

ENVIROCON® GRAVITY WALL DESIGN

GRAVITY WALL

DESIGN MANUAL

DESIGN CRITERIA, PROJECT SPECIFICATIONS
AND STRUCTURAL DESIGN METHOD

For Interbloc® and Stonebloc® gravity retaining walls designed
with Envirocalc®.

AS/NZS 1170.0 AS/NZS 1170.1 AS 4678

envirocon.net.au

1800 834 486

IMPORTANT NOTICE

DISCLAIMER

This guide is general information about how the Envirocon® systems and the Envirocalc® design tool relate to Australian standards. It is not a design, a certificate of compliance or engineering advice for any project. Every wall must be designed for its own site and loads, and signed off by an independent engineer registered to practise in the relevant state or territory.

CONTENTS

01	INTRODUCTION	03
	Purpose · Scope of work · Means of compliance	
02	DESIGN PARAMETERS	04
	General · Loadings · Limit state design · Soil conditions	
03	PROJECT SPECIFICATIONS	05
	General notes · Foundations	
04	STRUCTURAL DESIGN	07
	Inputs · Pressure coefficients · Overall load · Bearing capacity · Internal load	
05	NOTATION	14
	Symbols used in the calculations	

01 INTRODUCTION

PURPOSE, SCOPE AND THE STANDARDS BEHIND EVERY ENVIROCALC® DESIGN

1.1 PURPOSE

This manual sets out the design criteria, project specifications and structural design method used by Envirocon's Envirocalc® engineering calculator for gravity retaining walls built from Envirocon® Interbloc® and Stonebloc® precast concrete blocks in Australia. It follows the structure of the Design Features Report (DFR) that Envirocalc® generates for each design.

The Design Features Report is a detailed document defining the structure's design criteria and recording key decisions or outcomes. It outlines design loading, structural modelling assumptions, material properties, foundation requirements, and design standards. The DFR also defines the calculation procedure and checking principles to be followed, providing a clear explanation of the full design.

1.2 SCOPE OF WORK

The scope covered by the report is the design and documentation of the gravity retaining wall named in the project title, at the project address. The user enters the project title, project number, client, client contact and the scope description. The scope is limited to the external and internal stability of the block wall under static and earthquake loading, and to the bearing capacity of the founding soil beneath the wall. Design of any engineered foundation beneath the wall, global (slope) stability and drainage design are outside the scope and remain with the design engineer.

1.3 MEANS OF COMPLIANCE

The following standards have been used:

AS/NZS 1170.0:2002	Structural design actions, Part 0: General principles
AS/NZS 1170.1:2002	Structural design actions, Part 1: Permanent, imposed and other actions
AS 4678:2002	Earth-retaining structures

Design actions and load combinations are taken from AS/NZS 1170.0 and AS/NZS 1170.1. Earth pressures, design uncertainty factors on soil strength and the stability checks follow AS 4678. Serviceability is not assessed by the tool (see 2.3).

02 DESIGN PARAMETERS

2.1 GENERAL

The design parameters in this section are entered by the user. The user confirms the importance level of the structure and its design life, and the design loads are then assessed in accordance with AS/NZS 1170.0:2002. The report records the values entered, for example: the structure is an Importance Level 2 structure and the design life is 50 years. The user is responsible for selecting the importance level and design life that apply to the project under AS/NZS 1170.0 and the relevant Australian building regulations.

2.2 LOADINGS

2.2.1 DEAD AND IMPOSED LOADS

Permanent (dead) and imposed (live) loads behind the wall are entered by the user. The imposed surcharge Q is entered in kPa. A permanent surcharge G can be entered directly or calculated by the tool from a driveway or slab thickness and the width of that slab within the virtual back of the wall. Any load source within a horizontal distance of $1.5 H$ of the wall, where H is the retaining height, is treated as being within proximity of the wall and is included.

