Guide

Track Reconditioning Guidelines

Version 2.0

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Standard governance

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Document history

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  • revision of some definitions  
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Preface

The Asset Standards Authority (ASA) is a key strategic branch of Transport for NSW (TfNSW). As the network design and standards authority for NSW Transport Assets, as specified in the ASA Charter, the ASA identifies, selects, develops, publishes, maintains and controls a suite of requirements documents on behalf of TfNSW, the asset owner.

The ASA deploys TfNSW requirements for asset and safety assurance by creating and managing TfNSW's governance models, documents and processes. To achieve this, the ASA focuses on four primary tasks:

- publishing and managing TfNSW's process and requirements documents including TfNSW plans, standards, manuals and guides
- deploying TfNSW's Authorised Engineering Organisation (AEO) framework
- continuously improving TfNSW's Asset Management Framework
- collaborating with the Transport cluster and industry through open engagement

The AEO framework authorises engineering organisations to supply and provide asset related products and services to TfNSW. It works to assure the safety, quality and fitness for purpose of those products and services over the asset's whole-of-life. AEOs are expected to demonstrate how they have applied the requirements of ASA documents, including TfNSW plans, standards and guides, when delivering assets and related services for TfNSW.

Compliance with ASA requirements by itself is not sufficient to ensure satisfactory outcomes for NSW Transport Assets. The ASA expects that professional judgement be used by competent personnel when using ASA requirements to produce those outcomes.

About this document

This document provides guidelines for track reconditioning. This document can assist in the investigation, design and rehabilitation of existing track formation and ballast.

This document is a second issue.

The changes to previous content include the following:

- revision of some definitions
- additional information added for clarity
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1. **Introduction**

Track reconditioning involves the removal of rail, sleepers, ballast and material underneath to a predetermined depth of the existing formation and the reconstruction of these components in accordance with T HR CI 12110 ST *Earthworks and Formation* together with drainage improvements. Reconditioning is generally carried out due to bearing capacity failure of the formation, a drainage failure or to replace the fouled ballast with clean ballast where ballast cleaning is not possible due to the local conditions.

2. **Purpose**

The purpose of this document is to provide guidance for track reconditioning.

This document is prepared to assist in the site investigation, design and rehabilitation of the existing track formation and ballast.

2.1. **Scope**

This document provides guidance for track reconditioning for different scenarios of the track failures in TfNSW Metropolitan Heavy Rail Network (formerly known as RailCorp network). Refer to TS TOC 1 *Train Operating Conditions (TOC) Manual - General Instructions* which defines the areas associated with the network.

These guidelines are recommended courses of action only. The AEO responsible for managing the track assets should choose the appropriate course of action based on the type of failure and the required level of service.

This document covers the following:

- determining the need for reconditioning
- investigation prior to track reconditioning
- basic design model for track formation design
- capping materials
- drainage
- geosynthetics
- track reconstruction solutions
- chemical stabilisation
- construction considerations
- platform stability during track reconditioning
• stability of other structures
• rock foundation

2.2. **Application**

This guideline applies to AEOs who perform civil maintenance tasks and designs of track reconditioning for TfNSW Metropolitan Heavy Rail Network.

3. **Reference documents**

The following documents are cited in the text. For dated references, only the cited edition applies. For undated references, the latest edition of the referenced document applies.

**Australian standards**

AS 1289.6.3.2 Methods of testing soils for engineering purposes – Method 6.3.2: Soil strength and consolidation tests – Determination of the penetration resistance of a soil – 9 kg dynamic cone penetrometer test

AS 3706.2 Geotextiles – Methods of test – Method 2:-Determination of tensile properties – Wide strip and grab method

AS 3706.3 Geotextiles - Methods of test – Method 3: Determination of tearing strength – Trapezoidal method

AS 3706.4 Geotextiles – Methods of test – Method 4: Determination of burst strength – California bearing ratio (CBR) – Plunger method

AS 3706.7 Geotextiles – Methods of test – Method 7: Determination of pore-size distribution – Dry-sieving method

AS 3706.9 Geotextiles – Methods of test – Method 9: Determination of permittivity, permeability and flow rate

**Transport for NSW standards**

ESC 200 Track System

TMC 300 Structures General

T HR CI 12130 MA Track Drainage

T HR CI 12111 SP Earthwork Materials

T HR CI 12060 ST Retaining Walls

T HR CI 12065 ST Station Platforms

T HR CI 12110 ST Earthworks and Formation

T HR CI 12130 ST Track Drainage
T HR TR 00192 ST Ballast

Other reference documents

A.J. Scala 1956, Simple Methods of Flexible Pavement Design Using Cone Penetrometers, New Zealand Engineering, Volume 11, No. 2


Roads and Maritime Services RMS – QA Specification 3051 Granular Base and Subbase Materials for Surfaced Road Pavements

4. Terms and definitions

The following terms and definitions apply in this document:

AEO Authorised Engineering Organisation

ASA Asset Standards Authority

ballast cleaning process for removing fines from in – track ballast by removing the ballast from the track, sieving it and returning graded ballast to the track in a continuous operation. Often includes adding of new ballast

capping layer a layer of compacted, specified coarse grained material that provides a sealing layer to the earthworks

CBR California bearing ratio; Load expressed as a percentage of a standard load, required to penetrate a specimen of soil for a specified distance at a given rate (AS 1289.0)

compaction process of packing soil particles more closely together by rolling or other mechanical means so that air is removed from the voids thus increasing the dry density of the soil (AS 1289.0)

crib ballast the track ballast located between adjacent sleepers

DCP dynamic cone penetrometer

formation an earthworks structure including all foundation, structural treatment and capping layer, on which ballast is laid

formation level finished level at the top of capping at the centre of the formation preparatory to laying ballast

geocell a polymeric cellular structure, consisting of a regular open network of connected strips, linked by extrusion or adhesion or other methods
geogrid a polymeric structure, unidirectional or bidirectional, in the form of manufactured sheet, consisting of a regular network of integrally connected elements, which can be linked by extrusion, bonding or interlacing, whose openings are larger than the constituents.

geosynthetics the range of polymeric products comprising eight main categories: geotextiles, geogrids, geonets, geomembranes, geosynthetic clay liners, geofoam, geocells and geocomposites (AS 7638)

gatechnical engineer an appropriately qualified and experienced engineer, acting for an AEO, with relevant competencies for geotechnical risk assessment, geotechnical investigation, design, construction and maintenance activities relating to geotechnical assets

geotextile a permeable, polymeric (synthetic or natural) textile material, in the form of manufactured sheet, which may be woven, nonwoven or knitted

GPR ground penetrating radar

MARV minimum average roll value is derived statistically as the average value less two standard deviations

OHW overhead wiring

rail level theoretical level of the running surface of the rails. In the case of superelevated track it is the low rail.

