TS 01051:1.0

CRN CS 410

Standard

Engineering Standard - Geotechnical Formation and Earthworks

Issue date: 30 January 2022

Effective date: 30 January 2022

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Document information

Owner: Director Corridor Infrastructure & Engineering, AMB, SER

Mode Heavy rail

Discipline Civil

Document history

Revision	Effective date	Summary of changes
1.2	30 January 2022	TfNSW template applied.
2.0	30 January 2022	First full UGLRL issue

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1. Purpose, scope and application

This Standard establishes design requirements and acceptance standards for embankments, cuttings and earthworks capping layer.

It is applicable to all Country Regional Network (CRN) mainline and siding tracks.

2. References

2.1. Australian and International Standards

AS 1289 *Methods of testing soils for engineering purposes*

AS 3798 *Guidelines on earthworks for commercial and residential developments*

Unless otherwise specified, all references relate to the latest standard versions, including amendments and relevant superseded standards.

2.2. CRN documents

CRN CS 215 *Transit Space*

CRN CS 240 *Ballast*

CRN CS 330 *Miscellaneous Structure*

CRN CS 420 *Track Drainage*

CRN CS 520 *Level Crossings*

CRN CP 411 *Earthworks Materials*

2.3. Other references

Nil

2.4. Definitions

Authorised Geotechnical Engineer:	A person with delegated engineering authority for geotechnical design activities relating to earthworks.
Borrow Pit:	Excavation made for the procurement of material.
Capping Layer:	Layer of compacted material that provides a sealing layer to the earthworks.
CBR:	Soaked California Bearing Ratio, determined on a compacted sample.
Cohesionless Soil:	Material consisting mostly of sand and gravel mixture, generally with less than 5% fines (i.e. particles finer than 75 µm diameter).

Cohesive Soil:	Material consisting mostly of silt and clay and has a well-defined moisture-density relationship when tested in accordance with AS1289.5.1.1 or AS1289.5.2.1.
Collapsible Soil:	Soil that may suffer a significant decrease in volume under load or when it becomes nearly saturated, which may have existed in this metastable state for a long time.
Compaction:	The process whereby the density of soil is increased by mechanical means. This typically involves, rolling, impact or vibration, or a combination of these processes.
Contaminated Material:	Material that may contain toxic substances or soluble compounds harmful to environment, water supply or agriculture.
Cutting:	An earth or rock excavation that is made below an existing surface to create the railway formation.
Dispersive soil:	Soil that has the ability to pass rapidly into suspension in the presence of water.
Earthworks:	The activities covered by this standard.
Earthworks Level:	Level at the centre of the earthworks prior to placing of the capping layer.
Embankment:	An earth or rock-fill structure above an existing and/or excavated surface to create the rail track formation.
Expansive Soil:	Soil that will suffer a high-volume change when in contact with water. Any increase or decrease in the moisture content of such soil, would cause swelling or shrinkage, respectively. This type of soil is also called *Reactive Soil* and *Swelling Soil*.
Formation:	The earthworks structure including all foundation, structural treatment and capping layer, on which ballast is laid.
Formation Level:	Finished level at the centre of the formation preparatory to laying ballast. It includes the capping layer.
Formation Width:	Width at formation level.
Foundation Treatment:	A special layer or treated zone at the base of a formation for the purpose of reinforcing, strengthening or drainage.
General Fill:	The zone below the structural zone of the embankment.
Geosynthetics:	Prefabricated sheet made of polymeric materials which may be permeable or non-permeable. This material may be used as filter-drainage (if permeable) or foundation reinforcement. It includes geotextile, geonet, geogrid and geocell.
Lot	The defined area along the rail corridor not exceeding one days output, consisting of a continuous portion of homogeneous and/or representative material or end product produced under essentially constant conditions. The Lot length shall be shortened to account for critical infrastructure such as turnouts.
Rail Level:	Design level of the running surface of the rails. In the case of superelevated track, it is the low rail.
Relative Compaction	For cohesive soils, the dry density ratio determined in accordance with AS 1289.5.4.1, or the Hilf density ratio determined in accordance with AS 1289.5.7.1.

	For cohesionless soils, the density index determined in accordance with AS 1289.5.6.1.
Relative Density:	The field dry density expressed in terms of maximum/minimum densities established by laboratory test (used for cohesionless soils).
Right of Way:	The strip of land over which railroads are built.
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 may contain large open voids.
Shoulder Distance:	Distance from the track centreline to the edge of the formation.
Soluble Soil:	Soil containing perishable particles such as gypsum or rock salt.
Stockpile:	Placement of material that has been selected, loaded, transported and unloaded in a heap outside the confines of a borrow pit or of an excavation that forms part of the works.
Structural Zone:	The material designed to carry train loading immediately below the capping (typically not less than the area bounded by a 45° angle from the sleeper ends). .
Top Soil:	A natural surface soil that may contain organic matter.

3. Engineering authority

Design and selection of infrastructure detailed in this standard for use on the CRN may only be undertaken by persons who have been granted appropriate Engineering Authority by the Principal Track and Civil Engineer.

4. Design requirements

4.1. General

Earthworks and formation design includes:

- cuttings
- embankments
- capping layer.

New lines shall be constructed on a corridor wide enough to accommodate earthworks and formation designed and constructed in accordance with the requirements in this document. The corridor shall also accommodate associated drainage and access roads as detailed in relevant CRN engineering standards.

4.2. Design investigation

Before any earthwork activity is undertaken, all necessary assessment and investigation shall be carried out to determine the nature and extent of the work.