2.2.2 HORIZONTAL ACCELERATION COMPONENT

The horizontal acceleration used for the earthquake case is entered by the user as a peak ground acceleration, expressed as a fraction of g . Envirocalc® does not derive the horizontal acceleration component from a hazard model or from a site classification; the value entered is used directly to calculate the earthquake earth pressure coefficient

and the inertial forces of the wall and the backfill above the heels. The report records the value entered, for example: peak ground acceleration = $0.15g$.

The design engineer is responsible for deriving the horizontal acceleration for the site, for example from AS 1170.4 and the site subsoil class, and for any amplification or displacement allowance appropriate to the wall type.

2.3 LIMIT STATE DESIGN

Serviceability limit state design parameters are considered not critical for the foundation design. Ultimate limit state design (strength) has been carried out in accordance with the appropriate standards referenced in 1.3 Means of compliance, and as detailed in the structural calculations in Section 4 of this manual.

2.4 SOIL CONDITIONS

The backfill and base soil parameters are entered by the user from a site-specific geotechnical investigation. The report should describe the topography of the site, the type of soil present, the groundwater level encountered and, where the site is close to an existing slope, a slope stability analysis. The investigation should recommend the subsoil and backfill parameters to be used in design: density, undrained shear strength, effective friction angle and effective cohesion of the base soil, and density, friction angle, cohesion and slope of the backfill. Envirocalc® does not estimate soil parameters from a material description. The geotechnical investigation may change the design, and this should be made clear to the client at the estimating stage.

03 PROJECT SPECIFICATIONS

3.1 STANDARD NOTES

3.1.1 GENERAL NOTES

REF	NOTE
G.1	Structural drawings shall be read in conjunction with the Specification, Architectural, Civil, and Building Services documents.
G.2	All existing components are to be confirmed on site. Make appropriate provisions for unforeseen situations.
G.3	The stability of the structure during construction, including temporary works design, is the responsibility of the Contractor.
G.4	The method of excavation and temporary support of all cut faces is the responsibility of the contractor.
G.5	All materials and workmanship shall be in accordance with the current Codes of Practice except where varied by the specification or the drawings.
G.6	No substitutions are permitted and all Envirocon® manufacturer's specification is to be followed.

3.1.2 FOUNDATIONS

REF	NOTE
F.1	Foundation material shall be approved by the Engineer for ultimate bearing capacity 450kPa at FGL and other requirements specified on the drawings prior to the construction of any footings.
F.2	Subgrade below base course for slabs shall be of a suitable material and be compacted to 95% of maximum dry density.
F.3	All walls and columns shall be concentric with supporting foundations unless otherwise noted on drawings.
F.4	Behind all retaining walls back fill with free draining granular fill and install any de-watering drains specified by the Architect. Min GAP40 compacted in 150mm layers.
F.5	The contractor shall not excavate access tracks into the site that compromise the stability of the site or form cut faces to adjacent properties.
F.6	The temporary stability of all exposed cuts is the responsibility of the contractor.
F.7	The hardfill shown under the slab (if noted on the drawings) may be deleted in lieu of the excavated surface being cut clean with a smooth edge bucket and the final surface being of a tight, compact material. Crusher dust and DPM are to be used, over the top of this clean-cut surface.
F.8	All soft material is to be removed. If the top layer of cut material is loose it is to be re-compacted with a plate compactor or roller to a hard firm finished layer.
F.9	The Engineer is to verify the subgrade prior to DPM laying.

NOTE

F.1 carries the 450kPa ultimate bearing capacity and F.4 the GAP40 fill specification from the original manual. Both are project notes that the design engineer should confirm or edit for the site and for Australian material grading terminology.

04 STRUCTURAL DESIGN

Section 4 describes the calculation set that Envirocalc® performs and prints in the structural design part of the report. Every input is listed with its symbol, each check is shown with its equation and result, and a check is reported as passed or failed. All forces and moments are per metre run of wall.

4.1 INPUTS

BACKFILL PARAMETERS

The user enters the characteristic values from the geotechnical investigation. Envirocalc® applies a design uncertainty factor to each strength parameter to obtain the design value used in the calculations. The uncertainty factors are shown in the inputs and can be edited by the user.