RMS Roads and Maritime Services

resurfacing the combined process of levelling, lining and tamping track

rockfill fill compacted almost exclusively of fragments of broken rock. It generally consists of a large portion of gravel, cobble, and larger sized fragments, and could contain large open voids

spoil excess (surplus) material and/or contaminated material from excavations which is not required to complete the works, or material from excavations whose quality is unacceptable for work

sub-ballast permeable capping which is more appropriate than the impermeable capping under certain circumstances where the foundation consists of free draining materials such as rockfill or sands. Sub-ballast limits the fouling of ballast by preventing upward migration of fine material from the subgrade.

subgrade the existing ground below the capping layer upon which the track structure is constructed; provides a stable foundation for the capping and ballast layers and comprises imported soil in embankments and an in situ material or imported soil in cuttings

TfNSW Transport for NSW

unsuitable material the material that occurs in the borrow site or below the foundation level of embankment and is not considered as suitable due to its adverse characteristics
5. Determining the need for reconditioning

The purpose of track reconditioning is to reconstruct the track formation and to reballast to restore the track structure to a standard that is appropriate for the current or anticipated future track loading. A clear understanding of the nature of the track problem and its extent is necessary before determining the need for track reconditioning.

Photographs which illustrate examples of track formation problems are shown in Figure 1 through to Figure 8.

![Figure 1 - Loss of track support due to track formation failure – heave in ballast shoulder or cess](image)

Heave in the ballast shoulder or cess is generally observed in soft saturated subgrades and is characterised by progressive deformation due to shallow shear failures. Heave is evident in the ballast toe or beyond the edge of the ballast. Progressive failure results in the formation of a 'ballast pocket' below the track. When saturated, the trapped water within the ballast pocket aggravates the formation stability. A heave also causes further deterioration as it blocks the cess drainage.
A dip in the track may indicate ballast settlement or a subgrade problem. When a track dip cannot be corrected through normal track maintenance process, it may indicate that the problem involves track foundation inadequacies at deeper levels.

Mud pumping occurs due to the attrition of fine grained subgrade by the overlying ballast or the attrition of heavily fouled ballast itself in the presence of trapped water. Mud pumping can also occur at track sections over rigid slabs; see Figure 15 and Figure 16. Water can get trapped within the ballast due to a number of reasons. Track depression, fouled shoulder ballast, deep
ballast pockets and dysfunctional drainage are some of the causes for trapping water within the track structure.

The creation of slurry occurs in the formation at the ballast and subgrade interface; the slurry is pumped up through the ballast under cyclic movement of the sleepers during rail traffic. Mud pumping can progressively lead to localised deep subgrade failures.

Figure 4 - Mud volcano due to poor drainage and vegetation growth

Mud volcanoes are generally observed at track locations underlain by rigid formations or rigid slabs. For example, shallow jointed rock subgrade or lime treated subgrades. Rigid formation or the slab can crack due to repeated train loadings. As a result, trapped water underneath is squeezed out through cracks with fine soil particles in the subgrade. The movement of sleepers under train loading causes the material underneath the slab to disintegrate. In the long term this can create a void underneath the rigid slab.
Figure 5 - Ballast fouling and wet subgrade

Main sources of ballast fouling are known to be ballast breakdown, foreign particle infiltration from top especially on coal routes and subgrade or capping upward infiltration. Heavy fouling is observed mostly in old track constructions where a proper capping layer has not been installed.

Figure 6 - Mud pumping through ballast due to water trapped in the formation
Ballast attrition is known as polishing of the ballast due to cyclic movements of the sleeper under train traffic. This is evident by the light grey powder on the ballast and rounded ballast particles. Ballast attrition reduces the frictional properties of the ballast and eventually leads to track stability problems.

Impeded track drainage can lead to bog hole formation. The trapped water within the track structure results in slurry formation under cyclic train loads. Bog hole formation is found to occur in both soft rock cuttings and fill locations. If left untreated, then the bog holes can lead to progressive formation failure and severe track geometry problems.
Track reconditioning should be carried out when any of the following conditions are present:

- continued poor track performance - evidenced by the rapid deterioration of the top (vertical alignment of the rails) or the top and line (as defined in ESC 200 Track System) of the track despite repeated attempts at resurfacing, ballasting or ballast cleaning
- visible signs of formation failure - evidenced by heaving beyond the ends of sleepers or between sleepers
- bog holes – ballast is fouled or mud is actively pumping through the ballast

Track reconditioning usually requires removal of the track. However, some of the track problems can be solved without removal of the track.

Track reconditioning methods that do not require track removal include the following:

- shoulder and crib ballast replacement (manual and machine)
- cut-off drains (see Section 5.1 for further information)
- sledding
- ballast cleaning
- lime slurry injection

Track reconditioning methods that require track removal include the following:

- skim reconditioning (see Section 5.2 for further information)
- formation reconstruction (see Section 5.3)

When the track is removed and the formation is lowered to increase height clearances, the correct ballast depth should be provided. The reconstruction of the lowered formation should follow the investigation and design principles set out in this guide.

