Master Specification
Part RD-EW-D1

Design of Earthworks for Roads

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Government of South Australia
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Contents

RD-EW-D1 Design of Earthworks for Roads

1 General

a) This Master Specification Part specifies the requirements for the design and verification of earthworks for roads, including:

i) the documentation requirements, as set out in section 2;

ii) the design requirements, as set out in section 3;

iii) the volumetric change requirements, as set out in section 4;

iv) the performance monitoring requirements, as set out in section 5;

v) the slope stability requirements, as set out in section 6;

vi) the water table requirements, as set out in section 7;

vii) the requirements for the design of cuttings in rock, as set out in section 8;

viii) the requirements for the design of controlled blasting, as set out in section 9; and

ix) the Witness Point requirements, as set out in section 10.

b) This Master Specification Part does not apply to the design of:

i) backfill for reinforced soil structures, which must comply with the requirements set out in ST-RE-D1 “Design of Reinforced Soil Structures”; and

ii) Tunnels, which must comply with the requirements set out in TUN-CIV-DC1 “Tunnel Civil Requirements”.

c) The design of earthworks for roads must comply with the Reference Documents, including:

i) AS 2187.2 Explosives - Storage and use, Part 2: Use of explosives;

ii) AS 2870 Residential slabs and footings;

iii) AS 3798 Guidelines on earthworks for commercial and residential developments; and

iv) Special provisions for the design of residential slabs and footings and structural design of small structures - South Australian Conditions (available from: https://www.engineersaustralia.org.au/).

2 Documentation

2.1 Design Documentation

2.1.1 Design Basis

In addition to the requirements of PC-EDM1 “Design Management”, the Design Documentation must include a Design Basis containing in relation to the design of earthworks for roads:

a) all interpretations, clarifications or assumptions made;

b) all Reference Documents, material properties, durability, performance requirements, design loadings and Design Life used for the design; and

c) a description of the design methodology, rationale, and design software.

2.1.2 Design Report

In addition to the requirements of PC-EDM1 “Design Management”, the Design Documentation must include a Design Report containing in relation to the design of earthworks for roads:

a) all relevant analyses and calculations for the design, including calculations which address:

   i) compliance with the volumetric change, settlement / creep and slope stability requirements of this Master Specification Part;

   ii) the volumetric change calculation requirements in section 4.2;

   iii) the moisture change calculation requirements in section 4.3;

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

   v) ground improvement of foundation soils and rock prior to embankment construction;

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

   vii) moisture conditioning and compaction of earth fill;

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

   ix) any surcharging of completed embankment;

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

   xi) 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;

b) description of the proposed construction methodologies;

c) details of all assumed and specified material properties in accordance with the requirements of RD-EW-C1 “Earthworks”, and the details of any testing regimes that have been used to inform the design of earthworks;

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

e) where applicable, evidence that existing pavements meet the requirements of section 4.1c);

f) the proposed method of verifying the actual I_{ss} (%) values of the construction materials as required by section 4.2c);

g) details of any moisture barriers used in accordance with section 4.3b), which must be clearly specified on the relevant Design Drawings;

h) any proposed instrumentation and the proposed inspection and monitoring regime in accordance with the requirements of section 5;

i) where required, a dewatering plan in accordance with section 7b);

j) for the design of batter slopes in rock:

   i) details of the geotechnical model developed in accordance with the requirements of section 8b);

   ii) a kinematic analysis in accordance with the requirements of section 8c); and

   iii) a risk management strategy in accordance with the requirements of section 8d);

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

l) where blasting is proposed to be used, the peak particle velocity limits likely to be sustained by structures in the vicinity of the Works in accordance with the requirements of section 9c); and

m) where required, a blast design strategy as required by section 9h).

2.2 Maintenance Plan

In addition to the requirements of PC-CN2 “Asset Handover”, the Maintenance Plan must include a monitoring regime and maintenance plan for rock cuttings in accordance with the requirements of section 8h).

2.3 Quality Management Records

In addition to the requirements of PC-QA1 “Quality Management Requirements” or PC-QA2 “Quality Management Requirements for Major Projects” (as applicable), the Quality Management Records must include:

a) evidence that the volumetric change has met the requirements of section 4.4, in accordance with the requirements of section 4.2; and

b) all surface movement measurement charts required by section 5g).

3 Design requirements

3.1 Design Life

Unless otherwise specified in the Contract Documents, earthworks for roads must have a Design Life in accordance with Table RD-EW-D1 3-1.