PARAMETER	SYMBOL	NOTE
Characteristic angle of friction	ϕ_r	From the geotechnical report
Design uncertainty factor for friction	$\Phi_{u\phi r}$	Applied to $\tan \phi_r$ to give the design angle of friction ϕ_r^*
Design angle of friction	ϕ_r^*	Calculated
Backfill slope	β	Angle of the backfill surface above the horizontal
Characteristic cohesion	c_r	From the geotechnical report
Design uncertainty factor for cohesion	Φ_{ucr}	Applied to c_r to give the design cohesion c_r^*
Backfill design cohesion	c_r^*	Calculated
Backfill density	γ	kN/m ³

BASE SOIL PARAMETERS

PARAMETER	SYMBOL	NOTE
Undrained shear strength	c_{uf}	Used for the short-term (undrained) checks
Characteristic cohesion	c_f	Effective cohesion, used for the long-term (drained) checks
Design uncertainty factor for cohesion	Φ_{ucf}	Gives the base soil design cohesion c_f^*
Characteristic angle of friction	ϕ_f	Effective friction angle
Design uncertainty factor for friction	$\Phi_{u\phi f}$	Gives the design angle of friction ϕ_f^* (also written ϕ_d in the bearing capacity calculations)
Base soil density	γ	kN/m ³

4.1 INPUTS (CONTINUED)

STRUCTURE DIMENSIONS

The wall geometry is taken from the Envirobuild® model or entered directly: height of retaining wall H , base of retaining wall B , foundation block length L (600 mm or 1200 mm depending on the block), number of heels, base and height of each heel (B_{h1} , H_{h1} to B_{h4} , H_{h4}) and wall embedment depth H_{em} . Walls of uniform thickness and walls with one to four heels are supported.

LIVE LOAD AND DEAD LOAD

Imposed surcharge Q in kPa. Permanent surcharge G in kPa, either entered or calculated from the driveway thickness T_{dl} and the width within the virtual back of the wall W_{dl} .

LOAD AND RESISTANCE FACTORS

The calculations apply the following factors, which are set in the tool for the Australian standard selection: G_{do} and G_{lo} on permanent and imposed actions that destabilise the wall in the static case, G_{dr} on resisting actions in the static case, G_{edo} , G_{elo} and G_{edr} for the equivalent earthquake cases, ϕ_n on resisting forces and moments, and δ , the wall friction angle used to resolve the earth pressure into vertical and horizontal components. The values of these factors are not currently printed in the report and should be listed in the inputs so that a reviewer can check them against AS/NZS 1170.0 and AS 4678 (see Appendix A).

4.2 PRESSURE COEFFICIENTS

ACTIVE/AT REST EARTH PRESSURE COEFFICIENT

The static earth pressure coefficient K_a , the earthquake earth pressure coefficient $K_{a,eq}$ and the passive earth pressure coefficient K_p are shown as values. The user can override the calculated value of each coefficient so that a more conservative value can be used where the site or the wall condition requires it.

K_a STATIC · ACTIVE OR AT REST	$K_{a,eq}$ EARTHQUAKE	K_p PASSIVE
--	---	---

Although the notation K_a is used for the earth pressure coefficient in the static case, the value used may represent either the at rest or active earth pressure coefficient, depending on the value entered by the user.

4.3 OVERALL LOAD CALCULATIONS

STATIC CASE: ACTIONS

Pressure caused by the backfill, and its vertical and horizontal components:

$$\begin{aligned} P_{a,bf} &= K_a G_{do} \gamma H^2 / 2 \\ P_{av,bf} &= P_{a,bf} \sin(\delta) \\ P_{ah,bf} &= P_{a,bf} \cos(\delta) \end{aligned}$$

Pressure caused by the surcharge, and its components:

$$\begin{aligned} P_{a,su} &= K_a ((G_{lo} Q) + (G_{do} G)) H \\ P_{av,su} &= P_{a,su} \sin(\delta) \\ P_{ah,su} &= P_{a,su} \cos(\delta) \end{aligned}$$