### 5.1. Formation drainage option

In some situations track conditions can be improved sufficiently without reconditioning if drainage of the formation is improved (see Section 9 for details on drainage). Cut-off drains installed across the whole track to a level below the ballast formation interface will drain the depressions in the formation. These cut-off drains or finger drains should typically be at intervals of 3 m.

The removal of the shoulder ballast and its replacement with clean ballast releases water trapped in the track profile, while the replacement of the crib ballast with clean ballast improves track performance.

Cess drains should be lowered below the formation level to permit drainage.
5.2. Skim reconditioning

Skim reconditioning is a viable solution only when the following applies:

- the formation has not failed and no improvements are required for the subgrade
- no original capping
- possible to raise the track

During skim reconditioning, the track is removed and the clean top ballast is excavated. The fouled bottom ballast is graded and compacted to form a structural capping layer. A 50 mm thick capping layer should be laid on the exposed compacted fouled ballast layer to provide a smooth cross fall and to fill any voids that are present. The track is then re-laid and ballasted.

This method is generally used when replacing timber sleepers with concrete sleepers.

5.3. Formation reconstruction

Formation reconstruction is generally known as full reconditioning. Full reconditioning involves subgrade improvement (as required), the installation of a new capping layer and laying fresh ballast, together with the provision of drainage improvements.

6. Investigations prior to track reconditioning

Track improvement requires an adequate field investigation to assess the existing condition of the track substructure. The assessment of the track substructure should include the assessment of ballast, capping, subgrade and the existing drainage conditions of the track and surroundings that can impact the track stability.

The causes of track formation failure and the details of the subsurface conditions should not be assumed before or during track reconditioning work. All reconditioning projects should have a geotechnical investigation carried out by a competent geotechnical engineer at the early planning stage.

The geotechnical investigation should include, but is not be limited to, the following:

- subsurface conditions – depth below rail and the condition of ballast, capping, subgrade, bedrock and any existing geotextiles or any other objects
- ground water level
- details and the conditions of the existing drainage installations, cess and access road levels below rail and conditions, and existing drainage inlets and the outlets in the area
- determination of the cause of failure – foundation failure, ineffective or poor drainage conditions, ballast fouling, mud pumping
• adjoining structures – effect on stability of platforms, other footings, overhead wiring structures and culverts if any
• reconditioning options – ballast cleaning, skim reconditioning or full reconditioning
• reconditioning design – depth of excavation below rail level and back filling layers and so on
• subgrade improvement – using geosynthetics, rock fill or geocells
• drainage improvements
• any other observations that may affect the track performance such as mud pumping on the adjacent track

Intrusive field investigations require locating underground services in the area before commencing the investigation.

6.1. Investigation procedures

The investigation of a track should consist of the following:

a. Excavation of test pits at regular intervals – The test pits should be excavated at approximately 20 m to 100 m intervals depending on the length of the track section, or at predetermined locations in the four foot and at obviously failed locations.

Test pits are excavated to determine the following:
  o depth and condition of the ballast
  o existence, depth and condition of the capping
  o condition, compactness or consistency and type of subgrade
  o existence, the depth and condition of other materials or objects if any
  o degree of saturation of all material layers
  o information about the interface profile, if visible, to indicate the degree of rutting or consolidation
  o ground water level
  o any ballast contamination
  o obtain adjacent footing depths of abutments, platforms and so on
  o depths to the undertrack crossings, if any, located within the investigation depth

The depths to each layer should be measured below the low rail level.

Investigations should include bog holes, broken pipes, blocked pipes or voids.
Investigations should be located between two sleepers and preferably in the four foot or the outside rail and extend to below the formation level, or about 1.2 m below the rail level as shown in Figure 9.

Figure 9 - Ballast depth and formation investigation for reconditioning

Excavations across the whole track between sleepers provide the most information, especially about the formation profile. These excavations are expensive and intrusive and should be done less frequently as a control measure.

Excavation should not proceed if ballast collapse continues to occur into the test pit.

b. In situ strength tests using a dynamic cone penetrometer (DCP) or similar penetration test instrument should be conducted close to the rail. This is to estimate the in situ California Bearing Ratio (CBR) profile. The DCP test should be carried out in accordance with AS 1289.6.3.2 Methods of testing soils for engineering purposes – Method 6.3.2: Soil strength and consolidation tests – Determination of the penetration resistance of a soil – 9 kg dynamic cone penetrometer test. Tests should start from below the ballast layer and continue to a minimum depth of 2.5 m below rail level to provide an estimate of the in situ CBR value.

c. Samples of the subgrade should be selected for classification testing, and to assist in the design of graded filters (sub-ballast) or geotextiles or to determine if stabilising materials can be effectively used in improving subgrade performance.

d. Samples of the top and bottom ballast should be taken for contamination testing and to determine ballast recovery for ballast recycling if not contaminated. Sample size should be a minimum of 30 kg in weight.

e. A description of the degree of saturation of the track subsurface should be recorded; details of the cess drainage and any existing systems, and an evaluation of its condition should be undertaken.
f. Survey details of the track – details of cess drain inverts, culvert inverts and adjacent areas, and areas beyond boundary if necessary, are required for the design of drainage improvement, assessment and recommendations. Complete drainage design will require separate detailed investigation.

g. Test pits should not be left open and backfilled with same or better quality material.

6.1.1. **Investigation of track by using ground penetrating radar**

Investigation of the track using ground penetrating radar (GPR) is a nondestructive technique which provides high resolution radar images of the subsurface. This involves sending radar pulses into the substructure and measuring the reflected waves off the material boundaries and interpreting the return wave based on electromagnetic properties of substructure layers.

Studies have shown that this method can locate the interfaces of the track bed, and distinguish the fouled ballast from the clean ballast, track sections of possible track formation problems due to varying moisture content. However, this method will not provide information on subgrade strength. This technique can be used for determining platform wall thickness, structure footing thickness and conditions.

