GEOFABRICS®
Smarter Infrastructure

RAIL TRACK

Geosynthetic Design Guide for Maintenance Operations

TRACK SUB-STRUCTURE

A rail track is made up of the rail, the fastening system, sleepers, ballast and capping/structural layer. 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 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. A ballasted track foundation comprises of the following layers:

- Ballast
- Capping/Structural Layer
- Subgrade (Natural ground)

Ballast

Ballast is the free draining granular material placed at the top of the substructure layer in which the sleepers are embedded. It is typically a uniform particle size of approximately 60 mm.

Capping/Structural Layers

Capping layers and structural layers are well-graded natural or artificially blended gravels/soils which have sufficient fines to permit compaction to high densities. Their function is to improve load spreading and increase track stiffness, as well as providing a free draining formation.

Subgrade (Natural ground)

The subgrade is the upper part of the earthworks or natural ground upon which the capping layers and ballast layers are placed. The subgrade is the most inconsistent and potentially weakest component of the track, yet it is the foundation on which all other components are supported.

Basic Soil Classification

DESCRIPTION		SOIL TYPE	CHARACTERISTICS
Very Coarse Soil	Max particle size > 200 mm	Boulders	Only seen in trial pits.
Very Coarse Soil	Max particle size 200 mm	Cobbles	Difficult to recover from boreholes.
Coarse Soil	50% or more > 4.75 mm	Gravel	Angular particles either well-graded, uniformly graded or gap graded.
Coarse Soil	50% or more < 4.75 mm	Sand	Particle grading similarly described as for gravel. Individual particles of fine sand are visible to the naked eye. Sand has no cohesion when dry.
Fine Soil	50% or more < 0.075 mm Non-Cohesive	Silt	Individual particles are small and barely visible to the naked eye. Silt has some cohesion, powders easily between fingers when dry and disintegrates in water.
Fine Soil	50% or more < 0.075 mm Cohesive	Clay/Silt Clay	Clay and silts often occur as a mix and analysis is required to determine the proportions. Silt particles are dusty when dry. Clay is cohesive is greasy and sticky when wet and hard when dry. Clay shrinks when drying and cracks. Clay will disintegrate in water.

TRACKBED FAILURE

There are various mechanisms that can result in a failure of the trackbed, and although there may be links between each they must be viewed independently in order to establish the most effective way to treat them. There are four common types of trackbed failure: Ballast Deterioration; Mud pumping Failure; Capping Layer Failure; or Subgrade Failure.

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, freight and coal dust can add to the problem.

Mud Pumping Failure

Mud pumping occurs as a result of cyclic loading on ballast in contact with a fine grained subgrade, such as silts or clays, which when abraded and mixed with water is pumped upwards. This is due to the repeated loading and unloading of the sleepers. The outcome of mud pumping is similar to ballast deterioration, i.e. loss of track geometry, formation of “slurry” and the appearance of wet spots. When the “slurry” migrates towards the base of the sleepers 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 with drainage being a determining factor. If ballast is placed upon a susceptible subgrade, with poor drainage, mud pumping can develop quickly 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”.

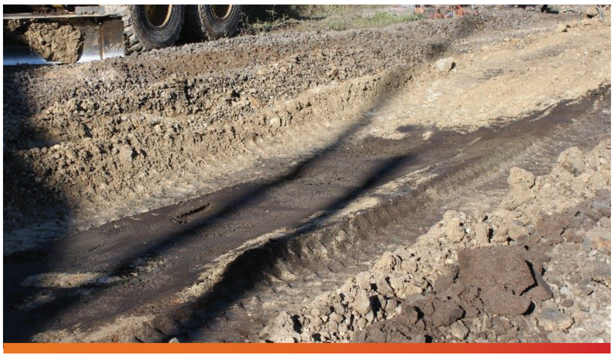
AN EXAMPLE OF MUD PUMPING FAILURE

Capping Layer Failure

The capping layer is a well compacted layer of road base material between the formation and the ballast. The capping layer is designed to prevent water entering the formation from above and to stop small particles of silts and clays from migrating upwards into the ballast. Instability of the track's capping layer can be attributed to: a weak subgrade, inadequate capping layer, inadequate thickness of the ballast layer, presence of expansive soils and poor drainage. All these issues could result in subgrade shear failure, ballast pocket formation, mud pumping or ballast heaving.

