# Formation and Earthworks – Train System

# Engineering Standard

Rail Commissioner

CS1-DOC-001538

Government of South Australia
Rail Commissioner

# DOCUMENT CONTROL

## Document Status

| DOCUMENT OWNER: UNIT MANAGER, TRACK & CIVIL ENGINEERING | | | |
|---|---|---|---|
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| **Document Review Schedule:** | | This document is due for review as required | |

## Document Amendment Record

| REVISION | CHANGE DESCRIPTION | DATE | PREPARED | REVIEWED | APPROVED |
|---|---|---|---|---|---|
| 0 | First release | December 2018 | Royce Mariadas | Keith Charlton | Mark Pronk |
| 1 | Maintenance requirements moved to TMP | February 2020 | Sophie Wilkinson | Royce Mariadas | Mark Pronk |

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## 1. Introduction

The Department of Planning, Transport and Infrastructure (DPTI) owns, operates and maintains the Adelaide Metropolitan Passenger Rail Network (AMPRN) under the Rail Accreditation assigned to the Rail Commissioner.

This document provides design, monitoring and maintenance requirements for formation and earthworks on the AMPRN.

This standard supersedes *CP-TS-959: TransAdelaide Code of Practice Volume 2- Train System Formation and Earthworks.*

## 2. Purpose

The purpose of this standard is to ensure that:

a) Earthworks are designed and constructed appropriately
b) Earthworks are maintained safely;
c) In the event of earthworks becoming unstable or failing, precautions and actions are taken to ensure safety of train operations.

## 3. Scope

This standard provides requirements for earthworks within the rail corridor for the:

a) Design and construction of new earthworks and geotechnical structures;
b) Monitoring and maintenance of new and existing earthworks;
c) Identification of existing geotechnical special locations; and
d) Determination of defined events which may lead to unsafe conditions at those locations.

This standard is not intended for use for temporary works and piled foundations.

## 4. References

### 4.1. DPTI Documents

| DOCUMENT NAME | DOCUMENT NUMBER |
|---|---|
| Infrastructure Management and Principles | CP-TS-953 |
| Structures | CP-TS-957 |
| Engineering Standard – Drainage – Train System | CS1-DOC-001218 |
| Supply of Pavement Materials | Master Specification, R15 |
| Drafting Standard for AutoCAD Drawings | AM4-DOC-000364 |
| Stormwater Design – Road Design Standards | DD 300 |
| Identification and Numbering of Technical Documents and Drawings | FR-AM-GE-806 |
| Rail Safety Risk Management | PR-RC-RM-004 |
| Development and Approval of Engineering Waivers | PR-AM-GE-807 |
| Design Decision Records Procedure | PTS-MU-10-EG-PRC-00000016 |
| Type Approval for Railway Products | AM4-DOC-000466 |
| Management of Change | PR-RC-MC-009 |
| Management of Change - AMPRN Asset Baseline | PR-AM-GE-674 |
| Identification and Numbering of Technical Documents and Drawings | FR-AM-GE-806 |
| Rail Drawings Acceptance Procedure | PR-AM-GE-1013 |

| | |
|---|---|
| Procedure for Assessment of Engineering Competence for Rail Safety Workers | PR-AM-GE-1170 |
| Formation Repair Mud-hole Treatments | TC4-DOC-000457 |
| Register of Special Locations | KNet # 13060019 |
| Drainage and Earthworks Assets – Train System – Technical Maintenance Plan. | CS1-DOC-002684<br>KNet # 15177637 |

### 4.2. DPTI Drawings

| DOCUMENT NAME | DOCUMENT NUMBER | KNET# |
|---|---|---|
| Standard Drawing, Cross Section, Cut and Fill in Rail Reserve, Typical Details | CS1-DRG-360493 | 13383391 |
| Standard Drawing, Formation and Earthworks, Single and Twin Tracks, Typical Details | CS1-DRG-360494 | 13383668 |