GPR provides the following benefits:

- nondestructive method for the evaluation of substructure conditions and performance
- determining ballast and capping layer thicknesses
- ballast depth irregularities
- variation in ballast fouling
- identification of sites for renewal by ballast cleaning
- locating the track bed interfaces with continuous profiling
- providing information on subsurface shear zones and increased water content of embankments
- providing information of void locations
- minimising survey time due to high speed GPR scanning and data acquisition
- ability to monitor the track sub-structure deterioration over time
- lowering risk to staff as this reduces working near operational tracks
- detection buried objects such as large boulders within the subgrade
- locating subsurface drainage pipes and trenches
- cost effective method
Note: One of the limitations of GPR is that it is strongly influenced by the presence of metallic objects like steel sleepers.

7. Basic design model for track formation design

The basic design model consists of the standard 300 mm ballast thickness below the sleeper supported by 150 mm thickness of capping material as shown in Figure 10. This is satisfactory when the underlying subgrade material provides sufficient support. The underlying subgrade is required to have a minimum CBR of 8.

![Figure 10 - Track formation – basic design model](image)

Refer to T HR TR 00192 ST Ballast for ballast depth requirements, and T HR CI 12111 SP Earthworks Materials for capping material requirements.

For the tracks on fill, the material immediately beneath the capping layer (structural fill)) should have a soaked CBR ≥ 8. The required thickness of this material varies depending on the quality of the founding material. The thickness 'H' of structural fill material for different founding material is given in the Table 1.

Refer to T HR CI 12111 SP for structural fill material requirements.

<table>
<thead>
<tr>
<th>Founding material – CBR</th>
<th>Thickness 'H' (mm) structural material</th>
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</thead>
<tbody>
<tr>
<td>&gt;3% to 8%</td>
<td>500</td>
</tr>
<tr>
<td>&gt;1% to 3%</td>
<td>1000</td>
</tr>
</tbody>
</table>

DCP testing is carried out, during field investigation for track reconditioning, to a minimum depth of about 2.5 m below rail level to determine the strength of the formation. A correlation between DCP tests and CBR can be used to estimate the subgrade CBR. Refer to Appendix A for details.
8. **Capping materials**

Capping as specified in T HR CI 12111 SP is used for some or all of the following reasons:

- reduce the applied stresses on to the subgrade (generally a layer of 150 mm thickness (minimum) is sufficient for satisfactory subgrade conditions)
- fill in irregular over break situations in rock excavations to assist in drainage
- provide a drainage barrier to shed storm water from above
- provide separation between the ballast and the subgrade

The performance of the capping depends on the quality of the material, the quality of its compaction on placement and the finished crossfall.

Refer to T HR CI 12111 SP for capping material requirements.

Refer to T HR CI 12110 ST for compaction requirements.

8.1. **Flexible impermeable capping**

Capping material as specified in T HR CI 12111 SP should be used to provide a high strength flexible impermeable granular capping layer. This layer is designed to seal the subgrade and direct surface water away from the track structure. Capping acts as a structural layer reducing stresses to the subgrade. Any material that is used as capping should be tested for compliance before use.

The correct compaction levels and the crossfall should be achieved as specified. Poorly compacted capping saturates rapidly and fouls the ballast. This can result in further track and ballast problems.

Refer to T HR CI 12110 ST for compaction requirements.

Refer to Section 5.1 and Section 9 of this document for drainage requirements.

8.2. **Sub-ballast**

Sub-ballast can be more appropriate than an impermeable capping where the foundation consists of free draining materials such as rock fill or sand.

Sub-ballast can provide a better solution than impermeable capping in areas where the subgrade is constantly wet, or in soft rock formations. The performance of sub-ballast is not diminished by saturation to the same extent as capping. Sub-ballast is also more easily compacted.

In addition to the load bearing capacity, the sub-ballast is designed as a filter material to limit fouling by subgrade material and to prevent fouling the ballast.
Sub-ballast is used for the following purposes:

- spread vertical load from the ballast
- prevent intermixing of ballast and subgrade
- prevent upward migration of fines from the subgrade into the ballast
- permit migration of moisture
- prevent subgrade attrition by ballast

The grading of the sub-ballast is important and should be specifically designed for a particular subgrade and ballast. Laboratory testing of both the subgrade and the ballast is required to be able to design a grading for sub-ballast. Minimum thickness of the sub-ballast layer should be 150 mm.

9. Drainage

The root cause of the track formation problems in most instances is found to be the water remaining in the substructure layers for prolonged periods.

The success of any existing track or reconstructed track formation is determined by the following:

- the effectiveness of the drainage of water from the ballast above
- the capping and of the subsoil water beneath the capping
- the effective drainage of runoff water accessing the right of way

An effective drainage system should be constructed as part of track reconditioning. The benefit of track reconditioning will not be realised if the drainage is not improved in the area.

T HR CI 12130 ST Track Drainage provides requirements for designing and construction of track drainage for the track formation during reconditioning.

The cross fall of the top of capping should be constructed in accordance with the basic design model given in the Section 7.

The following factors should be taken into account for track drainage during reconditioning work:

- removal of water from the formation and diversion of water away from the track for discharging to a water outlet
- preventing the drain blockages with fines
- preventing ballast spill into the drains
- erosion control of the drained water
• preventing water seepage and ground water runoff from entering the rail corridor to protect the formation

• installing flushing points for maintenance purposes

• effect of drainage system located adjacent to the existing structures such as platforms, retaining walls, overhead wiring structures and abutments and so on

For surface drainage to be effective, grades should be uniform, without local hollows. Ponding of water in cess drains or surface drains results in gradual deterioration of the formation strength.

Subsurface drains should be constructed in the following situations, where:

• adequate surface drainage cannot be provided due to site specific constraints

• the gradient is inadequate for the surface drainage towards the drainage outlet

• any restrictions are applied to the surface drainage

Reconditioning should not create a condition where water ponds beneath the track.

If the investigation discovers saturated conditions, then a subsoil drainage system is required. Subsoil drains are slotted pipe drains to intercept the ground water.

