TRANSPORT FOR NSW (TfNSW)

SPECIFICATION D&C R57

DESIGN OF REINFORCED SOIL WALLS

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IC-DC-R57

VERSION FOR:
DATE:

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Foreword

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Base Specification

This document is based on TfNSW QA Specification R57 Edition 2 Revision 11.

TfNSW SPECIFICATION D&C R57

DESIGN OF REINFORCED SOIL WALLS

1 GENERAL

1.1 SCOPE

This Specification sets out the requirements for the design of Reinforced Soil Walls (RSW). It includes design requirements for the reinforced fill material, soil reinforcement, facing elements and associated components.

The requirements for construction of RSW are set out in Specification TfNSW D&C R58.

This Specification does not cover the requirements for the design of reinforced slopes or foundations for structures other than RSW. This Specification assumes that the design of structures on top of, behind or within RSW has been carried out in accordance with AS 5100.

1.2 STRUCTURE OF THE SPECIFICATION

This Specification includes a series of annexures that detail additional requirements.

1.2.1 Details of Work

Project specific requirements are shown in Annexure R57/A.

1.2.2 (Not Used)

1.2.3 Schedule of Identified Records

The records listed in Annexure R57/C are **Identified Records** for the purposes of Specification TfNSW D&C Q6 Annexure Q/E.

1.2.4 Referenced Documents

Standards, specifications and test methods are referred to in abbreviated form e.g. AS 1289. For convenience the full titles are given in Annexure R57/M.

1.3 DEFINITIONS

1.3.1 General Definitions

The terms “you” and “your” refer to “the entity undertaking the design”.

Abutment	A structure or wall which extends beyond the bridge to retain the earth and support the ends of the bridge.
Capping	The element over the top course of facing elements to complete the RSW to specified finished levels.

Engineer	Professional engineer who is a member of Engineers Australia (or equivalent) and with appropriate qualifications and experience for the type of engineering work engaged in.
Extensible soil reinforcement	Soil reinforcement which is strained to greater than 1% under the serviceability tensile force.
Facing connections	Any connections, whether mechanical, frictional or other type, between facing elements and the soil reinforcement, designed to transfer loads between the soil reinforcement and facing elements.
Facing elements	Elements retaining the reinforced fill material, with provision for connection to the soil reinforcement.
Foundation	Portion of ground in contact with the RSW and supporting the loads from it.
Geosynthetic reinforcement	Soil reinforcement made of polymeric materials used in geotechnical engineering e.g. linear straps and geogrids.
Geotechnical Engineer	Engineer(s) with qualifications and experience in geotechnical engineering.
Inextensible soil reinforcement	Soil reinforcement which is strained to less than or equal to 1% under the serviceability tensile force.
Reinforced fill material	Granular soil, decomposed rock or crushed rock fill material in the RSW in which the soil reinforcement is embedded.
Reinforced Soil Wall (RSW)	A retaining structure, with the face within 20° of vertical, which comprises soil reinforcement embedded in reinforced fill material, together with any facing elements, facing connections and footings.
RSW Designer	Engineer(s) with qualifications and experience in the design of RSW.
RSW System	A system which has been pre-assessed and approved by Transport for NSW as suitable for specific RSW applications, and which may be subject to certain conditions for use. For this purpose, a "system" includes the reinforcing elements, wall facings and any associated components such as connections, joint fillers and sealants.
RSW System Owner	A company which has a RSW System approved by Transport for NSW (refer to Clause 1.5). The RSW System Owner also certifies that all components supplied for construction of a RSW meet the RSW System specifications under TfNSW D&C R58.
Sill beam	A concrete abutment which is bearing on a reinforced soil wall.
Soil reinforcement	Components which are embedded in the reinforced fill material and act through interface friction, bearing or other means to improve the stability and structural adequacy of the RSW.

1.3.2 Design Definitions

Characteristic value The material and load factors in this Specification are calibrated using characteristic values. The designer must make safe estimates of the characteristic values for use in design.

Characteristic values must be based on a careful assessment of the range of values which could reasonably be expected to occur in the field. It is emphasised that a statistical analysis of a limited amount of measured data may be useful but will rarely lead directly to characteristic values. The designer is referred to Section 7.3.4 of AS 5100.3 for further information.

The guaranteed minimum values for yield stress and tensile strength of steel may be used for the characteristic values.

Dead loads Permanent effects acting on the RSW as defined in Clauses 5.1 and 5.2 of AS 5100.2 but excluding differential settlement and/or mining subsidence effects.

Design value for material parameter Characteristic value of material parameter multiplied by the appropriate material factor, except for the soil frictional angle ϕ which is specified in Clause 4.4.

Design strength (or resistance or capacity) Strength (or resistance or capacity) calculated from design values of material parameters, incorporating the economic ramification factor as appropriate.

Design load Nominal load multiplied by the appropriate load factor.

Live loads Thermal and transient effects acting on the RSW as defined in Clauses 22.1.2 and 22.1.3 of AS 5100.2 but excluding earthquake effects.

Nominal load The unfactored loads and load effects as specified in this Specification.

1.4 NOTATION

The symbols used in this Specification are listed below. This list may not be complete; however, where a symbol is first used in the text, they are usually first defined in the text.

a	distance of the centre line of the sill beam from inside face of facing elements, measured horizontally
a_{cs} a'_{cs}	characteristic value for connection strength (ultimate and serviceability respectively) between geosynthetic reinforcement and segmental retaining wall units
a_u a'_u	characteristic value for shear capacity (ultimate and serviceability respectively) between segmental retaining wall units
a_{ih}	design horizontal acceleration coefficients developed within the RSW
a_{iv}	design vertical acceleration coefficients developed within the RSW
b	width of the sill beam measured normal to the facing elements
c_b	characteristic value of cohesion intercept of foundation soil under effective stress conditions
c^*_b	design value of cohesion intercept of foundation soil under effective stress conditions

c_{ub}	characteristic value for undrained shear strength of foundation soil
c^*_{ub}	design undrained shear strength of foundation soil
e	eccentricity of resultant design load S^*_v from centre line of the base of the RSW
e_j	eccentricity of resultant design load S^*_{vj} from centre of the j^{th} layer of soil reinforcement
h_j	depth of the j^{th} layer of soil reinforcement from the top of the facing elements at height (H_1) of the RSW
q^*_r	design bearing pressure acting on the base of the RSW according to an idealised Meyerhof distribution, calculated from resultant design load S^*_v
q^*_{ult}	bearing capacity of foundation soil using design values for soil parameters
q^*	design bearing capacity of foundation soil incorporating the economic ramification factor
s_{vj}	vertical spacing of soil reinforcement at the j^{th} level of soil reinforcement in the RSW
z_j	depth of the j^{th} layer of soil reinforcement from the upper level of the mechanical height (H) of RSW
B	transposed width of RSW in accordance with Meyerhof's approach
D_m	wall embedment depth
E	eccentricity of resultant design load S^*_{vb} from centreline of sill beam
F^*_e	design earthquake forces acting on the RSW from the bridge superstructure given in Annexure R57/A
F^*_h	horizontal component of design load (dead and live) acting on the RSW from the bridge superstructure given in Annexure R57/A
F^*_{hd}	dead load component of F^*_h acting on the RSW from the bridge superstructure given in Annexure R57/A
F^*_{h1}	live load component of F^*_h acting on the RSW from the bridge superstructure given in Annexure R57/A
F_m	nominal load due to mining subsidence effects
F^*_m	design load due to mining subsidence effects
F_s	nominal load due to differential settlement effects
F^*_s	design load due to differential settlement effects
F^*_v	vertical component of design load (dead and live) acting on the RSW from the bridge superstructure given in Annexure R57/A
F^*_{vd}	dead load component of F^*_v acting on the RSW from the bridge superstructure given in Annexure R57/A
F^*_{vl}	live load component of F^*_v acting on the RSW from the bridge superstructure given in Annexure R57/A
H	mechanical height of the RSW
H_1	facing height of the RSW
k_h	nominal horizontal pseudo-static acceleration coefficient
k_v	nominal vertical pseudo-static acceleration coefficient
$K^*_1(z_j)$	design coefficient of earth pressure mobilised at depth z_j within the zone of reinforced fill material

K^*_o	design coefficient of at rest earth pressure within the zone of reinforced fill material
K^*_{a1}	design coefficient of active earth pressure within the zone of reinforced fill material
K^*_{a2}	design coefficient of active earth pressure behind the zone of reinforced fill material
K^*_{a3}	design coefficient of active earth pressure behind sill beam and/or behind the zone of reinforced fill above the top level of the RSW
L	length of bottom layer of soil reinforcement at the base of the RSW, measured from the inside face of facing elements
L_j	length of j^{th} layer of soil reinforcement measured from the inside face of facing elements to the far end of the soil reinforcement. For trapezoidal sections, L_j is the transformed length as shown in Clause 4.6.6.
L_{bj}	length of j^{th} layer of soil reinforcement within non-yielding zone
N_m	number of soil reinforcements per metre width
Q_1	nominal vertical live load above the zone of reinforced fill material
Q_2	nominal vertical live load behind the zone of reinforced fill material
R_u	ultimate strength (or resistance or capacity)
S^*	design action
S^*_h	resultant horizontal design load per linear metre acting at the base of the RSW appropriate to the load combination under consideration
S^*_v	resultant vertical design load per linear metre acting at the base of the RSW appropriate to the load combination under consideration
S^*_{vj}	resultant vertical design load per linear metre acting at the j^{th} layer of soil reinforcement appropriate to the load combination under consideration, but excluding the effects of loading from sill beam
S^*_{hb}	resultant horizontal design load per linear metre at the base of the sill beam appropriate to the load combination under consideration. It includes horizontal loads from the bridge, earth pressures on the virtual back of the sill beam, and includes earthquake effects as appropriate.
S^*_{vb}	resultant vertical design load per linear metre at the base of the sill beam appropriate to the load combination under consideration. It includes sill beam self weight, vertical forces from dead and live loads on the sill beam heel behind the curtain wall, and bridge bearing loads.
T^*_{dc}	design tensile strength of soil reinforcement based on post-construction creep deformation considerations
T^*_{dcj}	T^*_{dc} of the j^{th} layer of soil reinforcement
T^*_{dr}	design tensile strength of soil reinforcement based on long term rupture considerations
T^*_{drj}	T^*_{dr} of the j^{th} layer of soil reinforcement
T^*_j	maximum design tensile force (per metre width) to be resisted by the j^{th} layer of soil reinforcement (see Clause 4.8.2)
T^*_{pj}	design tensile force (per metre width) in the j^{th} layer of soil reinforcement induced by design values of self weight of fill/soil above the j^{th} layer of soil reinforcement, surcharge and any associated lateral soil thrust effects acting on the virtual back of the RSW, as prescribed in Clause 4.8.2. T^*_{pj} must exclude the effects of loading from sill beam.

T^*_{sj}	design tensile force (per metre width) in the j^{th} layer of soil reinforcement induced by S^*_{vb}, as specified in Clause 4.8.2
T^*_{tj}	design tensile force (per metre width) in the j^{th} layer of soil reinforcement induced by S^*_{hb}, as specified in Clause 4.8.2
W_j	width of the individual j^{th} layer of soil reinforcement
W^*_2	any vertical load effect due to soil above zone of reinforced fill material which has not been included in the calculation of S^*_{vb}
Z	earthquake hazard factor, equivalent to an acceleration coefficient with an annual probability of exceedance of $^1/_{500}$ (i.e. a 10% probability of exceedance in 50 years)
$\alpha(z_j)$	coefficient of reduction of soil reinforcement tensile force at the facing connections/facing elements at depth z_j. The coefficient is defined as the ratio of soil reinforcement tensile force at the facing connections/facing elements to the soil reinforcement tensile force at the locus of maximum tension.
β_1, β_2, etc	inclination of a potential failure plane to the vertical plane
β_s	Slope of ground adjacent to toe of RSW
δ^*	design friction angle along the virtual back of the RSW
ϕ_b	characteristic value for peak angle of friction of foundation soil under effective stress conditions
ϕ_1	characteristic value for angle of friction at constant volume of reinforced fill material under effective stress conditions
ϕ_2	characteristic value for angle of friction at constant volume of soil behind the zone of reinforced fill material under effective stress conditions
ϕ_3	characteristic value for angle of friction at constant volume of soil above the zone of reinforced fill material under effective stress conditions
ϕ^*_b	design peak angle of friction of foundation soil under effective stress conditions
ϕ^*_1	design angle of friction at constant volume of reinforced fill material under effective stress conditions
ϕ^*_2	design angle of friction at constant volume of soil behind the zone of reinforced fill material under effective stress conditions
ϕ^*_3	design angle of friction at constant volume of soil above the zone of reinforced fill material under effective stress
γ_1	characteristic value for weight per unit volume of reinforced fill material (dry, wet, buoyant or saturated as appropriate)
γ_2	characteristic value for weight per unit volume of soil behind the zone of reinforced fill material (dry, wet, buoyant or saturated as appropriate)
γ_3	characteristic value for weight per unit volume of soil above the zone of reinforced fill material (dry, wet, buoyant or saturated as appropriate)
γ_b	characteristic value for weight per unit volume of foundation soil (dry, wet, buoyant or saturated as appropriate)
γ_s	characteristic value for weight per unit volume of sill beam (bulk or buoyant as appropriate)

γ_w	density of water
λ_{cs} λ'_{cs}	characteristic value for angle of friction for connection (ultimate and serviceability respectively) of geosynthetic reinforcement to segmental retaining wall units
λ_u λ'_u	characteristic value for angle of friction (ultimate and serviceability respectively) between segmental retaining wall units
μ_p	interaction coefficient relating $\tan(\phi_1)$ to the interface friction angle for reinforcement pullout under large deformation conditions
μ_{s1}	interaction coefficient relating $\tan(\phi_1)$ to the interface friction angle for sliding on reinforcement under large deformation conditions
μ_{sb}	interaction coefficient relating $\tan(\phi_b)$ to the interface friction angle for sliding on reinforcement under large deformation conditions
θ	inclination of facing elements to the vertical plane
σ_{vj}	vertical effective stress acting on the j^{th} level of soil reinforcement according to an idealised Meyerhof distribution, calculated from the design load, S^*_{vj}
$\sigma^*_{vj(avg)}$	average vertical effective stress along L_{bj}. It is limited to the undistributed factored dead and live loads directly above the j^{th} layer of soil reinforcement under consideration.
ω_1	inclination of backfill immediately behind facing elements to the horizontal plane
Ψ	angle between the normal to the wall face and the longitudinal alignment of the soil reinforcement
Υ_{g1}	load factor for γ_1
Υ_{g2}	load factor for γ_2
Υ_{g3}	load factor for γ_3
Υ_{gs}	load factor for γ_s
Υ_{gw}	load factor for γ_w
Υ_{q1}	load factor for Q_1
Υ_{q2}	load factor for Q_2
$\Phi_{\gamma b}$	material factor for γ_b
Φ_{cb}	material factor for c_{ub} and c_b
$\Phi_{\phi b}$	material factor for $\tan(\phi_b)$
$\Phi_{\phi 1}$	material factor for $\tan(\phi_1)$
$\Phi_{\phi 2}$	material factor for $\tan(\phi_2)$
$\Phi_{\phi 3}$	material factor for $\tan(\phi_3)$
Φ_c	material factor for characteristic value for structural connection resistance
Φ_{po}	material factor for characteristic value for pull out resistance of soil reinforcement from the facing connections/facing elements
$\Phi_{\mu p}$	material factor for μ_p
$\Phi_{\mu s}$	material factor for μs_1 and μ_{sb}
Φ_n	economic ramification factor

1.5 Reinforced Soil Wall Systems Approved for Use in the Works

Use in your design only RSW Systems that have been approved by TfNSW.

A list of the TfNSW approved RSW Systems, the respective System Owner, their applications and their conditions for use can be obtained from:
https://www.rms.nsw.gov.au/business-industry/partners-suppliers/documents/approved-products-materials/approved_rsw_systems_and_conditions_of_use.pdf.

Comply fully with the Conditions of Use for the respective System.

2 Site Investigation

Arrange for an assessment of the available site information, including the topography and relevant soil parameter values required for the RSW design, by a Geotechnical Engineer and a RSW Designer.

Carry out any further site investigations as required to obtain reliable estimates of all relevant soil parameters and the composition and profile of the ground water necessary for the RSW design.

Determine the characteristic value for peak angle of friction ϕ_b and cohesion intercept c_b of foundation soil under effective stress conditions in the laboratory using triaxial tests carried out in accordance with BS 1377 or equivalent.

Determine the characteristic value for undrained soil shear strength c_{ub} of foundation soil by insitu and/or laboratory tests, which may include one of the following methods:

(a) insitu vane shear test;

(b) unconsolidated undrained triaxial test;

(c) cone penetration test.