### 4.3. Australian Standards

| DOCUMENT NAME |
|---|
| AS 1289 Methods of Testing Soils for Engineering Purposes |
| AS 5100 Bridge Design |
| AS 1141 Methods for Sampling and Testing Aggregates |
| AS 1726 Geotechnical Site Investigations |
| AS 4799 Installation of Underground Utility Services and Pipelines within Railway Boundaries |

## 5. Design

### 5.1. Design Codes

Design of earthworks and geotechnical structures shall, where necessary, include geotechnical investigation and specialist geotechnical advice of the site and or materials. Geotechnical structures and their stability should be determined in accordance with the following documents:

- Railway loading shall be determined in accordance with the Australian Bridge Design Code unless otherwise specified by the Unit Manager Track & Civil Engineering.
- Geotechnical stability shall be determined in accordance with the appropriate Australian Standards.

### 5.2. Design of Earthworks and Formation

#### 5.2.1. Earthworks and Formation for New Construction and Major Upgrading Works

The design of earthworks and formation shall ensure stability and durability throughout their design life. An assessment of existing ground conditions shall be carried out and inputs shall be obtained by site investigation for design works. Site investigation shall be carried out in accordance with AS 1726.

Earthworks and formation for new mainlines and loops, backroads and sidings shall comply with the appropriate dimensions shown on Drawings CS1-DRG-360493 and CS1-DRG-360494

The following elements shall be taken into account in design:

- Cess and sub surface drainage

- Special requirements for drainage in multiple track areas
- Top Drains above Cuttings
- Presence of contaminated material

Earthworks and formation design shall:

a) be undertaken by a suitably experienced geotechnical engineer taking into account the proposed operating regime for the line, expected ground movements and the existing subgrade and drainage requirements.

b) target a desirable formation design life of 50 years minimum by reducing subgrade stresses to an acceptable long term value.

c) include drainage design to cater for run off.

### 5.2.2. Formation

#### 5.2.2.1. Formation types

a) The formation is the surface on which the track (including ballast) is laid. Traditionally, it was the finished surface of the earthworks. However, present day practice requires the material in the finished earthworks to be analysed for its ability to satisfactorily support the track whether wet or dry. A layer of graded material is introduced to cap the formation. The thickness of the capping layer is a minimum of 200mm of PM1/20QG in accordance with Supply of Pavement Materials, Specification - R15.

b) Track built before the adoption of the present day methods in sub-clause (a) may show signs of stress and necessitate the undertaking of remedial work. Where the track shows signs of formation failure or signs of stress, a geotechnical assessment should be carried out to design a capping along with treatment to the sub-grade, if required, as a result of the geo-technical investigation and assessment.

When track is to be upgraded on existing formation, the formation should be free of identifiable defects such as:

i. Excessively narrow shoulders;
ii. Retained moisture;
iii. Ballast settlement; or
iv. Formation deformation.

#### 5.2.2.2. Formation Crossfall Design

The finished formation for double track shall be graded to fall towards the sides of the track. On single track, the fall will be all to one side (whichever is the most convenient to accommodate drainage). The design of the fall in areas of multiple tracks (e.g. yards & platforms) shall be carried out in conjunction with the design of the stormwater drainage system to ensure that the formation is adequately drained. The degree of cross-fall shall range from 1 in 20 to 1 in 45 depending on other influences (such as cuttings in solid rock, over bridges, etc.). On all other areas the preferred cross fall is 1 in 40.

#### 5.2.2.3. Formation depth design

Changes in formation level relative to top of rail may occur due to changes in rail type, sleeper type or structure type. At these locations, the change in depth shall occur over a relative grade of 1 in 200 without compromising the stormwater drainage system design for the location. Where this will create a low point in the formation, the stormwater drainage design shall incorporate suitable transverse drains to remove water from the formation.

