relevant information relating to the track bed, track performance and drainage. During the desk study it is important to confirm that any track performance issues are not related to deficiencies in the earthworks such as a slip or embankment settlement, in which case embankment stabilisation measures are required. Where earthwork problems are suspected the route Geotechnical Engineer shall be consulted in the first instance to assess the likelihood of earthwork movements.

For the purpose of any track bed investigation, if any part of lineside drainage falls within 1.4m of running edge, it is considered to be an integral part of the track bed.

Where required, the track bed investigation should include additional investigation to assess the buildability of any required formation or drainage treatment.

5.2 The Desk Study

5.2.1 SI Scope

For each track renewal or enhancement with a ballast renewal element, an SI Scope shall be prepared to demonstrate that that track bed condition has been fully considered and a targeted site investigation specified. The following information sources are required as a minimum to support the desk study (see Table 1). If necessary a site visit shall be undertaken.

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Table 1- Desk Study Information Sources

INFORMATION SOURCE
5 Mile Line Diagram (including Track Gradient)
National Electronic Sectional Appendix (NESA)
National Hazard Directory
CDDS & CCQ Charts (including Works Records)
35m Vertical Profile (HSTRC)
Tonnage (EMGTPA)
OMNICOM / HD Video
British Geological Survey (BGS)
Ground Penetrating Radar (GPR)
Problem Statements (TRS)/Draft Specification / Maintainer's Details
Structure Records
Historical Trial Hole Records (where available)
Ballast Contamination Risk Assessment (NR/SP/ENV/044)
MARLIN (Land Contamination)
Previous Reports / Investigations
Site Walkover Notes (if applicable)
Buried Services / Utilities Records

The scope report shall consist of the following:

- Summary of site problems
- Purpose of investigation
- Drainage investigation requirements
- Ballast contamination requirements
- Structure pit requirements
- Trial hole location table shall detail the following:
 - location of samples (ABS or trial hole)
 - type of samples to be undertaken & required depth
 - Any specialist testing requirements

The desk study incorporates a schematic which aligns all of the key data sources typically in ½ mile sections presented on A3 sheets detailing the following:

- 35m vertical deterioration rates & HSTRC data

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- Track gradients & topography
- A site diagram including all features that impact on the track bed investigation and design
- Track gradients, visible drainage and structures
- Ground Penetrating Radar radiogram
- Adjacent tracks, S&C, UTX plus any other relevant track furniture or obstruction

The desk study schematic shall be used for the following:

- Route Evaluation including line speed increases to determine potential track bed treatments prior to any site investigation
- Support planning of high output ballast cleaning campaigns prior to site investigation
- To determine potential critical velocity problem areas where the line speed is to be increased so a falling weight deflectometer (FWD) survey can be targeted and undertaken
- Route analysis to determine potential earthworks instability problem areas
- Route evaluation to support the RAM [T] with future renewals programmes providing informed asset information relating to the ballast and formation conditions and track performance, allowing targeted renewals to be undertaken

5.3 The Track Bed Investigation

1. The site investigation will be undertaken as specified in the SI Scope. The purpose of the site investigation is to confirm the existing track bed and drainage conditions, subgrade stiffness, ballast contamination and interface with structures from a buildability point of view. With all this information the proposed track bed treatment can be accurately designed and specified.
2. In order to install a particular track bed solution it is important to understand all site constraints which may affect construction such as structural foundations, location of cable troughing, Under Track Crossing (UTX) or other obstructions.
3. Where the desk study has identified potential ballast contamination, appropriate testing of the track bed materials should be undertaken for the purpose of spoil handling and disposal. The protocols for this process are set down in [NR/L3/ENV/044](#). The depth of sampling should be appropriate to the proposed depth of excavation for the track renewal.
4. As part of the desk study the Track Bed Engineer should have gained an appreciation of the track gradients and topography plus any available information on existing drainage, geology, hydrogeology and hydrology as appropriate for the site. During the site investigation a condition survey of any

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existing track drainage system in the vicinity of the proposed track renewal should be undertaken and the following minimum drainage information recorded:

- the type of drainage system
 - location of the catch pit, invert level and water level relative to nearest rail,
 - general condition of pipes, channel drains and catch pits
 - direction of water flow and pipe diameters.
5. Track bed drainage relies on water draining laterally from the formation, the investigation should consider the lateral drainage path from the track bed to the existing drainage system and in some cases trial trenches should be specified for the length of the sleeper up to the edge of the drainage pipe. On sites with no drainage system, the cess conditions will be recorded.
 6. Where drainage is deemed to be inadequate further site investigation work such as ground permeability testing should be specified and undertaken.
 7. All track bed materials encountered will be logged in accordance with BS EN 5930, Code of Practice for Site Investigations. All materials will then be coded according to the Network Rail Logging Key (see Figure 2).

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1 BALLAST

a) With no subgrade erosion

- 1  Clean Ballast
- 2  Slightly Dirty Ballast
- 3  Dirty Ballast
- 4  Very Dirty Ballast (non-cohesive)
- 5  Very Dirty Ballast (cohesive)
- 6  Very dirty ballast (slurried)

b) With subgrade erosion

- 7  Slurried Ballast < 10% fines
- 8  Slurried Ballast > 10% fines
- 9  Ballast - Voids filled with silt/fine sand
- 10  Ballast - Voids Filled with soft/firm clay

2 TRACKBED LAYERS/FILLS

a) Derived from naturally occurring Sands and Gravels. (% refers to clay/ silt content)

- 11  Fine/Medium Sand (<5%)
- 12  Coarse Sand (<5%)
- 13  Sand and Gravel (<5%)
- 14  Clayey/silty Sand and/or Gravel (5 to 20%)
- 15  Slurried Sand and/or Gravel (5 to 20%)

b) Quarry Products

- 16  Stone dust (<5%)
- 17  Coarse Crushed stone aggregate (<5%)
- 18  Clayey/silty Crushed Stone Aggregate (5 to 20%)
- 19  Slurried Crushed Stone Aggregate

c) Ash

- 20  Fine ash (sand sized) (<5%)
- 21  Coarse ash (gravel sized) (<5%) and
- 22  Clayey/silty Ash (5 to 20%)
- 23  Slurried Ash

d) Other granular trackbed materials

- 24  Fine grained, susceptible to erosion (<5%)
- 25  Coarse Granular Layer (<5%)
- 26  Clayey/silty Granular Layer (5 to 20%)
- 27  Slurried Granular Layer
- 28  Any of 2 a-d in a clay matrix (20 to 50%)

3 SUBGRADE

Use legends from section 2 where appropriate,
legend with bold outline indicates natural ground

a) Homogenous Fine Soils (Clay and Silt)

- 31  Organic/Very Soft
- 32  Soft Cu < 40kN/m²
- 33  Firm Cu = 40 to 75kN/m²
- 34  Stiff Cu = 75 to 150kN/m²
- 35  Very Stiff / Hard / Very weak Mudstone Cu > 150kN/m²

b) Mixed (Fine and Coarse) Soils

- 36  Unstratified (clayey/silty Coarse Soil OR sandy or gravelly Fine Soil)
- 37  Interbedded or weathered/ weakly cemented fine grained rocks

c) Rock or Rockfill

- 38  Weak fine grained (mudstone, limestone, chalk, fine sandstone)
- 39  Moderately strong to hard rock

4 PITCHING LAYERS

- 29  Clean pitching
- 30  Slurried Pitching

5 SAMPLE LOSS IN ABS

- 0x  Soil penetrated by ABS, but not recovered
- 0d  Soil displaced by ABS – indicative of very soft soil

6 ADDITIONAL INFORMATION

- g** – permeable geotextile separator
- c** – permeable geocomposite
- m** – reinforcing mesh (geogrid)
- p** – impermeable membrane (polythene)
- h** – impermeable geocomposite
- w** – water level (wet samples)
- ws** – standing water (recorded in drill hole)
- hs** – historical slurring
- 34** – shear strength kN/m²
- e** – likely chemical contamination
- L** – >10 % limestone ballast

Figure 2 - Network Rail Logging Key - Version 3