In the preliminary assessment, planning and design of earthworks, the following items shall be considered:

- Site investigation (Survey and Geotechnical)
- Adjoining property (Drainage issues and other impacts)
- Preservation items
- Rehabilitation (Clean up and revegetation)
- Drainage (Surface and subsoil)
- Erosion and siltation (Prevention and mitigation)
- Sloping ground, (Issues associated with drainage, stability and erosion)
- Slope stability (Stability of temporary and/or permanent slopes)
- Cuttings and trenches, (Stability of excavation and impact on adjoining structures)
- Retaining structures, (considered if required to reduce batter slopes or support adjacent structures)
- Problematic soils requiring special consideration including reactive (expansive) soils, dispersive soils, collapsible soils, soluble soils, soft-compressible soils, and potential acid or sulfate soils.
- Properties of fill material (Maximum dry density, Optimum moisture content)
- Surcharging of slopes
- Calculation of quantities
- Geosynthetics (Geotextile, Geogrid, etc.) - appropriate use of.
- Construction vibrations, (Impact on adjacent structures and properties)
- Non-potable water to be used for soil compaction
- Contamination of soil, (disposal and/or treatment of).

4.2.1. Site investigations

Site investigation for earthworks may include test pits, bore holes, test rolling, field and laboratory tests or other methods necessary to assess the degree of compaction, strength and composition of the existing filled ground. Analysis of the results obtained from these investigations will allow adequacy assessment of the existing filled ground or the extent of

remedial works that may be required. Such remedial works may include improvement or complete removal of the material.

4.2.2. Adjoining property and infrastructure

Consideration shall be given to the following

- Assessment of adjoining property and infrastructure for the potential for damage due to excavation, compaction, vibration, noise, run-off, dust or other effects of the earthworks
- Liaison with the adjoining owners and obtain all relevant approvals

4.2.3. Preservation items

Surveys are necessary to identify rare flora and/or fauna or heritage items, which may require preservation or relocation. This item shall be carried out in accordance with environmental and heritage regulations and standards.

4.2.4. Rehabilitation

Rehabilitation of areas which are affected by different construction activities such as borrow areas, stockpiles, excavated or fill batters, spoil disposal areas, haul routes, stormwater control, camp, office and workshop sites, should be included in drawings and specifications so that materials such as topsoil, mulched native vegetation (which can contain useful seed stock and nutrients) and bulk- fill materials used for rehabilitation are identified and preserved for re-use. Rehabilitation works should be completed before the constructor vacates the site.

4.2.5. Drainage

Temporary and permanent diversion of permanent or seasonal watercourses prior to or during construction of the earthworks and associated works may affect the quantity or quality, or both, of the stormwater run-off. Special provisions may be necessary to minimise the effects and to protect the legal rights of adjacent and downstream landowners.

Approval from adjacent land owners and relevant authorities shall be obtained prior to the placement of fill on flood prone lands or construction of drainage structures, i.e. culverts in natural watercourses.

The placement of fill or construction of cuts may impact the flow of subsurface water and may lead to localised instability. Special provisions may be necessary to account for the potential effect of the works in such cases.

4.2.6. Erosion and siltation

Protection of the earthworks from erosion, both during and after construction, shall be taken into account. Run-off from the works, and areas affected by the works, may be subject to special

provisions. Siltation of eroded materials in downstream structures requires special consideration.

4.2.7. Sloping ground

Special precautions may be needed where the earthworks are constructed on sloping ground. These include:

- Benching of the surface of the natural ground to assist in the placing of the fill, and to key the fill to the foundation soil
- Berms or benches above, within, or at the foot of cuts to intercept stormwater run-off or detritus
- Subsoil drainage to lower the ground water level
- Stabilising existing failure planes prior to construction

4.2.8. Existing filled ground

Existing filled ground, for which the conditions of the placement are not adequately documented, should not be assumed to be either of the standard of compaction or of the composition adequate to support fill or any other loads. In many cases un-engineered fill and/or domestic refuse may be present which are considered unsuitable to support fill or other loads.

4.2.9. Slope stability

The basis for the assessment of the short and long-term stability of natural slopes, cut-face slopes and fill slopes is:

- Geotechnical investigation and analysis ; and
- Local experience with similar materials under similar conditions.

Each stability assessment needs to take into account any existing slopes, proposed undercut and surcharge of the slopes, dynamic loads (such as induced vibrations, earthquake) and the effect of water seepage on the slopes. Each slope should be selected with regard to the required access, including maintenance.

4.2.10. Trenches

Excavations for trenches require special consideration for support. Relevant authorities place limitations on the maximum depth to which trenches may be excavated without shoring. In this regard, safety regulations should be considered.

The effect of trench excavation on the stability of any adjacent embankment, cutting, formation, track or structure shall also be considered.

4.2.11. Retaining structures

The compaction of fill against retaining structures may induce higher pressures than adopted in the design. The nature of the fill to be used, the specified level of compaction, and the type of compaction equipment to be used, should be assessed in selecting design loads on retaining structures.

Retaining structures are to be designed in accordance with *CRN CS 220 Miscellaneous Structures.*

4.2.12. Problematic soils

Soils requiring special consideration include reactive or expansive soils known as volumetric unstable soils, dispersive soils, collapsible soils, soluble soils, soft-compressible soils, and potential acid sulphate soils.

Adequate suitability tests in accordance with AS 1289 shall be carried out for such soils to assess the nature and potential effects on earthworks.

Reactive or Expansive soils

Materials containing highly expansive clays are considered unsuitable for fills. The properties of such materials can be improved to suit embankment fill by blending with appropriate additives. Additional tests are required to identify expansive soils and to determine improved material characteristics after blending.