#### 5.2.3. Capping Design

Capping layer is a layer of selected materials compacted to seal the subgrade underneath and provides support to the ballast layer above.

Capping material shall comply with properties mentioned in section 5.3.7 and shall be laid on a subgrade with a minimum soaked CBR of 8%.

### 5.3. Earthworks and Formation Materials

#### 5.3.1. Definition of Earth and Rock

Earth is defined to include all materials such as soil, clay, sand, gravel and weathered or loose rock which could normally be removed by ripping by a bulldozer of nominal 290-kilowatt brake power with heavy duty tyres.

Rock is defined to include any material, which cannot be so removed and shall include boulders greater than 1 cubic metre in volume.

#### 5.3.2. Topsoil

Topsoil shall be removed over the area to be occupied by the completed works plus a clearance of 2 metres either side, to a depth of 150 mm. Topsoil suitable for vegetation propagation shall be placed in a stockpile clear of the work to enable its re-use in landscaping and revegetation. Topsoil stockpiles shall be appropriately protected from erosion by either vegetating or covering.

#### 5.3.3. Unsuitable Material

Unsuitable material includes topsoil, peat and other highly organic soils, logs, stumps, perishable material, refuse, stones, material susceptible to spontaneous combustion, free draining materials susceptible to scouring (e.g. very fine sand), silt clay lumps and organic clay and material with soaked CBR<1. Such material shall be excavated, to a minimum depth of 300 mm, and disposed off-site except for topsoil required for vegetation propagation.

Where unsuitable material exists in excessive depths the advice of a Geotechnical Engineer is required.

Dispersive soils can be used only in accordance with guidelines provided by a Geotechnical Engineer and with prior approval.

#### 5.3.4. Free Draining Filter Material

Free draining filter material shall be crushed rock, river gravel or slag composed of hard, strong and durable particles from an approved quarry source, and complying with the following Table 5.3.4:

**Table 5.3.4: Free Draining Filter Material Properties**

| TEST METHOD REQUIREMENT | DESCRIPTION | CRITERIA | MIN FREQUENCY OF TESTING |
|---|---|---|---|
| AS1289, 3.6.1 | Particle Size Distribution<br>% Passing 53.0mm sieve<br>%Passing 37.5mm sieve<br>% Passing 26.5mm sieve<br>% Passing 19.0mm sieve | <br>100<br>90-100<br>20-55<br>0-5 | One per 1000t |
| AS1141, section 32 | Soft and friable particles | Max. 5% | |
| AS1141, section 30 | Clay Lumps | Max. 0.5% | |
| AS1141, section 23 | Los Angeles Value (Grading A) | Max. 30% | |
| AS1141, section 6 | Particle density | Min. 2.3t/m3 | |

### 5.3.5. Embankment Material

Embankments are earth fill or rock fill structures above an existing or excavated surface to create the rail track formation.

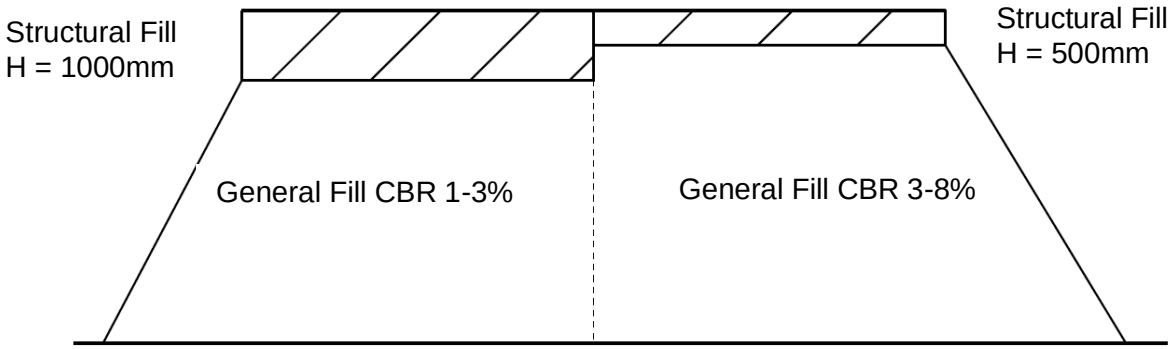
The embankment shall consist of two zones of embankment material.