3 Design Control

Notwithstanding TfNSW D&C Q6, provide design control in accordance with the requirements of AS/NZS ISO 9001 Clause 7.3.

Design records must include calculations produced during design and verification.

The internal and external design of the RSW must be carried out by an Engineer(s) experienced in the design of RSW. Design, verification and certification of the geotechnical aspects of the RSW design covered in Clause 4.7 (External Design) must be carried out by a Geotechnical Engineer. Design, verification and certification of all other aspects of the RSW design (Internal Design) must be carried out by a RSW Designer.

Obtain from the RSW System Owner certification that the design complies with all the requirements of this Specification.

4 DESIGN

4.1 PRINCIPLES OF DESIGN

The design must be in accordance with limit state principles. The requirements to be satisfied in the design are those of Clause 7 of AS 5100.3.

The overall approach governing the design must generally be as specified in Clause 7 of AS 5100.3 and the requirements of this Specification. For each design requirement under consideration, the following relationship must be satisfied:

$$\phi R_u \geq S^*$$

where R_u is the ultimate strength (or resistance or capacity), ϕ is a strength reduction factor and S^* is the design action effect.

The design strength (or resistance or capacity) ϕR_u is a function of the material parameters and must be derived from the design values of the material parameters. The calculation of some design strengths (or resistances or capacities) such as bearing capacity, sliding resistance and soil reinforcement pull out resistance depend on the design loads as well as the design values of material parameters. In such cases, use design loads which are relevant to the load case under consideration in the derivation of the design strength (or resistance or capacity), unless otherwise specified.

Include an economic ramification factor Φ_n when calculating ϕR_u. Determine Φ_n in accordance with Clause 4.4.

Calculate the design action S^* in accordance with the load combinations tabulated in Table R57.1.

The anticipated movements of the RSW must be smaller than the limits specified in this Specification for the Serviceability Limit State.

4.2 DESIGN REQUIREMENTS

The design of the RSW must be in accordance with Clause 4 and the details shown in the Design Documentation drawings and Specifications. The design must take into account the following:

(a) (i) Ultimate and Serviceability Limit States;

(ii) requirements for components and materials used in the RSW as specified in Clause 5 of this Specification;

(iii) durability of the materials and components used in the RSW;

(iv) sequence and method of construction as stated in the design output in Clause 4.9.

(b) The requirements specified in Annexure R57/A.

(c) The design of structural members, e.g. footings, facing elements, facing connections and soil reinforcement. Design the facing elements and their connections for fire resistance, where specified in Annexure R57/A.

(d) Post-construction service deflections specified in Annexure R57/A, for the most onerous combination of:

(i) design loads;

(ii) soil reinforcement strain and long term creep;

(iii) temperature effects;

(iv) environmental degradation;

(v) foundation displacements.

(e) Design temperatures for the RSW System must not be less than 35°C in the zone which lies within 1 metre below finished ground level or 1 metre behind facing elements. Outside this zone, design temperatures for the RSW System must not be less than 25°C. Where necessary, the RSW Designer must use higher design temperatures for the structure depending on environmental conditions.

(f) The design must make adequate provision for sub-surface and surface drainage to prevent build-up of pore water pressure in or behind the RSW, and must contain details of all required drains, filters and outlets etc in the design output.

For RSW which abut hillsides or are located in areas where water may enter the RSW block from behind or above, provide a full height drainage layer at the virtual back of the RSW.

Where water may enter the RSW block from above, or where the ground surface above it is unpaved, provide a suitable impermeable layer, e.g. a geomembrane liner, to prevent water from entering the RSW block and to discharge the water to the drainage layer at the virtual back of the RSW.

Provide a separate surface drainage system to collect surface stormwater runoff, and discharge the water collected to a stormwater drainage system. Do not use the subsurface drainage system for drainage of surface water.

With the exception of RSW which are permanently submerged or subject to flooding, the design water table level must be the ground surface level in front of the RSW.

For RSW subject to flooding, assume the water table level in front of the RSW to be a minimum of 1 metre below the flood level which is assumed to occur within the RSW. More extreme circumstances may occur under flood conditions and these must be considered by the designer.

For permanently submerged RSW, consideration must be given to the appropriate water level within and outside the RSW, particularly in tidal situations.

(g) Any future extensions of the RSW in width and/or height as shown in the Design Documentation drawings and Specification.

(h) Loads and displacements imposed by piles in or adjacent to the RSW as detailed in the relevant Design Documentation drawings and Specification, both during installation and in-service. The following minimum provisions apply:

(i) where piles pass through the reinforced fill material (e.g. to support the bridge abutment), the design must coordinate the soil reinforcement locations with the pile locations and allow for all tolerances in the construction of the pile and the RSW.

(ii) where piles are placed in or adjacent to the RSW, the design must allow for any pile-soil interaction or other effects, both short and long term.

(iii) where piles are driven in or adjacent to the RSW, the design must allow for possible pile driving effects on RSW components. Where there is a possibility of disturbing facing elements during pile installation, make special provisions, e.g. a compressible filler placed adjacent to the landward side of the RSW at the pile location, or pre-boring used where there is an absolute certainty that soil reinforcement will not be disturbed. Extend the filler and/or preboring a minimum of 500 mm below the underside of the RSW block.

(iv) where piles are used to support bridge abutments, accommodate any horizontal forces transmitted from the bridge structure to the RSW due to pile-soil interaction in the design.

(v) for the case where piles are located within the reinforced fill material, post-construction movements of the RSW must not exceed the permissible pile movement specified in item (f) of Annexure R57/A.

(i) Where a RSW neither retains road embankments nor supports bridges, there is no possibility of these occurring in the future, design the RSW for a minimum nominal vertical live load of 10 kPa.

Otherwise, accommodate a minimum nominal vertical live load of 20 kPa on the RSW in the design unless specified otherwise in item (i) of Annexure R57/A.

(j) The effect of nearby structures and services on the RSW, both during and after construction e.g. leaking water mains.

(k) Post-construction strain of soil reinforcement must not be greater than 0.5% for RSW supporting sill beams, and within H of the abutment, and not greater than 1% for other RSW. Post-construction service deflections must comply with item (e) of Annexure R57/A.

(l) The maximum value of ϕ_1, ϕ_2, and ϕ_3, adopted in the design must be 34° in the absence of test data. If site specific test data is available before placement of the fill takes place, the maximum value adopted for ϕ_1 must be 36°. In all cases, the design value must be less than or equal to the actual tested shear angle of the soil when tested in accordance with Q181C: Draft 1994 or Q181C: 2008. For soil foundations, the maximum values of c_b and ϕ_b adopted in the design must be 20 kPa and 40° respectively. Give special consideration to foundations comprised of rock.

(m) The design life of the RSW (see Annexure R57/A (a)).

(n) The RSW System specification.

(o) ψ, the angle between the normal to the wall face and the longitudinal alignment of the soil reinforcement, must be ≤ 20°.

(p) Exclude the effect of passive earth pressures exerted on the foot of the wall below ground level when the passive earth pressure may increase the margin of safety on sliding in the design.

For bearing capacity calculations, the effect of this foundation material may be assumed to be retained provided that excavations are restricted (e.g. a small trench 0.6 m wide by 1.0 m deep) in front of the RSW. Where larger excavations may occur, the effect of this foundation material must be assumed to be excluded.

(q) Superimposed loadings from minor structures as appropriate e.g. impact on traffic barrier kerbs.

(r) The design must take into account both short and long term soil properties to allow for conditions during and after construction, and any foreseeable changes in pore water pressures.

(s) Any material, including scour protections, which are susceptible to scour in a 100 year average recurrence interval (ARI) flood, must be ignored in the design of RSW.

4.3 LOAD COMBINATIONS

As a minimum requirement, the following load combinations must be considered in the design:

Load Combination	Details
A	Loads applicable during construction
B	Maximum values of all loads, excluding earthquake effects
C	Maximum overturning loads with minimum gravity loads, excluding earthquake effects
D	Dead loads with partial live loads, earthquake and differential settlement effects
E	Maximum overturning loads with minimum gravity loads, partial live loads, earthquake and differential settlement effects
F	Dead and live loads with mining subsidence/differential settlement effects at the Serviceability Limit State

Table R57.1 details the load combinations to be considered in design together with the appropriate load factors.

Table R57.1 - Loads Combinations to be Considered and Appropriate Load Factors

<table>
<tr><th colspan="2" rowspan="3">Items</th><th rowspan="3">Load factors or design loads</th><th colspan="5">Ultimate Limit States</th><th>Serviceability Limit State</th></tr>
<tr><th colspan="6">Load combinations</th></tr>
<tr><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th></tr>
<tr><td rowspan="7">Dead Loads</td><td>Wt. of sill beam and structural components</td><td>Load factor Υ_{gs} for γ_s</td><td>1.0</td><td>1.25</td><td>1.0</td><td>1.25</td><td>1.0</td><td>1.0</td></tr>
<tr><td>Wt. of water [(2)]</td><td>Load factor Υ_{gw} for γ_w</td><td>1.0</td><td>1.0</td><td>1.0</td><td>1.0</td><td>1.0</td><td>1.0</td></tr>
<tr><td>Wt. of soil etc. within zone of reinforced fill material</td><td>Load factor Υ_{g1} for γ_1</td><td>1.0</td><td>1.25</td><td>1.0</td><td>1.25</td><td>1.0</td><td>1.0</td></tr>
<tr><td>Wt. of soil etc. behind zone of reinforced fill material</td><td>Load factor Υ_{g2} for γ_2</td><td>1.0</td><td>1.25</td><td>1.25</td><td>1.25</td><td>1.25</td><td>1.0</td></tr>
<tr><td>Wt. of soil etc. above zone of reinforced fill material incl. effect of soil loads on sill beam</td><td>Load factor Υ_{g3} for γ_3</td><td>1.0</td><td>1.25</td><td>1.0</td><td>1.25</td><td>1.0</td><td>1.0</td></tr>
<tr><td>Vertical load from bridge superstructure</td><td rowspan="2">Design loads (refer Annex. R57/A)</td><td>0</td><td>F^*_{vd} (max)</td><td>F^*_{vd} (min)</td><td>F^*_{vd} (max)</td><td>F^*_{vd} (min)</td><td>F^*_{vd} (max)</td></tr>
<tr><td>Horizontal load from bridge superstructure</td><td>0</td><td>F^*_{hd} (max)</td><td>F^*_{hd} (max)</td><td>F^*_{hd} (max)</td><td>F^*_{hd} (max)</td><td>F^*_{hd} (max)</td></tr>
<tr><td rowspan="4">Live Loads [(1)]</td><td>Traffic load above zone of reinforced fill material</td><td>Load factor Υ_{q1} for Q_1</td><td>0</td><td>1.5</td><td>0</td><td>0.5</td><td>0</td><td>1.0</td></tr>
<tr><td>Traffic load behind zone of reinforced fill material</td><td>Load factor Υ_{q2} for Q_2</td><td>0</td><td>1.5</td><td>1.5</td><td>0.5</td><td>0.5</td><td>1.0</td></tr>
<tr><td>Vertical load from bridge superstructure</td><td rowspan="2">Design loads (refer Annex. R57/A)</td><td>0</td><td>F^*_{vl} (max)</td><td>F^*_{vl} (min)</td><td>0.5 F^*_{vl} (max)</td><td>0.5 F^*_{vl} (min)</td><td>F^*_{vl} (max)</td></tr>
<tr><td>Horizontal load from bridge superstructure</td><td>0</td><td>F^*_{hl} (max)</td><td>F^*_{hl} (max)</td><td>0.5 F^*_{hl} (max)</td><td>0.5 F^*_{hl} (max)</td><td>F^*_{hl} (max)</td></tr>
<tr><td colspan="2">Earthquake effects from bridge superstructure</td><td>Design loads (refer Annex. R57/A)</td><td>0</td><td>0</td><td>0</td><td>F^*_e</td><td>F^*_e</td><td>0</td></tr>
<tr><td colspan="2">Earthquake effects on RSW and sill beam but excluding earthquake effects from bridge superstructure</td><td>Load factor on nominal load (refer Clause 4.3.1)</td><td>0</td><td>0</td><td>0</td><td>1.0</td><td>1.0</td><td>0</td></tr>
<tr><td colspan="2">Mining subsidence effects from bridge superstructure</td><td>Design loads (refer Annex. R57/A)</td><td>0</td><td>F^*_m</td><td>F^*_m</td><td>0</td><td>0</td><td>F^*_m</td></tr>
<tr><td colspan="2">Differential settlement effects from bridge superstructure</td><td>Design loads (refer Annex. R57/A)</td><td>0</td><td>F^*_s</td><td>F^*_s</td><td>F^*_s</td><td>F^*_s</td><td>F^*_s</td></tr>
</table>

Notes:

(1) Collision loads on traffic barrier kerbs, wind pressures on noise barriers and traffic impact loads on the RSW must be included in the live loads in accordance with AS 5100 where appropriate.

(2) In load cases A, B, C and F, a load factor of unity on water must be used in conjunction with the design water table with due allowance for flooding. In load cases D and E, a load factor of unity on water must be used in conjunction with the design water table, but flooding need not be considered simultaneously with earthquake effects.

Loads, load factors, material parameters and material factors for the RSW are shown in Figure R57.1.

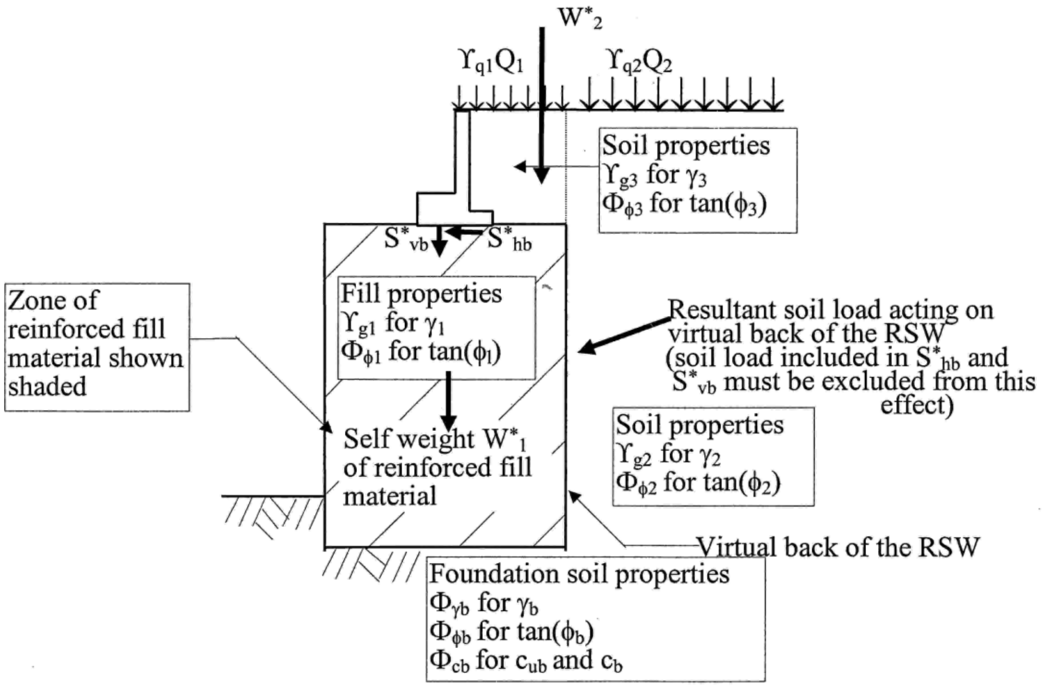


Figure R57.1 - Typical Loads, Load Factors, Material Parameters and Material Factors for RSW (earthquake effects, mining subsidence and differential settlements effects not shown). Refer to Table R57.1 for the different load combinations.

S^*_{vb} and S^*_{hb} are the resultant vertical and horizontal design loads per linear metre at the base of the sill beam. These forces depend on the load combination under consideration and may include effects of loads from the bridge, the sill beam self weight, soil on the sill beam heel and earth pressures on the back of the sill beam curtain wall.

It must be noted that the sill beam may not be sufficiently rigid to distribute the bridge bearing load evenly to the base of the sill beam. The RSW Designer must make adequate provisions in the design of the RSW for any such localised concentrations.

4.3.1 Earthquake Effects

4.3.1.1 General

Design the RSW for earthquake forces with respect to both internal and external design. Add the dynamic stresses to the static stresses (from self-weight, surcharge, live loads and static thrust) acting on the RSW. Also include other earthquake forces where they are transferred to the RSW. Where applicable, the earthquake forces from the bridge superstructure are given in item (d) of Annexure R57/A.