Low density or potentially collapsing soils

Low density or potentially collapsing soils such as loess lose their volume when saturated or compacted in or beneath earthworks. When calculating quantities, compression of the fill or foundation of such material should be taken into account.

Potential acid sulphate soils

In certain areas, particularly in coastal marine deposit areas, the presence of considerable amounts of iron sulphates is possible. Disturbing or exposing these soils to air may cause formation of sulfuric acid. Excavation and movement of such soils are subject to strict environmental controls that normally expect chemical treatment to avoid contamination of streams and drains. Consultation with the relevant environmental authority is required prior to the excavation, handling or use of such soils.

4.2.13. Compaction moisture content

The optimum moisture content determined by laboratory methods in accordance with AS 1289 is used for construction control to achieve desired engineering behaviour of the embankment fill. After assessing the suitability of each source material, the maximum dry density and the optimum moisture content shall be determined before starting construction.

The optimum moisture content for compaction under field conditions depends on the material type, equipment used, layer thickness, climate conditions and nature of the foundation. In general, the heavier the compaction effort or the thinner the layer, the lower the optimum moisture content will be. The construction specification or laboratory compaction test results indicate the water content associated with the maximum dry density or relative compaction.

4.2.14. Surcharging of slopes

Cut face and fill slopes, sides of trenches and slopes supported by retaining structures should not be loaded, e.g., by construction equipment, materials, soil and the like, unless the assessment of the slope stability included an allowance for the particular load(s).

4.2.15. Calculation of quantities

In calculating quantities of fill, the following should be taken into account:

- Volume changes due to excavation, spreading and compaction
- Compression of the foundation.

NOTE: The degree of volume change is dependent on the type and texture of the material and required relative compaction. It can be assessed as part of the site investigation, using field density and laboratory compaction tests.

4.2.16. Geosynthetics

Proprietary products are available with particular properties suitable to act as a filter, drainage layer and/or physical separator to allow water flow, whilst avoiding migration of soil particles, or as a tensile reinforcement element. Such materials may be construction expedients, or may form part of the permanent earthworks. Geosynthetics should be carefully chosen for the intended purpose in accordance with CRN Engineering Specification *CRN CP 411 Earthworks Materials* and have an adequate service life under the intended conditions.

4.2.17. Construction activities vibrations

Consideration shall be given to construction activities, particularly those using equipment such as compactors or blasting, that can cause vibrations and damage to nearby structures, either directly from extra stresses transmitted to the structure by the vibration, or indirectly, by causing settlement of the foundations

4.2.18. Non-potable water

Suitability of non-potable water for increasing the moisture content of fill should be evaluated by field and laboratory tests. Saline waters should not be used in the following cases:

- areas where vegetation may be established
- fill where steel or reinforced concrete is buried.

4.2.19. Contamination

Any known or suspected ground or groundwater contamination shall be investigated. Relevant authorities have set limits on the quantity of contaminants permitted in ground in various applications. Removing contaminated soil from the site, importing contaminated soil or keeping it on site requires approval from the relevant authorities. The effects of any investigation on planned earthworks, including safety and environmental aspects, shall be considered

4.3. Design flood level

Where track is on a flood plain, the formation level shall be designed so that it is not overtopped in a 1 in 100-year flood, subject to environmental impact assessment in accordance with legislation and assessment of the impact of potential flooding on earthworks and other structures.

4.4. Formation

The formation for single track mainlines and single track sidings shall comply with the appropriate dimensions shown in Appendix 1

The formation for double track mainlines and double track sidings shall comply with the appropriate dimensions shown in Appendix 2

The formation for multiple track mainlines and multiple track sidings shall comply with the appropriate dimensions shown in Appendix 2 subject to the requirement that the water from one track shall not cross another track to get away. For example, if there are three tracks, there shall be at least one subsurface centre drain.

To allow for maintenance and operations activities, shoulder distances shall comply with the requirements detailed in Table 1 – Shoulder width

Table 1 – Shoulder width

Shoulder distance (mm)	
Plain track	
Main line	4250
Siding	3000
Main line or siding with parallel access road	5500
Special Requirements	
Train crew walkways	4250
Clear width of road from back of any structure	3000

Where the shoulder distance in Table 1 cannot be achieved as part of a new design:

- a risk assessment shall be conducted to consider risks associated with the maintenance and operations activities
- the shoulder distance shall be sufficient to support the track structure and provide protection of formation below.

Where reduced shoulder distances exist due to physical constraints, an assessment shall be made of the need for safety refuges, handhold devices and limited clearance signs. The requirements are specified in CRN Engineering Standard *CRN CS 330 Miscellaneous Structures*.

Track centres shall be in accordance with CRN Engineering Standard *CRN CS 215 Transit Space*.

5. Documentation

All activities of earthworks shall be documented. Appropriate documents should be prepared in the following stages:

- Investigation and planning
- Design and specification
- Construction
- Handover

5.1. Investigation and planning

Investigations for planning of earthworks for use by the designer, the constructor and other interested parties should include the following:

- Outline of the need for, and objectives of, the project
- Site investigation of the project and any associate sites including:
    - foundation and subgrade materials
    - special areas due to presence of groundwater, seepage, rock, problematic soils
    - available fill materials and, where applicable, details of the overburden
    - suitability of the fill materials for the intended purposes
    - classification of materials to be removed off site
    - suitability of water for placement of the fill.
- Where applicable, an outline of other plans that have been considered in the investigation
- The quality assurance requirements for the project.

