Roads

Master Specification

RD-EW-D1 Design of Earthworks for Roads

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DEPARTMENT FOR INFRASTRUCTURE AND TRANSPORT

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Document Management

Contents

RD-EW-D1 Design Standard: Earthworks for roads

1 General

1.1 This Design Standard specifies the requirements for the design of earthworks for roads, including material selection, construction methodology, geometric design, water / moisture control measures and surface treatment. It excludes the design of backfill for Reinforced Soil Structures (refer to ST-RE-D1 "Design of Reinforced Soil Structures").

2 References

2.1 Unless specified otherwise, all design must be undertaken in accordance with the following:

a) AS 2187.2 Explosives – Storage, Transport and Use – Use of Explosives.

b) AS 2870 Residential Slabs and Footings.

c) AS 3798 Guidelines on Earthworks for Commercial and Residential Developments.

2.2 Unless specified otherwise, the definitions in the following documents shall apply to the terms used for the design of earthworks:

a) Austroads Publication "Glossary of Terms", available from https://austroads.com.au/publications.

b) RD-EW-C1 "Earthworks" of the Department's Master Specification for Transport Infrastructure.

3 Design Report

3.1 The earthworks design must be documented in a Design Report which includes:

a) a "Design Basis Report" containing:

i) any interpretations, clarifications or assumptions made;

ii) all technical standards, references, material properties, durability, performance requirements, design loadings and design lives used for the design; and

iii) a description of the design methodology / rationale and design software.

b) all relevant analyses and calculations for the design, including calculations to demonstrate that volumetric change, settlement / creep and slope stability comply with the specified design criteria at the end of construction and during the design life of the earthworks;

c) description of the proposed construction methodologies;

d) details of all assumed and specified material properties (with reference to RD-EW-C1 "Earthworks") and the testing regime to verify these properties are achieved;

e) complete details of any techniques to improve material properties, such as preloading or vertical drainage systems;

f) details of any associated structures or measures such as rock bolting, rock netting, soil nails, geotextiles, subsoil drains and surface treatments (e.g. hydroseeding, matting and mulching); and

g) any proposed instrumentation and the proposed inspection and monitoring regime.

3.2 The calculations must address:

a) the nature, strength, compressibility and variability of existing fill and natural soils;

b) ground improvement of foundation soils prior to embankment construction;

c) the nature, strength, compressibility and variability of proposed earth fills;

d) moisture conditioning and compaction of earth fill;

e) rate of embankment construction and any staging of embankment construction;

f) any surcharging of completed embankment;

g) effects of variations in soil moisture content arising from seasonal effects or during long term moisture changes to the equilibrium moisture condition; and

h) the effect of proposed drainage and landscaping including proposed vegetation and any measures taken to reduce the effect of the vegetation on soil moisture content.

4 Design Requirements

Design Life

4.1 Earthworks must be designed for the following minimum design life:

Table RD-EW-D1 4-1 Design Life - Minimum Requirements

Element	Design Life (years)
Embankments, including reinforced embankments	100
Cut batters, including batter treatments	100

Design Objectives

4.2 To the extent practicable, the design must:

a) provide a safe run off area for errant vehicles;

b) provide a natural fit into the surrounding terrain;

c) specify near-surface materials that are suitable for supporting long term vegetation growth where new landscaping is shown on the drawings;

d) permit the establishment and growth of new vegetation above contamination containment cells where shown on the drawings;

e) minimise ongoing maintenance costs;

f) provide a safe work environment for personnel undertaking maintenance;

g) minimise adverse environmental effects, including maximising the reuse of excavated materials and minimising the impact on vegetation;

h) minimise the length of traffic barriers consistent with safety requirements; and

i) limit level changes and undulations in the finished pavement surface.

Design Criteria

4.3 Earthworks must be designed to meet the specified performance criteria for:

Volumetric Change:

a) settlement due to consolidation / creep in embankments and volume change in material under embankments or subgrade in cut; and

b) non load dependent soil volumetric changes, including reactive soil movements.