Table RD-EW-D1 3-1 Design Life - minimum requirements

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

3.2 Design objectives

To the extent practicable, the design of earthworks must:

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

b) provide a natural fit into the surrounding terrain in accordance with the urban design requirements of the Contract Documents including the requirements of PR-LS-D1 “Landscape and Urban Design”;

c) use near-surface materials that are suitable for supporting long term vegetation growth for new landscaping;

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

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 while still meeting the safety requirements of the Contract Documents; and

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

3.3 Durability and maintenance access

The design of earthworks must meet the following performance requirements in relation to durability and maintenance access:

a) detrimental effects from water, including those related to concentrated flows, erosion, ponding of water, must be avoided to the greatest extent practicable;

b) the surface must be highly resistant to surface scour and erosion and will not suffer detrimental effects from a 10% AEP event;

c) the Works must be designed to not undermine or destabilise any existing batter slopes or structures;

d) earthworks must be designed to be Readily Accessible for maintenance purposes and must not inhibit maintenance normally required of the road and environs can be readily and economically undertaken; and

e) batter slopes must be designed to accommodate plant and equipment access to allow ready installation of any treatment measures which may become necessary and to facilitate inspection and maintenance of the face of the batter.

3.4 Verification of material design parameters

The design of earthworks must include a proposed testing regime to verify that the estimated values for the design parameters for the volumetric change (such as shrink or swell and the coefficient of volume change) and strength (such as c', φ', cu') have been achieved during construction for all fill materials.

4 Volumetric change

4.1 General

a) The design of earthworks must factor in volumetric change, which includes:

   i) changes in levels due to consolidation and creep;

   ii) shrinkage and heave due to both seasonal and long term moisture changes;

   iii) volume change in material under embankments or subgrade in cut; and

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

b) The Contractor must ensure that:

   i) the resultant volumetric change will have no adverse effect on the performance of the pavements and structures;

   ii) the design takes 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.

c) Where existing pavements are being rehabilitated or augmented with additional lanes:

   i) the performance of those existing pavements must be assessed for compliance with Table RD-EW-D1 4-1; and

   ii) unless otherwise specified in the Contract Documents, where it can be demonstrated in the Design Documentation that the existing pavements are performing in accordance with Table RD-EW-D1 4-1, then shrinkage or heave calculations due to both seasonal and long term moisture changes do not need to be provided, if the following conditions are also met:

      A. ground conditions are generally consistent between the existing and new pavements;

      B. pre-construction moisture condition of subgrades are maintained during construction;

      C. the depth of new pavement is equal to, or greater than, the adjacent existing pavement;

D. the new or rehabilitated pavement is not being grade separated;

E. the management of potential ingress of moisture into the subgrade (including through stormwater management, sealed shoulders, subsurface drainage and capping layers) for the new or rehabilitated pavement is not inferior to that employed for the existing pavement; and

F. the existing pavement has not, during its intended Design Life, been rehabilitated or repaired to correct any Defect or loss of shape which can be attributed to shrinkage or heave due to both seasonal and long-term moisture changes.

4.2 Calculations

a) The Design Documentation must include all necessary calculations and supporting documentation to demonstrate that the predicted volumetric change at the time periods in section 4.2b) will meet the requirements of section 4.4, and must cover the following issues:

i) effects of the presence of organic soils;

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

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

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

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

vi) any methods for accelerating or limiting volumetric change;

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

viii) the effect of seasonal and long term variations in soil moisture content in accordance with the requirements of section 4.3a); and

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

b) Evidence that the volumetric change has met the requirements of section 4.4 must be provided at:

i) completion of construction of the earthworks;

ii) the end of the Defects Liability Period; and

iii) 5 years after completion of the relevant earthworks,

and must cover the following issues:

iv) the items set out in section 4.2a); and

v) any difference between the as-constructed moisture content and the predicted equilibrium moisture content,

which must be provided as part of the Quality Management Records.

c) The Design Documentation must include the proposed method of verifying the actual I_{ss} (%) values of the construction materials.