4.3.1.2 Dynamic Stresses

The soil behind the zone of reinforced fill material exerts a dynamic thrust on the virtual back of the RSW. The evaluation of the thrust must be in accordance with soil mechanics principles. Use either the pseudo-static “Mononobe-Okabe” approach using nominal pseudo-static acceleration coefficients (typically half of the peak ground acceleration), or dynamic analyses using the estimated ground acceleration spectrum.

The nominal horizontal and vertical pseudo-static acceleration coefficients are defined as k_h and k_v respectively. Determine the value of k_h for pseudo-static analyses from Table R57.2.

Table R57.2 - Nominal Horizontal Acceleration

Hazard factor (Z) in accordance with AS 1170.4	**Nominal horizontal pseudo-static acceleration coefficient (k_h)**	
	RSW supporting sill beams for bridges on principal interstate freeways and highways or on urban freeways	All other RSW
> 0.14	0.15	0.12
0.10 – 0.14	0.12	0.10
0.08 – 0.09	0.09	0.07
< 0.08	0	0

a_{ih} and a_{iv} are the design horizontal and vertical acceleration coefficients respectively developed within the RSW, and are related to k_h and k_v as follows:

$a_{ih} = (1.45 – k_h)\, k_h \quad a_{iv} = (1.45 – k_v)\, k_v$

Unless otherwise stated, take a_{iv} and k_v, whether positive or negative (i.e. acting either up or down), as not less than half of a_{ih} and k_h respectively. For RSW which do not support a bridge sill beam, take a_{iv} as zero. For other cases, apply k_v in the most critical direction.

For permanently submerged RSW, the effect of dynamic water pressures on and within the RSW may be evaluated in accordance with the approach of Matasuzawa et al (ASCE Journal of Geotechnical Engineering, Volume III, No.10, October 1985).

The following assumptions are considered to apply:

(a) Dynamic water pressure forces on the water side of the RSW must be determined from Westergaarde’s theory and taken to reduce the static water pressures on the outside of the RSW.

(b) Dynamic water pressure forces on the landward side of the RSW must be determined using the above mentioned method and applied together with static earth and water pressures.

(c) Dynamic water pressure forces on the water side and on the landward side of the RSW must be taken to act simultaneously to destabilise the structure.

Assess the effect of dynamic water pressures for both internal and external stability for all failure modes, e.g. pullout, sliding etc.

For RSW subjected to flooding, it is considered that the possibility of earthquake loads and flooding occurring together is remote. The design of the RSW does not need to allow for these effects simultaneously.

4.3.1.3 Earthquake Effects - External Design

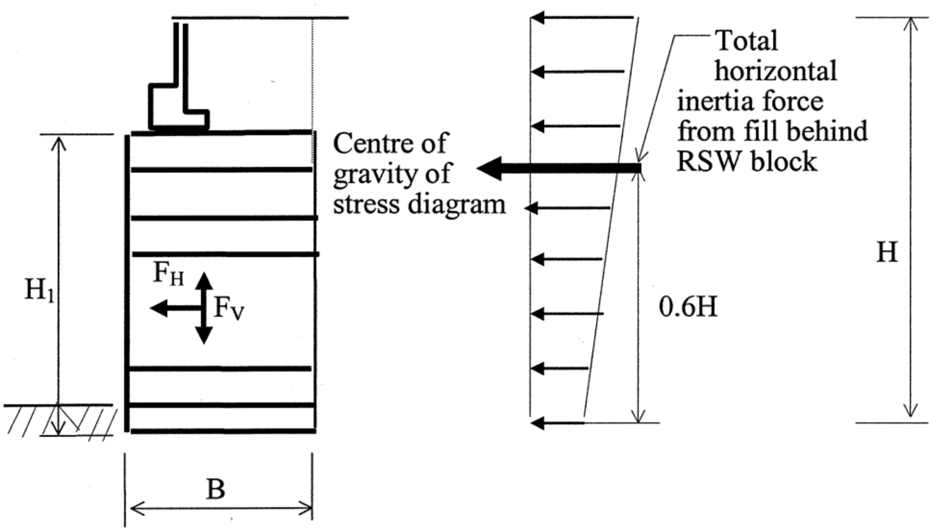
In external design, it is unlikely that the dynamic thrust exerted by the soil behind the zone of reinforced fill material and the inertia force of the RSW block will peak simultaneously.

Take the dynamic inertia force arising from acceleration of the RSW block as 50% of the calculated value; i.e. take the horizontal inertia force of the RSW block as:

$0.5\ a_{ih} \times$ mass of wall (per unit width)

Calculate the vertical inertia force in a similar manner. For calculation of wall inertia forces, restrict the width of the RSW block to the mechanical height H.

Calculate the dynamic stresses applied by the inertia effects in the backfill to the RSW using the pseudo-static "Mononobe-Okabe" approach with the hazard factors given in Table R57.2, or using the estimated ground acceleration spectrum as input into a dynamic analysis. With the pseudo-static method, the distribution of applied stress and the location of the resultant force are shown in Figure R57.2.



Inertia Force of RSW block : $F_H = 0.5\ a_{ih}\ \gamma_1\ B\ H_1$

$F_V = \pm\ 0.25\ a_{iv}\ \gamma_1\ B\ H_1$

with $B \leq H$

Figure R57.2 - Distribution of Inertia Force Applied to Rear of RSW Block

Apply wall friction in accordance with Clause 4.6.1 of this Specification. For external stability, consider the combined effects of static stresses, dynamic stresses from the backfill to the RSW and the inertia of the RSW block together with the inertia effects of fill above the RSW and dynamic and static forces transmitted from the bridge superstructure.

In the overall slip failure analysis, obtain the nominal earthquake force by multiplying the appropriate gravity loads by k_h and k_v respectively.

4.3.1.4 Earthquake Effects - Internal Design

In internal design, distribute the total horizontal inertia force acting on the block of reinforced fill material to the different layers of soil reinforcement in proportion to their resistant area. Combine the internal dynamic force with the static tensile forces generated from the weight of the structure, applied static earth pressure and other surcharge forces to give the maximum tensile force in the reinforcement.

The horizontal dynamic force is equal to the weight of the active zone multiplied by the acceleration coefficient a_{ih}. The active zone is considered to be identical to that defined for the static calculations, with the area bounded by the wall face and the loci of maximum reinforcement tension as given in Figure R57.11.

Distribute the dynamic force among the individual reinforcing strips in accordance with their resistant area as a proportion of the total resistance. Obtain the resistant area of an individual layer by multiplying the width of the reinforcement and the embedded length in the resistant zone, L_{bj} (per unit width of wall).

The ratio of the horizontal internal dynamic force distributed to an individual layer of reinforcement to the total dynamic force must be as the ratio of the resistant area of that layer to the sum of the resistant area of all of the layers of reinforcement (per unit width of wall).

In the wedge analysis, obtain the design earthquake force by multiplying the appropriate gravity loads of the wedge segment by a_{ih} and a_{iv}, as appropriate.

4.3.1.5 Detailing for Earthquake Effects

The design of the RSW must ensure that:

(a) Any failure is in a ductile mode, i.e. yielding of soil reinforcement, or breaking of bond between the reinforced fill material and the soil reinforcement occurs before failure at connections. Achieve this by multiplying the material factors Φ_{po}, Φ_{up} and Φ_{us} used to calculate the pull out resistance of soil reinforcement by a factor of 0.9.

(b) For RSW supporting a sill beam, loss of support to the sill beam will not occur. The Engineer responsible for the bridge design will have allowed for a minimum edge distance at the support as shown on the drawings for the bridge structure. Maintain this minimum edge distance.

4.3.1.6 Liquefaction

Assess the foundation materials for any liquefaction potential induced by an earthquake, particularly for saturated granular materials. Where it can be demonstrated that granular materials have a relative density index of greater than 65% or an SPT value (at 60% energy rating) in excess of 25, the material can be considered to be resistant to liquefaction. Where the thickness of saturated granular material exceeds 10 m, the resistance to liquefaction requires more detailed consideration.

4.3.2 Differential Settlement and/or Mining Subsidence Effects

Design the RSW to accommodate any differential settlement and/or mining subsidence effects specified in item (d) of Annexure R57/A.

4.4 MATERIAL AND ECONOMIC RAMIFICATION FACTORS

Derive the design values for soil shear strength parameters from the following equations:

$$\tan(\phi^*) = \Phi_{\phi} \tan(\phi)$$

$$\tan(\phi^*_{b}) = \Phi_{\phi b} \tan(\phi_{b})$$

$$c^*_{b} = \Phi_{cb}\, c_{b}$$

$$c^*_{ub} = \Phi_{cb}\, c_{ub}$$

where ϕ and c are the estimated characteristic values for the soil friction angle and cohesion respectively; and

Φ is the appropriate material factor shown in Table R57.3.

Table R57.3 - Material Factors

Item	Material factors	Ultimate Limit States	Serviceability Limit State
		Load combinations	
		A, B, C, D, E	F
Soil strength parameters	$\Phi_{\phi 1}$, $\Phi_{\phi 2}$, $\Phi_{\phi 3}$	1.0	1.0
	$\Phi_{\phi b}$	0.8	1.0
	Φ_{cb}	0.5	1.0
Foundation soil density	$\Phi_{\gamma b}$	1.0	1.0
Tensile strength of soil reinforcement – Inextensible System	Refer to Conditions of Use for System for values of T^*_{dr} and T^*_{dc}		
Tensile strength of soil reinforcement – Extensible System			
Pull out resistance of soil reinforcement from reinforced fill material	$\Phi_{\mu p}$	0.75	1.0
Sliding resistance between soil reinforcement and reinforced fill material/foundation soil	$\Phi_{\mu s}$	0.85	1.0
Pull out resistance of soil reinforcement from the facing connections/facing elements	Φ_{po}	0.70	1.0
Structural strength of connection Pullout resistance of connection from facing element	Φ_{c}	0.85	1.0

An economic ramification factor Φ_{n} has been included in the equations for R^*. Φ_{n} is specified in Table R57.4. Obtain the RSW classification as a major or minor structure from item (b) of Annexure R57/A.

Table R57.4 - Economic Ramification Factor Φn

RSW Design Life	RSW Classification [1]	Case (Clause Reference)	Ultimate Limit States	Serviceability Limit State
			Load combinations	
			A, B, C, D, E	F
> 5 years, ≤ 100 years	Major	Clause 4.7.4	1.0	1.0
		Other than Clause 4.7.4	0.9	1.0
	Minor	All	1.0	1.0
≤ 5 years	Major	All	1.0	1.1
	Minor	All	1.1	1.1

Note:

[1] Refer Annexure R57/A for classification.

The appropriate values of material and economic ramification factors must not be less stringent than those specified in Table R57.3 and Table R57.4. However, the RSW Designer must select the appropriate values of material and economic ramification factors used in the design based on the nature of the RSW System, test data representative of the materials to be used in the Works, and the reliability of all parameters used in the design.

State clearly in the design output all material factors used in the RSW design.

4.5 DIMENSIONS AND EMBEDMENT OF THE RSW

Prior to external or internal design, define the overall geometry of the RSW. The dimensions of the RSW must not be less than the minimum values specified in Table R57.5.

Table R57.5 - Minimum Dimensions of RSW

Application	Minimum soil reinforcement length	
RSW not supporting sill beams	Walls with uniform reinforcement length	greater of 2 metre or (0.6H + 1) metre
	Trapezoidal walls	refer to Figures R57.3(d), R57.3(e) and R57.5(a)
	Stepped walls	refer to Figure R57.5(b)
RSW supporting sill beams	greater of 7 metre or (0.6H + 2) metre	
Walls subject to low thrust from retained fill such as negative backslope or embedded walls - see Figures R57.3(f) and R57.3(g)		0.6H
Trapezoidal walls: Vertical spacing of soil reinforcement is as follows: where $L_j/H < 0.55$, then $s_{vj}/H \le 0.125$ $0.55 \le L_j/H < 0.65$, $s_{vj}/H \le 0.167$ $0.65 \le L_j/H$, $s_{vj}/H \le 0.222$		

Note: Read this table in conjunction with Figures R57.3 and R57.5.

Base the geometric size of a RSW upon the concept of a mechanical height, H, which is defined in Figure R57.3.

Acceptable details for trapezoidal sections are shown in Figures R57.3 (d) and R57.3 (e).

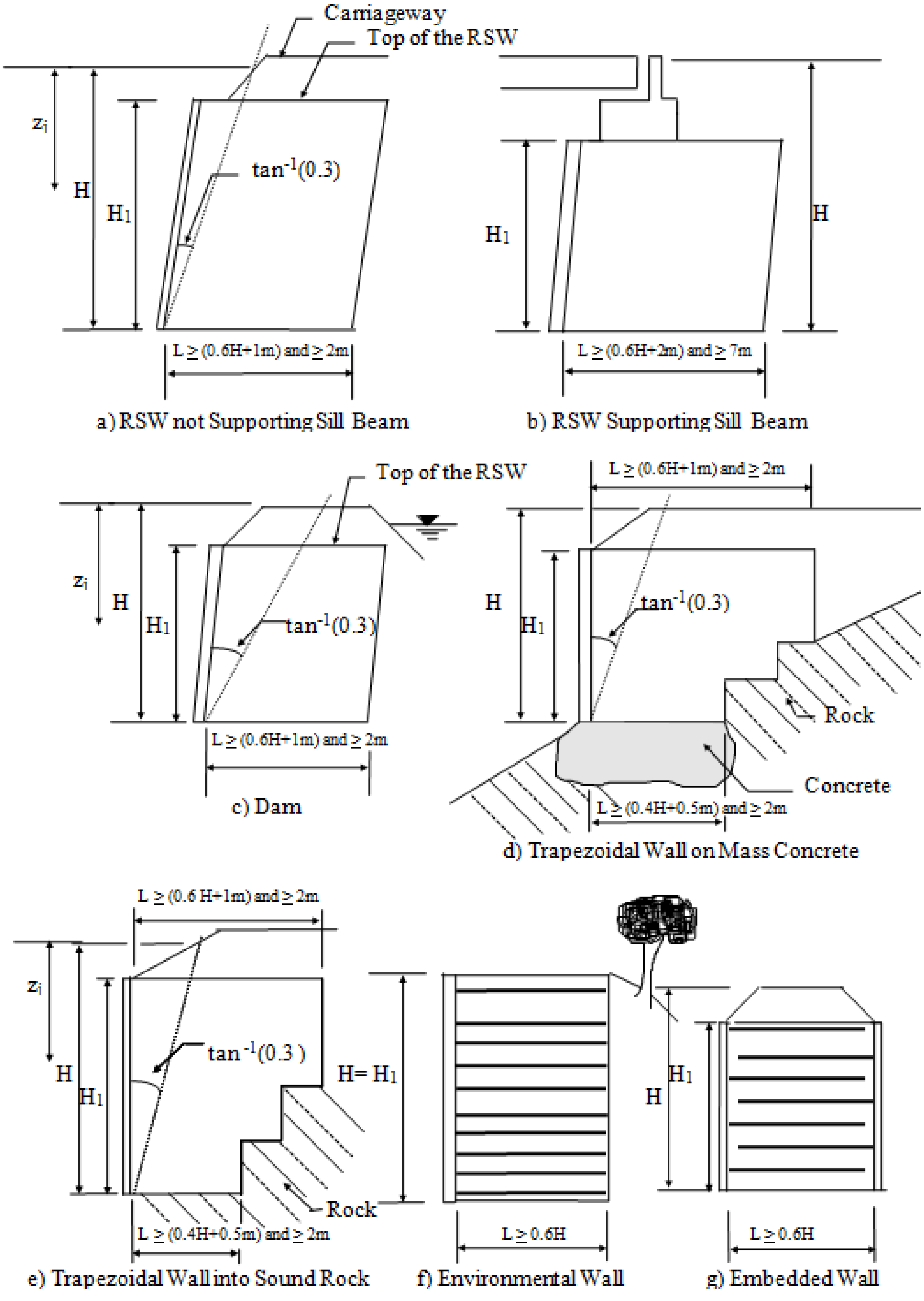


Figure R57.3 - Minimum Dimensions of RSW

For the purposes of this clause, the lengthening of the upper layers of soil reinforcement to account for the effects of short term horizontal impact type loading (e.g. impact loads on a traffic barrier and vehicle braking loads) does not mean that the limitations on trapezoidal sections contained in this

Specification apply. Do not take seismic loads and wind loads as short term horizontal impact type loads.

Do not use trapezoidal sections under the following circumstances:

(a) where foundations are not formed by excavation into sound rock;

(b) where the RSW supports a sill beam.

For the purposes of this clause, sound rock is defined as rock which is slightly weathered (or better) with medium strength (or better) in accordance with AS 1726. The Geotechnical Engineer must make allowance for joints and other factors affecting rock behaviour.

The toe of the RSW must be embedded below the ground surface. The embedment D_m is defined in Figure R57.4, and must not be less than that given in Table R57.6, which is applicable to RSW with slenderness ratios greater than $L/_H = 0.6$, and in good ground conditions.

