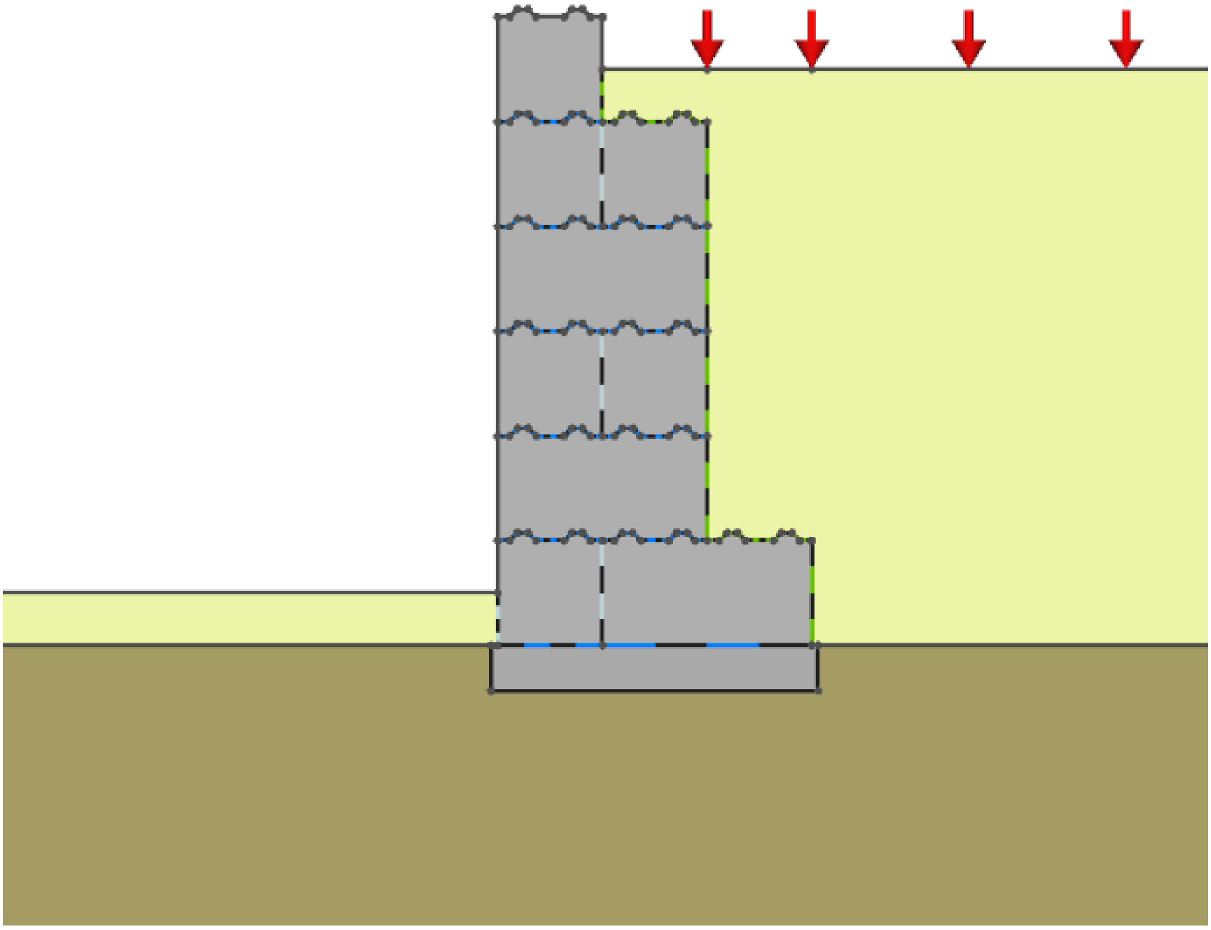
ELITE PRECAST CONCRETE LIMITED

REFERENCE GUIDE FOR DESIGNING RETAINING WALLS USING INTERLOCKING CONCRETE BLOCKS



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Tellus Design Limited
SE008, e-Innovation Centre, Telford Campus, Priorslee, Telford, Shropshire, TF2 9FT, UK
Tel: 01952 288331