Subgrade 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 usually occurs only on a single side accompanied by loss of level on one rail.



AN EXAMPLE OF SUBGRADE FAILURE

TRACKBED ASSESSMENT

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 shown on the following pages of this guide.

Ballast

The ballast is the upper layer in the structure and typically refers to a 60mm 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.

Ballast with no pumping.

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.

Ballast with pumping.

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.

AN EXAMPLE OF BALLAST WITH PUMPING

Capping

Capping Layers are commonly constructed from naturally occurring sands and gravels, and crushed stone aggregates. The particle size of the materials vary extensively, from fine sand through to well-graded coarse sand and gravel. They may also contain a proportion of clays or silts.

Subgrade

Important attributes of a subgrade are susceptibility to pumping (particle size distribution), strength/stiffness and lithology.

Ballast and Capping Depth

The stiffness characteristics of the subgrade and the necessary track loading will govern the required depth of granular layers which form the track sub-structure therefore it is important to be confident that the depth of the track sub-structure is adequate before proceeding with any formation treatment. In cases where there has been problems with the track geometry, it is recommended that an assessment of the track sub-structure is undertaken but where the track has previously supported good geometry without excessive maintenance it is reasonable to assume that the stiffness characteristics are sufficient, provided that:

a. There are no underlying reasons to suspect that subgrade stiffness has been affected;

b. The track is not going to be lowered;

c. The capping layer is in good condition and will not be disturbed by any proposed treatment.