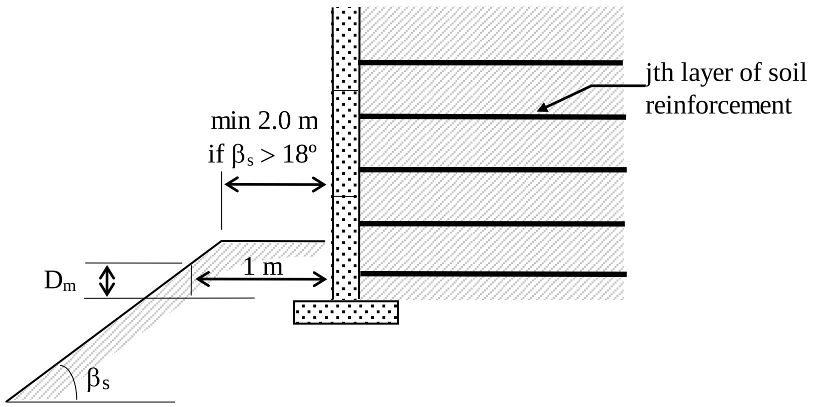


Figure R57.4 - Definition of Embedment D_m

Table R57.6 - Minimum Embedment of RSW

Slope of the ground at toe, β_s (refer to Figure R57.5)		**Embedment, D_m (m)**
$\beta_s = 0°$	RSW not supporting sill beams	$H/_{20}$
	RSW supporting sill beams	$H/_{10}$
$\beta_s = 18°$	RSW not supporting sill beams	$H/_{10}$
$\beta_s = 27°$	RSW not supporting sill beams	$H/_7$
$\beta_s = 34°$	RSW not supporting sill beams	$H/_5$

Notes:

(1) $D_m \geq 0.3$ m

(2) For $\beta_s > 0$, minimum embedment D_m for RSW supporting sill beams must be subjected to special consideration.

Give special consideration for trapezoidal walls. Restrictions on the cross-sectional dimensions of the RSW with trapezoidal and stepped cross sections are given in Figure R57.5.

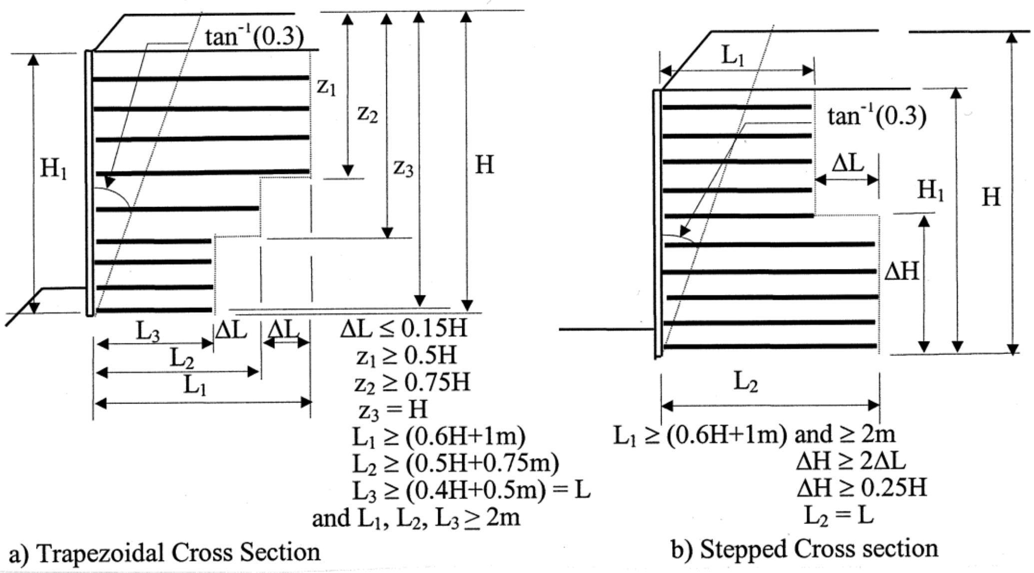


Figure R57.5 - Special Requirements for Trapezoidal and Stepped Cross Sections

On sites where the Geotechnical Engineer considers the foundation to comprise weak or soft soils, a greater embedment depth may need to be provided.

Where the slope of the ground adjacent to the toe of the RSW, β_s, is greater than 18°, provide a berm at the toe of the RSW with minimum width of 2 m, to provide sufficient safe working area for compaction using a small roller and for carrying out inspections after completion of the RSW. In this case, the embedment depth is measured from the top of the berm. Provide to the berm 2% crossfall away from the RSW for drainage.

4.6 INFORMATION FOR EXTERNAL AND INTERNAL DESIGN

4.6.1 Design Friction Angle δ^* Along Virtual Back of RSW

The sign convention for δ^* is as shown in Figure R57.6.

Select the friction angle δ^* along the virtual back of the RSW by considering the anticipated relative movement between the retained fill and the zone of reinforced fill material.

If the reinforced fill material cannot move downward relative to the retained fill, take δ^* as follows:

(a) Inextensible soil reinforcement

$\delta^* \leq (1.2 - L/H)\ \phi^*_2$ or $(1.2 - L/H)\ \phi^*_1$, whichever is less

(b) Extensible soil reinforcement

for $\omega_3 \geq 0$ $\quad \delta^* \leq \omega_3$ or $0.5\phi^*_1$ or $0.5\phi^*_2$, whichever is less

for $\omega_3 < 0$ $\quad \delta^* \leq 0$

where ω_3 is the equivalent slope angle at a horizontal distance $0.5H_v$ from the top of the virtual back of the RSW as defined in Figure R57.6.

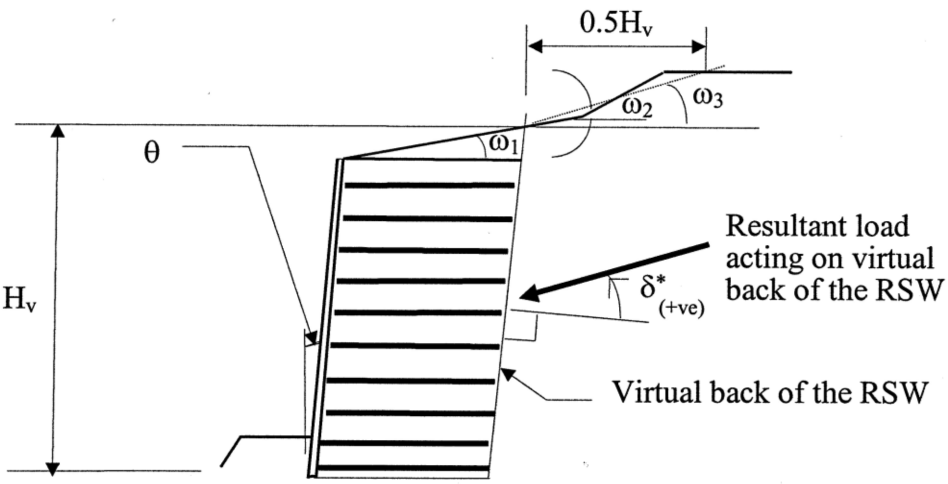


Figure R57.6 - Sign Convention for Design Friction Angle δ^* and Definition of ω_3

4.6.2 Angle of Inclination θ of Facing Elements to Vertical Plane

Determine the angle of inclination θ of facing elements to the vertical plane in accordance with Figure R57.7. The angle θ must not be more than 20°.

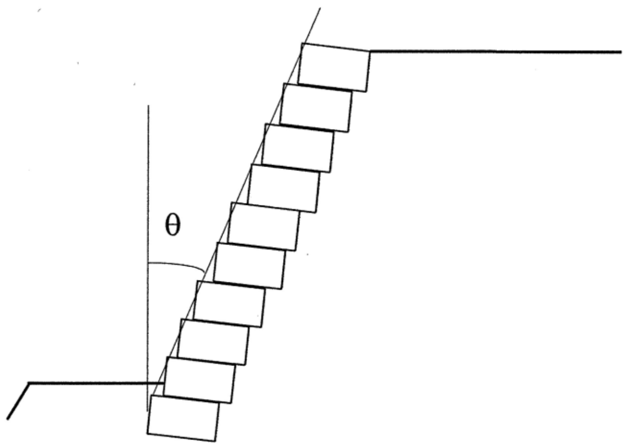


Figure R57.7 - Definition of Angle of Inclination θ of Facing Elements to the Vertical Plane

4.6.3 Design Earth Pressure Acting on Virtual Back of RSW

Where the backfill slope angle is constant (i.e. ω_2 is a constant) behind the virtual back of the RSW, calculate the minimum design active earth pressure acting at an angle δ^* to the normal to the virtual back of the RSW in accordance with the Coulomb Earth Pressure Theory, using a coefficient of active earth pressure as follows:

$$K^*_{a2} \text{ or } K^*_{a3} \geq \frac{\cos^2(\theta + \varphi^*_2)}{\cos^2\theta\cos(\theta - \delta^*)\left\{1 + \sqrt{\dfrac{\sin(\varphi^*_2 + \delta^*)\sin(\varphi^*_2 - \omega_2)}{\cos(\theta - \delta^*)\cos(\theta + \omega_2)}}\right\}^2}$$

Where the backfill slope angle ω_2 varies behind the virtual back of the RSW, the backfill design active earth pressures acting on the virtual back of the RSW must be the maximum earth pressure calculated from the trial wedge method as described in Chapter 11.11 of “Foundation Analysis and

Design" by Joseph E. Bowles, 4th Edition, McGraw Hill, 1988, or by taking a conservative constant slope angle using the equation above.

4.6.4 Design Earth Pressure Acting behind Sill Beam

Calculate the design earth pressure behind a sill beam ignoring wall friction, and acting normal to the sill beam curtain wall.

4.6.5 Design Coefficient of Earth Pressure within Zone of Reinforced Fill Material

For a RSW with an angle of inclination θ of facing elements to the vertical plane, derive minimum values of coefficient of active and at rest earth pressure, K^*_{a1} and K^*_o as follows:

$$K^*_{a1} \geq \frac{\cos^2(\theta + \phi^*_1)}{\cos(\theta)[\cos(\theta) + \sin(\phi^*_1)]^2}$$

$$K^*_o \geq \frac{\cos^2(\theta + \phi^*_1)}{\cos(\theta)[\cos(\theta) + \sin(\phi^*_1)]}$$

Take the design coefficient of earth pressure at depth z_j, $K^*_1(z_j)$, within the RSW as follows:

(a) Extensible soil reinforcement

$K^*_1(z_j) = K^*_{a1}$, for all z_j

(b) Inextensible soil reinforcement

(i) For $z_j \leq 6$ m

$K^*_1(z_j) = (1 - z_j/6)\, K^*_o + (z_j/6)\, K^*_{a1}$

(ii) For $z_j > 6$ m

$K^*_1(z_j) = K^*_{a1}$

Take the earth pressure as acting normal to facing elements.

4.6.6 Trapezoidal Cross Sections

Analyse each trapezoidal cross section as follows:

(a) For Clauses 4.7.4, 4.8.5 and 4.8.6, analyse the trapezoidal section using the actual reinforcement layout.

(b) For Clause 4.8.4, take L_{bj} as the actual physical length of soil reinforcement beyond the line of maximum tension in the calculation of pullout resistance. For other requirements in this clause, analyse the trapezoidal section by transforming it into an equivalent block as shown in Figure R57.8.

(c) For Clauses other than 4.7.4, 4.8.4, 4.8.5 and 4.8.6, analyse the trapezoidal section by transforming it into an equivalent block as shown in Figure R57.8. The length of soil reinforcements of the transformed section must exceed the minimum value specified in Clause 4.5.

(d) For Clause 4.7.2, take foundations effective width as the actual physical length of the bottom layer of soil reinforcement or $(L - 2\,|e|)$, whichever is the lesser.

(e) Take inclination of facing, θ, as zero for all design purposes.

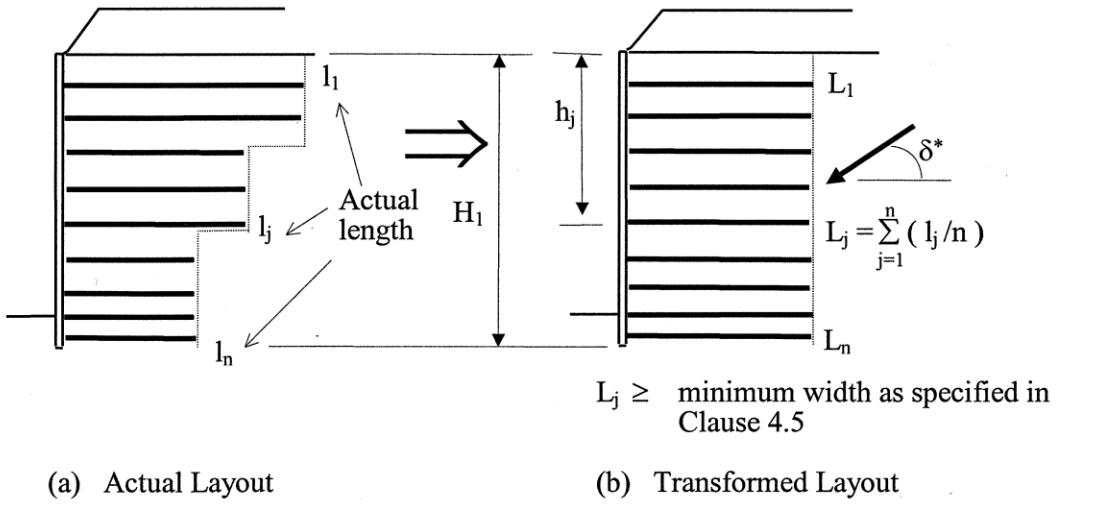


Figure R57.8 - Transformation of Trapezoidal Section to Uniform Length Model

4.6.7 Sill Beams

For sill beams, under the serviceability load case, the maximum permissible vertical pressure at the underside of the sill beam must be:

(a) 150 kPa for dead loads only;

(b) 200 kPa when other loads are included.

The eccentricity E of resultant forces S^*_{vb} (refer Figure 57.14) must not exceed:

(i) $b/_8$ for dead loads only;

(ii) $b/_6$ when other loads are included.

4.7 EXTERNAL DESIGN

4.7.1 General

The external design of the RSW must be carried out by a Geotechnical Engineer.

The design must consider both Ultimate and Serviceability Limit States and must include, but not be limited to, the following failure mechanisms:

(I) Ultimate Limit States:

- (i) bearing failure;
- (ii) sliding;
- (iii) slip failures.

(II) Serviceability Limit State:

- (i) settlement, tilting, eccentricity, rotational and lateral movement;
- (ii) slip failures.

4.7.2 Bearing Failure

For design purposes, assume an idealised Meyerhof distribution to be acting on the base of the RSW (refer to Figure R57.9). Calculate the design bearing pressure q^*_r as follows:

$$q_r^* = \frac{S_v^*}{B}$$

For non-trapezoidal sections, take B as $L - 2|e|$. For trapezoidal section, take B as the actual physical length of the bottom layer of soil reinforcement or $L - 2|e|$, whichever is the lesser.

S^*_v and e in the above equation must include the effect of all loads relevant to the load combination under consideration.

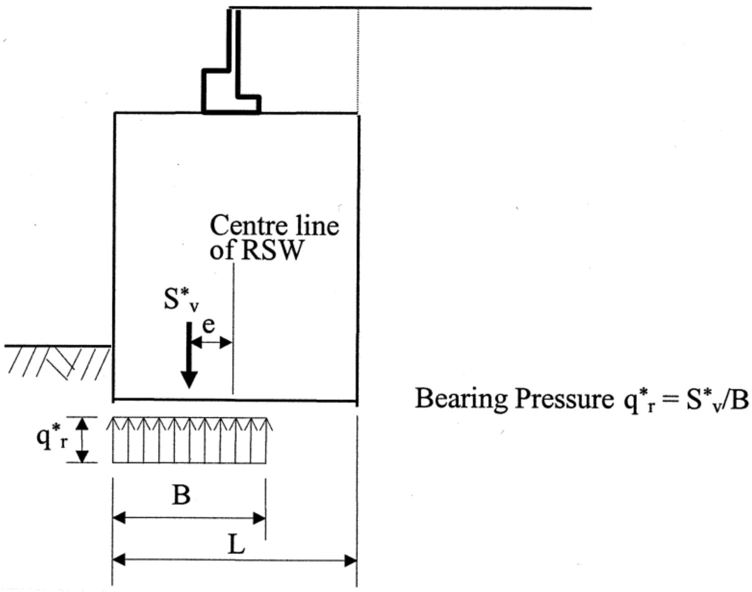


Figure R57.9 - Idealised Meyerhof Pressure Distribution Along Base of RSW

The design bearing capacity q^* must be larger than or equal to the design bearing pressure q^*_r. The design bearing capacity q^* must satisfy the following:

$$q^* = \Phi_n \, q^*_{ult}$$

$$q^* \geq q^*_r$$

For RSW founded on soil or extremely low to low strength rock, calculate q^*_{ult} in accordance with Appendix A of Geoguide 1, using the design values of foundations shear strength parameters derived in accordance with Clause 4.4 of this Specification.