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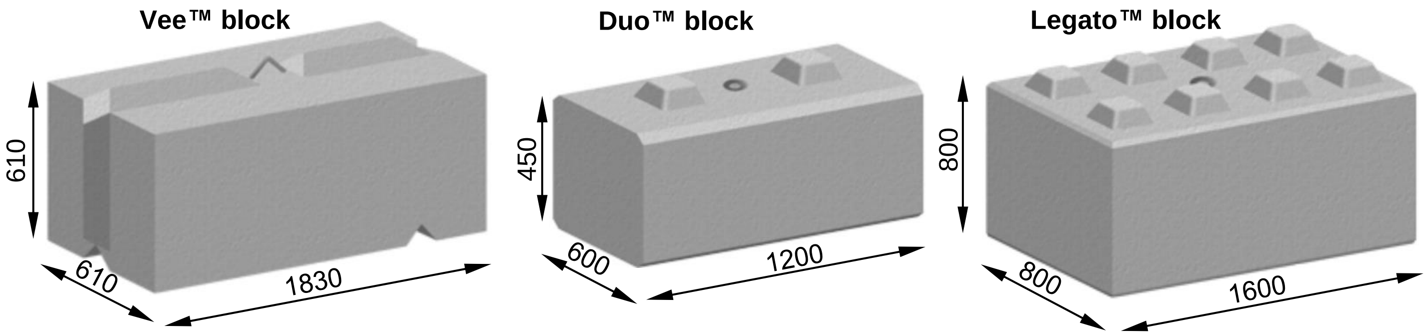
Conditions and limitations

1. Introduction

This document has been prepared to provide guidance when designing retaining walls using Elite Precast Concrete Limited's interlocking concrete blocks. It is intended to assist civil/structural engineers and architects in the best practice of designing these types of gravity retaining structure.

Elite Precast Concrete Ltd (EPCL) supply three interlocking concrete block systems; Vee™, Duo™ and Legato™. Each system comprises precast blocks manufactured from high strength unreinforced concrete. The blocks are dry laid and incorporate interlocking elements to distribute loads between adjacent blocks. For each block type, the 'standard' block size is supplemented by blocks of different dimensions to facilitate various wall layouts. The standard block dimensions for the three systems are shown in Figure 1.1.

Figure 1.1 Standard block dimensions (mm)



These interlocking block systems may be used for both free-standing walls and retaining walls. Typical free-standing wall applications include:

- Flood barriers
- Traffic calming/segregation
- Security barriers/fencing

For free-standing wall applications, the structure may be required to resist hydrostatic loads from flood waters, vehicle impact loads and wind pressure.

Retaining wall applications are many and varied, but include the following applications for interlocking blocks:

- Bay walls/push walls to storage facilities for grain, salt, silage, aggregate and waste materials
- Earth retaining walls to support embankments/cuttings for both temporary and permanent works

For retaining wall applications, the structure must be designed to resist the forces from the retained material acting on one side of the wall. Over its intended service life, other loads may also be applied to the structure.

Some of the advantages of using large precast concrete block systems for retaining structures include:

- Relatively low cost
- Simple and quick to build – dry laid ensures structure can be loaded without waiting for concrete/mortar to set
- Durable with low on-going maintenance costs
- Re-usable – structures can be readily dismantled and reused elsewhere

Different organisations may be responsible for the design, manufacture, installation and maintenance of the retaining wall as described below:

- Design – Professionally qualified civil, structural or geotechnical engineer. May also require an independent third- party engineer to perform a design check, especially for road and rail infrastructure projects
- Manufacture – Precast concrete manufacturer, such as Elite Precast Concrete Ltd
- Installation – Civil/building contractor or specialist earthworks sub-contractor
- Maintenance – Owner/operator of the infrastructure or storage facility

2. Design method

This guidance document is primarily concerned with the design of retaining walls rather than free-standing walls. However, many of the design considerations are equally applicable to be both types of structure.

The design of retaining structures in the UK should conform with the requirements of the structural Eurocodes and associated UK National Annexes. These Eurocodes have largely replaced British Standards, although other documents exist that provide non-contradictory complimentary information for use with the Eurocodes. In addition, some major client organisations, such as Network Rail and Highways England, have their own standards that address aspects of retaining wall design. For this guidance document, the following standards are relevant:

- BS EN1990 (+ UK NA to BS EN1990) – Eurocode 0 – Basis of structural design
- BS EN1991 (+ UK NA to BS EN1991) – Eurocode 1 - Actions on structures
- BS EN1997 (+ UK NA to BS EN1997) – Eurocode 7 – Geotechnical design
- BS 8002:2015 – Code of practice for earth retaining structures (non-contradictory complimentary recommendations for use in conjunction with BS EN1997-1 and its UK NA)
- PD 6694-1:2011 – Published Document - Recommendations for the design of structures subject to traffic loading to BS EN 1997-1:2004