Total active pressure and its components:

$$\begin{aligned} P_a &= P_{a,bf} + P_{a,su} \\ P_{av} &= P_{av,bf} + P_{av,su} \\ P_{ah} &= P_{ah,bf} + P_{ah,su} \end{aligned}$$

Location of the total active pressure above the base, from the moments of the backfill and surcharge components:

$$h_{pa} = (M_{backfill} + M_{surcharge} + M_{diff,backfill}) / P_a$$

SUMMARY AND FACTORED ACTIONS

The report tabulates the backfill, surcharge and total active pressure components and the own weight of each wall block (W_1 to W_4) and of the backfill above each heel (W_{s1} to W_{s3}), with the total weight W_{total} .

EFFECTIVE WIDTH OF THE FOUNDATION

The location of the resultant vertical force from the heel, X , the eccentricity e , and the effective width B' are calculated from the moments of the block weights about the heel. The effective width is the smaller of the two values and is used in the sliding and bearing capacity checks. The middle-third criterion is checked by comparing $B/6$ with $B'/2$.

$$\begin{aligned} X &= [W_1(B - B_1/2) + W_2(B - B_2/2) + W_3(B - B_3/2) + W_4(B - B_4/2)] / (P_{av} + W_{total}) \\ e &= P_{ah} h_{pa} / (P_{av} + W_{total}) \\ B'_1 &= 2(e + X) \quad B'_2 = 2(B - e - X) \quad B' = \min(B'_1, B'_2) \end{aligned}$$

Check: $B'/2$ against $B/6$

4.3 OVERALL LOAD CALCULATIONS (CONTINUED)

OVERTURNING STABILITY CHECK

The overturning moment from the horizontal component of the active pressure is compared with the stabilising moments from the vertical component of the active pressure, the block weights and the backfill above the heels, taken about the toe. The net moment must be negative (stabilising greater than overturning) for the check to pass.

$$M_{ah} = P_{ah} h_{pa} \cdot M_{av} = P_{av} B$$

$$M_{w1} = W_1 B_1/2, M_{w2} = W_2 B_2/2, M_{w3} = W_3 B_3/2, M_{w4} = W_4 B_4/2$$

$$M_{ws1} = W_{s1} (B_{h1} - B_{s1}/2), M_{ws2} = W_{s2} (B_{h2} - B_{s2}/2), M_{ws3} = W_{s3} (B_{h3} - B_{s3}/2)$$

$$M_w = (M_{av} + M_{w1} + M_{w2} + M_{w3} + M_{w4} + M_{ws1} + M_{ws2} + M_{ws3}) \phi_n$$

$$M_{net} = M_{ah} - M_w \text{ (must be less than zero)}$$

SHORT TERM SLIDING

Sliding resistance in the short term (undrained) condition comes from the undrained shear strength of the base soil over the effective width, plus the horizontal passive resistance from the embedded depth.

$$P_{fr} = \phi_n c_{uf} B'$$

$$P_p = G_{dr} ((2 c_{uf} H_{em}) + (0.5 \gamma H_{em}^2))$$

$$P_{pH} = \phi_n P_p$$

$$P_{sR} = P_{fr} + P_{pH}$$

$$P_{ah} = P_{ah,bf} + P_{ah,su}$$

$$S.F. = P_{sR} / P_{ah} \text{ (at least 1.0)}$$

LONG TERM SLIDING

Sliding resistance in the long term (drained) condition comes from friction on the base, using the design friction angle of the base soil, plus the passive resistance from the embedded depth.