In the calculation of q^*_{ult}, for non-trapezoidal sections, take foundation's effective width as $L - 2|e|$. For trapezoidal sections, take the foundation's effective width as $L - 2|e|$ or the actual physical length of the bottom layer of soil reinforcement, whichever is the lesser.

Apply a load factor of 1.0 to the density of the foundation soil (dry, submerged or saturated as appropriate).

Where necessary, the Geotechnical Engineer must specify in the design output details of the method of preparing and improving the foundation to achieve the design bearing capacity.

4.7.3 Sliding

The design must take into account the stability against forward sliding of the RSW at the interface between the reinforced fill material and the foundation soil, and sliding on or between any soil reinforcement layers.

The following conditions at the base of the RSW must be satisfied:

(a) For long term stability, where there is soil-to-soil contact at the base of the RSW:

$$\Phi_n S^*_v \tan(\phi^*_1) \geq S^*_h \quad \text{and}$$

$$\Phi_n [S^*_v \tan(\phi^*_b) + c^*_b B] \geq S^*_h$$

(b) For short term stability, where there is soil-to-soil contact at the base of the RSW:

$$\Phi_n c^*_{ub} L \geq S^*_h$$

(c) For long term stability, where there is soil reinforcement-to-soil contact at the base of the RSW:

$$\Phi_n \Phi_{\mu s} \mu_{s1} \tan(\phi^*_1) S^*_v \geq S^*_h \quad \text{and}$$

$$\Phi_n \Phi_{\mu s} \mu_{sb} [\tan(\phi^*_b) S^*_v + c^*_b B] \geq S^*_h$$

(d) For short term stability, where there is soil reinforcement-to-soil contact at the base of the RSW:

$$\Phi_n \Phi_{\mu s} \mu_{sb} c^*_{ub} L \geq S^*_h$$

where μ_{s1}, and μ_{sb} are product specific coefficients.

The Geotechnical Engineer must select the appropriate values of μ_{s1} and μ_{sb} in the design based on the nature of RSW System and the variability of parameters involved in the design. In no case must the selected values be greater than the values stated in Conditions of Use for the corresponding system.

4.7.4 Overall Slip Failures

Perform stability analyses (both circular and non-circular failure surfaces), examining an extensive number of trial slip surfaces, to identify the most critical overall slip surface(s).

It may be assumed that no slip surface will pass through the strip contact area representing a bridge sill beam. When the facing consists of a structural element formed in one piece, the shear resistance of the facing may be included in the analysis.

Use load combination F in Table R57.1 of this Specification with all load factors set to 1.0 and earthquake effects included in the analysis where appropriate. Do not apply the material factors in Table R57.3. The calculated factor of safety must apply to soil shear strength as well as reinforcement strength (tensile capacity and pullout strength) in order to reach a limit equilibrium state.

Where earthquake together with live load effects are included in the analysis, the load factor for earthquake effects and live load effects may be set to 0.75 and 0.5 respectively. Take the strength of the fill (ϕ_1, ϕ_2, and ϕ_3) at constant volume conditions. The minimum overall factor of safety achieved must be 1.35 for RSW not supporting sill beams and 1.6 for RSW supporting sill beams.

An acceptable alternative is to check the overall stability using the peak friction angle or other suitable material shear strength with a minimum overall factor of safety of 1.6. In this case, limit the peak effective friction angle for the earthworks to a maximum of 40° and the effective cohesion to a maximum of 10 kPa.

Where a RSW retains an overlying cut batter alone, check the local stability of the batter slope using conventional techniques.

In the case of a slip surface passing through the RSW, the resistance provided by the soil reinforcement intercepted by the slip surface may be included in the analysis.

Determine the design resistance of the j^th^ layer of soil reinforcement intercepted by a slip surface as the lesser of:

$\Phi_n N_m T^*_{dcj} \cos(\Psi)$; and

$\Phi_n \Phi_{\mu p}\, 2\, N_m W_j L_{bj} \mu_p \tan(\phi^*_1)\, [\sigma^*_{vj(avg)}] \cos(\Psi)$

Exclude loading from the sill beam from the calculation of pull out resistance provided by the soil reinforcement.

For the purpose of this clause, L_{bj} is defined as the length of the j^th^ layer of soil reinforcement within the non-yielding zone outside the potential overall slip surface under consideration. An example of this is shown in Figure R57.10.

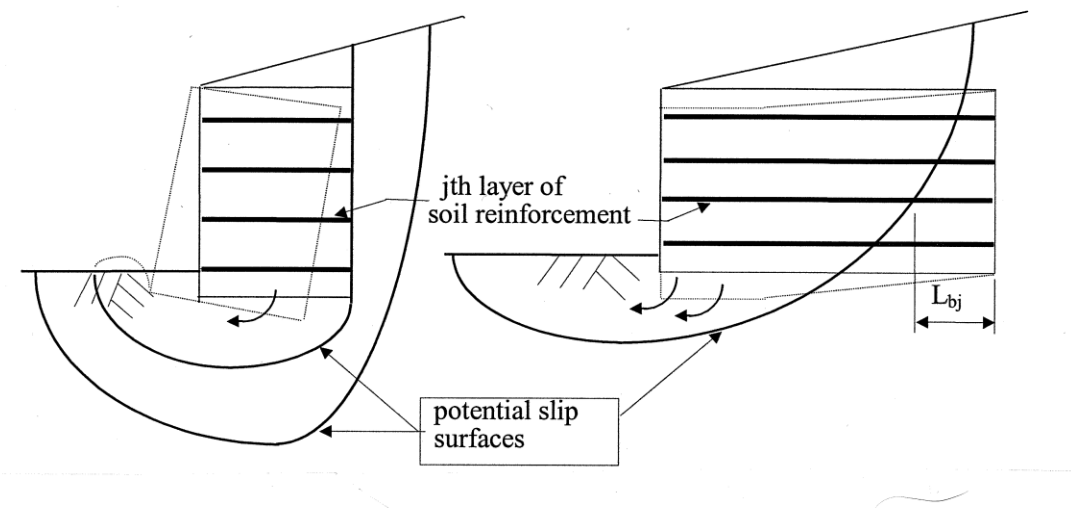


Figure R57.10 - Examples of Overall Slip Surfaces

4.7.5 Settlement, Tilting, Rotational and Lateral Movement

Limit post-construction horizontal and vertical movement of the RSW due to settlement, tilting, rotational and lateral movement to that specified in item (e) of Annexure R57/A.

4.7.6 Eccentricity at RSW Base

$e/_L$ must be less than $1/_6$ for the Serviceability Limit State.

4.8 INTERNAL DESIGN

4.8.1 General

The internal design of the RSW must be carried out by a RSW Designer. The design must take into account, but not be limited to, the following limit states and failure mechanisms:

(I) Ultimate Limit State

(i) stability of individual soil reinforcement, involving rupture of reinforcement and soil pull out failure;

(ii) stability of wedges;

(iii) forward sliding of the wall;

(iv) structural failure of facing connections and pull out failure of facing connections from facing elements;

(v) structural failure of facing elements;

(vi) durability.

(II) Serviceability Limit State

(i) stability of individual soil reinforcement, involving post-construction creep and soil pull out failure;

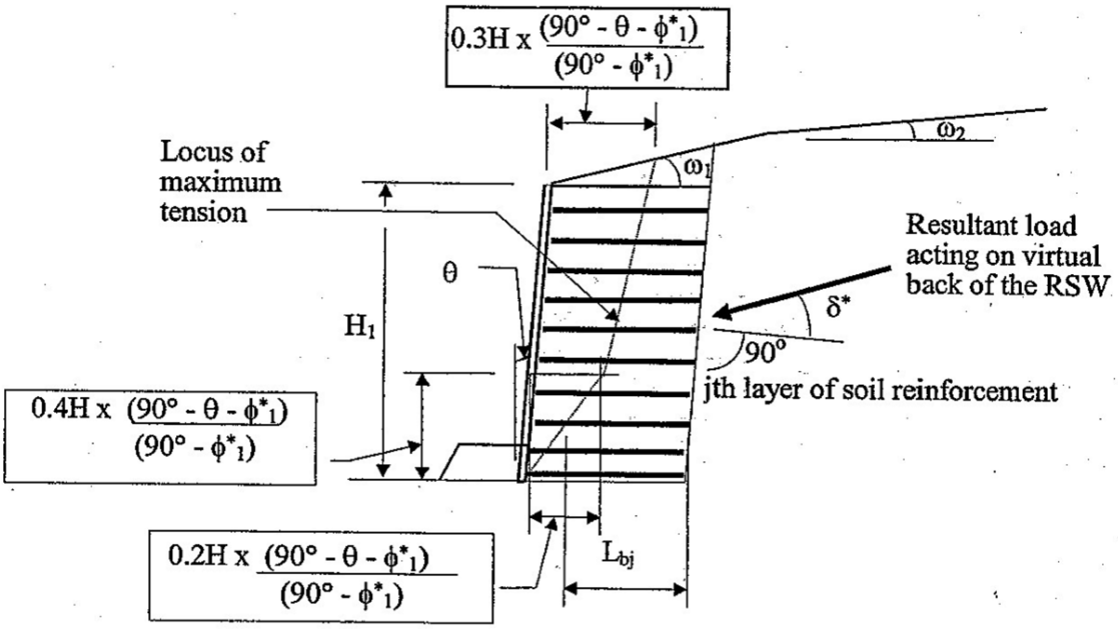
(ii) stability of wedges;

(iii) structural failure of facing connections and pull out failure of facing connections from facing elements.

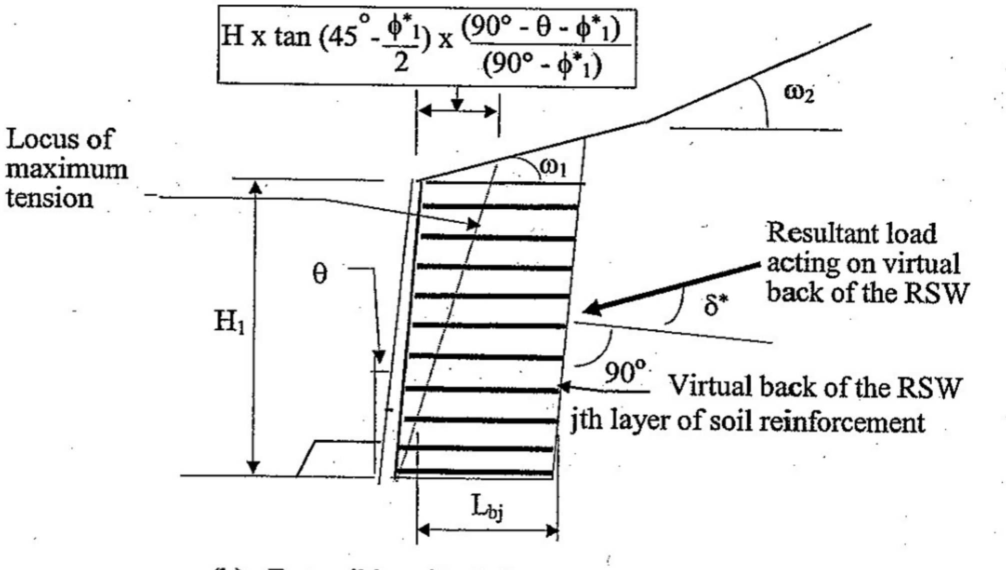
Where necessary, carry out additional checks using established soil mechanics principles which have been proven (theoretically as well as by use of full scale monitoring records) to be applicable for such situations.

4.8.2 Maximum Tensile Force and Locus of Force

For the purpose of this Clause, L_{bj} is defined as the length of j^{th} layer of soil reinforcement beyond the locus of maximum tension as shown in Figure R57.11. Figures R57.11 (a) and (b) define the loci of maximum tension for inextensible and extensible soil reinforcement respectively for RSW not supporting sill beams. Figures R57.11 (c) and (d) define the loci of maximum tension for inextensible and extensible soil reinforcement respectively for RSW supporting sill beams.



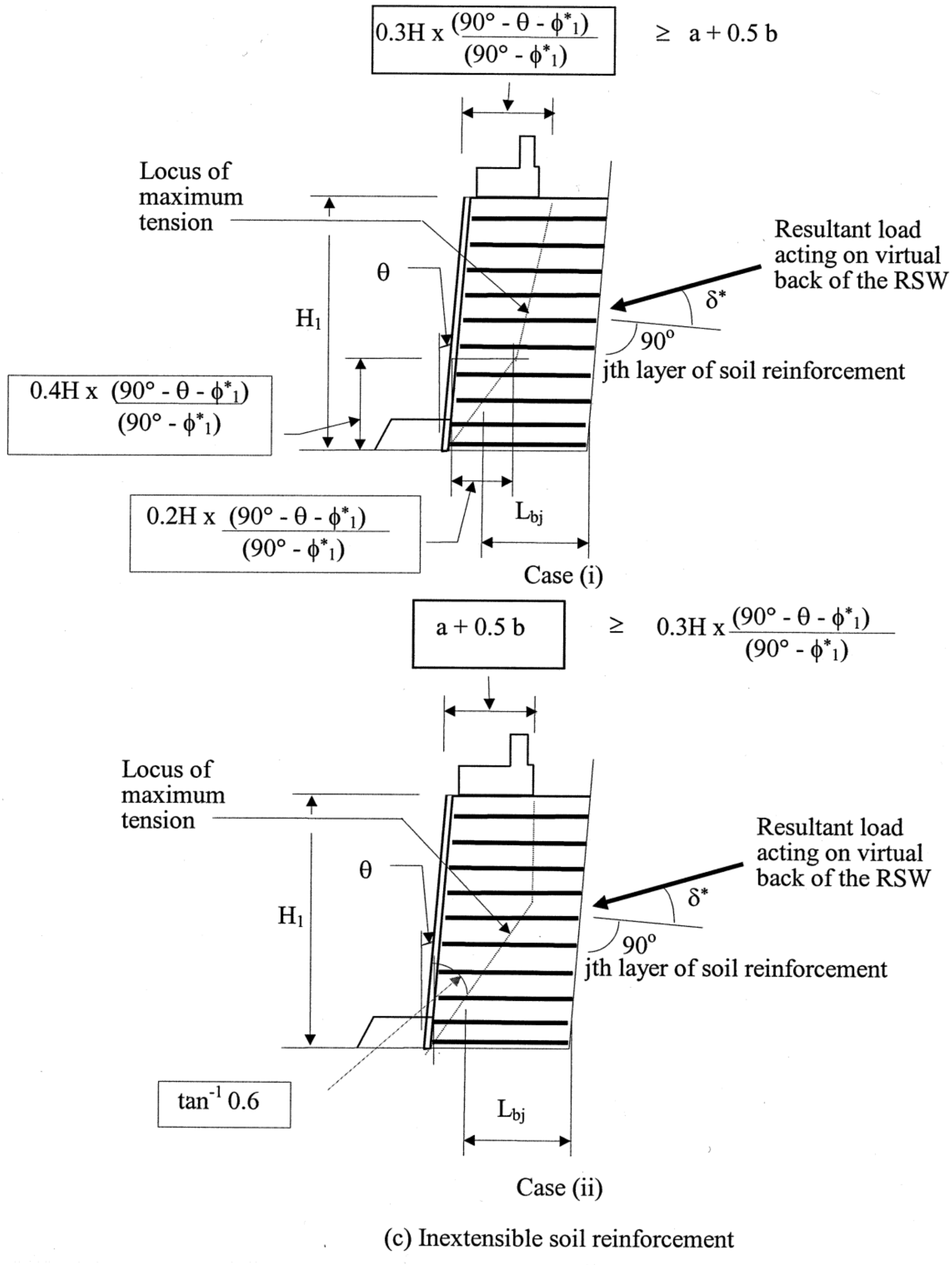
(a) Inextensible soil reinforcement



(b) Extensible soil reinforcement

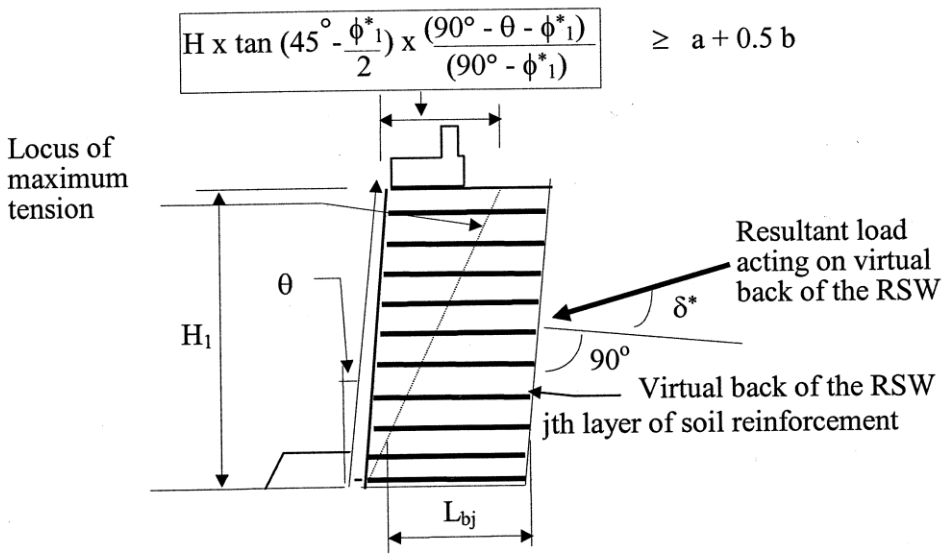
Note: θ and ϕ^*_1 are in degrees.