4.3 Moisture changes

a) The calculation of seasonal or long-term surface movements must be in accordance with AS 2870 Residential slabs and footings, and the following requirements:

i) for the purpose of the calculating seasonal surface movements, the active zone for seasonal soil moisture variation must be 4.0 m from the top of pavement;

ii) the differential mound movement (y_m) must be taken as equal to the computed ground movement (y_s) unless it can be shown that a reduction is possible due to the extent of the sealed surfaces surrounding the pavement;

iii) total soil suction variation at surface level must be 0.6 pF units, decreasing linearly with depth to zero pF units 4.0 m below the top of the pavement surface level, unless potentially adverse site conditions exist (including geomorphological or vegetation features) that could lead to high moisture variation over short distances that would warrant a higher total soil suction variation at the surface;

iv) the depth of the crack zone must be 3.0 m from the existing ground surface. Where a site has been previously cut less than 2 years prior to the relevant earthworks construction, the depth of the cracked zone may be reduced by the depth of the cut;

v) α for cuts and fills must be calculated in accordance with AS 2870 Residential slabs and footings, and must not be less than 1.0;

vi) for the purpose of calculating movements and volume change, the term building construction in AS 2870 Residential slabs and footings, means all earthworks, structures, and pavement construction;

vii) the effects of new and existing trees and any other vegetation used as a surface treatment in the landscape design on surface movements must be accounted for in the earthworks design;

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

ix) the volume change in each layer must be 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;

x) 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 requirements of Special provisions for the design of residential slabs and footings and structural design of small structures - South Australian Conditions; and

xi) the period of time for the suction change to reach the equilibrium condition may exceed 1 year after the completion of the relevant Works.

b) Moisture barriers provided in accordance with the Reference Documents may be provided within embankments to prevent the effects of moisture ingress of stormwater or desiccation from vegetation, and where used must be clearly shown on the Design Drawings.

c) The Contractor must control moisture change, which may include one or more of the following measures:

i) low permeability capping materials adjacent to the edge of pavement;

ii) horizontal and vertical separation of drains; or

iii) sub-soil and sub-pavement drainage.

4.4 Performance criteria for volumetric change

Unless otherwise specified in the Contract Documents, the design of the Works must achieve the performance criteria set out in Table RD-EW-D1 4-1.

Table RD-EW-D1 4-1 Performance criteria for volumetric change

Element	Surface movements	Performance criteria over Design Life
Flexible pavements(1)	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 m apart:
		a) motorways (including ramps) - 20 mm
		b) urban and rural arterial, urban and rural connector - 25 mm
		c) access roads - 30 mm
Structures	Pavement interface differential movement	Maximum of 5 mm where no bridge approach slab is provided
		Maximum of 10 mm 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
		Retaining walls must also meet the settlement and performance requirements specified in ST-RE-D2 “Design of Retaining Walls”

Table notes:
(1) If rigid pavements are to be designed and constructed, then the performance criteria for volumetric change will be specified in the Contract Documents.

5 Earthworks performance monitoring

a) The Contractor must implement a monitoring program to ensure that the performance criteria in section 4.4 are being met for the period between completion of the earthworks and the later of:

   i) the expiry of the relevant Defects Liability Period; and

   ii) 5 years after completion of the relevant earthworks.

b) For the period referred to in section 5a), both horizontal and vertical surface movement must be recorded:

   i) every month, as a minimum, for the first 6 months after the relevant earthworks are completed;

   ii) quarterly beyond the first 6 months after the relevant earthworks are completed; and

   iii) at an agreed rate of monitoring beyond 2 years after the relevant earthworks are completed if it can be demonstrated to the satisfaction of the Principal that the performance criteria of this Master Specification Part are being met.

c) At bridge abutments a total of 4 surface movement measurement points covering both vertical and lateral movements must be provided at 5 m and 15 m spacings from each bridge abutment.

d) The Contractor must ensure that a sufficient number of surface movement measurement points are provided in suitable locations to demonstrate compliance with the volumetric change performance criteria set out in section 4.4.

e) Surface movements must be measured by a suitably qualified surveyor whose experience and accreditation meets the requirements of PC-SI1 “Site Surveys”.

f) Surface movement measurements must be plotted graphically on a logarithmic time scale along with any calculations of predicted surface movements that have been prepared previously by the Contractor.

g) The surface movement measurement charts required by 5f) must be provided to the Principal within 5 Business Days of the recording of each measurement, which will constitute a **Witness Point**.

h) 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.

i) Surface movement must be measured by reference to a stable benchmark proposed by the Contractor (such as a deep benchmark).