1. Structural Zone
2. General Fill

The zones of the embankment shall be defined by the thickness of the structural zone (H) at the top of the embankment as determined by the following relationship with the general fill:

General Fill CBR*3-8% - H = 500mm
General Fill CBR*1-3% - H = 1000mm
* *(Soaked California Bearing Ratio, Standard Compaction).*

**Figure 5.3.5: Depth of Structural Fill Required**




Material for use in the structural zone shall comply with the following Table 5.3.5

**Table 5.3.5: Structural Fill Material Properties**

| TEST METHOD REQUIREMENT | DESCRIPTION | CRITERIA | MIN FREQUENCY OF TESTING |
|---|---|---|---|
| AS1289, 3.6.1 | Particle Size Distribution<br>% Passing 53.0mm sieve<br>% Passing 2.36mm, sieve<br>% Passing 425um, sieve<br>% Passing 75um, sieve | <br>80-100<br>15-100<br>0-70<br>0-30 | One per 1000t |
| AS1289, 3.1.2 | Liquid Limit | Maximum 40 | |
| AS1289, 3.3.1 | Plasticity Index | Maximum 20 | |
| AS1289, 5.2.1 | Maximum dry density | Minimum 1.8t/m3 | |
| AS1289, 6.1.1 | Soaked California Bearing Ratio (Standard compaction) | Minimum 8% | |

Unsuitable material (refer 5.3.3) shall not be used as General Fill. General Fill shall have a Liquid Limit less than 40, and the product of the Liquid Limit and the percentage passing the 425 micron sieve shall not exceed 1800. Non-cohesive filling with a Plasticity Index less than 6 shall only be used with prior written approval and in accordance with such conditions as may be required to protect the filling from erosion.

Material not complying with the above requirements shall only be used with prior approval.

### 5.3.6. Cutting

Cuttings are the removal of soil or rock from its natural location to create rail track formation.

A typical design for cuttings shall provide stable batter slope and secure foundation for the track structure. The design shall include drainage and cutting floor stabilization as necessary.

In cuttings, subgrade for formation shall meet the minimum requirement of soaked CBR not less than 8 %. The subgrade shall be tested as per AS 1289, 6.6.1.

Structural fill materials and depths shall be used as mentioned in Table 5.3.5 and Fig 5.3.5 to improve the strength of the subgrade if required. Other treatments to improve subgrade strength can be adopted when the treatment is designed by a specialist geotechnical engineer and approved by the Unit Manager, Track and Civil Engineering.

The design of cuttings shall also consider a buffer zone at the toe of cuttings to accommodate rock slips or soil washout.

### 5.3.7. Formation Capping Material

The formation capping material shall have properties that conform to the requirements for PM1/20QG to R15: Supply of Pavement Materials as given below.

**Table 5.3.7 PM1/20QG Material Properties**

| TEST METHOD REQUIREMENT | DESCRIPTION | CRITERIA | MIN FREQUENCY OF TESTING |
|---|---|---|---|
| TP134 | Particle Size Distribution<br>% Passing 26.5mm sieve<br>% Passing 19mm sieve<br>% Passing 13.2mm sieve<br>% Passing 9.5mm sieve<br>% Passing 4.75mm sieve<br>% Passing 2.36mm, sieve<br>% Passing 425um, sieve<br>% Passing 75um, sieve | <br>100<br>95-100<br>77-93<br>60-83<br>44-64<br>29-49<br>13-23<br>5-11 | One per 1000m3 |
| AS1289.3.1.2 | Liquid Limit | Max.25 | |
| AS1289.3.3.1 | Plasticity Index | Min 1%<br>Max 6% | |
| AS1289.3.4.1 | Linear Shrinkage | Max 3% | |
| AS1289.5.2.1 | Maximum dry density | Min.2.0t/m3 | |
| AS1141.23 | LA Abrasion Grading 'B' | Max 30% | |
| AS1289.6.1.1 | Soaked California Bearing Ratio (Standard compaction) | Min.50% | |