Subsoil drainage is required for the following reasons:

• drain any porous subsoil material

• lower the water table where it is near the ground surface

• reduce excess pore water pressure due to train loadings in foundations or artesian pressure, for example, springs

Subsoil drainage systems require headwalls at the outlets and flushing points for maintenance. These features should be clearly visible and signposted. The design should specify the maintenance plan including inspection and flushing frequency.

More detailed information on surface and subsoil drains is available in T HR CI 12130 ST Track Drainage and T HR CI 12130 MA Track Drainage.

The cess drains are surface drains and should be provided at sides of the track and parallel to the track to drain the surface water flowing along the formation level. The top of cess drains should be lower than the top of the formation to facilitate drainage and to divert water away from the tracks. The cess drains should be cleaned to prevent any blockages and to facilitate drainage towards the water outlets.

Catch drains should be provided on top of the cuttings to divert water away from the cutting and to prevent water flowing down over the cutting face to the track area.
10. Geosynthetics

Geosynthetics have been used in track reconditioning because it is believed that benefit can be gained in subgrade support and separation of the dissimilar materials in the track structure. Experience and investigations reveal that geosynthetics provide little benefit unless used appropriately and can create additional problems.

The most appropriate uses of geosynthetics in track reconstruction are as follows:

- filtration and separation
- subgrade support

The geosynthetics for filtration, separation and subgrade support have significantly different properties. Better performance in one area can mean a reduced performance in the other.

Geosynthetics installations within the track formation should not impede future track maintenance activities such as tamping and ballast cleaning.

The durability of geosynthetics should be considered when selecting the product. Durability of geosynthetics is generally linked to the following:

- duration of exposure to sunlight on site
- soil conditions
- composition and structure of geosynthetics
- expected lifetime of the construction
- exposure to moisture

10.1. Geotextiles

Geotextile is a permeable geosynthetic made of either woven or non-woven textile materials. Geofabric is also often used to describe a geotextile.

The basic functional requirements for geotextile that is placed in a rail track are as follows:

- Maintain separation of two types of materials of different particle sizes and gradings that would mix under the influence of repeated loading and water migration through the track.
- Filter or hold back soil particles while allowing the passage of water without clogging.
- Allow seepage water away from the track formation layers while holding back the soil particles. Seepage flow can be both laterally and longitudinally along the plane of geotextile and by the gravity through the geotextile without building up of excess pore water pressures.
- Reduce the subgrade deformation due to the load and increase the load bearing capacity due to better stress distribution.
If the reinforcement is required for the formation layers, then geogrid should be the appropriate geosynthetics.

### 10.1.1. Separation of dissimilar materials

Geotextiles are commonly used to provide separation of differently graded materials and the retention of earth material from migration to different zones.

If a geotextile is installed in the track without adequate drainage provision, then water can retain in the track structure and the instability of the track can get worsened.

Generally geotextiles are not recommended to be placed beneath the ballast and capping interface. If geotextiles are considered to be placed at the ballast capping interface, then the benefits should be assessed to confirm its site suitability for each case by taking into account the following:

- Geotextiles were originally placed beneath the ballast to reduce fouling of the ballast by fine material from the formation. It was also used when the capping had not been sufficiently compacted. However, research of ballast performance has shown that where the subgrade and capping are constructed properly, the major contribution to ballast fouling is from ballast breakdown and contamination from the surface. The presence of geotextiles, therefore fails to protect the ballast from contaminants. Local experience has shown that in many cases, the material above the geotextile is fouled to a greater extent than the material below it.

Figure 11 shows an example of complete clogging as a result of material fouling.

![Figure 11 - Excavated geotextile showing complete clogging in service](image)

- The geotextile can suffer severely from abrasion by the ballast and very quickly loses its separating capabilities. Where the geotextile has been used in wet and soft conditions or
when capping has not been compacted adequately, the high dynamic loads from rail traffic induces extreme pressures at the ballast formation interface. As a result, the filtering action of the geotextile becomes negligible.

- Ballast cleaning operations have also been severely hampered by the presence of the geotextiles. Damaged geotextiles can create further formation problems.

When placing capping or sub-ballast material over coarse rock fill, a geotextile is necessary to prevent the fine material of the capping from falling into the voids of the coarse fill.

### 10.1.2. Filtration

Using geotextiles in subsoil drainage systems is recommended as it avoids the costly process of graded aggregate filters. A geotextile wrapped around coarse aggregate or a slotted pipe provides substantial cost savings. However, it is necessary to sample and test the soils in which the subsoil drain will be placed to determine the appropriate geotextile to use. Some soils can only be filtered by specific types of geotextile. Soils with a high content of fine silts and clays require a detailed investigation and in some cases cannot be drained by subsoil drains wrapped in geotextile.

The important properties of the geotextile are its filtering properties, hydraulic properties and the strength properties which maintain the integrity of the geotextile during and post construction process. See Table 2 and Table 3 for guidance of the properties of geotextiles.

### 10.1.3. Drainage applications

Geotextiles allow drainage while retaining the soil particles. It can control the excess pore water pressure build up within the subgrade as well.

Geotextiles used for drainage applications require adequate permeability and transmissibility to drain the water away from the formation layers. At the same time the pore size of the geotextile should be fine enough to retain fine soil particles in the track substructure.

The selection of suitable geotextiles with appropriate hydraulic properties, pore size and strength for individual applications is important. Provisions should be made to drain the water out of the track structure in combination with the track drainage system, so that no water will be retained within the geotextile or the surrounding soil layers.

### 10.2. Geogrids

A geogrid is specifically designed to provide tensile reinforcement to the track substructure. Geogrids are superior to geotextiles in this function because of their higher modulus and tensile strength. The performance of a geogrid should not be destroyed by coarse aggregate.

The geogrid selection should be on the basis of the grading of the material in contact with it. The grid opening size is related to the maximum size of the aggregate with which it interlocks.
The manufacturers provide selection criteria for their products for various uses. Different variants are available as composite material where a geotextile is bonded to the geogrid.