Section 9.1.1 of Eurocode 7 defines a retaining wall is as a structure which '*…retains ground comprising soil, rock or backfill and water. Material is retained if it is kept at a slope steeper than it would eventually adopt if no structure were present'.*

There are many types of retaining structure which have been grouped into three main categories in Eurocode 7:

- Gravity walls – relatively wide walls having a base footing
- Embedded walls – relatively thin walls relying on lateral earth resistance and their own structural resistance, such as cantilever sheet pile walls
- Composite retaining structures – walls composed of both gravity and embedded wall elements, such as double sheet pile wall cofferdams

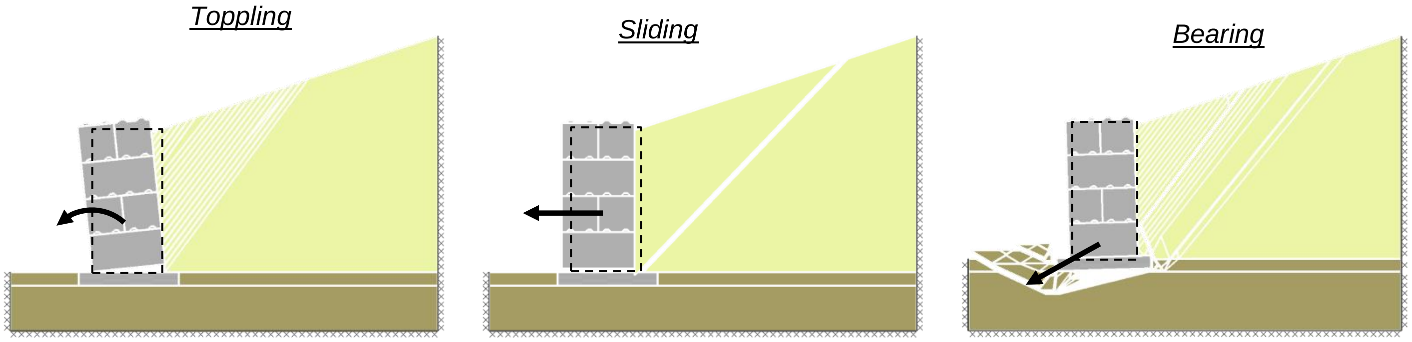
Walls formed from interlocking concrete blocks are designed as gravity walls, defined in BS 8002:2015 as follows:

> *Gravity retaining walls are earth retaining structures that depend primarily on their own self-weight (and that of any enclosed material) to support the retained ground and any structures or loads placed upon it.*

Section 9.2 of Eurocode 7 lists the minimum limit state requirements for all types of retaining structure including loss of overall stability, failure of a structural element, excessive movement and unacceptable leakage. In addition, the standard lists the following limit states that shall be considered for gravity walls (see Figure 2.1):

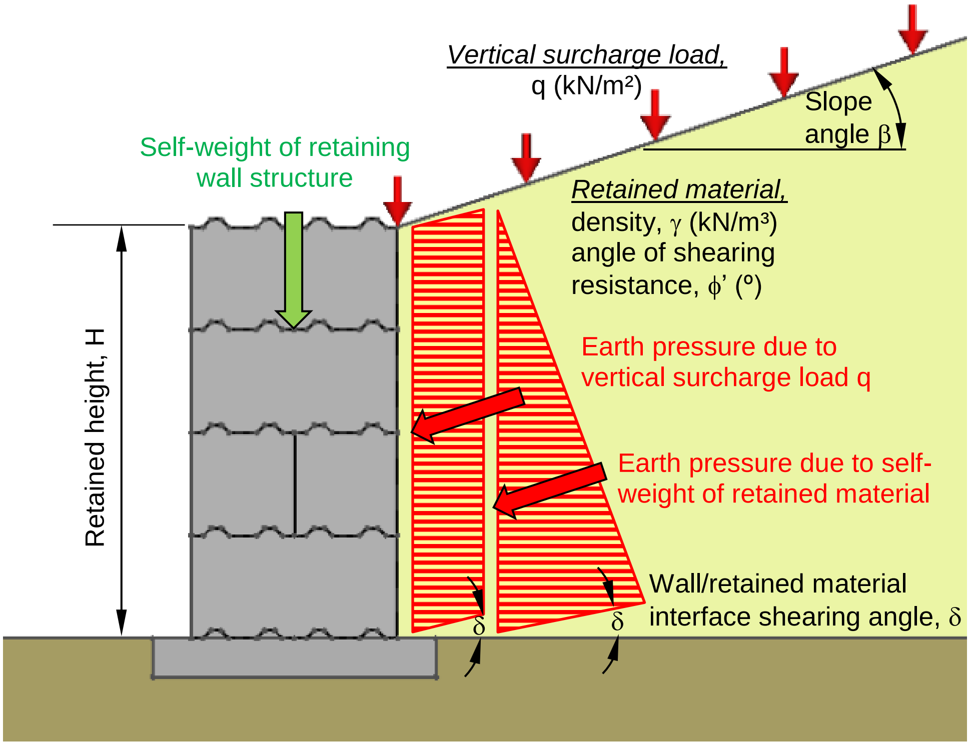
- bearing resistance failure of the soil below the base
- failure by sliding at the base;
- failure by toppling;

