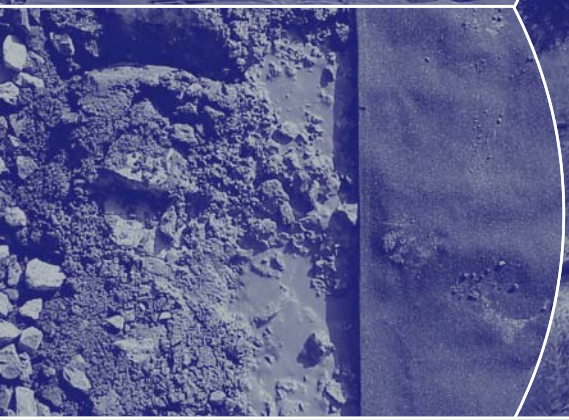
GEOfabrics®

Rail Design Guide



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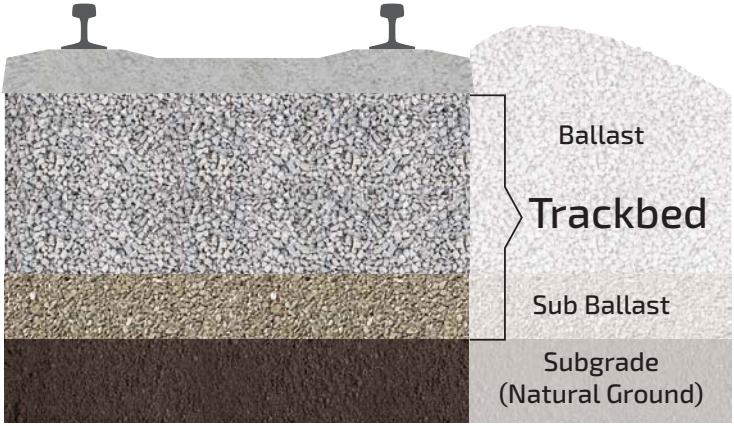
SECTION 1
Track Sub-structure

A typical ballasted railroad construction will comprise a number of components, each with a distinctive design functionality. In order to understand the applications for synthetic materials in the structure each component must be understood. A railroad track is made up of a number of components, the rail, fastening system, ties, ballast and sub-ballast within a structural system. The system needs to survive the trafficking and climate so that the subgrade is adequately protected and that the performance of the track is effectively supported during the design life.

A primary function of the layers that make up the track sub-structure is to distribute wheel/rail contact forces, this is to make sure that the stresses in the subgrade are at a satisfactory level. The use of geosynthetics within this structure can significantly reduce track substructure renewal costs as well as enhancing its performance, reducing maintenance costs and increasing the lifetime of the design. In order to understand which materials will enhance the system we must first examine the track sub-structure.

The track sub-structure is the foundation that supports the track and facilitates drainage. When referring to the ballasted track the foundation comprises of the following layers:

- Ballast
- Sub-ballast
- Subgrade



Railroad Trackbed Components

Ballast

Ballast is the granular material placed at the top of the substructure layer in which the sleepers are embedded, its major function is to distribute force so that the stresses applied to the subgrade are of an acceptable level to ensure the stability of the system. In order to maintain track alignment it is necessary for the ballast to resist a number of forces; vertical, lateral and longitudinal.

Conventional rail ballast is formed from crushed stone, normally igneous in origin with a uniform particle size, typically 50mm. The ballast should have a high resistance to abrasion, a rough surface texture, appropriate aspect ratio and a good resistance to environmental attack. The grading of ballast should be such that there are large enough voids to enable effective drainage, it's secondary although no less important function.

In order for the ballast layer to perform properly it must be of an adequate thickness, have a proper particle size and grading. The required thickness of the ballast layer is based on the structural capacity of the track so that it is able to facilitate the distribution of the applied loadings of passing trains.

When examining ballast there are four basic characteristics that can be described; the size, the general condition, the mineralogy and whether it is contaminated with clay slurry.

Ballast when new is commonly between 37-50mm in size range, and ballast below this size would be considered undersized.

When referring to general condition there are four recognised stages of ballast deterioration:

1. **Clean ballast** – single-sized with a low level of fines within the voids.
2. **Slightly dirty ballast** – there are fines that have accumulated within the voids but they are far from being filled.
3. **Dirty ballast** – the voids are filled with fines but they are generally granular and permeable.
4. **Very dirty ballast** – the voids are completely filled with fines and are impermeable.

When this terminology is used it relates to amount of fines that have accumulated within the voids of the ballast and not the amount of dust or wet slurry that is adhering to the ballast itself.

The geological source of the ballast will influence the quality of the system. If the quality of the stone is poor the rate of deterioration could be rapid.