Figure R57.11 (a) & (b) - Loci of Maximum Tension for Soil Reinforcement for RSW Not Supporting Sill Beams

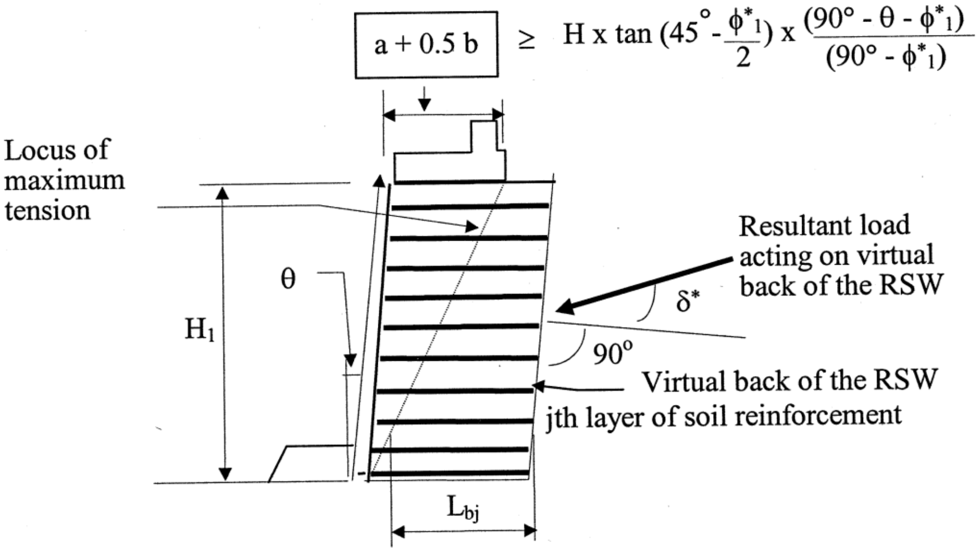


Note: θ and ϕ^*_1 are in degrees.

Figure R57.11 (c) - Loci of Maximum Tension for Soil Reinforcement for RSW Supporting Sill Beams (Inextensible Soil Reinforcement)



Case (i)



Case (ii)

(d) Extensible soil reinforcement

Note: θ and ϕ^*_1 are in degrees.

Figure R57.11 (d) - Loci of Maximum Tension for Soil Reinforcement for RSW Supporting Sill Beams (Extensible Soil Reinforcement)

The maximum tensile force per metre width, T^*_j, to be resisted by the j^{th} layer of soil reinforcement at a depth of z_j must be calculated from the summation of the appropriate forces as follows:

$T^*_j = T^*_{pj} + T^*_{sj} + T^*_{tj}$ at the locus of maximum tension

See Figure R57.12 for further details.

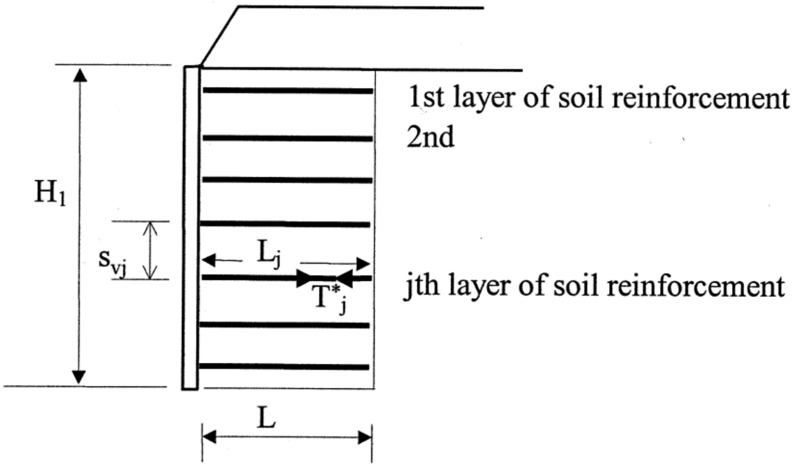


Figure R57.12 - Internal Design for RSW

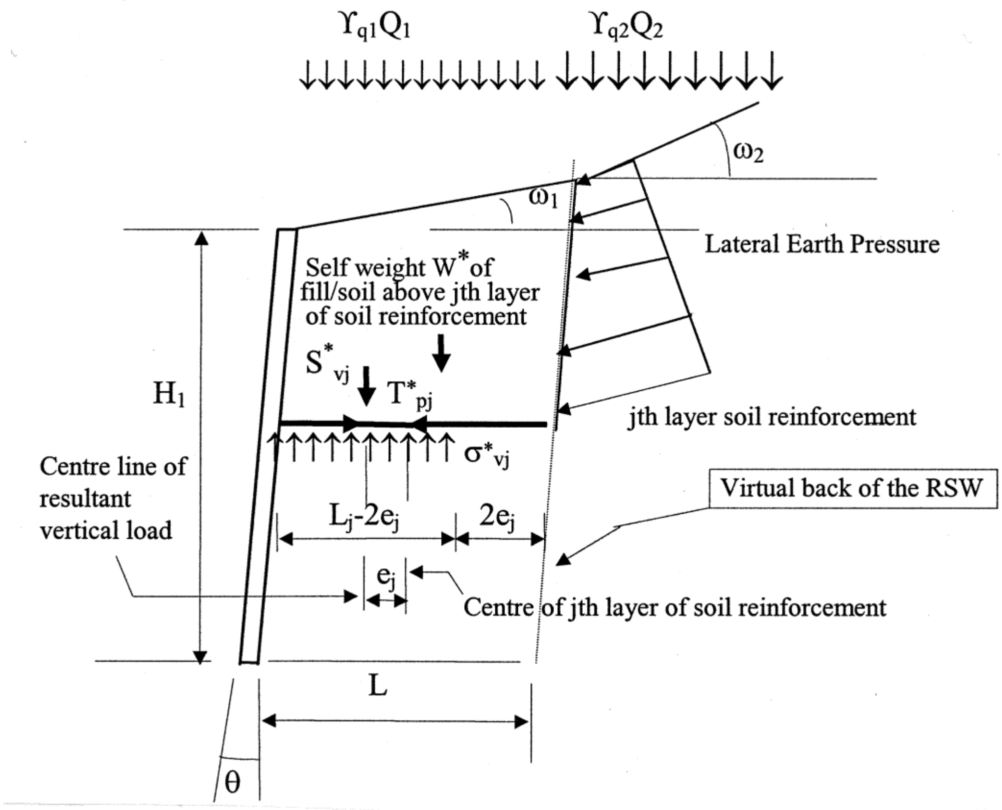
(a) T^*_{pj} is the tensile force (per metre width) at the j^{th} layer of soil reinforcement due to the loads acting on the wall as shown in Figure R57.13, including earthquake loads. Derive T^*_{pj} as follows:

$$T^*_{pj} = K^*_1(z_j)\,\sigma^*_{vj}\,(s_{vj} + s_{vj+1})\,0.5$$

For design purposes, idealise σ^*_{vj} as a Meyerhof distribution as shown diagrammatically in Figure R57.13, where:

$$\sigma^*_{vj} = \frac{S^*_{vj}}{L_j - 2|e_j|}$$

S^*_{vj} and e_j in the above equation must include the effects of soil self weight, dead and live surcharges and retained soil which are relevant to the load combinations under consideration. Exclude effects of soil loading acting onto the sill beam which are already included when deriving S^*_{vb} and S^*_{hb} in the calculation of S^*_{vj}.



Notes:

(1) Check soil reinforcement pull-out failure for all e_j values.

(2) Include additional loading due to earthquake effects on fill material above j^{th} layer of soil reinforcement the calculation of T^*_{pj}.

(3) Exclude any loading from the sill beam.

Figure R57.13 - Stress Imposed Due to Self Weight W*, Surcharge and Lateral Earth Pressure

For computation purposes, evaluate the effects of loading from the sill beam separately according to paragraphs (b) and (c) below.

(b) T^*_{sj} is the tensile force (per metre width) at the j^{th} layer of soil reinforcement due to loading from the sill beam as shown in Figure R57.14. T^*_{sj} must be derived as follows:

$$T^*_{sj} = \frac{K^*_1(z_j)S^*_{vb}}{D_j}\left(1 + \frac{6|E'|}{D_j}\right)\left(s_{vj} + s_{vj+1}\right)0.5$$

where

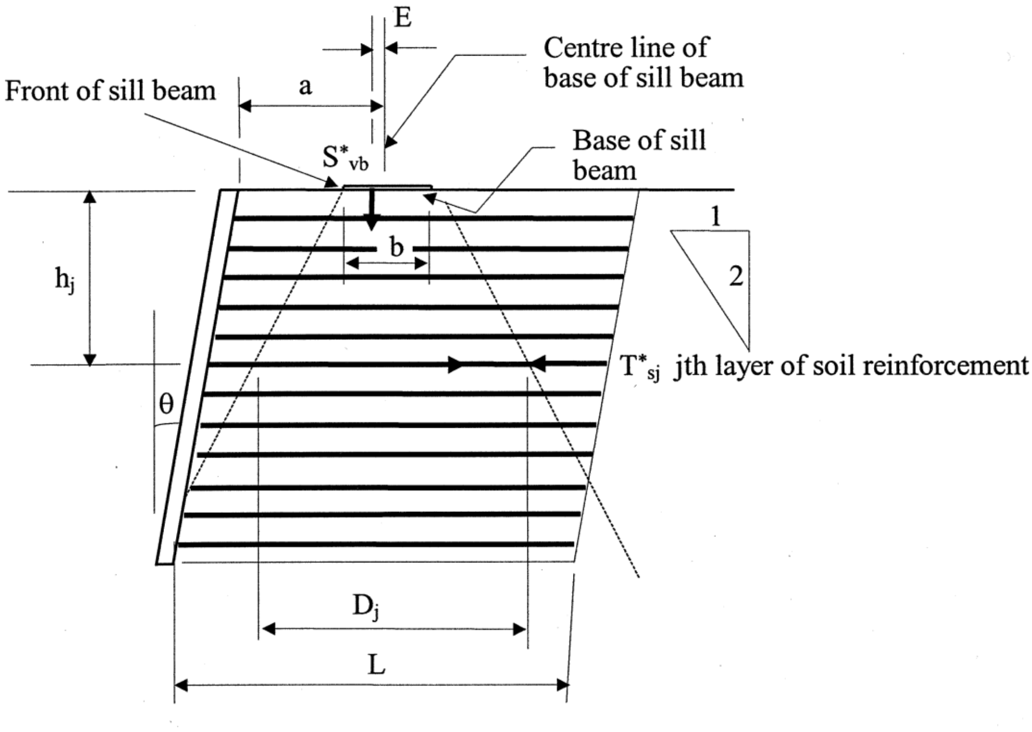
$D_j = (h_j + b)$ if $h_j \le (2a - b)/[1 - 2\tan(\theta)]$

$D_j = (h_j + b)/2 + a + h_j \tan(\theta)$ if $h_j > (2a - b)/[1 - 2\tan(\theta)]$

and $E' = E + (b + h_j - D_j)/2$

E is +ve if S^*_{vb} is in front of centre line of base of sill beam
E is -ve if S^*_{vb} is behind centre line of base of sill beam

The dispersion of stress from the sill beam must be calculated using a 1 (horizontal) to 2 (vertical) dispersion, but limited by facing elements or other special configurations as appropriate. This is shown diagrammatically in Figure R57.14.



(Note : D_j may be greater than L)

Figure R57.14 - Tension Due to Resultant Vertical Load S^*_{vb} Only

(c) T^*_{tj} is the tensile force (per metre width) at the j[th] layer of soil reinforcement due to horizontal loads acting on the base of the sill beam as shown in Figure R57.15. Derive T^*_{tj} as follows:

T^*_{tj} must be the greater of

$$2\,S^*_{hb}\,G\,(1 - h_j\,G)\,(s_{vj} + s_{vj+1})\,0.5; \text{ and}$$

$$\frac{6K^*_1(z_j)S^*_{hb}h_j}{L_j^2}(s_{vj} + s_{vj+1})\,0.5$$

where

$$G = \frac{1 - \tan(\xi)\tan(\theta)}{(a + b/2)\tan(\xi)}$$

but in no case must G be taken as less than $1/H_1$; and

$$\cot(\xi) = \sqrt{\sec(\phi_1^*)\left[\sec(\phi_1^*) + \tan(\theta)\mathrm{cosec}(\phi_1^*)\right]} - \tan(\phi_1^*)$$

The soil shear stress distribution is shown in Figure R57.15.

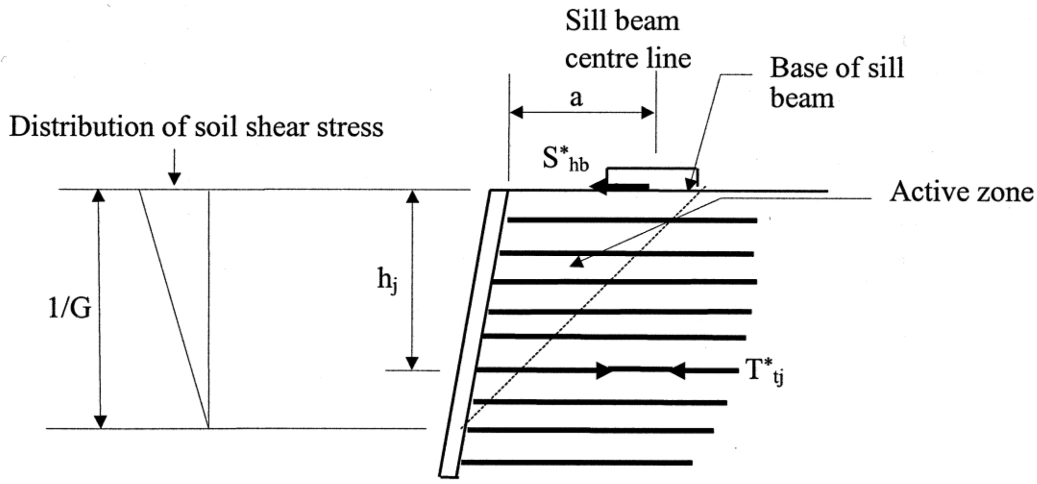


Figure R57.15 Dispersal of Horizontal Shear Through Reinforced Fill Due to Horizontal Load S^*_{hb}

4.8.3 Soil Reinforcement Tensile Force at the Facing Connections/Facing Elements

Due to the redistribution of soil reinforcement tensile forces near the facing connections/facing elements, the soil reinforcement tensile force at the facing connections/facing elements may be smaller than T^*_j. The coefficient of reduction of soil reinforcement tensile force at the facing connections/facing elements must not be less than as specified in Table R57.7.

Calculate the soil reinforcement tensile force at the facing connections/facing elements from the product of $\alpha(z_j)$ and T^*_j.