5.2. Design and specification

The functional requirements of the design should be documented in the specification and drawings for the earthworks project. This documentation should be sufficiently complete to allow the constructor to unambiguously carry out the works, and for the superintendent (and the geotechnical inspection and testing authority, as necessary) to be able to interpret the design and administer the works.

Such documentation will typically include (or have consciously excluded), the following, as well as any other matters that may be of particular importance to the particular project.

- Adequate specification and drawings to allow the proper planning, execution and supervision of the works. Plans, sections and elevations should clearly show areas of earthworks, identifying areas which require specific treatments. Particularly on larger projects, the specification and drawings should adequately define the following:
    - The areas in which spoil may be dumped or stockpiled
    - Restrictions on clearing and stripping
    - Drainage requirements during and after construction

  - Criteria for selection of materials for placement in various parts of the fill and for material to be excluded from fill. Material descriptions should be clear, unambiguous and in accordance with AS 1726
  - Criteria for standard of surface trim of completed earthworks
  - Details of tests, including minimum frequency, to be carried out for testing to ensure the fill complies with the specified criteria
  - The scope of the commission to be given to the geotechnical inspection and testing authority
  - Either the methods to be used for construction or the requirements to be met by test in the finished project. It is generally unwise to mix performance and method specifications. Where a performance specification is adopted, restrictions on methods should be limited to those absolutely necessary (for example, to limit the risk of damage to nearby structures).
- Site investigation information, together with details of, and provisions for, access to any further relevant information for the purpose of design or construction planning. Selective provision of available site investigation data can give rise to serious problems, either engineering or legal, or both, and should not be done without due consideration of the issues involved.
- Any other relevant information in the possession of the designer.

5.3. Construction

Adequate records need to be kept during construction, including conditions encountered, works as executed, as built drawings, testing records and any alterations to the specification and drawings. As a minimum, these records should show the following:

- The areas in which fill is placed
- Levels after stripping
- Location of any trees or large shrubs that may have been removed
- Materials exposed after stripping and the criteria upon which the decision to cease stripping was made
- Levels after completion of the filling
- Details of test rolling, if undertaken
- Types of fill material in various zones
- Sources of fill material in various zones, where applicable

- Location and level of each compliance test, together with test results. Where a test is a retest of a lot that was previously rejected, this should be stated
- Action taken where testing indicated that the specified criteria had not been met
- Any areas in which the fill material or compaction is of a lesser standard or a greater standard than elsewhere on the site

5.4. Site record

Daily diaries and detailed drawings of works, as executed, should be maintained by site staff. Typical site records include:

- A daily geotechnical report, generally appropriate for larger projects
- A geotechnical site visit record
- An earthworks summary report, generally appropriate for small projects

5.5. Handover documentation

Project documentation should comprise handover documentation that includes the following:

- geotechnical investigation reports
    - work as executed drawings
    - quality assurance records including the following:
    - test certificates o acceptance certificates
    - monitoring reports
    - nonconformance reports and concessions
    - signed inspection records
    - site records
- instrumentation details, monitoring records and monitoring requirements if applicable
- maintenance requirements including any tests during the design life
- any other documentation as specified in the contract

6. Cuttings

The design of cuttings shall be subject to a geotechnical investigation and design and shall take into account the potential for failure to adversely impact on the track, property, infrastructure, rail personnel and the public.

Design of cuttings shall provide for excavation of material within the limits of the batters, including benching and terracing of cut batters, cleaning of batter surfaces, treatment of cutting floors and foundation treatment below the track. Cuttings in both soil and rock should provide a stable, safe foundation for the structure.

Benching in cuttings shall be provided in both soil and rock as necessary.

6.1. Excavation

Proposed excavation specified in the design, shall consider:

- erosion
- slip failures
- safe height and slopes angles

Excavation at the base of cutting shall be finished at a level to suit the capping thickness, with cross falls and cess drains provided.

Where the subgrade in the floor of the cutting has a CBR that exceeds that of the structural fill for the adjacent embankment, the floor of the cutting shall be ripped and recompacted for a depth of between 200mm and 300mm depending on the material. The maximum dimension of any particles in the ripped or loosened zone shall not exceed 150 mm.

Where the subgrade in the floor of the cutting has a CBR less than 8, it is to receive similar treatment as would embankment material as detailed in Section 7.2.

6.2. Cut to fill transition

depth of 600 mm below and parallel to the cutting floor as shown in Figure 1.

Following excavation to the cutting floor, a terrace shall be excavated for the width of the embankment to a depth of 600 mm below and parallel to the cutting floor as shown in Figure 1.

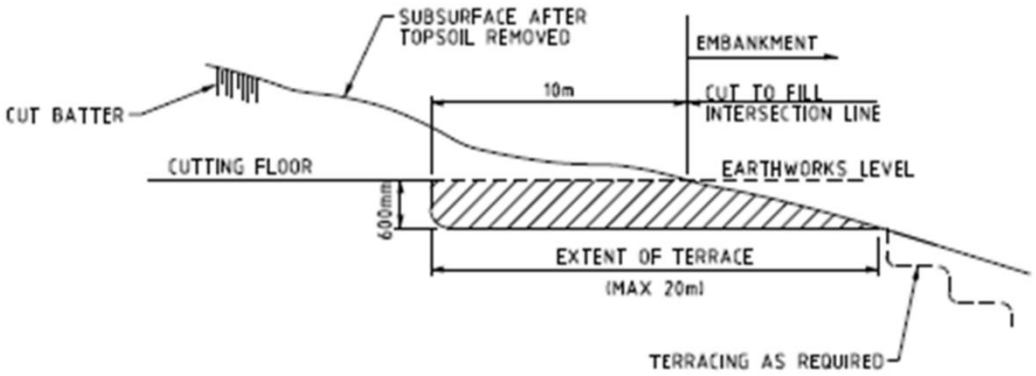


Figure 1 – Cut to fill transition

6.3. Batter slopes

Batter slopes in soil and rock cuttings in excess of 3 m high and closer than 6 m from the track centreline, shall be determined on the advice of the Authorised Geotechnical Engineer.