Sub-ballast

A well designed sub-ballast layer should be permanent, unlike the ballast layer which has a limited life and requires regular replacement, typically after a billion gross tonne of traffic. A modern sub-ballast consists of well-graded, sandy, gravel-sized. Its function is to improve load spreading and increase track stiffness, as well as providing a free draining formation. The grading of the sub-ballast is designed to form a dense layers that is not resistant to deformation when compacted. In addition to this, the sub-ballast will also be required to provide a filter function when placed over fine grained subgrades, preventing the upwards migration of fine material whilst allowing effective dispersion of pore water pressure. Some railroads include a layer of sand placed directly on the subgrade to perform this latter function. The sub-ballast has a critical role in the drainage; it is usually provided with a crossfall to direct most of the water away from the underlying subgrade. There are various design approaches used to determine the combined depth of ballast and sub-ballast.

Subgrade (Natural Ground)

The subgrade is the upper part of the earthworks or natural ground upon which the sub-ballast and ballast layers are placed. Subgrade is the most inconsistent and potentially weakest of track components, yet it is the foundation on which all other components are supported. The subgrade must function as a stable foundation layer, be structurally sound and consistent during any environmental change.

The subgrade will be a determining factor in the design of the overlaying granular layers. The natural ground will normally be a mix of different soil types and it is the proportional mix of these soils that will be one of the determining factor in the design remedy to fix any existing problems. Subgrade must be stable under self-weight of the track and sub-structure so that it does not weaken through consolidation settlement or massive track instability/ shear. It must also be stable under trafficking and not be subject to strain plastically to form a progressive shear failure.

There is a basic classification of soils that can be used as an initial assessment of the natural ground:

Common Description	Principal soil type	Description	Characteristics
Very Coarse Soil	Boulders	Max Particle >8in (200mm)	Can only be seen complete in trial pits.
	Cobbles	Max Particle 8in (200mm)	Often difficult to recover from boreholes.
Coarse Soils (50% or more larger than #200 Sieve (0.075mm))	Gravel	50% or more larger than #4 Sieve (4.75mm)	Particle shapes can be described e.g. angular typical of dredges gravel. Can be well-graded, uniformly graded or gap graded based upon particle size distribution.
	Sand	50% or more finer than #4 Sieve (4.75mm)	Particle grading can be similarly described as for gravel. Individual particles of fine sand are visible to the naked eye. Sand possesses no cohesion when dry.
Fine soils (50% or more are finer than #200 Sieve (0.075mm))	Silt	Typically, Non-Cohesive, Liquid Limit (LL) <50	Individual particles of coarse silt are so small as to be barely visible to the naked eye. Silt possesses some cohesion but powders easily between the fingers when dry. Silt disintegrates in water.
	Clay/Silt Clay	Cohesive, LL ≥50	Clay and silts frequently occur as a mix and laboratory analysis is required to determine the proportions. Clay is cohesive. It can be broken into lumps when dry but not powdered. It softens when wetted and sticks to the fingers. It shrinks when drying and usually shows cracks. Clay will disintegrate in water.

Trackbed stiffness

Good quality track geometry necessitates sufficient and uniform stiffness, this is determined largely by the depth and stiffness of the ballast and sub-ballast layers as well as the stiffness of the natural ground/subgrade. There are various parameters used to define track stiffness, but from the point of view of the track substructure the tie support stiffness, typically expressed in kN/mm/rail is considered to be the most important. The elastic modulus of an individual granular layer is difficult to measure directly, although a surface modulus of the lower track substructure can be determined by performing a load test (eg. LWD or plate bearing test) at the top of the sub-ballast,

The required total depth of ballast + sub-ballast is determined by the stiffness of the subgrade and the traffic. On existing lines the track substructure is of an adequate thickness to facilitate traffic and any assessment would often principally relate to the filtration requirements to ensure that the ballast remains clean. Most assessments can be made using existing data on track geometry and maintenance. When track geometry is in question it may be necessary to investigate the track sub-structure, however in most cases it is assumed that stiffness is acceptable as long as there is no obvious reason to suspect subgrade stiffness has been affected by an existing condition or there is going to be a change in design.

Drainage

It is important for a trackbed to have sufficient drainage, and additional drains are normally provided in an area where water within the trackbed will compromise performance. The performance of a trackbed treatment can be affected by the level of drainage on site.

When assessing remediation, existing trackbed drainage and the surrounding backfill should be assessed to determine their condition and efficiency. This can be split into three basic descriptions:

Poor drainage: A site which has pre-existing drainage problems, for example, where standing water is frequently found within 0.5m of the base of the sleeper.

Satisfactory drainage: A site where water is maintained at 0.5m between the base of the sleeper or lower with the exception of heavy rainfall.

Good drainage: A site that has never had a drainage problem, surcharging of the drainage does not occur more than once per decade.