$$P_{fr} = \phi_n (P_{av} + W_{total}) \tan(\phi_d)$$

$$P_p = 0.5 K_p G_{dr} \gamma H_{em}^2$$

$$P_{pH} = \phi_n P_p$$

$$P_{sR} = P_{fr} + P_{pH}$$

$$S.F. = P_{sR} / P_{ah} \text{ (at least 1.0)}$$

EARTHQUAKE CASE: ACTIONS

The earthquake case repeats the static calculations with the earthquake earth pressure coefficient $K_{a,eq}$, the earthquake load factors, and the inertial forces of the wall blocks and the backfill above the heels. Each inertial force is the weight of the component multiplied by the horizontal acceleration entered in 2.2.2 (W_{l1} to W_{l4} , W_{ls1} to W_{ls3} , total W_{ltotal} , acting at height h_l).

$$P_{a,bf} = K_{a,eq} G_{edo} \gamma H^2 / 2$$

$$P_{a,su} = K_{a,eq} ((G_{elo} Q) + (G_{edo} G)) H$$

Components, totals and h_{pa} as for the static case

$$e = (P_{ah} h_{pa} + W_{ltotal} h_l) / (P_{av} + W_{total})$$

$$M_l = W_{ltotal} h_l$$

$$P_p = G_{edr} ((2 c_{uf} H_{em}) + (0.5 \gamma H_{em}^2))$$

$$M_{net} = M_{ah} + M_l - M_w \text{ (must be less than zero)}$$

$$S.F. = P_{sR} / (P_{ah} + W_{ltotal}) \text{ (must be at least 1.0)}$$

Only the short-term sliding check is performed for the earthquake case, since earthquake loading is a short-term event.

4.4 BEARING CAPACITY CALCULATIONS

Bearing capacity is checked for the short-term static case, the short-term earthquake case and the long-term static case. The bearing stress is assumed to be uniform across the effective width B' , so maximum stresses at the heel and toe are not checked separately. The effective area of the footing uses the foundation block length L .

SHORT TERM (UNDRAINED), STATIC AND EARTHQUAKE

$$V = W_{total} + P_{av}$$

$$q_d = V / B_{eff} \text{ (design bearing pressure)}$$

$$\phi_d = 0, N_q = 1, N_c = 5.14$$

$$\lambda_{ci} = 0.5 (1 + \sqrt{(1 - P_{ah} / (B_{eff} c_{uf}))})$$

$$p_{Vcap} = \phi_n (c_{uf} \lambda_{cs} \lambda_{ci} \lambda_{cg} N_c + q \lambda_{qg})$$

Check: p_{Vcap} against q_d

$$B_{eff} = B', L_{eff} = L, A_{eff} = B_{eff} L_{eff}$$

$$q = H_{em} \gamma \text{ (overburden)}$$

$$\lambda_{cs} = 1, \lambda_{cg} = 1, \lambda_{qg} = 1$$

In the earthquake case the horizontal action used in the inclination factor includes the inertial forces, and the effective width is the earthquake-case value.

4.4 BEARING CAPACITY CALCULATIONS (CONTINUED)

LONG TERM (DRAINED), STATIC

$$\phi_d = \text{atan}(\tan(\phi_f) \cdot \Phi_{u\phi f})$$

$$N_q = \exp(\pi \tan \phi_d) \tan^2(45^\circ + \phi_d/2)$$

$$N_c = (N_q - 1) \cot \phi_d \cdot N_\gamma = 2 (N_q + 1) \tan \phi_d$$

$$\lambda_{cs} = \lambda_{qs} = \lambda_{ys} = 1; \lambda_{cg} = \lambda_{qg} = \lambda_{yg} = 1$$

$$\lambda_{qi} = (1 - 0.7 P_{ah} / (V + A_{eff} c_f \cot \phi_d))^3$$

$$\lambda_{ci} = (\lambda_{qi} N_q - 1) / (N_q - 1)$$

$$\lambda_{yi} = (1 - P_{ah} / (V + A_{eff} c_f \cot \phi_d))^3$$

$$p_{Vcap} = \phi_n (c_f N_c \lambda_{cs} \lambda_{ci} \lambda_{cg} + q N_q \lambda_{qs} \lambda_{qi} \lambda_{qg} + 0.5 \gamma B_{eff} N_\gamma \lambda_{ys} \lambda_{yi} \lambda_{yg})$$

Check: p_{Vcap} against q_d

NOTE

Shape and ground inclination factors are set to 1.0 in the current calculation set (strip footing on level ground). Where the wall sits near a slope or the footing is not a strip, the design engineer should check these factors separately.