Unless shown otherwise in the design or as advised above, cutting slopes shall be in accordance with Table 2.

Table 2 – Batter slopes

Material	Slope Horizontal	Slope Vertical
Sand	2.5	1.0
Clay, loose gravel	2.0	1.0
Sandy clay, boulder clay, compacted gravely soil, talus	1.75	1.0
Highly jointed, weathered rock	1.5	1.0
Sound shale dipping sharply towards railway formation, tight cemented gravel *	1.0	1.0
Ordinary rock *	1.0	1.0
Solid well bedded rock *	0.25	1.0

- Maximum height without bench – 7 m.
- * Batter slopes in rocks shall be confirmed by the Authorised Geotechnical Engineer.

Where benches are required, the minimum requirements (shown in Table 3) shall apply.

Table 3 – Benching requirements

Access	Benching requirements
where access for maintenance is required	Bench width shall be a minimum of 4 m graded at an appropriate angle such as 1V:10H back into the batter.
Where access for maintenance is not required	Minimum bench width may be less than 4 m, provided the long-term integrity of the bench in providing and maintaining batter drainage can be demonstrated.

Slope support systems to allow steeper design batters in soil and weathered rock materials may be appropriate to minimise the lateral extent of cutting, particularly on steeper slopes or where property acquisition is required. Such works shall be based on specific geotechnical design.

7. Embankments

7.1. Embankment base

The natural ground at the base of the embankment shall be prepared by the removal of unsuitable material. Unsuitable material shall be evaluated in accordance with *CRN CP 411 Earthworks Materials*.

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

Sloping ground or rock surfaces steeper than 1V:7H, on which fill material is to be placed, shall be benched in the form of horizontal terraces at a width suitable for construction plant for the full width of the sloping ground to be filled.

7.2. Embankment material

Unless otherwise specified by an Authorised Geotechnical Engineer, embankment materials shall comply with CRN Engineering Specification *CRN CP 411 Earthworks Materials*,.

The embankment shall typically consist of two zones of embankment material:

- General Fill
- Structural Zone.

7.3. Compaction standards

To achieve a stable and durable embankment, the material shall be prepared and compacted in accordance with Section 10.

General Fill: Compaction B

Structural Zone: Compaction A

7.4. Sampling and testing

After compaction of each layer, sampling locations will be selected for moisture content and relative density tests.

Field density and laboratory tests shall be carried out in accordance with Australian Standards. The test results must be representative of the tested layer at its full depth, width and length.

7.5. Drainage blanket

Where specified or directed by the Authorised Geotechnical Engineer, a free draining filter layer which is called drainage blanket, shall be provided under the embankment.

The drainage blanket shall comprise a geotextile fabric as specified in *CRN CP 411 Earthworks Materials* laid along the base and around a layer of free draining filter material to a depth of 300 mm, and spall protection provided at the outlet. The base of the drainage blanket shall grade no gentler than 30H to 1V away from the embankment.

The free draining filter material shall be crushed rock, river gravel or slag composed of sound, hard, strong and durable particles, and complying with *CRN CP 411 Earthworks Materials*.
Embankment profile

Embankment batter slopes up to a height of 3 metres, should be 2:1 (horizontal: vertical). For higher embankments, the batter slopes shall be determined by stability analysis taking into account material properties, height, foundation conditions, static and dynamic loading and potential seepage forces. Advice shall be sought from the Authorised Geotechnical Engineer if there is any doubt concerning the embankment stability.

Minimum factors of safety for slope stability shall be

- Permanent structures ≥1.5
- Temporary structures ≥1.3
- During construction ≥1.3

Batters of 3:1 may be used where grassing is necessary or where stock have to cross the line.

The completed batter must be free of rills running down the face of batter. Any loose material on the batter shall be promptly removed as the work progresses.

7.6. Rock facing embankments

Where shown in the design, embankment batters (including embankments at bridge structures) shall be provided with a facing of clean, hard, durable rocks (Rip-rap) separated from the earth fill embankment with a graded filter or geotextile sheet in accordance with specifications detailed in *CRN CP 411 Earthworks Materials*. Rock facing shall be placed outside of the general embankment dimensions.

Rock used for rock facing shall comply with *CRN CP 411 Earthworks Materials*.

7.7. Settlement embankments

Settlement predictions of new embankments shall demonstrate that the embankment remains fully functional for the design life and through periodic track maintenance. Any settlements may be adjusted to maintain the serviceability requirements of the track.

The settlement limits are dictated by the track geometry tolerance limits. Refer to *CRN CS 210 Track Geometry and Stability* for track tolerance limits.

The values in Table 4 may be used as guidance for a typical embankment design.

Project specific settlement requirements shall be established for designs including the following cases:

- construction is over soft compressible deposits
- different serviceability levels are envisaged
- adjacent structures require more restrictive deformation limits

For embankments over soft compressible deposits, greater than 90% of primary consolidation settlement should be achieved prior to laying the track.