There are various mechanisms that can result in a failure for the trackbed, and although there may be links between some they must be viewed distinctly in order to establish the most effective way to prevent and cure each of them. There are five principal types of trackbed failure:

1. Ballast deterioration
2. Erosion Pumping Failure
3. Subgrade strength failure (cess heave)
4. Poor stiffness characteristics
5. Critical velocity

1. Ballast deterioration

Rail ballast is subjected to repeated loading under traffic and mechanical maintenance. As it ages it breaks down gradually until the voids become filled with fines. This reduces the effectiveness of tamping and the ballasts ability to drain, however the track geometry is not significantly impacted until the fines reduce the permeability to the point at which the pore water pressure is unable to dissipate under vehicle loading.

This is a particular problem when ballast is saturated under heavy rainfall. This type of failure is often characterised by wet spots and the deterioration of track geometry. Fines deposited from other environmental factors such as wind and freight can add to the problem.

2. Erosion pumping failure

Mud pumping occurs as a result of cyclic loading on ballast in contact with a fine grained subgrade, such as silt or clay, which when abraded and mixed with water is pumped upwards. This is due to the repeated loading and unloading of ties caused by a moving train imposing a cyclic load to the roadbed/subgrade interface. The outcome of mud pumping is similar to ballast deterioration, i.e. loss of track geometry and the appearance of wet spots.

A small amount of slurry at the base of the ballast will have a minimal influence on track geometry. However, when slurry migrates towards the base of the ties the load-bearing functionality of the ballast can be significantly compromised. At this point, the failure in the ballast performance, reduction in track modulus and consequential reduction in bearing capacity cannot be rectified by tamping.

The rate at which mud pumping develops will vary dependent upon a number of factors. Where there is a fine grained soil present at the ballast/sub-ballast interface a slurry will always develop over time. If the drainage is good and the line is lightly loaded, the level of slurry produced within the ballast may be low and not significantly inhibit the performance of the ballast. Importantly, if the ballast is placed upon a susceptible subgrade, with poor drainage, mud pumping can develop in less than a year under trafficking. Even with good drainage, mud pumping cannot be rectified without a modification to the track substructure to inhibit the upwards migration of slurry. The process is self-perpetuating, new clean ballast may help in the short term, but this is not a solution.

The worst pumping problems often occur shortly after re-ballasting either on a track already affected by mud pumping or occasionally where the re-ballasting operation removes an existing sub-ballast layer which had provided adequate subgrade protection.

Movement of fines to track level

3. Subgrade strength failure

Subgrade strength failure results in heaving of the ballast shoulders due to a rotational failure which occurs between the base of the trackbed layers and the ground surface. This heaving can occur on both sides of the track foundation although the final movement occurs only on a single side accompanied by loss of level on one rail. This mode of failure is unlikely with the use of modern maintenance where deep layers of ballast are required.

4. Poor stiffness characteristics

The stiffness of the trackbed is a critical factor in the determination of track geometry. In order to ensure good track geometry it is important for the track to have adequate and uniform stiffness. This is determined by the depth and stiffness of all the granular layers that form the trackbed layers together with the stiffness of the upper part of the underlying subgrade. Trackbed stiffness is normally defined by dynamic sleeper support stiffness (K), expressed in kN/mm/sleeper end.

If the stiffness of the trackbed is too low, this will result in excessive ballast settlement. When the total settlements are large, it can result in a high differential settlement during repeated loading. This variability in trackbed stiffness will influence the vertical alignment and geometry.

There are two principal ways to determine the elastic modulus of a trackbed layer, directly, e.g. in a triaxial apparatus or by performing a load test at the ground surface to measure a reaction modulus and then back analysing the data.

5. Critical velocity

The stiffness of the trackbed is not normally influenced by traffic speed, however over deep layers of soft ground, the trackbed appears softer as speed increases. This is linked to a low velocity of surface wave propagation whereby as the train approaches the critical velocity the ground displacement increases. Where this phenomenon occurs it is possible to make a slight increase in critical velocity by improving the trackbed, however a significant improvement can only be achieved with deep ground treatment.

This section is to allow for an assessment of the trackbed structure in order to determine what/if any remediation is required. Starting from the upper ballast layer, the condition of the track layers can be categorised, this will allow a track engineer to select the most appropriate solution from the matrix in section 5 of this guide.

1. Ballast

The ballast is the upper layer in the structure and typically refers to a 50mm single-sized crushed stone. A visual assessment of the ballast can offer an indication of residual life, the suitability for cleaning and the stability of the formation. It is essential to distinguish between the two principal sources of ballast contamination to determine the most appropriate method of remediation.

A) Ballast with no subgrade erosion

In instances where the underlying subgrade is stable the ballast will only be contaminated with the products of ballast breakdown, environmental fines and dropped fines. In other words there is no upwards migration of fines from the lower layers.

B) Ballast with subgrade erosion

In instances where the formation and drainage are not good fines will migrate upwards into the ballast. The drainage conditions on site will have a large impact on this.