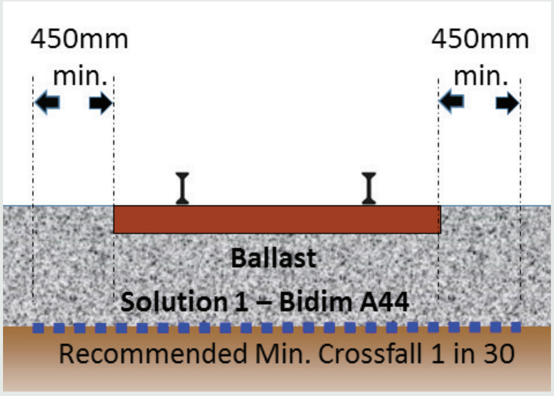
TRACKBED ASSESSMENT & SOLUTION TABLE

<table>
<tr><th></th><th>REF</th><th>DESCRIPTION</th><th>NOTES</th><th>GOOD DRAINAGE</th><th>SATISFACTORY DRAINAGE</th><th>POOR DRAINAGE</th></tr>
<tr><td rowspan="6">Ballast Assessment</td><td>1</td><td>Clean ballast</td><td>Single sized ballast with little or no fines.</td><td colspan="2" rowspan="4">No geosynthetic required</td><td rowspan="3">No geosynthetic required</td></tr>
<tr><td>2</td><td>Slightly dirty ballast</td><td>Fines beginning to accumulate but voids far from being filled.</td></tr>
<tr><td>3</td><td>Dirty ballast</td><td>Voids are mostly filled with fines, but are essentially granular and permeable.</td></tr>
<tr><td>4</td><td>Very dirty ballast (non-cohesive)</td><td>Voids are completely filled with fines but are non-cohesive granular.</td><td>SOLUTION 1</td></tr>
<tr><td>5</td><td>Very dirty ballast (cohesive)</td><td>Ballast has degraded and voids are filled with a cohesive soil. It may be unclear if there is a pumping problem so further assessment is recommended.</td><td colspan="2">SOLUTION 1</td><td>SOLUTION 3</td></tr>
<tr><td>6</td><td>Very dirty ballast (slurry)</td><td>Voids are filled with slurry, which indicates a clear mud pumping issue.</td><td colspan="3">SOLUTION 3</td></tr>
<tr><td rowspan="6">Capping Assessment</td><td>7</td><td>Fine sand < 5% clay content</td><td>Liable to intermixing.</td><td colspan="2">SOLUTION 1</td><td>SOLUTION 3</td></tr>
<tr><td>8</td><td>Medium sand < 5% clay content</td><td rowspan="3">Any granular layer with a low silt/fine sand content which is not contaminated with either fine soil or slurry.</td><td colspan="3" rowspan="2">SOLUTION 1</td></tr>
<tr><td>9</td><td>Coarse sand < 5% clay content</td></tr>
<tr><td>10</td><td>Sand and Gravel</td><td colspan="3">No geosynthetic required</td></tr>
<tr><td>11</td><td>Clay and Sand/Gravel</td><td>Granular material with a significant proportion of silt/clay. It will be susceptible to pumping when exposed to water/rainfall, and will need protection to ensure its stability. The solution will depend on drainage.</td><td colspan="2">SOLUTION 1</td><td>SOLUTION 3</td></tr>
<tr><td>12</td><td>Slurried Sand/Gravel</td><td>Voids of aggregate contain slurry thus indicates grading is poor and there is inadequate protection of the subgrade.</td><td colspan="3">SOLUTION 3</td></tr>
<tr><td rowspan="10">Subgrade Assessment</td><td>13</td><td>Organic/Very soft</td><td rowspan="5">Homogenous Fine Clays and Silts. Pumping susceptible subgrade.</td><td colspan="3" rowspan="7">SOLUTION 3</td></tr>
<tr><td>14</td><td>Soft</td></tr>
<tr><td>15</td><td>Firm</td></tr>
<tr><td>16</td><td>Stiff</td></tr>
<tr><td>17</td><td>Very Stiff / Hard/Very Hard Mudstone</td></tr>
<tr><td>18</td><td>Clays and Silts mixed with</td><td rowspan="2">Mixed Fine and Coarse Soils. Pumping susceptible subgrade.</td></tr>
<tr><td>19</td><td>Weathered weakly cemented fine grained soils and rocks</td></tr>
<tr><td>20</td><td>Weak fine grained rocks</td><td rowspan="2">Rock or rockfill</td><td colspan="3" rowspan="2">SOLUTION 2</td></tr>
<tr><td>21</td><td>Moderately strong to hard rock</td></tr>
<tr><td>22</td><td>New Capping Layer construction for Turnouts and Level Crossings</td><td>Serious consideration should be given to protect the integrity of the new Capping Layer to prevent future costly maintenance of the Turnout and Level Crossing</td><td colspan="3">SOLUTION 3</td></tr>
</table>

SOLUTIONS

Geosynthetics have been used to perform a number of functions within rail renewals and reconstructions for approximately half a century. When correctly specified and used, they have proven to significantly enhance the performance of the trackbed by reducing the cost of maintenance and increasing the allowable design life. Geosynthetics comprise of an assortment of synthetic polymer materials that are specially manufactured to be used in geotechnical, geoenvironmental, hydraulic and transportation engineering applications.

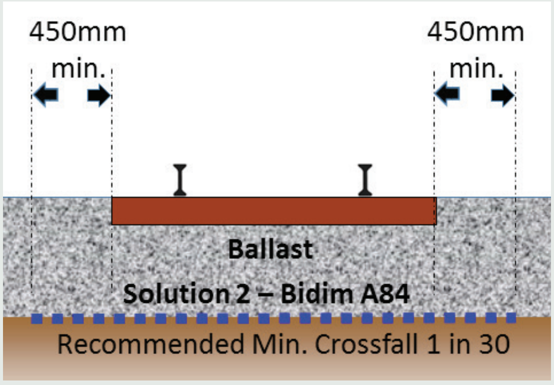
Solution 1 - bidim A44 + Reballast



Criteria for use:

- Satisfactory drainage.
- Adequate depth of Trackbed Layers.
- No contamination of the ballast with cohesive materials.
- Capping or subgrade is made up of sand size particles and smaller (<14mm).