Table 4 – Embankment settlement requirements

Description	1 year of operation	3 years of operation	100 year design life
Maximum cumulative settlement	200mm	30mm	200mm
Maximum settlement rate	Not specified	10mm/year	Not specified
Longitudinal differential settlement(1)	0.25% (1:400)	0.25% (1:400)	0.25% (1:400)
Transverse differential settlement(1)	0.20% (1:500)	0.20% (1:500)	0.20% (1:500)

Note (1) - Denotes a maximum limit within a three-year tamping cycle

The values in Table 4 apply solely to the top of embankments providing support to the track structure. If the predicted cumulative settlement exceeds the values in Table 4, alternative construction with ground improvement should be considered.

The values in Table 4 are not applicable at turnout locations and bridge approaches. At those locations more stringent settlement criteria are required.

The values in Table 4 assume that first tamping adjustment will be at the end of three years of operation.

The embankment design shall ensure that any settlement that occurs after opening for traffic can be rectified by routine track maintenance tamping.

8. Structural zone

The thickness of the structural zone below the capping shall be specified by an Authorised Geotechnical Engineer. As a guideline for mainline track the formation thickness should be:

- for underlying material with CBR* of 3 to 8%, depth = 500mm
- for underlying material with CBR* of 1 to 3%, depth = 1000mm

* (for embankments Soaked California Bearing Ratio with Standard Compaction shall be used, for other locations in-situ California Bearing Ratio with Standard Compaction may be used.)

The width of the structural zone shall be such to carry the vertical loads imparted by rail traffic.

Compaction shall be as per *Compaction A* in Section 10.

9. Capping layer

The capping layer shall be constructed in a single layer having a compacted thickness of a minimum of 150 millimetres.

The material shall be spread in a uniform horizontal layer so as to achieve the specified compacted thickness for the full width of the capping layer.

Capping shall be laid on subgrade with a minimum CBR of 8% unless otherwise approved by an Authorised Geotechnical Engineer.

Capping material shall comply with *CRN CP 411 Earthworks Materials*.

Compaction shall be as per *Compaction C* in Section 10.

10. Compaction requirements

The Compaction standards shall be as follows:

Compaction A: Cohesive soils - Not less than 100% maximum dry density as determined by AS 1289 Tests 5.1.1 and 5.3.1 (Standard Compaction)

Compaction B: Not less than 95% maximum dry density as determined by AS 1289 Tests 5.1.1 and 5.3.1 (Standard Compaction).

Compaction C: Not less than 95% Maximum Dry Density as determined by AS 1289, Test 5.2.1 (Modified Compaction)

Alternative test methods may be approved by the Principal Track and Civil Engineer.

11. Tolerances for earthworks

Unless otherwise specified by an Authorised Geotechnical Engineer in the design documentation, tolerances for different sections of earthworks shall comply with the following provisions.

11.1. Vertical tolerances

11.1.1.1 In embankments

- Top of the structural zone + 0mm to -50mm
- Top of the general fill zone ± 40mm.

11.1.2. In cuttings

- Floor of cut (top of common earthworks): other than rock ± 40mm
- Floor of cut (top of common earthworks): rock + 0mm to -80mm
- Top of Structural Zone: other than rock + 0mm to -50mm.

11.1.3. At transitions between cut and fill

- Floor of cut to fill transition: +0mm to -50mm.

11.1.4. Top of benches and berms

- Top of benches and berms: +0mm to +100mm.

11.1.5. Capping layer

- The finished surface of the capping: ±25mm.
- The algebraic difference of the deviations from the correct level for any two points 20 metres apart on the centreline shall not exceed 15mm.
- The deviation from a three (3) metre straight edge laid on the surface parallel to the centreline shall not exceed 10mm.

11.2. Horizontal tolerances

The width of the base and top of cuts and fills and the widths of benches and berms shall not be less than the specified dimensions. Maximum positive tolerance is 300mm, unless approved by an Authorised Geotechnical Engineer.

The width of the capping layer from the design centreline to the finished top of embankment slopes or toe of batters in cuttings shall be not less than the dimensions stipulated in Table 1

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

11.3. Slope tolerances

11.3.1. In cuttings

The tolerances for the excavation of batters shall comply with the figures provided in Table 5.

Table 5 – Tolerances for batter slopes

Location	Tolerance (mm) Slope 1H:1V or flatter	Tolerance (mm) Steeper than 1H:1V
Batters at toe of batter	+ 0, - 150	+ 0, - 200
2m above toe of batter and higher	± 300	+ 300, - 600
Between level of toe of batter and 2m above toe of batter	Pro rata basis	Pro rata basis

Note: Plus (+) is towards the track and minus (-) is away from the track. Tolerances are measured perpendicular to the plane of the slope.

12. Drainage

Cess drains, sub-surface drains, top drains and interceptor drains shall be provided for cuttings and shall comply with the requirements in CRN Engineering Standard *CRN CS 420 Track Drainage*.

13. Walkways

Where walkways are provided on the formation, they shall meet the following requirements:

- They shall be free draining, permitting uninterrupted flow of water from the track formation away from the track
- They shall not impact on the performance or maintenance of track infrastructure
- They shall have a minimum width of 600mm
- They shall be suitable length, width and location for the purpose for which they have been intended
- They shall be positioned to limit the requirement to cross the track

Where walkways/landing area for dismounting from the rolling stock at sleeper level, shall meet the requirements for walkways above plus:

- They shall be no lower than the top of sleeper
- They shall transition to the formation level walkway as soon as practicable, at a slope of not more than 1:6
- They shall be of a minimum length of 1.5 times the length of the intended locomotives, nominally 35m

- The landing area shall be positioned to allow safe dismount of train crew from the rolling stock
- The surface material shall be free of trip hazards.
  Where ballast is to be used as a surface material, ballast shall comply with the requirements in *CRN CS 240 Ballast*

Where a walkway across the track is proposed, the walkway shall be deemed to be a service level crossing and shall conform with *CRN CS 520 Level Crossings.*