For situations where severe construction constraints exist, a geogrid is placed below the structural fill to reduce subgrade deformation due to load and to reduce the amount and thickness of the structural fill required. A geogrid for such a purpose is required to have a high tensile strength and low elongation and to develop good bond with the contact material.

The recommended minimum strength is 20 kN/m when the geogrid is transverse to the track and 20 kN/m when it is longitudinal to the track. The interlocking of the geogrid with aggregates is important. When selecting a geogrid, attention should be paid to the profile and rigidity of the grid webbing. A geogrid with a square web profile and high rigidity will perform well in interlocking with aggregate.

The durability of geogrids should also be considered for each application.

10.3. Geocells

Geocells are rigid polymer strips that can be arranged vertically in a three dimensional cellular structure and filled with granular material. The compartmentalised polymer strips containing the in-filled soil can make a stiff and stable mattress like structure supporting the track formation.

Remedial design associated with geocells should take into account the following:

- appropriate product for strength and durability
- appropriate installation technique without damage during construction
- appropriate drainage construction
- appropriate drainage provisions and installations
- appropriate infill material and compaction
- bearing capacity of the subgrade

10.4. Properties of geosynthetics in track reconstruction projects

The properties given in Table 2 and Table 3 are minimum values for guidance only. Selection of the appropriate geosynthetics should be made for each case based on the soil type in contact with it, its intended functions and the applied stress during installation and service.

Table 2 shows the minimum average roll values (MARV) of geotextiles that primarily prevent mixing of dissimilar materials.
### Table 2 - Separation and stabilisation

<table>
<thead>
<tr>
<th>Property</th>
<th>Test method</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tearing strength, trapezoidal</td>
<td>AS 3706.3</td>
<td>555 N minimum</td>
</tr>
<tr>
<td>Burst strength, CBR method *</td>
<td>AS 3706.4</td>
<td>4000 N minimum</td>
</tr>
<tr>
<td>Grab tensile strength</td>
<td>AS 3706.2</td>
<td>1000 N minimum</td>
</tr>
<tr>
<td>G rating</td>
<td>Ausroads</td>
<td>3500</td>
</tr>
<tr>
<td>Pore size 1</td>
<td>AS 3706.7</td>
<td>240 μm maximum</td>
</tr>
<tr>
<td>Permittivity</td>
<td>AS 3706.9</td>
<td>0.5 sec^{-1} minimum</td>
</tr>
</tbody>
</table>

*Note 1 – Generally the geotextile pore size should be less than the largest soil particles to be restrained.*

Table 3 shows the properties of geotextiles MARV that can be used for drainage and filtration applications.

### Table 3 - Drainage and filtration

<table>
<thead>
<tr>
<th>Property</th>
<th>Test method</th>
<th>Value Class A</th>
<th>Value Class B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength, trapezoidal</td>
<td>AS 3706.3</td>
<td>590 N minimum</td>
<td>400 N minimum</td>
</tr>
<tr>
<td>Burst strength, CBR method</td>
<td>AS 3706.4</td>
<td>4600 N minimum</td>
<td>3400 N minimum</td>
</tr>
<tr>
<td>Grab tensile strength</td>
<td>AS 3706.2</td>
<td>1200 N minimum</td>
<td>800 N minimum</td>
</tr>
<tr>
<td>G rating</td>
<td>Ausroads</td>
<td>3500</td>
<td>2500</td>
</tr>
<tr>
<td>Flow rate @ 100 mm head</td>
<td>AS 3706.9</td>
<td>$Q_{100} \geq 50$ l/m²/s</td>
<td>$Q_{100} \geq 50$ l/m²/s</td>
</tr>
<tr>
<td>Permittivity</td>
<td>AS 3706.9</td>
<td>0.5 sec^{-1} minimum</td>
<td>0.5 sec^{-1} minimum</td>
</tr>
<tr>
<td>Coefficient of permeability</td>
<td>AS 3706.9</td>
<td>$40 \times 10^{-4}$ m sec^{-1} minimum</td>
<td>$40 \times 10^{-4}$ m sec^{-1} minimum</td>
</tr>
</tbody>
</table>

Class A - applications where installation stresses are more severe than class B

Class B - applications where fabrics are laid against relatively smooth surfaces with no direct contact with sharp edged angular aggregates and compaction requirements are light

### 11. Track reconstruction solutions

Track reconditioning is usually carried out if the subgrade does not meet the criteria given in Section 7. Methods of improving the performance of the existing subgrade material should be considered in the planning of the reconditioning. The options for track reconstruction detailed in Section 11.1 and Section 11.2 are suggestions only. Each situation should be assessed by a geotechnical engineer for conditions particular to the site.
11.1. Track reconstruction by structural fill methods

Reconstruction of the formation is conducted by excavation of unsuitable material and replacement with suitable material to suit the basic design model. See Figure 10 for basic design model of track formation.

For soft subgrade, this option would require sufficient time and space to permit the removal of unsuitable material and replacement with suitable material to provide the support defined in the model.

Refer to T HR CI 12111 SP and T HR CI 12110 ST for structural fill requirements and preparation and compaction for earthworks construction requirements. A capping layer of 150 mm (minimum) is required. If the structural fill also meets the requirements for capping as stated in T HR CI 12111 SP, in which case the structural fill would continue up to the formation level.

11.2. Track reconstruction using reinforcements of rock fill and geosynthetics

The use of geotextiles or geogrids, geocells and rockfill can assist to reduce the amount of excavation and fill material especially, in soft subgrade.

11.2.1. For subgrade with CBR = 3 to 8

Where the subgrade has been found to have an in situ CBR of between three and eight, a geogrid placed below a quality fill material reduces the excavation depth. The fill material is recommended to have a CBR of at least 20 at 100% standard compaction and a minimum thickness of 350 mm. The geogrid reinforcement should be of a high strength and low elongation type material, otherwise the benefits will not be realised. See Figure 12 for a diagram showing geogrid reinforcement. Refer to Table 3 for geotextile strength requirements.
11.2.2. For subgrade with CBR = 1 to 3

For geogrid reinforcement for subgrade with CBR 1 to CBR 3 see Figure 12.