REF	Description	Notes
1	Clean ballast	The ballast is essentially single-sized and there is little or no fine material in the voids.
2	Slightly dirty ballast	There are fines beginning to accumulate in the voids but the voids are far from being filled.
3	Dirty ballast	The voids are mostly filled with fines, but are essentially granular and permeable.
4	Very dirty ballast (non-cohesive/granular)	The voids are completely filled with fines but they are non-cohesive granular.
5	Very dirty ballast (cohesive)	The ballast has degraded under traffic above and the voids are filled with a cohesive soil. It may be unclear if there is a subgrade erosion problem as the issue could have occurred over a long period. Further assessment of the lower trackbed layers is recommended.
6	Very dirty ballast (slurry)	The voids are filled with slurry, this condition indicates a clear subgrade erosion issue.

2. Sub-ballast

It is common for the lower level of the structure to be constructed from numerous materials, including naturally occurring sands and gravels, crushed stone aggregates and industrial waste.

The particle size of the materials can vary extensively, from fine sand through to well-graded coarse sand and gravel. They may also contain a proportion of clay or silt.

REF	Description	Notes
7	Fine Sand - 0.02mm ≤ D60 0.20mm (<5% clay content)	Liable to intermixing – while these are effective at protecting a subgrade they are not stable. Considerable intermixing of sand and ballast will occur especially if there is poor drainage.
8	Medium Sand - 0.20mm ≤ D60 0.60mm (<5% clay content)	Any granular layer with a low silt/fine sand content. It is not contaminated with either fine soil or slurry, either because it is itself providing good subgrade protection or that it is an element within the formation that is providing good protection.
9	Coarse Sand - 0.02mm ≤ D60 0.20mm (<5% clay content)	
10	Sand and Gravel	
11	Clay and Sand/Gravel	Any granular material which contains a significant proportion of silt/clay. A significant clay/silt content does not always indicate that subgrade erosion is occurring or has occurred in the past. However, it will be susceptible to erosion when exposed to water, and will need protection in order to ensure its stability. The appropriate solution will be dependent upon drainage.
12	Slurried Sand/Gravel	If the voids of an aggregate contain slurry this indicates that the grading is poor and there is inadequate protection of the subgrade. The blanket is unsuitable in this condition.

3. Subgrade (Natural Ground)

Important attributes of a subgrade are:

- Its susceptibility to erosion (particle size distribution)
- Its strength/stiffness
- Its lithology

A) Homogenous Fine Soils (Clay and Silt)

REF	Description	Notes
13	Organic/Very Soft	–
14	Soft Cu <40kN/m2	–
15	Firm Cu 40-75kN/m2	–
16	Stiff 75-150kN/m2	–
17	Very Stiff/Hard/Very Hard Mudstone Cu >150kN/m2	–

B) Mixed (Fine and Coarse) Soils

REF	Description	Notes
18	Unstratified (clay/silt mixed with coarse soil)	–
19	Interbedded or weathered/weakly cemented fine-grained rocks	–

C) Rock or Rockfill

REF	Description	Notes
20	Weak fine-grained	(mudstone, limestone, chalk, fine sandstone)
21	Moderately strong to hard rock	–

4. Required depth of ballast and sub-ballast

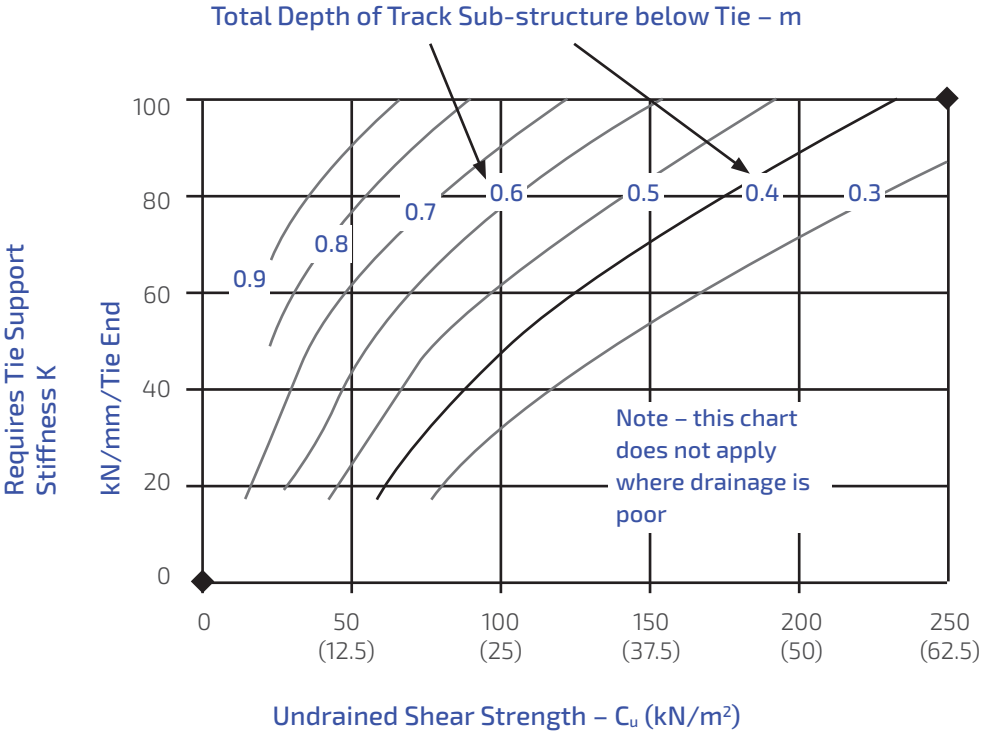
The stiffness characteristics of the subgrade and the necessary track loading will govern the required total depth of granular layers which form the track sub-structure. In most cases the existing track depth will be suitable and not require alteration, however it is important to be confident that the depth of the track sub-structure is adequate before proceeding with any formation treatment. Where traffic loads are not being increased, an assessment can be undertaken via an assessment of existing track maintenance records. In cases where there have been problems with the track geometry, it is recommended that an assessment of the track sub-structure is undertaken, either by intrusive sampling or in situ measurement of stiffness characteristics.