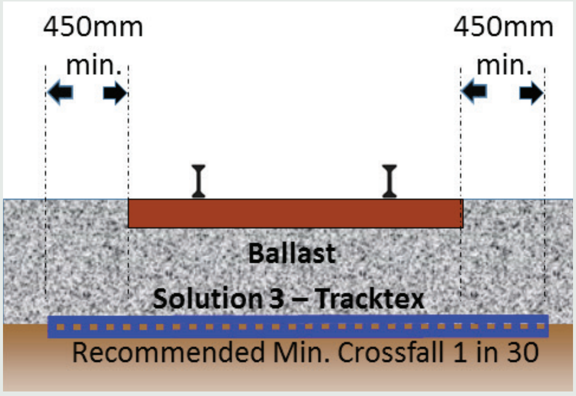
Solution 2 - bidim A84 + Reballast



Criteria for use:

- Satisfactory drainage.
- Adequate depth of Trackbed Layers.
- No contamination of the ballast with cohesive materials.
- Capping or subgrade is made up of a significant amount of coarse particles and larger (>14 mm).

Solution 3 – Anti-Pumping Geocomposite Tracktex + Reballast



Criteria for use:

- Well established mud-pumping problem.
- Less than 75mm of good capping material separating susceptible subgrade from the base of the ballast.

NOTES:

1. Where sufficient trackbed stiffness cannot be achieved a geogrid Tensar TX190L can be incorporated to improve support and ballast stabilisation.
2. Geotextile to extend 450 mm minimum beyond sleeper.
3. Geotextile to be laid at recommended crossfall of 1 in 30.
4. Uninterrupted drainage path to be provided in ballast.

EXPLANATION OF SOLUTIONS

A44 – Robust Geotextile

Function: Separation and Filtration – Coarse Soils

A44 is a robust needle punched nonwoven polyester geotextile manufactured from virgin high tenacity fibres engineered to provide high puncture resistance and high extension at break. A44 is Geofabrics standard separation and filtration geotextile for use below ballast with a new capping layer or where there is an existing good quality formation with a small percentage of coarse particles, i.e. less than 10% by weight <14mm.

A44 is targeted at suburban rail lines where the axle loads and traffic volumes are lower.

A84 – Very Robust Geotextile

Function: Separation and Filtration – Coarse Soils

A84 is a very robust needle punched nonwoven polyester geotextile manufactured from virgin high tenacity fibres engineered to provide high puncture resistance and high extension at break. A84 is Geofabrics robust grade separation and filtration geotextile for use below ballast with a new capping layer or where there is an existing good quality formation with a larger percentage of coarse particles, i.e. more than 10% by weight >14mm.

A84 is targeted at heavy haul rail lines where the axle loads and traffic volumes are much higher.

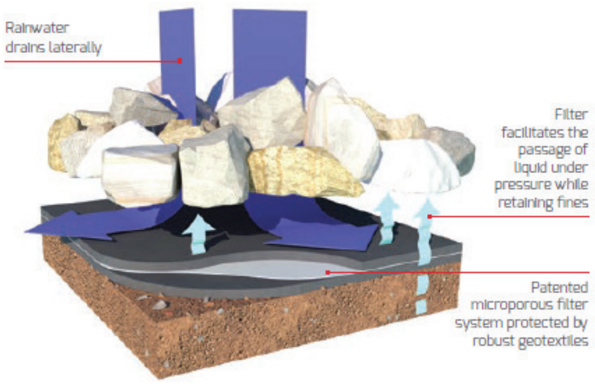
Tracktex – Anti-Pumping Geocomposite

Function: Separation and Filtration – Silts and clays

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;
- Pore water is relieved upwards through the Tracktex under cyclic loading;
- 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.