Notes for Table 5.3.7

1) The quarried pavement material shall have a uniform grading and shall not be graded from the coarse limit of the grading envelope to the fine limit of the grading envelope, or vice versa.

2) Compacted to 95% (min) Maximum Dry Density obtained by AS.1289 5.2.1 & with 9 kg surcharge.

### 5.3.8. Geofabrics and Geogrids

The use of geofabrics and geogrids should be considered by the geotechnical engineer carrying out the formation and capping design in the following situations:

1. Where poor subgrade conditions exist (i.e. where CBR value is 10 or less);
2. Through road crossings,
3. For the full length of passenger platforms.

**Geofabrics** shall be used to provide segregation of materials.

**Geogrids** shall be used to provide increased layer strength and to allow soft formation materials to be spanned.

## 5.4. Earthworks Construction

### 5.4.1. Clearing and Grubbing

The whole area to be occupied by the completed works including ancillary earthworks for drains and diversion levees is to be cleared and grubbed plus a clearance of 2m from tops of cuttings and toes of embankments. Clearing includes removal and disposal of all trees, stumps, logs, timber, scrub,

vegetation, minor structures, refuse and other material unsuitable for incorporation in the work.

Grubbing is to be carried out to the level of 0.5m below natural surface or 1.5m below finished earthworks level. Holes left after grubbing are to be filled with sound material and compacted in layers as for embankments.
If required by the environmental plan, fauna habitat logs shall be placed well clear of construction activities.

Disposal of all excess materials shall be managed in accordance with relevant regulations

### 5.4.2. Excavation for Cuttings

Excavation shall be carried out to the lines, levels, dimensions and slopes as designed. The excavated faces shall be neatly trimmed and the top edges of the cuttings neatly rounded. Under cutting of the slopes will not be permitted under any circumstances. Batter slopes in rock cuttings in excess of 3m high and closer than 6m from the track centreline shall be determined on the advice of a Geotechnical Engineer or Geologist.

Unless otherwise specified, cutting slopes shall be in accordance with the following Table 5.4.2:

**Table 5.4.2: Typical (Minimum) Cutting Slopes**

| MATERIAL | SLOPE HORIZONTAL : VERTICAL |
|---|---|
| 1 Sand | 2.5 : 1 |
| 2 Wet clay, loose gravel | 2 : 1 |
| 3 Sandy clay, boulders and clay, compact gravely soils | 1.75 : 1 |
| 4 Poor Rock (Fractured, friable) | 1.5 : 1 |
| 5* Sound shale dipping sharply towards railway formation, tight cemented gravel | 1 : 1 |
| 6* Ordinary Rock | 1 : 1 |
| 7* Solid well bedded rock | 0.25 : 1 |

** Maximum height without bench - 7m*
** A Geotechnical Engineer or Geologist shall confirm batter slopes in rocks*

Excavation shall be carried out in such a manner as to prevent erosion or slips, working faces shall be limited to safe heights and slopes, and the surface shall be drained to avoid ponding and erosion.

Slope design shall be reviewed following site inspection and investigation during excavation

Overhanging, loose or unstable material likely to slip should be cut back, removed or stabilised.

Rock cuttings and exposed rock surfaces shall be excavated so as to obtain smooth, uniformly trimmed surfaces. Batters in cuttings shall be carried around curves in an even and regular manner. Finished batters shall not have a slope steeper than designed.