![Figure 12 - Geogrid reinforcement](image)

Where the subgrade has been found to have a CBR of between one and three, a geogrid is recommended in place of a geotextile at the subgrade level. The recommendations stated in Section 11.2.1 for the type of fill apply with a minimum thickness of 500 mm in accordance with Figure 12.

11.2.3. For subgrade with CBR = 1 or less

Where the subgrade is found to have a CBR of one or less, coarse rock fill can be used to reduce the amount of excavation. A minimum excavation of 500 mm is recommended. Geotechnical advice should be obtained from a geotechnical engineer.

Typical coarse rock fill that is 50 mm to 200 mm in size (with no fine material) is tipped or rolled into the soft material. The quality of the material should be strong and durable. More material is added until the rock fill no longer penetrates the mud and the surface is just free of mud. A geogrid is then laid and the filling continued with rock fill up to the underside of the capping, with appropriate static rolling. No wheeled or tracked machinery should be permitted on the subgrade until sufficient rockfill has been placed to support it. An additional layer of geogrid should be added where the filling depth exceeds 500 mm.

The surfaces of the rock fill should be covered with a geotextile for separation between the rock fill and the capping as shown in Figure 13.
11.2.4. For subgrade with CBR = 1 or less (alternative method)

An alternative to the method outlined in Section 11.2.3 is to install geocells to improve the load support capacity of soft subgrade. This is suitable for soft ground conditions where the ground water is close to the surface. Geocells consist of an array of plastic hexagonal cells infilled with granular material. Geocells have been shown to increase the soil strength by confinement, reducing lateral spreading and causing the composite to behave as a more rigid mattress.

The thickness, composite arrangement and number of geocell layers should be individually designed for each particular situation. Design considerations should also include bearing capacity of in situ subgrade creep under cyclic loading and durability due to exposure to acids, bases, UV radiation or other environmental conditions. In a typical installation an excavation is made to the designed level of the geocell base. A geotextile is laid over the excavation to minimise the upward transmission of fines through the geocell into the ballast. The geocell is laid out, filled and the infill compacted. A 150 mm thick capping layer should be provided above the geocells with a cross fall of 1:30. Refer to T HR CI 12111 SP for capping material requirements.

See Figure 14 for a typical geocell reinforcement arrangement.
Ballast should be installed to the depth specified in T HR TR 00192 ST above the capping. The geocell installation is a solution to provide support, not to reduce ballast thickness.

The geocell used should meet the durability requirements of the track section being rehabilitated.

12. **Chemical stabilisation**

Chemical stabilisation of the subgrade is the improvement of the subgrade by mixing or injecting lime or, a lime and fly ash mixture into the subgrade.

Lime is an effective additive for stabilising high plasticity clayey soils. Mixing lime with clay minerals improves workability, reduces the plasticity and swelling potential in the presence of water. As a result, the strength of the soil is increased. The subgrade should be scarified and lime spread and mixed uniformly.

The most effective way to stabilise clays with lime is, in place mechanical mixing which disperses the lime among the clay particles. The subgrade should be scarified and lime spread and mixed uniformly. This requires adequate track possession and work space.

Lime injection methods require numerous inspection points to guarantee the uniform distribution of lime in the subgrade.

For less plastic clays, the use of lime to stabilise the clay is not as effective. However, procedures are available for lime and fly ash injection that will provide an improvement in strength of the subgrade. These procedures provide high-pressure injection to significant depths at close spacing.

Certain soils do not react with lime and cannot be effectively treated with it. Lime injection or stabilisation is not recommended unless sufficient investigation is conducted to support their use. Laboratory testing is required to determine if a soil is lime reactive. Geotechnical advice and laboratory testing is necessary to determine the appropriate percentage of lime required for the soil on a case by case basis.

Stabilisation by the injection of cement slurry is not recommended.

Other chemicals that are proposed to assist in the stabilisation of the subgrade should be evaluated for practicability and effectiveness. Geotechnical advice should be obtained to assist in the evaluation of any products that are being marketed as possible stabilisation measures.
13. **Construction considerations**

Construction considerations during track reconditioning include the following:

- minimise or eliminate construction traffic over exposed subgrade material
  
  After excavation of the ballast the formation is not usually very firm and the passage of wheeled or tracked machinery causes significant additional damage.
  
  Where possible, the construction method should be designed to avoid trafficking over the exposed formation. Excavating spoil by placing excavating machinery on adjacent undisturbed track or ground and pushing new fill in front of construction equipment is necessary when dealing with a soft formation. The structure of some clay is destroyed by the remoulding action of construction equipment. This damage to the soil structure is permanent and can reduce the material strength and affect the future performance of the formation.

- compact new fill in layers no deeper than 200 mm when loose

- thinner layers are required for light compaction equipment

- use proper compaction equipment and compact to the specified density

- construct the correct cross fall

- construct adequate drainage

14. **Platform stability during track reconditioning**

The stability of platforms is a common issue during track reconditioning works.

The age and the condition of the platforms should be considered before track reconditioning is undertaken. Some older platform can have heritage significance. The method of track reconditioning should minimise any effects on the platform.

A thorough geotechnical investigation and analysis of the stability of platforms is essential prior to any excavations during track reconditioning to maintain the integrity of platform wall.

An analysis would be required for bearing, sliding and overturning failure of the platform wall.

Test pits and DCP tests should be performed at selected locations along the platform wall to obtain the footing profiles, founding depths and soil conditions for analysis.

The existing platforms and foundations in the rail network are of varied construction depending on the time of construction, soil conditions and topographical features of the location. Some of the platform types in the network include the following:

- posts and panel

- brick walls on brick strip footings (deep or shallow)
• concrete ‘U’ sections founded on compacted ground
• concrete ‘L’ sections and panels, anchored

If the excavations are too close to the wall, this can undermine the footings leading to a bearing failure. If the walls are on shallow footings, the removal of material in front of the wall to excessive depths reduces the passive pressure on the wall causing a sliding or overturning failure of the wall. Before excavating for track reconditioning, it is important to know the founding depth of the platform wall and the founding material. If excavations are carried out below the water table, this can allow the soil to move towards the excavation causing movement of foundation.