Where the track has previously supported good geometry without excessive maintenance it is reasonable to assume that the stiffness characteristics are sufficient, provided that:

1. There are no underlying reasons to suspect that subgrade stiffness has been affected
2. The track is not going to be lowered
3. The sub-ballast is in good condition and will not be disturbed by any proposed treatment.

	Minimum Tie Support Stiffness (K) - kN/mm/sleeper end (Figures in brackets show FWD tie deflection in mm – 14 Ton peak load)
Transits <60mph	30 (2.0)
Freight Lines Passenger Lines < 100mph	60 (1.0) *
High Speed Lines > 100mph	100 (0.6)

* The required track performance can also be achieved on softer formations with the use of Geogrid reinforcement providing that the tie support stiffness is at least 30 kN/mm/tie end.


Total Depth of Track Sub-structure below Tie – m
Requires Tie Support Stiffness K
kN/mm/Tie End
100
80
60
40
20
0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
Note – this chart does not apply where drainage is poor
0
50 (12.5)
100 (25)
150 (37.5)
200 (50)
250 (62.5)
Undrained Shear Strength – C_u (kN/m²)
Figures in brackets give approximate sub-grade modulus E values (MN/m2)
Soft
Firm
Stiff
Very Stiff

Geosynthetics have been employed to carry out a number of functions within reconstruction and rehabilitation for approximately half a century. When correctly specified and employed, the application of geosynthetics has been proven to significantly enhance the performance of the trackbed in a number of ways, often reducing the cost of maintenance and increasing the allowable design life. Geosynthetics comprise of an assortment of synthetic polymer materials that are specially fabricated to be used in geotechnical, geoenvironmental, hydraulic and transportation engineering applications.

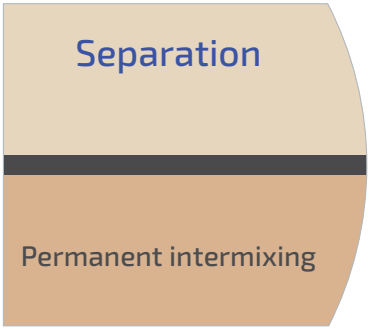
Functions:

There are four principal functions that geosynthetics fulfil when they are used within, beneath and around ballast and sub-ballast layers:

1. Separation
2. Filtration
3. Drainage
4. Reinforcement/Stabilisation.

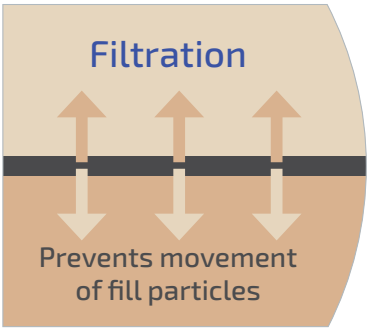
1. Separation

Separation is preventing the intermixing of soil types or soil/aggregate to maintain the integrity of each material yet still allow the free passage of liquids/gasses. Commonly used in between subbase/subgrade and around drainage materials. Geosynthetics are used to separate layers of the track support structure with different particle sizes and properties.



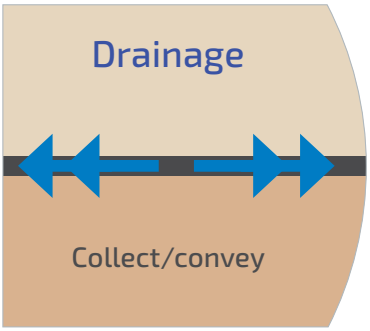
2. Filtration

Filtration is restraining soil particles subject to hydraulic forces whilst allowing the passage of liquids/gasses. This function is partnered with separation. The flow of water from the subgrade into the overlying granular layers may carry fines from the subgrade. This can occur because of the increase in stress levels in the subgrade due to the passage of trains. In this case the right geosynthetic can act as a filter, allowing for the passage of water while retaining the particles.