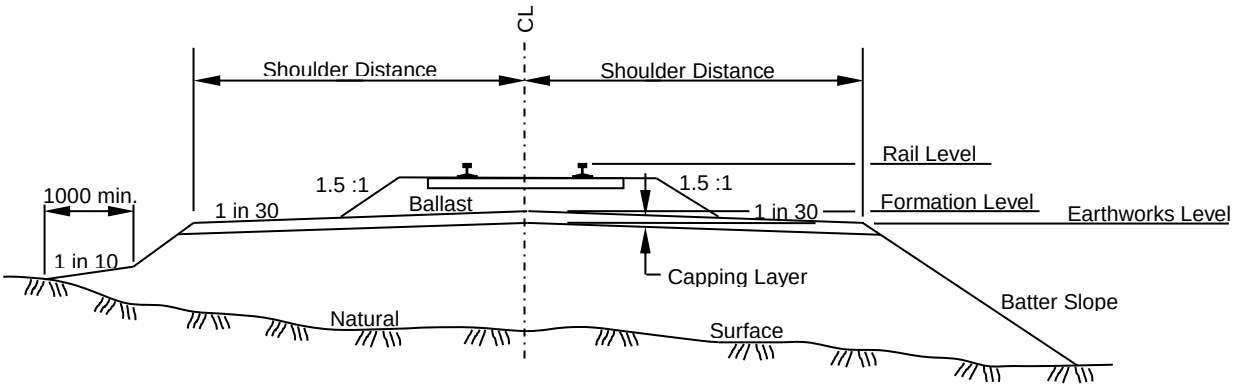
14. Rehabilitation of formation

preparing the work plan and design:

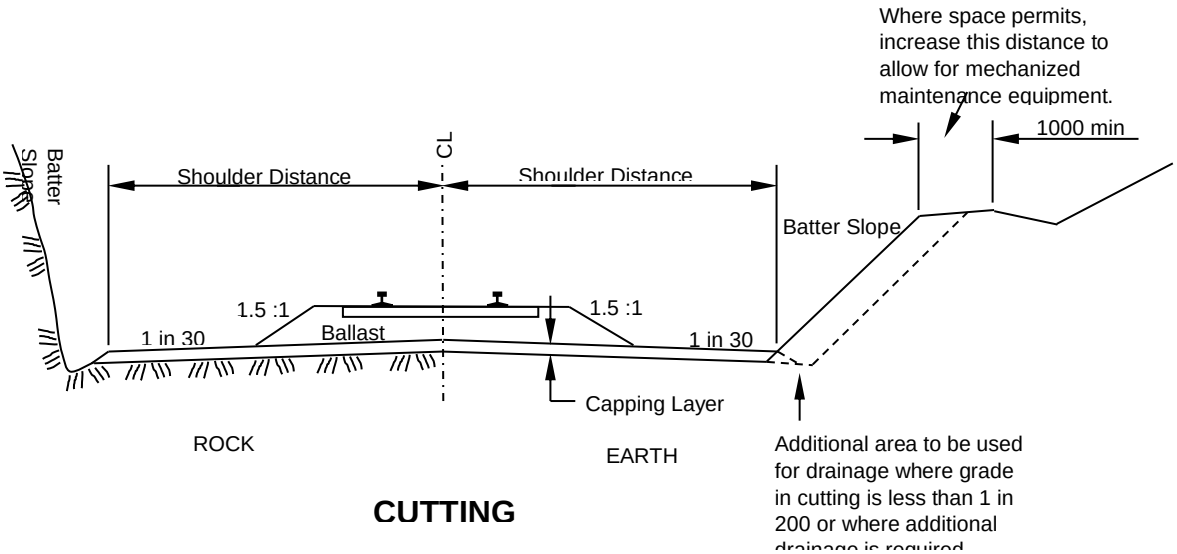
- Investigation and assessment of ground condition by the Authorised Geotechnical Engineer
- Rectification of drainage deficiencies
- Removal and disposal of failed ballast to the formation level
- Removal and disposal of failed formation material
- Provision of capping material on the original formation
- Provision of structural fill
- Provision of hard rock fill to replace soft subgrade
- Provision of trench (ballast filled) drains
- Repair/rectification of degraded, ineffective, blocked or sagging culverts