4.5 INTERNAL LOAD CALCULATIONS

Internal stability is checked at each block layer (Point 1 at the top of the first course, Point 2 at the second course, and so on). At each point the wall weight above the point, the inertial force on that weight, the backfill and surcharge pressures over the height above the point, and the location of the resultant are recalculated using the same equations as in 4.3. The overturning stability check is then repeated about the toe of the block at that level, for the static and earthquake cases, and the net moment must be negative.

The report prints two overturning results: the overall stability of the wall on its base (4.3) and the internal stability at each block layer (4.5). A wall can pass the overall check and fail at a layer level. Where an internal check fails, the wall section above that level needs more mass (a heel engaging more backfill, or a wider block) or vertical reinforcement, which is outside the scope of this manual.

05 NOTATION

SYMBOL	MEANING
H, B, L	Retaining height, base width and foundation block length of the wall
B_{h1} to B_{h4}, H_{h1} to H_{h4}	Base and height of each heel
H_{em}	Wall embedment depth below finished ground level in front of the wall
Φ_r, c_r, β, γ	Backfill friction angle, cohesion, slope and density
Φ_f, c_f, c_{uf}	Base soil friction angle, effective cohesion and undrained shear strength
Φ_{uφ}, Φ_{uc}	Design uncertainty factors on friction and cohesion (subscript r backfill, f base soil)
Φ*, c*, Φ_d	Design (factored) friction angle and cohesion
Q, G	Imposed and permanent surcharge
G_{do}, G_{lo}, G_{dr}	Load factors on permanent destabilising, imposed destabilising and resisting actions, static case
G_{edo}, G_{elo}, G_{edr}	Load factors for the earthquake case
Φ_n	Factor applied to resisting forces and moments
δ	Wall friction angle used to resolve earth pressure
K_a, K_{a,eq}, K_p	Static (active or at rest), earthquake and passive earth pressure coefficients
P_a, P_{av}, P_{ah}	Total active pressure resultant and its vertical and horizontal components (suffix bf backfill, su surcharge)
h_{pa}, h_i	Height of the active pressure resultant and of the inertial force resultant above the base
W₁–W₄, W_{s1}–W_{s3}, W_{total}	Weight of each block, of the backfill above each heel, and the total
W_i	Inertial force corresponding to each weight
X, e, B'	Location of the resultant vertical force from the heel, eccentricity, effective width
M_{ah}, M_i, M_w, M_{net}	Overturning moment, inertial moment, stabilising moment and net moment
P_{fr}, P_p, P_{pH}, P_{sR}	Base friction or adhesion resistance, passive resultant, factored horizontal passive resistance, total sliding resistance
V, q_d, q, P_{Vcap}	Vertical load, design bearing pressure, overburden pressure, bearing capacity
N_c, N_q, N_γ, λ	Bearing capacity factors and their shape (s), inclination (i) and ground (g) modifiers
S.F.	Ratio of factored resistance to factored action for a check

CONCRETE KEPT IN CIRCULATION

At Envirocon®, we lead the way in sustainable construction with our innovative precast concrete block system, designed to support the circular economy by transforming surplus concrete into durable, reusable building solutions.

As the country's first accredited construction product stewardship scheme, we create ultra-low embodied carbon products that can be reused, recycled, or repurposed at the end of their life, and our buyback guarantee keeps concrete in circulation and out of landfills.

THE ENVIROCON® SYSTEM

INTERBLOC®	Interlocking precast concrete blocks for retaining walls, storage bays and push walls.
ENVIROBUILD®	3D design, visualisation and block quantification.
ENVIROCALC®	Cloud-based gravity retaining wall design verification.

WEB

envirocon.net.au

PHONE

1800 834 486