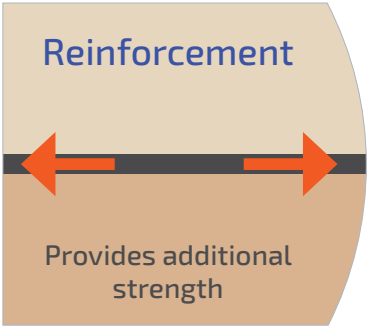
3. Drainage

Drainage is allowing fluids and gasses to flow through the plane of the material. Commonly provided by components in Geocomposites for surface water runoff. Good drainage is essential to prevent deterioration due to the action of the water originating from precipitation onto the track or pumped from the subgrade into the ballast layers.



4. Reinforcement

Reinforcement is providing additional strength to soils to enable structures to be constructed over weak and variable soils. Geosynthetics installed over unstable subgrades may eliminate the necessity to replace this soil, increasing the load-bearing capacity of the system by distributing the stress more evenly. The use of geosynthetics utilised within or beneath the ballast/sub-ballast layers has been proven to reduce settlements associated with the lateral spreading of materials. The principal considerations for this type of product relates to its ability to interact with the soil, resist mechanical damage, have effective tensile strength and stiffness.



GEOfabrics Rail Products

For many years GEOfabrics has developed and provided a broad spectrum of tailor engineered products that are specifically manufactured to address many of the problematic ground conditions that exist beneath railway track.

RK1 – Standard Geotextile

(Function: Separation and Filtration – Coarse Soils)

RK1 is a robust needlepunched nonwoven polypropylene geotextile manufactured from virgin high tenacity fibre engineered to provide high puncture resistance and high extension at break. RK1 is GEOfabrics' standard separation and filtration geotextile for use below ballast with a new blanket or where there is an existing good quality formation with a small percentage of coarse particles, i.e. less than 10% by weight <14mm.

With a maximum width of 6m, RK1 nonwoven, needlepunched geotextile is specified by engineers due to its robustness and its proven ability to function in the most demanding conditions – especially important under dynamic loading beneath track ballast.

Extensive testing has demonstrated RK1's class leading robustness and long service life under dynamic loading conditions. This is due to its high puncture resistance, high elongation to break, superior abrasion resistance, excellent filtration characteristics at all strains and high UV resistance. RK1 is manufactured using a randomly orientated fibre web to provide isotropic strength across the product.

RK9 – Robust Geotextile

(Function: Separation and Filtration – Coarse Soils)

RK9 is a robust needlepunched nonwoven polypropylene geotextile manufactured from virgin high tenacity fibre engineered to provide high puncture resistance and high extension at break. GEOfabrics' robust separation and filtration geotextile for use below ballast with where there is an existing good quality formation with a larger percentage of coarse particles, i.e. more than 10% by weight >14mm.

RK4

(Function: Separation and Filtration – Coarse Soils + Ballast Reinforcement)

RK4 is a bi-orientated polypropylene geogrid heat laminated to a robust needlepunched nonwoven polypropylene geotextile (GEOfabrics RK1) that has been manufactured from virgin high tenacity fibre engineered to provide high puncture resistance and extension at break. Used in trackbed applications for ballast confinement, reduction of mud pumping, subgrade stabilisation, filtration & separation between track ballast and subgrade.

RK4 uses a wide aperture geogrid specifically designed to confine rail ballast. The geogrids properties and composition provides a long-term resistance to mechanical and chemical degradation, even when used under very aggressive conditions. RK4 uses a geogrid which is manufactured from a unique process of extrusion and biaxial orientation to enhance its tensile properties. RK4 features consistently high tensile strength and modulus, excellent resistance to construction damages and environmental exposure. Furthermore, the geometry of RK4 allows strong mechanical interlock with the ballast being confined.

For areas where a more robust Geotextile is required (i.e. more than 10% by weight >14mm) it is possible to laminate RK9 to a geogrid where required.

Tracktex™ – The anti-pumping composite

Subgrade pumping has always been a problem in ballasted track, particularly on weakly cemented mudstones or over consolidated clays. These soils have a high shear strength and as such do not need a deep trackbed to support track loading, yet if unprotected the upper surface degrades easily to a slurry when exposed directly to water.

The open texture of ballast allows free water to come into contact with the exposed formation/subgrade surface. When the exposed surface contains fine-grained particles, these can be readily eroded by the water accumulating in the voids, forming weak, highly mobile slurry. This slurry is then 'pumped' up into the overlying ballast by each passing axle load. Contamination of the clean ballast layer by the fine soil particles in the slurry very quickly reduces the load-bearing properties of the ballast and leads to loss of track alignment in the affected area. A small amount of slurry can considerably reduce ballast life. Under extreme conditions the ballast will become unmaintainable within a very short time post-installation.