Slope Stability:

c) batters are stable and will not display any detectable instability or evidence of impending loss of stability during the Design Life;

d) topsoil installed on batters is stabilised with appropriate landscape treatments;

e) overhanging, loose or unstable material in cuts is prevented from slipping or falling; and

f) in cuts, any material which becomes detached is prevented from reaching the road shoulder.

Durability and Maintainability:

g) detrimental effects from water (e.g. concentrated flows, erosion, ponding of water) are kept to the minimum practicable;

h) the surface is highly resistant to surface scour and erosion and will not suffer detrimental effects from a 1 in 10 year Average Recurrence Interval storm event;

i) there is no undermining or destabilisation of any existing batter slopes or structures;

j) maintenance normally required of the road and environs can be readily and economically undertaken; and

k) plant and equipment access must be available to the final batter slope to allow ready installation of any treatment measures which may become necessary and to facilitate inspection and maintenance of the face of the batter.

4.4 Performance criteria may be specified in Contract Documents. If no performance criteria are specified, the values in this Design Standard shall apply.

Verification of Material Design Parameters

4.5 The design must include a testing regime to verify that the estimated values for the design parameters for the volumetric change (e.g. Shrink / Swell and the coefficient of volume change) and strength (e.g. c', φ', cu') have been achieved during construction for all fill materials.

5 Volumetric Change

General

5.1 "Volumetric Change" includes changes in levels due to consolidation, creep and shrinkage and / or heave due to both seasonal and long term moisture changes. Design and construction must be completed in such a way that Volumetric Change will have no adverse effect on the performance of the pavements and structures.

5.2 The design must take into account short and long term consolidation, seasonal moisture variations and the change of soil moisture as the material reaches the long term equilibrium condition.

Calculations

5.3 Calculations must be provided for Volumetric Change at the completion of construction and at the end of the defects liability period. Issues to be addressed in the calculations include:

a) effects of the presence of organic soils;

b) areas unsuitable to act as a foundation for structures;

c) the strengths, compressibility, volume change characteristics and variability of existing soils;

d) the depth of existing topsoil or organic material to be removed;

e) the strengths, compressibility, volume change characteristics and variability of earth fills;

f) any methods for accelerating or limiting Volumetric Change;

g) level of compaction effort and surcharge during fill construction;

h) any difference between the as-constructed moisture content and the predicted equilibrium moisture content;

i) the effect of seasonal and long term variations in soil moisture content; and

j) effect of proposed drainage and landscaping including proposed vegetation and any measures taken to reduce the effect of these;

5.4 The method of verifying the actual I_{ss} (%) values of the construction materials must be addressed.

Moisture Changes

5.5 The calculation of seasonal or long term surface movements must be in accordance with AS 2870 with the following clarifications:

a) for the purpose of the calculation of seasonal surface movements, the active zone for seasonal soil moisture variation shall be 4.0 m from the top of pavement;

b) the differential mound movement (ym) should be taken as equal to the computed ground movement (ys) unless it can be shown that a reduction is possible due to the extent of the sealed surfaces surrounding the pavement;

c) total soil suction variation at surface level shall be 1.2 pF units, decreasing linearly with depth to zero pF units 4.0 m below top of pavement surface level. A suction variation of less than 1.2 pF units at the surface may be adopted on a case by case basis and must be supported by, inter alia, the specific site characteristics and the level of geotechnical investigation undertaken. If a total suction variation at surface level less than 1.2 pF units is proposed by the designer then this shall constitute a **Hold Point**;

d) the depth of the crack zone is 3.0 m from the existing ground surface. Where a site has been cut less than two years prior to earthworks construction the depth of the cracked zone may be reduced by the depth of the cut;

e) α for cuts and fills must be calculated in accordance with section 2.3.2 of AS 2870 and must not be less than 1.0;

f) for the purpose of calculating movements and volume change, the words “building construction” in AS 2870 means all earthworks, structures, and pavement construction;

g) the effects of new and existing trees and other vegetation when specified as a surface treatment in the landscape design, on surface movements must be accounted for in the design;

h) (ys) must be calculated as the sum of the changes in each soil layer due to change in total suction;

i) the volume change in each layer is the product of layer thickness multiplied by Δu (in pF) multiplied by I_{pt}, where Δu equals the average change in total suction of the layer under consideration and I_{pt} is the instability index of the layer; and

j) the effect of existing and proposed trees, large bushes and dense plantings of shrubs on the design profile of total soil suction change must be estimated in accordance with the “Special Provisions” document of the Footings Group, South Australia.