Precautions should be taken to ensure the platform wall is not destabilised during the excavation and not to undermine the platform footings. Refer to T HR CI 12060 ST Retaining Walls, T HR CI 12065 ST Station Platforms and TMC 300 Structures General for requirements.

The excavations should not be left open overnight. The excavations should be backfilled and compacted at the end of each day's work.

Heavy mobile plant should not be allowed within 2 m of the platform edge when the excavations are still open. Compaction adjacent or near platform walls should be non-vibratory or hand held.

Strengthening of platform walls by means of anchoring should be considered where required prior to excavation work.

Monitoring of platform movement should be considered during the track reconditioning, if required.

15. Stability of other structures

Track reconditioning can affect other nearby structures such as retaining walls, bridge abutments, OHW structures and culverts.

The stability of those structures should be checked and ensured as described in Section 14.

16. Rock foundation

The investigation of track on a rock base follows the basic steps detailed in Section 6. Where there is evidence of track fouling as a result of foundation problems and the investigation reveals that the track is constructed on hard shale or sandstone, the potential of foundation rock pumping should be investigated by a geotechnical engineer.

16.1. Foundation rock pumping

Foundation rock pumping occurs in horizontally bedded rock under track work where the cyclic loading conditions cause deflections of the rock strata and abrasion along rock bedding planes. In the presence of water, fine material, resulting from the abrasive action, is forced through
fractures in the rock and contaminates the ballast. Depending on drainage conditions at the
track level, isolated cones of rock fines can exist in the ballast. The ballast can eventually be
completely fouled with fines. See Figure 15 for a diagram showing the pumping mechanism.

\[\text{Figure 15 - Bedrock formation pumping mechanism}\]

Pumping can occur up to 2 m below the track formation level. Where foundation rock pumping
is believed to be occurring, more detailed investigation of the rock strata is required. Rock
coring investigation methods including a geological evaluation of rock exposed in adjacent
cuttings are recommended. The cores should be examined to determine the depth at which the
abrasion at bedding planes is taking place. This type of investigation should be carried out by a
geotechnical engineer.

Refer to Figure 16 for a photograph showing bedrock formation pumping.

\[\text{Figure 16 - Example of bedrock formation pumping}\]

When the fouling of ballast due to pumping is severe and the track geometry is badly affected,
remedial measures are required to address rock pumping. The presence of water close to the
formation level is a major contributor to the problem and deep drains are necessary to control
the pumping. These drains should be in excess of one metre below the formation.
Alternative solutions to reconditioning should be considered where deep drains cannot be provided. These solutions can include structural concrete slabs and ground anchors. Specialist geotechnical and structural advice should be sought to determine the appropriateness of alternative solutions.

16.2. Irregular rock excavation

Track reconditioning is required where there is fouling of the ballast in rock foundation areas as a result of failure of the capping or abrasion of the rock. In rock cuttings where the excavated rock surface is irregular, water can be trapped in depressions under the track. This condition produces accelerated abrasion of the surface of the rock formation and fouling of the ballast. This situation can also arise during reconditioning where rock has been removed by ripping or hydraulic rock breakers.

A uniform cross fall on the top of the rock formation is important. In these situations any over break or depression should be filled with material that has characteristics as close as possible to those of the rock. A cement stabilised road base material, stabilised capping or roller compacted dry concrete are satisfactory. Layers of cement stabilised material should be greater than 50 mm thick to prevent disintegration under traffic.
Appendix A  Dynamic cone penetrometer – Guide to use and interpretation

The dynamic cone penetrometer (DCP) has become a valuable tool in geotechnical engineering to identify soft material and to identify the boundary between suitable and unsuitable material. A measure of soil strength can be found from the past correlations by Scala (1956) and Morris (Australian Road Research Board, 1973). Scala’s work focused predominantly on clays. The report by ARRB focused on clays in the Bankstown area.

The results of the DCP are recorded as number of blows for 50 mm of penetration. A sample sheet for recording the number of blows is provided in Figure 17. An equivalent in situ CBR can be obtained by using the graph provided in Figure 18. The practitioner should be aware of the in situ subgrade moisture content dependency of the assessed CBR in this manner.

For clay material, a reasonable level of confidence is possible; however, with sands and ash, a little correlation exists to obtain shearing or bearing capacity values.

The results obtained from layers of sand or ash, indicates a much lower resistance to penetration than for clay, but do not indicate correspondingly low bearing capacities. Experience in geotechnical engineering is necessary to make reliable interpretation of low DCP results in ash and sand.

The information from the DCP sounding in blows per 50 mm is plotted on a linear scale with depth and correlated with information from boreholes or test pits to identify critical layers. Figure 18 shows the relationship between CBR and number of blows.

Consistently high values in excess of 2 blows/50 mm over a 350 mm to 500 mm depth can be interpreted as a layer of material that provides good track support. Inconsistent values indicate heterogeneous material and the possibility of inadequate support. Rocky fill material provides extreme variations and should be interpreted carefully. Refer to AS 1289.6.3.2 for more information.
### DYNAMIC CONE PENETROMETER TEST

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<thead>
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<th>Depth below ground level (m)</th>
<th>Number of Blows per 50mm</th>
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<td>1.950 - 2.000</td>
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</tbody>
</table>

**Figure 17 - Sample of a DCP test record sheet**
Figure 18 - Graph for obtaining equivalent CBR value
Appendix B  Recommended reading

The following documents provide supplementary information to the contents of this guide:

A.J. Scala 1956, Simple Methods of Flexible Pavement Design Using Cone Penetrometers, New Zealand Engineering, Volume 11, No. 2


Roads and Maritime Services RMS – QA Specification 3051 Granular Base and Subbase Materials for Surfaced Road Pavements