Tracktex is a multilayer composite with a unique microporous filter media protected by specially engineered protective nonwoven geotextiles. The filter is an orientated microporous polymeric film with a series of microcells and interconnecting pores, characterised by its relative strength, and ability to transmit vapour.

Tracktex is able to effectively facilitate the passage of liquid under pressure, but the pores are such that the passages of clay fines are prohibited. Without pressure, water cannot pass through the filter, therefore any underlying clay formation will, over time, dry out and have an improved modulus.

Tracktex:

- prevents subgrade fines and slurry from migrating up into the ballast;
- facilitates desiccation and drying of the existing subgrade slurry by allowing pore pressures to dissipate under loading, improving the quality of the formation while preventing re-saturation from above;
- is proved sufficiently robust to installation and operational damage;
- is flexible enough to conform to uneven subgrade formations such that no slurry inducing voids exist.

Rainwater
drains laterally
Filter
facilitates the
passage of
liquid under
pressure while
retaining fines
Patented
microporous filter
system protected by
robust geotextiles

The matrix below can be used in conjunction with the references in section 3 to allow for an assessment of an appropriate remediation technique. Please note that this guide does not relate to an assessment of trackbed stiffness, if there is a concern over trackbed stiffness a more detailed assessment will be required.

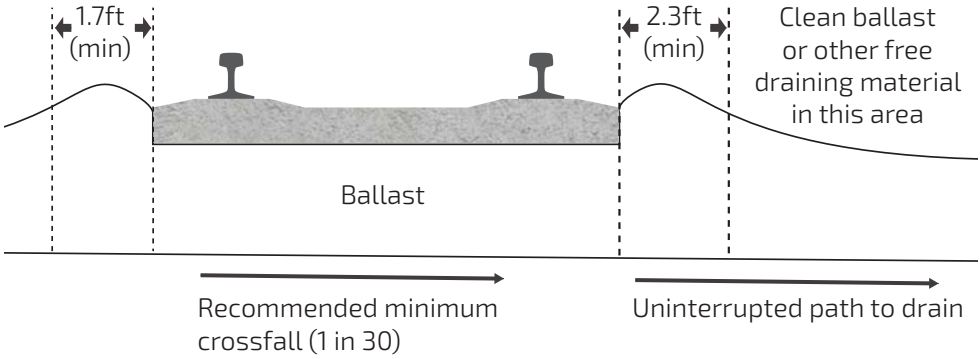
<table>
<tr><th rowspan="2">Formation</th><th rowspan="2">Trackbed Reference (Section 3)</th><th colspan="3">Drainage Assessment</th></tr>
<tr><th>Good Drainage</th><th>Satisfactory Drainage</th><th>Poor Drainage</th></tr>
<tr><td>Coarse Granular (no subgrade erosion)</td><td>3,4,8,9,10</td><td colspan="3">SOLUTION 1</td></tr>
<tr><td>Fine Granular: Potential for ballast intermixing</td><td>7</td><td colspan="2" rowspan="3">SOLUTION 2</td><td rowspan="2">SOLUTION 3</td></tr>
<tr><td>Silt/Clay mix with granular</td><td>5,11,18</td></tr>
<tr><td>Granular, Slurried</td><td>6,12</td></tr>
<tr><td>Erosion/abrasion susceptible subgrade (soft to stiff)</td><td>14,15,16,17</td><td colspan="3">SOLUTION 3</td></tr>
<tr><td>Erosion/abrasion susceptible subgrade (organic and hard)</td><td>13,19,21</td><td colspan="3">SOLUTION 4</td></tr>
</table>

Solution 1 – Re-ballast – No Geosynthetic Required

Minimum criteria recommended for use:

- No subgrade erosion problem
- Satisfactory drainage
- Adequate depth of track layers
- No contamination of the ballast with cohesive materials
- Typical excavation width shall be 12ft

Note: Where sufficient trackbed stiffness cannot be achieved a geogrid can be incorporated to improve support.

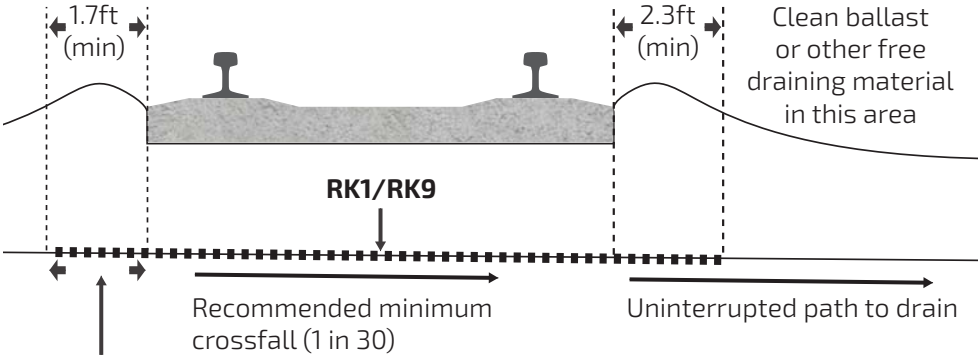


Solution 2 – Re-ballast plus Geotextile (RK1 or RK9)