6 Slope stability

a) In relation to slope stability for the design of earthworks for the Works:

   i) batters must be stable and must not display any detectable instability or evidence of impending loss of stability during the Design Life;

   ii) topsoil installed on batters must be stabilised with appropriate landscape treatments (refer to PR-LS-C7 “Topsoil and Earthworks”);

   iii) overhanging, loose or unstable material in cuts must be prevented from uncontrolled movement; and

   iv) in cuts, any material which becomes detached must be prevented from reaching the road shoulder.

b) As part of the design of earthworks for the Works, the Contractor must undertake a short and long-term slope stability analysis which must:

   i) cover slope geometries and soil conditions;

   ii) cover both static and dynamic (earthquake) conditions;

   iii) assess the risk category for slope failure with respect to the potential for loss of life or injury, and economic and environmental impacts, where:

      A. slopes that only impact open areas such as landscape zones can be considered low risk slopes; and

      B. slopes behind or above earth retaining structures, below bridge abutments or adjacent to pedestrian areas or main roads must be considered as high risk slopes;

   iv) assess the impact of any proposed excavations or changes in soil moisture regime on embankment or cutting stability; and

   v) utilise a rigorous limit equilibrium method of soil stability analysis which must cover non-circular slope failure geometries where appropriate.

c) The design of the Works must either:

   i) adopt the embankment design criteria specified in Table RD-EW-D1 6-1; or

   ii) where the embankment design parameters specified in Table RD-EW-D1 6-1 cannot be achieved, provide suitable earth retaining structures.

Table RD-EW-D1 6-1 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	Lower quartile
Post construction	1.5	20 kPa for arterial roads, expressways and motorways (including ramps)	Lower quartile
Seismic	1.1	a) 10 kPa for local roads; and b) 20 kPa for arterial roads, expressways and motorways (including ramps).	Lower quartile

7 Water table

a) The earthworks design must demonstrate that the Works will:

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

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

b) Where dewatering cannot be avoided, the Contractor must:

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

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

iii) provide a dewatering plan as part of the Design Documentation, containing full details of the proposed approach to dewatering including any dewatering systems to be used, and the quantity and proposed method of groundwater disposal and treatment; and

iv) ensure that dewatering water is disposed of in such a manner that it does not harm the environment and is in accordance with all applicable Laws.

8 Design of cuttings in rock

The requirements of this section 8 apply to the design of batter slopes in rock as part of the Works:

a) the design must be undertaken by a geotechnical engineer or geologist with relevant experience in rock cuttings;

b) the Contractor must develop a geotechnical model of the rock cuttings to facilitate the following principles for batter designs and treatments:

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

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

iii) consider long term performance and maintenance requirements; and

iv) install treatments during construction;

c) a kinematic analysis of rock cuttings must be provided as part of the Design Documentation, which covers uncontrolled movement (such as toppling, wedge, ravelling, rotational shear and planar failures);

d) a risk management strategy for the slopes, including a supporting probability analysis, must be provided as part of the Design Documentation;

e) working faces must be limited to safe heights and slopes, and the surface must be drained to avoid ponding and erosion;

f) the design must take into account the effect of water and where appropriate, include cut off drains at the top of all rock cuttings;

g) any drainage structures located on the rock cuttings, including berms, must be sealed; and

h) the Contractor must develop a monitoring regime and maintenance plan for the rock cuttings for their Design Life which must be submitted as part of the Maintenance Plan.

9 Design of controlled blasting

The requirements of this section 9 apply to the design of blasting processes used as part of the delivery of the Works:

a) ground vibration levels must not exceed the ground vibration limits specified in AS 2187.2 Explosives - Storage and use - Use of explosives;

b) where blasting is proposed in close proximity to existing Utility Services, the Contractor must meet the requirements of the relevant Utility Service Authority guidelines with respect to ground vibration and managing related impacts;

c) the Design Documentation must identify the peak particle velocity values likely to be sustained by structures in the vicinity of the Works;

d) airblast levels must not exceed the airblast limits specified in AS 2187.2 Explosives - Storage and use, Part 2: Use of explosives;

e) the Contractor must:

  i) perform property condition surveys in accordance with the requirements of PC-SI3 “Condition Surveys”; and

  ii) meet the environmental requirements specified in PC-ENV2 “Environmental Protection Requirements”;

f) the design must use appropriate techniques such as pre-splitting to obtain smooth, uniformly trimmed surfaces and to ensure protection of the batters;

g) where pre-splitting is used, the spacing of pre-split drill holes must not exceed 1,000 mm centre to centre;

h) the Contractor must submit a blast design strategy to the Principal as part of the Design Documentation, which must set out how the Contractor will:

  i) minimise damage to structures and stakeholders associated with blasting throughout the delivery of the Works; and

  ii) ensure that blasting is undertaken safely.

10 Witness Points

Table RD-EW-D1 10-1 details the review period or notification period, and type (documentation or construction quality) for each Witness Point referred to in this Master Specification Part.

Table RD-EW-D1 10-1 Witness Points

Section reference	Witness Point	Documentation or construction quality	Review period or notification period
5g)	Submission of surface movement measurement charts	Documentation	5 Business Days review