BIDIM RAIL GRADES SPECIFICATION

bidim nonwoven geotextiles are manufactured in accordance with ISO 9001:2015. bidim is a nonwoven, needle punched, continuous filament, polyester geotextile made in Australia.

	TEST	STANDARD	UNITS		A34	A44	A64	A74	A84
Mechanical Properties	Wide Strip Tensile Strength (MD/XMD)	AS 3706.2	kN/m	MARV Typical	18.5/18.5 21.5/21.0	26.5/26.5 30.0/30.0	37.5/37.5 42.0/42.0	43.5/43.5 46.5/46.5	52.0/52.0 58.0/58.0
	Wide Strip Toughness	AS 3706.2	kJ/m^2	MARV Typical	3.5/3.8 5.2/5.7	4.8/5.5 7.6/8.1	8.2/8.2 12.3/12.6	8.6/8.7 14.6/15.8	14.2/13.1 20.2/19.8
	Index Puncture Resistance	ASTM D6241	N	Typical	645	855	1060	1200	1310
	Trapezoidal Tear Strength (MD/XMD)	AS 3706.3	N	MARV Typical	440/440 540/540	590/590 750/750	830/830 1,030/1,030	1,065/1,065 1,175/1,175	1,200/1,200 1,425/1,425
	CBR Burst Strength	AS 3706.4	N	MARV Typical	3,400 3,700	4,650 5,000	6,400 6,950	7,300 7,900	9,000 9,600
	G Rating	Austroads	-	MARV Typical	2,510 2,800	3,500 4,000	5,100 5,600	5,550 6,150	7,600 8,500
	Resistance to Hydrocarbons (Diesel)	AS 3706.12	-	-	✓	✓	✓	✓	✓
Hydraulic Propertites	Pore Size (0_{95})	AS 3706.7	µm	Typical	75	75	75	75	75
	Permittivity	AS 3706.9	s^{-1}	Typical	1.65	1.2	0.90	0.60	0.55
	Coefficient of Permeability	AS 3706.9	m/s x 10^{-4}	Typical	43	43	43	43	43
	Flow Rate @ 100 mm Head	AS 3706.9	$l/m^2/s$	Typical	165	120	90	60	55

Notes:

1. **Typical Value:** A typical value is the arithmetic mean of a set of results. This implies that 50% of the tested specimens will typically exceed this value and 50% will typically not meet this value.
2. **Minimum Average Roll Value (MARV):** MARV is a statistical derivation for any distribution of data. It is defined as the mean or typical value less 2 standard deviations. Mathematically it is implied that 97.5% of the tested specimens will exceed the MARV.
3. (MD) = Machine Direction Strength.
4. (XMD) = Cross Machine Direction Strength.

TRACKTEX SPECIFICATION

TrackTex consists of a micro-porous, breathable filter sandwiched between bidim® nonwoven geotextiles, manufactured from mechanically entangled continous filament fibre.

PROPERTY	TEST STANDARD	UNITS	TYPICAL VALUE
Geotextile Fibre Type	Virgin Polyester Continuous Filament		
Thickness @ 2kPa	AS 3706.1	mm	9.50
Wide Strip Tensile Strength	AS 3706.2	kN/m	105
Wide Strip Tensile Elongation	AS 3706.2	%	80
Trapezoidal Tear Strength	AS 3706.3	N	2,700
CBR Burst Strength	AS 3706.4	kN	15
Drop Cone Puncture Resistance	AS 3706.5	mm	No Measurable Puncture
Opening Size	ISO 12956	µm	< 20
Resistance to degradation by light, heat and moisture (UV)	AS 3706.11	%	90
Geotextile resistance to degradation by Hydrocarbons	AS 3706.12 (mod[1])	%	90
Resistance to abrasion under ballast.	In-house	Visual	Tracktex has been subjected to a loading cycle equivalent to 140,000,000 gross tonnes of main-line traffic below 0.3 m of ballast in a full size rig measuring over 8 m^2. Upon completion of the test, there were no visible signs of damage to the central micro porous filter.

Notes:

1. Immersion time increased from 15 days to 365 days.

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