Criteria for use:

- Satisfactory drainage
- Adequate depth of Trackbed Layers
- No contamination of the ballast with cohesive materials
- There is an existing functioning blanket but it is less than 4 inches thick
- Typical excavation width recommended shall be 12-13ft
- Where the blanket is formed solely of sand sized particles and smaller, use RK1 Standard Geotextile, but if there is a significant amount of coarse particles (>14mm) in the formation, use RK9 Robust Geotextile

Note: Where sufficient trackbed stiffness cannot be achieved a geogrid Composite (RK4) can be incorporated to improve support.



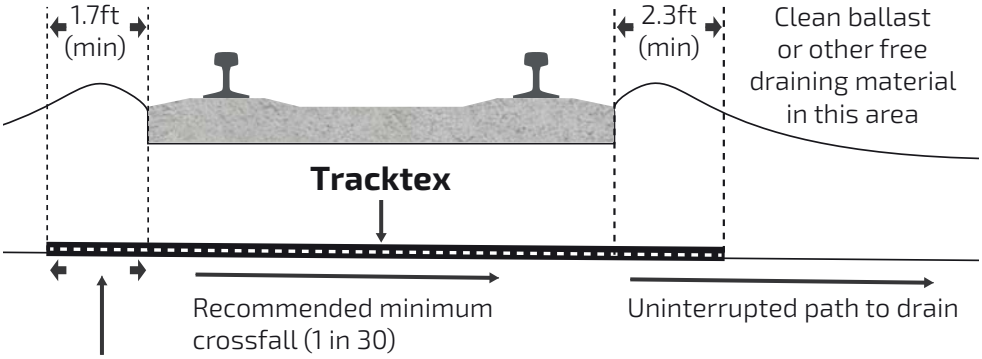
Geotextile to extent at least 1.7ft beyond sleeper. If not possible the dig should be extended as far as possible with the excess being brought up to the side of the excavation

Solution 3 – Re-ballast plus Anti-pumping Composite (Tracktex)

Criteria for use:

- Well established subgrade erosion problem
- Less than 3 inches of good blanketing material separating susceptible subgrade from the base of the ballast
- Typical excavation width shall be 13ft or greater

Note: Where sufficient trackbed stiffness cannot be achieved a geogrid Composite (Tracktex/Grid Composite) can be incorporated to improve support.



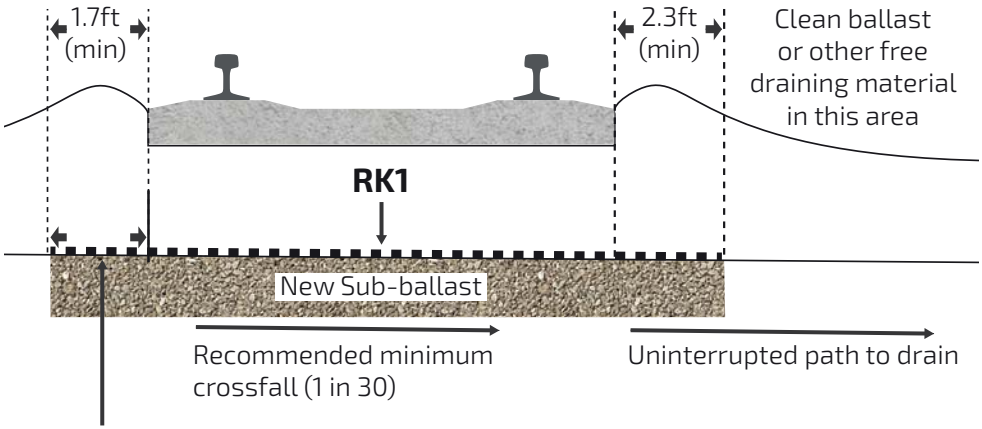
Geotextile to extent at least 1.7ft beyond sleeper. If not possible the dig should be extended as far as possible with the excess being brought up to the side of the excavation

Solution 4 – Re-ballast plus Sand Cushion/RK1

Criteria for use:

- Where the subgrade is very hard a sand cushion will soften the impact on the track components
- On chalk subgrades or pitching stones
- Typical excavation width shall be 13ft or greater

Note: Where sufficient trackbed stiffness cannot be achieved a geogrid Composite (RK4) can be incorporated to improve support. The depth of the sand cushion can also be increased.



Geotextile to extent at least 1.7ft beyond sleeper. If not possible the dig should be extended as far as possible with the excess being brought up to the side of the excavation

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