5.6 Moisture barriers in accordance with relevant Australian Standards may be incorporated within the construction of embankments to prevent the effects of moisture ingress of stormwater and / or desiccation from vegetation.

5.7 Where appropriate, the use of low permeability capping materials adjacent to the edge of pavement, horizontal and vertical separation of drains, sub-soil and sub-pavement drainage and other measures must be considered.

Performance Criteria for Volumetric Change

5.8 The design of the Works must achieve the following:

Table RD-EW-D1 5-1 Performance Criteria for Volumetric Change

Element	Surface Movements	Performance Criteria over Design Life
Flexible Pavements**	Total movement	No greater than 20 mm heave or settlement at any point over any 12 month period following the construction of the pavement, and no greater than 50 mm heave or settlement at any point over the design life.
	Differential movement	Maximum difference in level of the pavement surface between 2 points up to 10 metres apart: • Expressways (including ramps) – 20 mm • Arterial Roads – 25 mm • Other Roads – 30 mm
Structures	Pavement Interface differential movement	5 mm max where no bridge approach slab is provided. 10 mm max where a bridge approach slab of minimum 3 m length is provided and for transitions from rigid to flexible pavements.
Culverts and Retaining Walls	Any movement	Culverts and Retaining Walls are undamaged, do not pond water and performance is not diminished in any way.

**If rigid pavements are to be designed and constructed then the performance criteria for volumetric change will be specified in the Contract Documents.

6 Earthworks Performance Monitoring

6.1 The Contractor must implement a monitoring program that records surface movement for the period between completion of the earthworks and expiry of the defects liability period, or 5 years, whichever is longer. Surface movement must be recorded each month for the first 6 months and quarterly thereafter. A reduced rate of monitoring may be agreed after 2 years if movements are within the performance criteria.

6.2 At bridge abutments a total of 4 surface movement measurement (i.e. vertical and lateral movements) points are required located 5 m and 15 m from each bridge abutment.

6.3 An adequate number and placement of surface movement measurement points is required to prove that the performance criteria for volumetric change (see Table RD-EW-D1 5-1) has been achieved.

6.4 Surface movements must be measured by a Surveyor meeting the requirements that mentioned in clause 1 of PC-SI1 “Site Surveys”. Measurements must be plotted graphically (on a logarithmic time scale) and forwarded to the Principal within 1 week. If calculations of predicted surface movement have been prepared, these must also be shown on the plot.

6.5 If a Surface Movement Measurement Point is disturbed or lost it must be replaced as close as practicable to the original point before the next survey. Surface movement must be determined by reference to a stable benchmark (e.g. a deep benchmark).

7 Slope Stability

7.1 Slope stability analysis must be undertaken for both long and short term slope geometries and soil conditions. The minimum Factors of Safety (FoS) must comply with the following:

Table RD-EW-D1 7-1 Embankment Design Criteria

Application	Minimum Factor of Safety	Surcharge	Soil Shear Strength Parameter Values
During construction	1.3	10 kPa	Lower quartile
Post Construction	1.5	10 kPa for local roads	

Application	Minimum Factor of Safety	Surcharge	Soil Shear Strength Parameter Values
Post Construction	1.5	20 kPa for arterial roads, expressways (including ramps)	

7.2 Where these minimum values for the (FoS) cannot be achieved, suitable earth retaining structures must be provided.

7.3 In the slope stability analysis, the risk category for a particular slope must be assessed in terms of the potential for loss of life or injury to persons and the potential for economic and environmental impacts should the slope fail. Examples of high risk slopes are slopes adjacent to pedestrian areas or main roads. An example of a low risk slope is one that only impacts open areas such as landscaped zones. Slopes behind or above earth retaining structures or below bridge abutments are considered high risk slopes.

7.4 The impact of any proposed excavations or changes in soil moisture regime on embankment or cutting stability must be assessed.