Further guidance is provided in *CRN CM 403 Track Reconditioning Guide.*

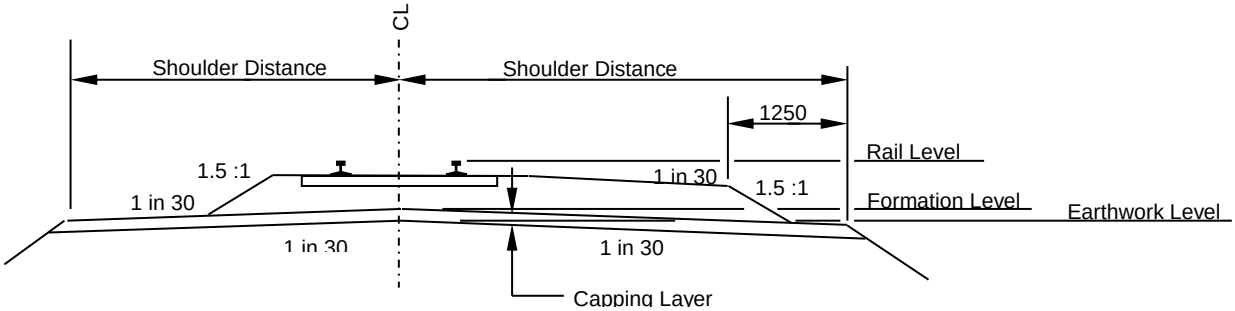
Appendix 1 Single track cross section



EMBANKMENT



CUTTING

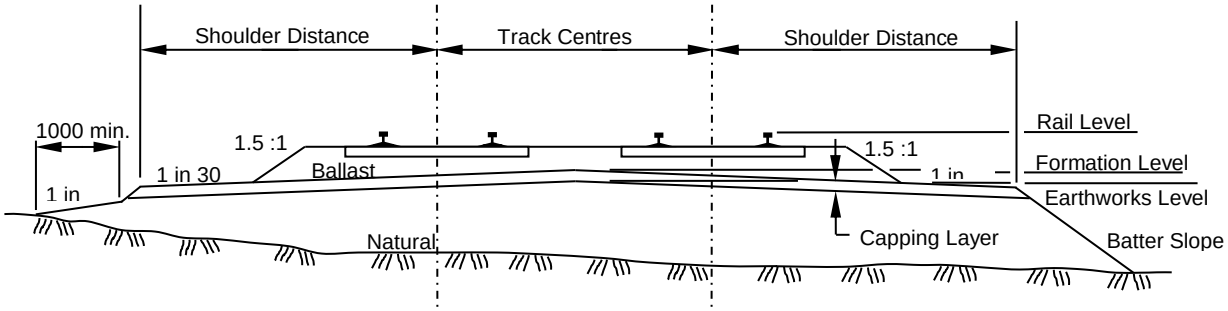


Typical section where shunters' and guards' walkways are required

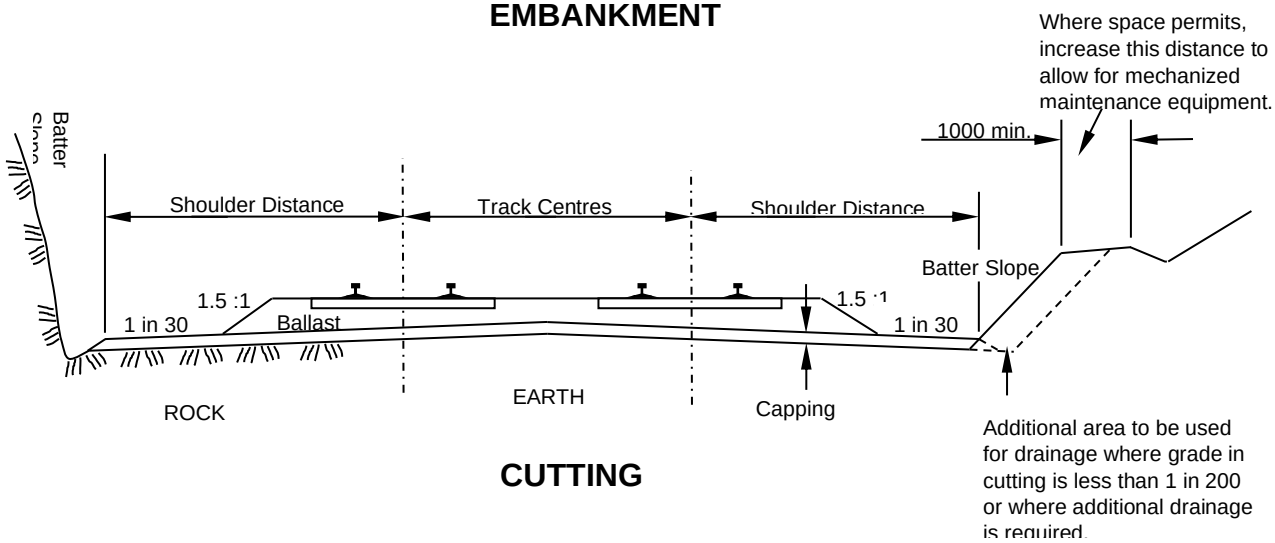
Typical section where examinations areas are specified.

SPECIAL WIDTH REQUIREMENTS

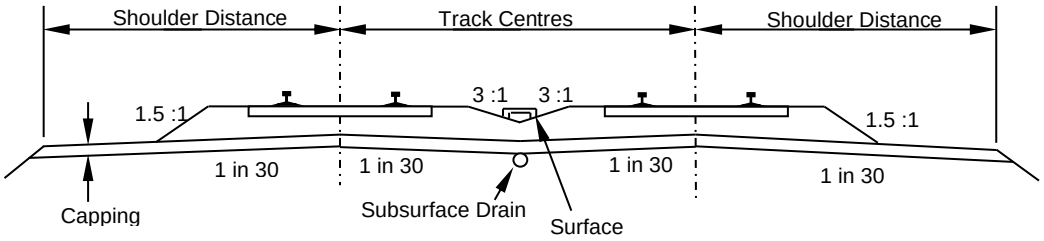
Appendix 2 Double track cross section



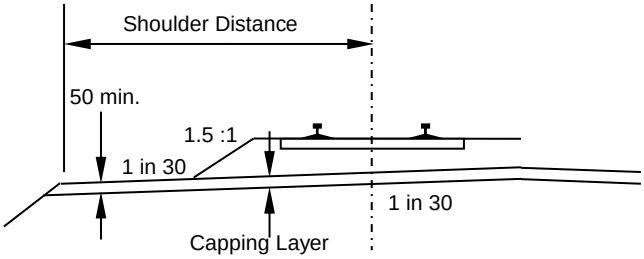
EMBANKMENT



CUTTING



CENTRE DRAIN



Typical section where train crew walkways are required.

SPECIAL WIDTH REQUIREMENTS