Table R57.7 - Coefficient of Reduction of Soil Reinforcement Tensile Force at the Facing Connections/Facing Elements

Extensible soil reinforcement	**Coefficient of reduction of soil reinforcement tensile force, $\alpha(z_j)$**
All facings with movement capacity or with movement capacity at connections	$\alpha(z_j) = 0.75 + 0.25\ (z_j/H)$
Stiff facing e.g. full height panels & no movement capacity at connections	$\alpha(z_j) = 1$
Inextensible soil reinforcement	**Coefficient of reduction of soil reinforcement tensile force, $\alpha(z_j)$**
All facings with movement capacity or with movement capacity at connections	$\alpha(z_j) = 0.85$ for $z_j/H \le 0.6$ $\alpha(z_j) = 0.85 + 0.375\ (z_j/H - 0.6)$ for $z_j/H > 0.6$
Stiff face, e.g. full height panels & no movement capacity at connections	$\alpha(z_j) = 1$

4.8.4 Design of Individual Soil Reinforcement

(a) Rupture and post-construction creep of soil reinforcement

At the locus of maximum tension at the j^{th} layer of soil reinforcement, the following conditions must be satisfied:

$\Phi_n N_m T^*_{drj} \cos(\Psi) \geq T^*_j$ for Ultimate Limit State

$\Phi_n N_m T^*_{dcj} \cos(\Psi) \geq T^*_j$ for Serviceability Limit State

At the facing connections/facing elements at the j^{th} layer of soil reinforcement, the following conditions must be satisfied:

$\Phi_n N_m T^*_{drj} \cos(\Psi) \geq T^*_j \alpha(z_j)$ for Ultimate Limit State

$\Phi_n N_m T^*_{dcj} \cos(\Psi) \geq T^*_j \alpha(z_j)$ for Serviceability Limit State

where T^*_{drj} and T^*_{dcj} are product specific design tensile strengths of the soil reinforcement. The RSW Designer must select the values of T^*_{drj} and T^*_{dcj} in the design based on the nature of RSW and the variability of all parameters involved in the design. The selected values must not be greater than the values specified in the Conditions of Use for System.

Also check the soil reinforcement tensile force at locations between facing elements and the locus of maximum tension by assuming a linear variation of soil reinforcement tensile force between the facing connections/facing elements and the locus of maximum tension. The design tensile force at any point along the length of the soil reinforcement at any layer must be less than or equal to $\Phi_n T^*_{dr}$ and $\Phi_n T^*_{dc}$, as appropriate.

It must be noted that the design temperature for the RSW within 1 metre below finished ground level or within 1 metre behind facing elements is higher than that inside the general reinforced fill material, as specified in Clause 4.2(e). Depending on the type of reinforcement, the design strengths T^*_{dr} and T^*_{dc} may be reduced by the higher temperatures and values not exceeding those given in the Conditions of Use for the System must be adopted for checking the relevant limit states.

(b) Pull out failure of soil reinforcement from zone of reinforced fill material beyond locus of maximum tension

Check the j^{th} layer of soil reinforcement must be checked at both Ultimate and Serviceability Limit States such that:

$$\Phi_n \Phi_{\mu p} 2 N_m W_j L_{bj} \mu_p \tan(\phi^*_1) [\sigma^*_{vj(avg)}] \cos(\Psi) \geq T^*_j$$

where μ_p is a product specific coefficient. The RSW Designer must select the value of μ_p for design based on the nature of RSW and the variability of parameters involved in the design. The selected value must not be greater than the value specified in the Conditions of Use.

The definition of L_{bj} for this clause is given in Figure R57.11 (a) and (c) for inextensible soil reinforcement and Figure R57.11 (b) and (d) for extensible soil reinforcement respectively.

Note: When L_{bj} is measured perpendicular to the wall face, delete the term $\cos(\Psi)$ in the equation above.

(c) Pull out failure of soil reinforcement from the facing connections/facing elements

The connections must be those specified for the accepted RSW System. Justify the characteristic values for facing pull out resistance adopted, unless otherwise specified in this Specification, by tests representative of the connection arrangement on site.

For modular block walls, the pull out resistance of soil reinforcement from facing elements (i.e. the modular units) must be the characteristic value for pull out resistance of soil reinforcement from facing elements multiplied by Φ_{po}. Evaluate the characteristic value for pull out resistance in accordance with Section 5.7.1 of the publication "Segmental Retaining Walls" published by National Concrete Masonry Association, USA, using values of a_{cs}, a'_{cs}, λ_{cs}, λ'_{cs} between the soil reinforcement and the segmental retaining wall units less than or equal to those values specified in the Conditions of Use for the System.

The product of Φ_n and the facing pull out resistance at any layer of soil reinforcement must be larger than or equal to the design soil reinforcement tensile force at facings connections/facing elements for all load combinations.

4.8.5 Stability of Linear Wedges

Consider linear wedge failures to identify the most critical potential linear wedges and analyse a sufficient number of trial wedges. Each of these trial wedges must be in a force equilibrium condition under the design loads and the product of the appropriate Φ_n and the relevant strengths (or resistances or capacities) of the reinforcement.

It may be assumed that no potential linear wedges will pass through the strip contact area representing a bridge sill beam.

When the facing consists of a structural element formed in one piece, the shear resistance of the facing may be included in the analysis.

For the j^{th} layer of soil reinforcement intercepted by a potential linear wedge under consideration, take the design pull out resistance from the soil, for the limit state under consideration, as follows:

__Ultimate Limit State__

The lesser of:

$\Phi_n N_m T^*_{drj} \cos(\Psi)$; and

$\Phi_n \Phi_{\mu p} 2 N_m W_j L_{bj} \mu_p \tan(\phi^*_1) [\sigma^*_{vj(avg)}] \cos(\Psi)$

__Serviceability Limit State__

The lesser of:

$\Phi_n N_m T^*_{dcj} \cos(\Psi)$; and

$\Phi_n \Phi_{\mu p} 2 N_m W_j L_{bj} \mu_p \tan(\phi^*_1) [\sigma^*_{vj(avg)}] \cos(\Psi)$

For the purpose of this clause, L_{bj} is defined as the length of the j^{th} layer of soil reinforcement within the non-yielding zone outside the potential failure linear wedge under consideration. An example of this is shown in Figure R57.16.

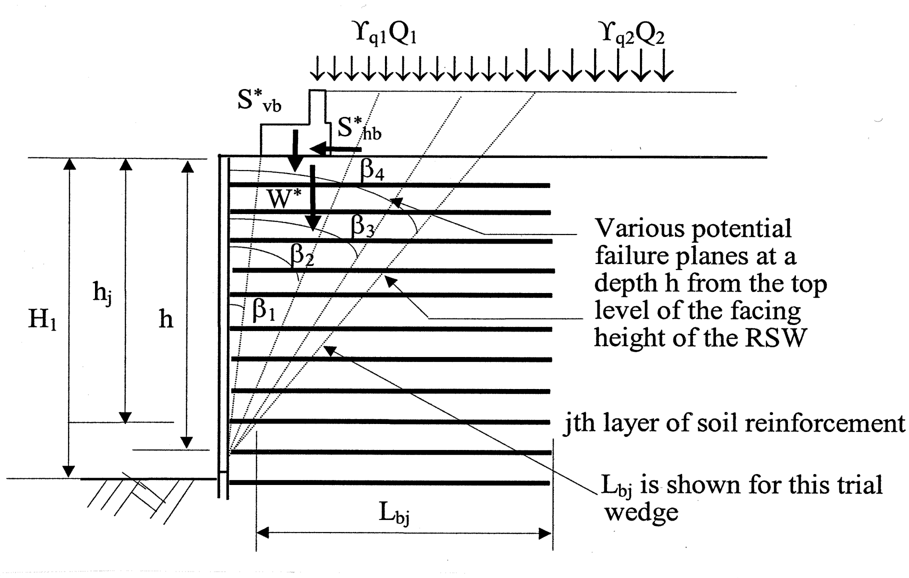


Figure R57.16 - Examples of Linear Wedges

4.8.6 Stability of Two-Part Wedges and Internal Slip Surfaces for Trapezoidal Sections

For trapezoidal sections, carry out the following limit equilibrium analyses:

(a) two-part wedge analyses;

(b) internal slip surface analyses (both circular and non-circular).

Consider a sufficient number of two-part wedge failures (or potential internal slip surface failures, both circular and non-circular) to identify the most critical potential two-part wedge (or internal slip surface). Each of these two-part wedges (or internal slip surfaces) must be in a force equilibrium condition under the design loads and the design strengths (or resistances or capacities).

It may be assumed that no potential two-part wedge and internal slip surface will pass through the strip contact area representing a sill beam.

When the facing consists of a structural element formed in one piece, the shear resistance of the facing may be included in the analysis.

The design resistance of the j^{th} layer of soil reinforcement intercepted by the failure planes must be evaluated in accordance with Clause 4.8.5 where L_{bj} is defined as the length of j^{th} layer of soil reinforcement within the non-yielding zone outside the two part wedge/internal slip surface under consideration.

Examples of potential failure planes are shown in Figure R57.17.

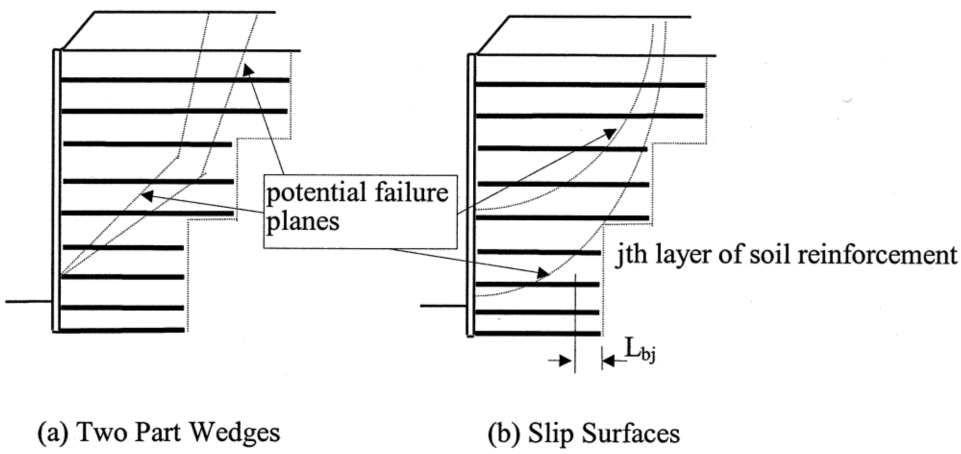


Figure R57.17 - Examples of Two-Part Wedges and Internal Slip Surfaces for Trapezoidal Sections

4.8.7 Forward Sliding of Any Portion of a Wall on Any Horizontal Plane

Consider the stability against this mode of failure at the following interfaces where applicable:

(a) fill on fill within any layer;

(b) soil reinforcement and fill on any layer of fill.

Refer to Clause 4.7.2 of this Specification for design requirements.

4.8.8 Structural Failure of Facing Connections and Pull Out Failure of Facing Connections from Facing Elements

For design purposes, the design soil reinforcement tensile force at facing connections must be taken as those specified in Clause 4.8.3.

Justify the characteristic value for the structural connection resistance, C, adopted by representative tests on the RSW System. The structural connection resistance must be the characteristic value for structural connection resistance multiplied by Φ_c; i.e.

$$C^* = \phi_c C$$

The product of Φ_n and the structural connection resistance at any layer of soil reinforcement must be larger than or equal to the design soil reinforcement tensile force at facing connections/facing elements for all load combinations and limit states; i.e.

$$\Phi_n C^*_j \geq T_j^* \alpha(z_j)$$

4.8.9 Structural Failure of Facing Elements

Design facing Elements to accommodate the design loads resulting from:

(a) horizontal soil pressures and the corresponding soil reinforcement tension load developed in facing connections as specified in Clause 4.8.3 of this Specification;

(b) forces arising from higher facing units and capping;

(c) any externally applied loads (temporary or permanent).

Design facings under a system of equilibrium forces.

For precast concrete panel facings, structural design of the facings must be in accordance with AS 5100.5.

For modular block walls, evaluate the stability of an individual unit in accordance with Section 5.7 of the publication "Segmental Retaining Walls" published by National Concrete Masonry Association, USA, using values of a_u, a'_u, λ_u, λ'_u between the segmental retaining wall units less than or equal to those values specified in the Conditions of Use for the System.

4.8.10 Differential Movement Capacity of the Facing Connections/Facing Elements

Limit the calculated movement of the facing connections/facing elements due to internal settlement (refer to Clause 4.7.4) to that specified in Table R57.8 and that due to differential settlement to 1 in 100.

Table R57.8 - Vertical Movement Capacities Required for the Facing Connections/Facing Elements to Cope with Internal Settlement of RSW

Structural form	Minimum vertical movement capacity of system required
Discrete panels	Joint closure of 1 in 150 relative to panel height
Full height panels	Vertical movement capacity of connections 1 in 150 relative to panel height
Semi-elliptical facings	Vertical distortion of 1 in 150 relative to panel height
Geotextile wrap-around facings	No specific limit except for appearance or serviceability considerations

4.8.11 Design for Soil Reinforcement Joints

(a) Geosynthetic reinforcement

All soil reinforcement joints for geosynthetic reinforcement designed to carry loads must have a design joint strength at the design temperature and design life at least equal to the design tensile strength of the geosynthetic reinforcement.

Determine the design tensile strength of geosynthetic reinforcement joints in accordance with BS 6906 Part 1:1987 or ISO 10321:1992, or equivalent.

Do not employ overlapping in the primary tensile direction in the RSW for load transfer.

(b) Metallic soil reinforcement

Lapping of soil reinforcement is not permitted.

4.9 DESIGN OUTPUT AND CERTIFICATION

Obtain the design output and certification in accordance with Clause 3.

The design output obtained must include:

(a) a design report stating the RSW System to be used, including the type of soil reinforcement, drainage layers, facing connections, facing elements and capping to be used.

The design report must state the design assumptions including parameters for the soil reinforcement, reinforced fill material, general backfill materials and foundation material used in the design.

Include the following detailed information in the design report:

(i) the specification of the physical, chemical and electrical properties of reinforced fill material, including a design grading envelope and where necessary appropriate pretreatment requirements to ensure that the characteristic values of material parameters used in the design can be achieved in the reinforced fill material after placement in the Works;

(ii) relevant characteristic values adopted in the design for:

(A) reinforced fill material parameters, e.g. ϕ_1, and γ_1;

(B) material parameters of soil above and behind zone of reinforced fill material, e.g. ϕ_3, ϕ_2 and γ_3, γ_2;

(C) foundation soil material parameters, e.g. ϕ_b, c_b, c_{ub}, and γ_b;

(D) the soil reinforcement interaction coefficients, e.g. μ_p, μ_{s1} and μ_{sb};

(E) pull out resistance of soil reinforcement from the facing connections/facing elements;

(F) connection strengths;

(iii) design tensile strength T^*_{dr} and T^*_{dc} for soil reinforcement;

(b) RSW drawings showing the proposed geometry of the RSW, drainage provisions, arrangement of soil reinforcement, extent of the foundation, and arrangement and finish of facing elements and capping;

(c) where necessary, details of the method, appropriate to the site conditions and verified by a Geotechnical Engineer, of preparing and improving the foundation to fully meet the design values of foundation soil material parameters;

(d) the sequence of construction of the RSW including the sequence of placing and compacting the reinforced fill material;

(e) the requirements for monitoring of the RSW incorporating requirements specified in item (g) of Annexure R57/A;

(f) any other requirements specified by the RSW Designer and the Geotechnical Engineer;

(g) certification in accordance with Clause 3 and any other requirements specified by the RSW System Owner.

5 MATERIALS

5.1 GENERAL

The RSW System Owner must certify that all components supplied by the System Owner for construction of a RSW meet the requirements of the RSW System specifications.

Design all components and materials to meet the specified design life and the required durability under site specific conditions.

Metallic components, i.e. soil reinforcement, facing connections, facing lugs and facing elements, in contact with each other must be of electrolytically compatible materials. Alternatively, provide electrical insulation with durability not less than the design life of the RSW between different materials.

5.2 SOIL REINFORCEMENT

Soil reinforcement must comprise one of the following:

(a) **Carbon steel** to AS 3678, AS 3679 or AS 4671 (steel of ductility class L must not be used), unless otherwise stated in the Conditions of Use of the System, and hot-dip galvanized in accordance with AS/NZS 4680, except that the average galvanized coating thickness must not be less than 85 μm.

In the design of the steel soil reinforcement, allow for a loss of section due to corrosion not less than the minimum sacrificial steel thickness shown in Table R57.9, unless otherwise stated in the Conditions of Use of the System.

Table R57.9 - Sacrificial Steel Thickness for Hot-dip Galvanized Steel Soil Reinforcement and Facing Connections

Structural Location	Minimum sacrificial steel thickness for each hot-dip galvanized steel surface exposed to corrosion (mm) (1, 2, 3)					
	Design Life (years)					
	5	10	20	30	50	100
Above water table / flood level of an average recurrence interval of 1 year	0	0	0.1	0.2	0.5	0.85
Below water table / flood level of an average recurrence interval of 1 year	0	0.05	0.3	0.35	0.65	1.0
In environment which is more aggressive than above	Determine by investigation					

Notes:

(1) Soil reinforcement assumed to be fully embedded within reinforced fill material conforming to the requirements of TfNSW D&C R57.

(2) Linear interpolation may be used for intermediate values.

(3) These values may not be applicable in the presence of stray electrical currents from adjacent power sources. In such cases, determine the values by investigation.