7.5 A rigorous limit equilibrium method of soil stability analysis must be undertaken (such as Spencer or Morgenstern and Price). The analysis must cover non-circular slope failure geometries where appropriate. Both the short and long term cases with static and dynamic (earthquake) conditions need to be considered.

8 Water Table

8.1 The earthworks design must show that the works will:

a) not permanently affect any existing groundwater table level; and

b) incorporate every reasonable endeavour to avoid temporarily lowering the existing groundwater table by dewatering.

8.2 If dewatering cannot be avoided, the design must:

a) ensure that the extent and depth of the area to be dewatered is held to a practicable minimum;

b) ensure that the duration of any dewatering is held to a practicable minimum;

c) provide full details of any dewatering system, including the quantity and proposed method of disposal in the Quality Plan; and

d) ensure that dewatering water is disposed of in such a manner that it does not harm the environment and is in accordance with the Environmental Protection Act 993.

8.3 Full details of any dewatering system, including the quantity and proposed method of disposal, must be included in the Design Report.

9 Design of Cuttings in Rock

9.1 Where batter slopes will be constructed in rock, the design must comply with this Clause and be undertaken by a Geotechnical Engineer or Geologist with relevant experience in rock cuttings.

9.2 A geotechnical model must be developed of the rock cuttings to facilitate the following strategies for batter designs and treatments:

a) engineer the batters to the appropriate angle, not the steepest angle to reduce earthworks volumes;

b) consider defect related mechanisms as well as global stability;

c) consider long term performance and maintenance requirements; and

d) install treatments during construction.

9.3 Kinematic analysis of rock cuttings must include consideration of toppling, wedge, ravelling, rotational shear and planar failures. A risk management strategy for the slopes, including probability analysis, must be provided.

9.4 Working faces must be limited to safe heights and slopes, and the surface must be drained to avoid ponding and erosion. The design must take into account the effect of water and where appropriate, include cut off drains at the top of all rock cuttings. Any drainage structures, including berms, located on the rock cuttings must be sealed.

9.5 The designer must include recommendations for monitoring and maintenance of the rock cuttings for their design life.

10 Design of Controlled Blasting

10.1 Where blasting is proposed to be used in the construction of earthworks, the design of the blasting process must comply with this clause.

10.2 Australian Standard 2187.2 'Explosives – Storage, Transport and Use – Use of Explosives' contains guidelines for ground vibration levels for human comfort and control of damage to structures. The values for human comfort have been chosen by regulatory authorities as used in overseas standards and guidelines. The design of the blasting must take into account Utility Services and liaise with the relevant authority for any special requirements.

10.3 Peak Particle Velocity (PPV) limits must be designed according to Table J4.5 (A) and (B) in AS 2187.2. The design must identify the PPV values likely to be sustained by structures within the Project Property Boundary.

10.4 Refer to AS 2187.2, Table J5.5 (A) and (B) for Air blast overpressure limits.

10.5 Refer to PC-SI4 "Geographic Information Systems (GIS)" for details on property condition surveys and PC-ENV2 "Environmental Protection Requirements" for environmental considerations.

10.6 The design must consider appropriate techniques e.g. (Pre-splitting) to be used on rock cuttings and exposed rock surfaces to obtain smooth, uniformly trimmed surfaces and to ensure protection of the batters. The spacing of pre-split drill holes must not exceed 1000 mm centre to centre.

10.7 An appropriate blast design strategy to minimise damage to structures / stakeholders and ensure safe blasting must be presented and constitutes a **Hold Point**.

11 Hold Points

11.1 The following is a summary of Hold Points referenced in this Part:

Table RD-EW-D1 11-1 Hold Points

Document Ref.	Hold Point	Response Time
5.5	Designer's proposal to change the total suction variation at surface level to be less than 1.2 pF	TBD
10.7	Blast design strategy	TBD

12 Records

12.1 The following records must be provided to the Department:

a) Drawings;

b) Construction drawings;

c) Relevant standard drawings from the Department's Road Design Standards and Guidelines;

d) Reports; and

e) Design Report (refer Clause 3).