Excavation at the base of the cutting shall be finished at a level to suit the capping thickness, and with crossfalls as designed. Compaction of the top 150mm layer in the base of cuttings or of material required to fill over-excavation shall be compacted to compaction standard A (refer to section 5.4.5), or shall be solid rock. In addition the finished surface shall not deviate from the bottom of a 3 metre straight edge laid in any direction by more than 25mm.

### 5.4.3. Preparation of Embankment Base

Preparation includes clearing, grubbing, and removal of topsoil and removal of unsuitable material and subsequent restoration under sections 5.3.2 and 5.4.1 it also includes cutting of terraces into slopes, scarifying and compaction of embankment base and provision of drainage works as specified below.

Where embankments are to be constructed on a natural slope or on the slope of an existing embankment steeper than 4 to 1 (horizontal to vertical), the existing slope is to be cut in horizontal terraces at least 1.5m wide. The terraces are to be cut progressively as the embankment is constructed. Suitable material excavated in cutting the terraces may be incorporated in the embankment but unsuitable material shall be removed.

The area of the base of the embankment shall be scarified to a depth of 100mm, parallel to the embankment axis. A layer of general fill 100mm thick shall be spread over the scarified area, and the whole shall be compacted to compaction standard B (refer to section 5.4.5).

Where designed, a drainage blanket is to be provided at the base of the embankment. It shall comprise a geotextile fabric (as approved by a Geotechnical Engineer) laid along the base and around a layer of free draining filter material to a depth of 300mm, with spall protection at the outlet. Manufacturer's instructions concerning installation of the fabric shall be followed.

### 5.4.4. Placing Embankment Material

Embankments shall be constructed full width in horizontal layers. Layers shall not exceed 200mm thickness unless it can be shown that the specified compaction can be obtained for a thicker layer. Notwithstanding, maximum layer thickness shall be 300mm. Layers or pockets of substantially varying material should be avoided. The maximum particle size should be less than 2/3 of the compacted layer thickness. Construction shall be carried out in such a manner as to ensure adequate drainage of the works, and to avoid scour and erosion. The top of the earthworks is to be trimmed in accordance with the requirements for preparation for capping.

### 5.4.5. Compaction on Embankment Material

Compaction shall be carried out at a moisture content which will allow the specified compaction to be achieved.

Where necessary water shall be added uniformly or drying carried out. Bond between layers is to be ensured, if necessary by wetting or scarifying.
Compaction Standards shall be as follows:

Compaction A — Cohesive soils - Not less than 100% Relative Compaction as determined by AS.1289.5.1.1 (Standard Compaction)

Rock fill or cohesionless soils - No visible deflection of surface under 10 tonne Vibratory rollers after 6 - 8 passes.

Compaction B: — Not less than 95% Relative Compaction as determined by AS.1289.5.1.1 (Standard Compaction).

Embankments shall be compacted to:

General Fill: — Below Structural Zone = Compaction B
Structural Zone = Compaction A

### 5.4.6. Embankment Profile

Embankment batter slopes shall be as designed. Unless shown otherwise, the standard batter slope for embankments shall be 1.75:1 (horizontal: vertical). If stability is expected to be a problem, batters may be flattened to 2:1 or more. Advice shall be sought from a Geotechnical Engineer if there is any doubt concerning embankment stability.

### 5.4.7. Earthworks Near Structures

Care shall be exercised in constructing earthworks within 5m of structures to avoid damage to the structures. Non-vibratory equipment should be used within this distance and adjacent to the structure further limitations, as defined in Table 5.4.7, apply. Adjacent to weep-holes free draining filter material encapsulated in geofabric should be placed, horizontally for at least 300mm from, and vertically for 450mm above, the weep – hole unless specified otherwise. Select back fill material complying with the requirement for capping material except that a minimum of 60% shall be retained on 2.36mm sieve, shall be used adjacent to structures as follows:

**Table: 5.4.7: Select Fill near Structures**

| STRUCTURE | MINIMUM WIDTH & HEIGHT OF SELECTED FILL | COMPACTION METHOD |
|---|---|---|
| Bridge abutment and wing walls | 2m wide for full height | Hand held compaction equipment for full structure height for a distance of 2/3 H (H=overall height of structure) |

| | | |
|---|---|---|
| Pipe culverts | 300mm width each side and above top pipes | Hand held compaction equipment for distance D from pipe to top pipe (D=diameter of pipe) |
| Box culverts and culvert wing and retaining walls | H/3 wide for full height | Hand held compaction equipment for full structure height for a distance of 2/3 H (H=overall height of structure) |

### 5.4.8. Tolerances For Earthworks

#### 5.4.8.1. Vertical Tolerances

**In Embankments**

Top of structural zone: +0 to –50mm
Top of general fill zone: +40 to –40mm

**In Cuttings**

Other than rock;
Floor of cut (top of common earthworks): +40 to –40mm
Top of structural Zone (Refer Clause 5): +0 to –50mm

Rock;
Floor of cut (top of common earthworks): +0 to –80mm

**At Transitions between cut and fill**

Floor of cut to fill transition +0 to –50mm

**Top of benches and berms**

Top of benches and berms +50 to –50mm

**Formation Crossfall**

The constructed formation crossfall shall not be flatter than 1 in 40, or be flatter by more than one tenth of the design crossfall, whichever is steeper.

**Table 5.4.8.1 Absolute minimum as-constructed crossfall**

| DESIGN CROSSFALL | AS-CONSTRUCTED CROSSFALL ABSOLUTE MINIMUM |
|---|---|
| 1 in 25 | 1 in 27.5 |
| 1 in 30 | 1 in 33 |
| 1 in 40 | 1 in 40 |

**Formation capping material**

Refer to section 5.3.7

#### 5.4.8.2. Horizontal Tolerances

Base width, width to top of cuts and bottom of fills, widths of benches and berms – not to be less than designed.

Maximum positive tolerance 300mm, unless otherwise agreed.

## 5.4.9. Capping Material

### 5.4.9.1. Preparation for Capping

The earthworks in embankments (or cuttings) shall be placed and compacted to a level 30mm above the base of the capping layer. Immediately prior to the placement of the capping, the fill shall be trimmed by grading to the final profile and compacted by a minimum of three passes of a smooth steel drum roller, which has a static mass not less than 10 tonnes.

The finished, rolled surface shall be true to profile to a tolerance of +0 to -40mm, and shall be free of depressions and ruts.
No traffic other than that required to place the capping shall be allowed on the finished surface.

The capping material shall be transported from the source to the work in vehicles which are so constructed that loss of material does not occur. It shall be suitably damp to prevent segregation during transit.

### 5.4.9.2. Spreading, Placing, Compaction and Trimming of Capping.

The capping layer shall be constructed in layers to a total compacted thickness of 150mm unless otherwise specified. The material shall be spread full width in uniform horizontal layers.

Spreading shall be undertaken by a method which will ensure segregation does not occur, and so as not to rut or disturb the compacted thickness.

Where required for compaction purposes, water shall be added as necessary to achieve optimum moisture content and mixed uniformly with the capping material by approved mechanical means. Compaction shall achieve a minimum density of 95 per cent relative compaction (modified) as determined by AS 1289.5.2.1.

Rock and rock fines shall be distributed throughout each layer so that all voids are filled. The top of the final layer shall be graded and trimmed, and material shall be added and compacted as necessary to produce an even surface.