(b) **Polymeric material**, demonstrated by testing as sufficiently strong, stable and durable to satisfy the performance and design requirements of this Specification. Tests must establish the performance and durability of the geosynthetic reinforcement under the following job specific environmental conditions:

(i) loading;

(ii) exposure to water;

(iii) site damage;

(iv) UV exposure;

(v) temperature;

(vi) chemical/bacterial composition of reinforced fill material;

(vii) aggressive fluids.

Consider any interaction of the above conditions in the design.

Characteristic values of material parameters for geosynthetic reinforcement used for design must allow for:

(A) Any creep deformation and creep rupture over the design life of the RSW at the design temperatures.

(B) Loss of strength due to environmental degradation (e.g. biological, hydrolysis and chemical attack).

(C) Variations in manufacturing process.

(D) Extrapolation uncertainties where test duration is less than the design life.

(E) Installation damage (including weathering during storage and/or mechanical damage during installation).

(F) Any other requirements specified for the RSW System.

5.3 REINFORCED FILL

For the characteristic value of the angle of friction at constant volume of the reinforced fill material under effective stress conditions adopted for your design, ϕ_1, obtain it by an assessment of the material at potential sources of supply and taking into account the requirements for verification and conformity testing in accordance with Clauses 2.10 and 4.8 of TfNSW D&C R58.

Determine the value of the angle of friction at constant volume in accordance with Q181C:Draft 1994 or Q181C:2008, pretreated in accordance with TfNSW Test Method T102 using 3 repeated compaction cycles.

Take the effective cohesion as zero.

In addition to any requirements particular to the RSW System, the reinforced fill material must comply with the following requirements:

(a) The reinforced fill material must be composed of inert, hard, durable granular material, without properties that would cause deterioration of the RSW components.

It must be either soil, decomposed rock or crushed rock fill material, free from organic or other deleterious material such as plastic, metal, rubber or other synthetic material, inorganic contaminants, dangerous or toxic material, or material susceptible to combustion.

Material derived from argillaceous rock such as shales and claystones or other materials which are susceptible to breakdown to a friable material must not be used as reinforced fill material.

(b) The reinforced fill material must meet the minimum physical properties shown in Table R57.10.

Table R57.10 – Physical Properties of Reinforced Fill Material

Property	Test Method (1)	Requirement
Maximum particle dimension	–	Soil reinforcement material: - steel: 150 mm (2) - geosynthetic: 75 mm (2)
Percentage passing AS sieve (3)	AS 1289.3.6.1	
37.5 mm		≥ 60
9.5 mm		25 – 100
2.36 mm (4)		15 – 100
600 µm		10 – 100
75 µm		0 – 15
Coefficient of Uniformity (5)	N/A	≥ 5
Liquid Limit LL (%) (3)	TfNSW T108	≤ 30
Plasticity Index PI (3)	TfNSW T109	≤ 12

Notes:

(1) Taking and preparing samples must be in accordance with AS 1289.1.2.1 and AS 1289.1.1 respectively.

(2) Dimension quoted refers to maximum particle dimension of the reinforced fill material, not the soil reinforcement (made from steel or geosynthetic). This maximum particle dimension must not, in any case, be greater than one third of lift thickness.

(3) Prior to testing, pretreat the material in accordance with Test Method TfNSW T102 using 3 repeated compaction cycles; and then in accordance with TfNSW T103 by artificial weathering using 5 cycles of alternate wetting and drying.

(4) Washing Method.

(5) Coefficient of Uniformity = D_{60}/D_{10}, where D_{60} and D_{10} are the equivalent sieve sizes in mm, as interpolated from particle size distribution curve and through which 60% and 10% of reinforced fill material passes respectively.

(c) The reinforced fill material must meet the chemical and electrical requirements stated in TfNSW D&C R58.

5.4 DRAINAGE LAYER

Unless specified otherwise, material for the drainage layer must comprise granular material and a suitable geotextile.

The granular material and geotextile must satisfy the requirements specified in Clause 2 of TfNSW D&C R58.

Alternatively, for RSW with H_1 less than 4 m, a prefabricated cellular material wrapped with a synthetic filter fabric with equivalent design drainage and strength properties may be used.

5.5 SOIL ABOVE AND BEHIND REINFORCED SOIL BLOCK

For the characteristic value of the angle of friction at constant volume under effective stress conditions of the soil above, and the soil behind, the reinforced soil block, ϕ_3 and ϕ_2 respectively, adopted for your design, obtain them by an assessment of the material at potential sources of supply and taking into account the requirements for verification and conformity testing in accordance with Clauses 2.10 and 4.8 of TfNSW D&C R58.

Determine the value of the angle of friction at constant volume in accordance with Q181C:Draft 1994 or Q181C:2008, pretreated in accordance with Test Method TfNSW T102 using 3 repeated compaction cycles.

Take the effective cohesion as zero.

In your design, assume that the soil above and behind the reinforced soil block, within a distance of $H/_2$ from the reinforced soil block, have the properties shown in Table R57.11.

Table R57.11 – Physical Properties of Soil Above and Behind Reinforced Soil Block

Soil Property	Test Method	Assumed Limits
Plasticity Index	TfNSW T109	≤ 12
Liquid Limit	TfNSW T108	≤ 30%

5.6 FACING ELEMENTS

Facing elements may be classified as either hard or soft. Hard facing elements may consist of concrete panels (either discrete or full height), steel sheet, steel grids or meshes, timber or a proprietary polymeric material. Soft facing elements are formed by wrapping each layer of soil reinforcement around individual lifts of reinforced fill material or pillows of fill material as specified in the RSW System.

The selection of facing element type depends on the required durability for the site conditions and the specified design life. Unless otherwise specified in the job specific requirements detailed in item (j) of Annexure R57/A, facing elements acceptable for the Works are shown in Table R57.12.

Table R57.12 – Acceptable Facing Type and Materials

Design Life and Location	Acceptable Facing Type and Materials
Design life ≤ 100 years, or areas in tidal and/or splash zones	Concrete block or masonry units Concrete panels
Design life < 50 years	
Coastal (≤ 50 km from coastline but excluding tidal and/or splash zones)	Concrete block or masonry units Concrete panels Treated timber - "Cypress Pine" only
Inland (> 50 km from coastline)	Concrete block or masonry units Concrete panel Treated timber - "Cypress Pine" only Steel grids or meshes
Design life < 5 years	Steel sheet and geofabric facing elements

Facing elements must also meet the requirements of the RSW System selected and the following requirements:

(a) **Concrete facing elements**: Requirements of Specifications TfNSW D&C B80 and D&C B115, and AS 5100.5. The amount of distribution reinforcement must be a minimum of 250 mm^2 of steel per metre for concrete facing elements with any dimensions (excluding diagonal dimensions) greater than 2300 mm.

(b) **Concrete masonry facing elements**: Requirements of AS 2733 and AS 3700. Testing of specimens cut from facing elements for compressive strength is permissible.

(c) **Timber facing elements**: Requirements of Specification TfNSW D&C 2380 and AS 1720.1.

(d) **Facing elements made of polymeric materials**: Requirements of Clause 5.2 (b).

(e) **Steel facing elements**: Provide corrosion protection adequate for the insitu conditions and the specified design life. Take into account any loss of section due to corrosion in the design.

(f) **Hot-dip galvanized steel facing elements**: Requirements of the relevant Australian and AS/NZS Standards. Unless stated otherwise in the Conditions of Use of the System, average galvanized coating thickness must not be less than 85 μm. The minimum sacrificial steel thickness must be as specified in Table R57.13.

Table R57.13 - Sacrificial Steel Thickness for Hot-dip Galvanized Steel Facing Connections/Facing Elements and Other Steel Components

Structural Location	Minimum sacrificial steel thickness for each hot-dip galvanized steel surface exposed to corrosion (mm) [1, 2, 3]					
	Design Life (years)					
	5	10	20	30	50	100
Above water table / flood level of an average recurrence interval of 1 year	0	0.05	0.3	0.35	0.65	1.0
Below water table / flood level of an average recurrence interval of 1 year	0.05	0.15	0.40	0.50	0.75	1.2
In environment more aggressive than above	Determine by investigation					

Notes:

(1) Soil reinforcement assumed to be fully embedded within reinforced fill material conforming to the requirements of TfNSW D&C R57.

(2) Linear interpolation may be used for intermediate values.

(3) These values may not be applicable in the presence of stray electrical currents from adjacent power sources. In such cases, determine the values by investigation.

5.7 FACING CONNECTIONS AND OTHER COMPONENTS

Provide facing connections and other components with corrosion protection adequate for the insitu conditions and the specified design life.

Unless stated otherwise in the Conditions of Use of the System, all steel facing connections must meet the requirements of Clause 5.2 (a). Other steel components must meet Table R57.13 for sacrificial thickness.

Allow in the design for a loss of section not less than 0.5 of the sacrificial steel thickness shown in Table R57.9 from each internal surface (in metal to metal contact or wholly enclosed within the connection) of all steel component parts.

The RSW Designer may specify a plastic coating as additional corrosion protection to galvanized steel. The plastic coating must be resistant to chipping, crushing and handling damage, and must be free of defects.

For connections made of polymeric materials, the requirements of Clause 5.2 (b) must be met.

5.8 CONCRETE

Concrete for RSW elements must meet the design requirements for the RSW, including all the requirements of AS 5100.5, this Specification and those of Design Documentation drawings and Specifications.

Concrete strength grades must not be less than:

(a) 25 MPa for footings and modular concrete blocks;

(b) 40 MPa for capping;

(c) 40 MPa for facing elements excluding modular blocks.

ANNEXURE R57/A – PROJECT SPECIFIC REQUIREMENTS FOR DESIGN OF RSW

Project: ....

(a) **Design Life** .... years

(b) **Classification of RSW:**

- MINOR (consequences of failure are small)
- MAJOR⊗ (consequences of failure are large)

⊗ RSW supporting sill beams and RSW likely to affect structures with Importance Levels of 2, 3, 4 or 5 as per Appendix F of AS 1170.0 must be classified as MAJOR.

(c) **Minimum clearance requirements** after all long term movements of the RSW have occurred:

	Under Bridge	Elsewhere
Horizontal	....	....
Vertical	....	....

(d) **RSW design must accommodate the following design earthquake forces F^*_e with respect to centre line of bearings, transferred to the RSW from the bridge superstructure under the ULS:** (**Note:** F^*_e = 1.2 nominal earthquake force)

Horizontal Force	....
Vertical Force	....

Nominal ground movements/nominal loads due to mining subsidence effects:

	Movements	Nominal loads, F_m
Horizontal (longitudinally)	....	....
Horizontal (transversely)	....	....
Vertical	....	

For Ultimate Limit States, $F^*_m = 1.5\, F_m$

For Serviceability Limit State, $F^*_m = 1.0\, F_m$

Nominal ground movements/nominal loads due to differential settlement# effects:

	Movements	Nominal loads, F_s
Horizontal (longitudinally)	....	....
Horizontal (transversely)	....	....
Vertical	....	

Differential settlement effects must be calculated assuming dead load effects only acting.

For Ultimate Limit States, $F^*_s = 1.5\, F_s$

For Serviceability Limit State, $F^*_s = 1.0\, F_s$

(e) Permissible post-construction service deflections of the RSW:

Horizontal (any point on the face of the RSW) ....

Vertical (any point on the top of facing elements) ....

(f) Permissible movement of bridge piles under the RSW

In any direction ....

The following assumptions have been made during the pile design regarding pile/RSW interaction:

....

> ***Example***
>
> *(i) The reinforced fill is assumed to exert loads on the piles.*
>
> *(ii) Piles are assumed to be supported laterally by the reinforced fill material.*
>
> *(iii) Piles are assumed to sustain movements identical to the reinforced fill at the pile.*
>
> *Delete this note before issue of Tender Documents.*

The pile design allows for lateral and vertical loads imposed by movements of the RSW given in (e) above and by the pile movements given herein.

(g) Monitoring requirements

Monitoring details are as specified in the Design Documentation drawings and Specification

(h) Heavy Load Platform HLP320 / HLP400

(i) Design dead and live loads applied to RSW:

(i) Loading from the bridge superstructure - As shown in the attached APPENDIX

(ii) Where the nominal vertical live load is greater than 20 kPa, the following load must be used

= ....

(j) Type of facing elements/capping accepted for the Works

Fire resistance requirement for facing elements

....

(k) Finish of facing elements and capping

(l) Details of drainage pipes or other minor structures on top of, behind or within the RSW

(m) Design dead and live loads applied to the RSW from the bridge superstructure

(Note: The format of this information is for the guidance of the Engineer responsible for the bridge's design only, and may be changed as required for specific projects.)

(I) Loads from Abutment A with respect to centre line of bearings

Loads	Serviceability Limit State				Ultimate Limit States			
	Vertical load F^*_v (kN)		Horizontal load F^*_h (kN)		Vertical load F^*_v (kN)		Horizontal load F^*_h (kN)	
	max F^*_v	min F^*_v	Longitudinal F^*_h	Transverse F^*_h	max F^*_v	min F^*_v	Longitudinal F^*_h	Transverse F^*_h
Dead loads								
Live loads								
Total								

(II) Loads from Abutment B with respect to centre line of bearings

Loads	Serviceability Limit State				Ultimate Limit States			
	Vertical load F^*_v (kN)		Horizontal load F^*_h (kN)		Vertical load F^*_v (kN)		Horizontal load F^*_h (kN)	
	max F^*_v	min F^*_v	Longitudinal F^*_h	Transverse F^*_h	max F^*_v	min F^*_v	Longitudinal F^*_h	Transverse F^*_h
Dead loads								
Live loads								
Total								

Notes: Forces are referred to along the reference axes.

Loadings from each bearing are to be shown.

ANNEXURE R57/B – (NOT USED)

ANNEXURE R57/C – SCHEDULE OF IDENTIFIED RECORDS

Refer to Clause 1.2.3.

C1 (NOT USED)

C2 SCHEDULE OF IDENTIFIED RECORDS

The records listed below are Identified Records for the purposes of TfNSW D&C Q6 Annexure Q/E.

Clause	Description of Identified Record
3	Certificates from Geotechnical Engineer and RSW designer, including specified design output

ANNEXURES R57/D TO R57/L– (NOT USED)

ANNEXURE R57/M – REFERENCED DOCUMENTS

Refer to Clause 1.2.4.

TfNSW Specifications

TfNSW D&C Q6	Quality Management System (Type 6)
TfNSW D&C B80	Concrete Work for Bridges
TfNSW D&C B115	Precast Concrete Members (Not Pretensioned)
TfNSW D&C R58	Construction of Reinforced Soil Walls
TfNSW D&C 2380	Timber for Bridges

TfNSW Test Methods

TfNSW T102	Pretreatment of Samples of Road Construction Materials by Compaction
TfNSW T103	Pretreatment of Road Construction Materials by Artificial Weathering
TfNSW T108	Liquid Limit of Road Materials
TfNSW T109	Plastic Limit and Plasticity Index of Road Construction Materials

Australian Standards

AS 1170	Structural design actions
AS 1170.0	General principles
AS 1170.2	Wind actions
AS 1170.4	Earthquake actions in Australia
AS 1289	Methods of Testing soils for engineering purposes
AS 1720.1	Timber structures – Design methods
AS 1726	Geotechnical site investigation
AS 2733	Concrete masonry units
AS 3678	Structural steel – Hot-rolled plates, floorplates and slabs
AS 3679	Structural steel – Hot-rolled bars and sections
AS 3700	Masonry structures
AS/NZS 4680	Hot-dip galvanized (zinc) coatings on fabricated ferrous articles
AS 4671	Steel reinforcing materials
AS 4969	Analysis of acid sulfate soil
AS 4969.1	Dried samples – Methods of test – Pre-treatment of samples
AS 4969.12	Dried samples – Methods of test – Complete suspension peroxide oxidation combined acidity and sulfur (SPOCAS) method
AS 5100	Bridge design
AS/NZS ISO 9001	Quality management systems – Requirements

Queensland Department of Transport Test Method

Q181C:Draft 1994	Determination of the Effective Angle of Friction at Constant Volume Conditions for Earthworks Materials
Q181C:2008	Effective Angle of Internal Friction at Constant Volume Conditions for Granular (Coarse Grained) Materials

International Organisation for Standardisation Standards

ISO 10321:1992	Geotextile Tensile Test for Joints/Seams by Wide-Width Method

British Standards

BS 1377	Method of Test for Soils for Civil Engineering Purposes
BS 6906 Part 1:1987	Methods of Test for Geotextiles – Determination of the Tensile Properties Using a Wide Width Strip

National Concrete Masonry Association, USA

Segmental Retaining Walls

Hong Kong Special Administrative Region, People's Republic of China

Geoguide 1	Guide to Retaining Wall Design