### 5.4.9.3. Proof Rolling

a) Proof rolling is the process of identifying any unsuitable material by moving heavy plant over the subgrade or existing surface and observing the resultant deformation in the underlying material. Material which is observed to move under the loading of the plant is deemed to be Unsuitable Material.

b) Proof rolling must:
   - in fill, cover all of the existing underlying material which will be covered by fill; in cut, cover all of the formation;
   - be carried out as soon as practicable, and in any case not later than 2 days, after topsoil stripping / clearing and grubbing (in areas of fill) or completion of the formation (in areas of cut);

- where soft ground conditions are present, be carried out after ground improvement processes (e.g. placement of geogrid, ballast and / or working platforms) have been completed; and
- be undertaken prior to any hauling over the prepared area.

c) The plant must move at walking pace (between 3 and 10 km/h) when undertaking proof rolling.

d) Except for small areas, proof rolling must be undertaken by a minimum of 3 passes of heavy plant which complies with the following:
- a pneumatic multi-wheel roller with a mass > 24t; or
- a fully loaded tandem truck or water cart of minimum 10 kl capacity which:
- has ground contact pressure under either the front or rear wheels of not less than 450 kPa per tyre;
- has a ground contact area which is not less than 0.035 m2 per tyre, and
- follows a rolling pattern that ensures the entire ground surface is subject to the specified number of passes.

e) In small areas where the above plant will not fit, at least 6 passes of the heaviest plant practicable must be used for proof rolling. A leg rammer may be used, but a plate compactor is not acceptable.

f) For the purposes of this clause, “pass” means the movement of the plant in a single direction. If the observation of deformation is inconclusive or the extent of unsuitable material is unclear, additional passes must be undertaken until a determination regarding the suitability of the material can be made.

g) Plant complying with the above requirements must be available on site during all earthworks, fill, subgrade and capping construction.

h) Proof rolling must not be carried out over any Utility Services without prior notification to the Utility Service Authority.

### 5.4.9.4. Capping Layer Tolerances

The following tolerances shall apply.

**Width**

The width from the design centreline to the finished top of embankment slopes or toe of batters in cuttings shall in no case be less than the dimensions required by the design.

The finished surface of the formation shall be +/- 25mm of the design level and: -

- The difference of the deviations from the correct level for any two points 20 metres apart on the centreline shall not exceed 10mm.
- The deviation from a three (3) metre straight edge laid on the surface parallel to the centreline shall not exceed 10mm.

**Transverse Slope**

When tested with a three (3) metre straight edge laid perpendicular to the track centre line(s) the deviation from design profile shall not exceed 10mm concavity.

### 5.4.10. Track Reconstruction

In repairing and upgrading the track formation, the following shall be taken into account when preparing the design:

- Excessively narrow shoulders;
- Retained moisture;
- Ballast settlement; or
- Formation deformation (localized and global)
- Rectification of drainage deficiencies
- Removal and disposal of fouled ballast to the formation level.
- Removal and disposal of failed formation material.
- Provision of Capping Material on the original formation
- Provision of sub-surface drains
- Provision of surface drains
- Repair/rectification of degraded, ineffective, blocked or sagging culverts.

Reference should be made to CS1-DOC-001218 Engineering Standard – Drainage – Train System

## 5.5 Defined Events and Special Locations

a) The defined events for sections of track potentially at high risk of geotechnical failure i.e. Geotechnical Special Locations, shall be determined. Defined events in accordance with CP-TS-953 (Infrastructure management and principles) may include earth movement, rainstorms, thunderstorms, earthquake, blasting, or inundation.

b) The defined events at Geotechnical Special Locations may be determined and reviewed through detailed investigation in accordance with CP-TS-953 (Infrastructure management and principles) and analysis in accordance with the above manuals and codes. The analysis shall take into account the environmental conditions at the location and documentation relating to unscheduled inspections resulting from previous defined event occurrences.

c) The register of Geotechnical Special Locations and the defined events requiring actions should be maintained, refer KNet #13060019.

# 6. Monitoring and Maintenance

For monitoring and maintenance requirements of formation and earthworks assets, refer to CS1-DOC-002684 Drainage and Earthworks Assets – Train System – Technical Maintenance Plan.