Figure 2.1 Ultimate limit states for gravity retaining walls



The retained ground (or stored materials) and imposed surcharge loads exert pressures on the retained side of the wall (see Figure 2.2). These are considered 'unfavourable' actions as they are acting to de-stabilise the structure. The self-weight of the retaining wall is usually a 'favourable' action, as the effects of it are to counter the effects of the unfavourable actions. For bearing failure, the self-weight of the wall may be 'favourable' or 'unfavourable'.

Figure 2.2 Favourable and unfavourable actions applied to gravity retaining wall



Methods for determining the values of retained earth pressures are included in Annex C of Eurocode 7. For gravity walls at the ultimate limit state, it is assumed that sufficient wall movement has occurred for active conditions to be applicable. The retained earth pressure, σ_a, is then calculated using the active earth pressure coefficient, K_a, based upon expression C.1 in Eurocode 7:

$$\sigma_a(z) = K_a \left[\int \gamma dz + q - u \right] + u - c\, K_{ac}$$

where the integration is taken from ground surface to depth z. For the wall shown in Figure 2.2 and assuming zero cohesion and no pore water pressures (i.e. u = 0kPa and c = 0kPa), the sum of the unfavourable actions acting on the retained side of the structure is therefore:

$$\Sigma P_a = [\tfrac{1}{2} \times K_a \times \gamma \times H^2] + [K_a \times q \times H]$$

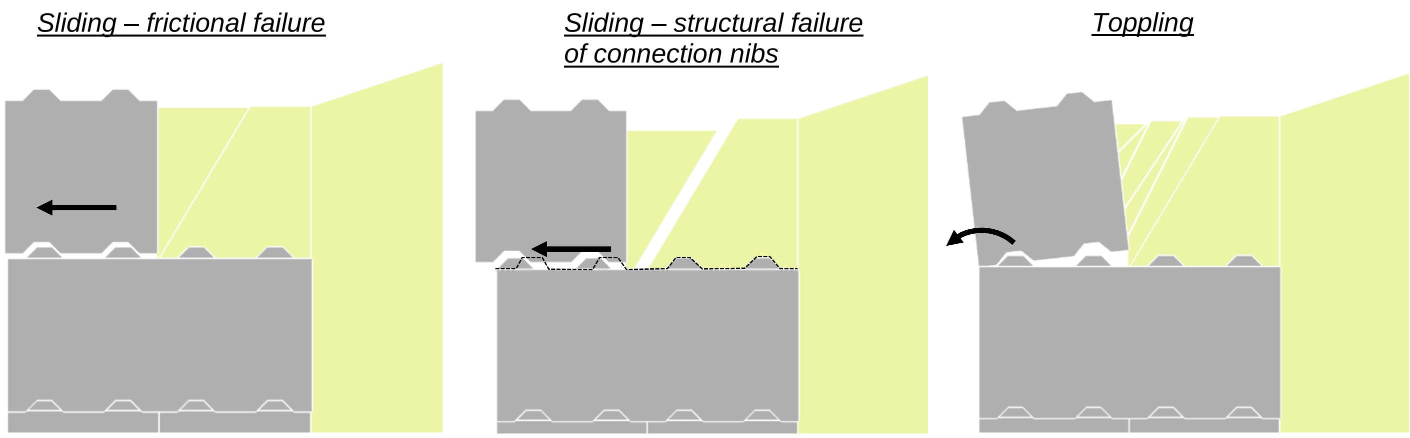
From these expressions, the magnitude of the unfavourable actions depends upon the values of the retained soil density, γ, the retained height of the wall, H, and the vertical surcharge load, q. Increasing the value of any of these parameters will increase the de-stabilising actions. The active earth pressure coefficient, K_a, is a function of:

- Angle of shearing resistance of the retained material, ϕ'
- Slope angle of the retained material behind the wall, β (must be $\leq \phi'$ for material with zero cohesion)
- Interface shearing angle between the retained material and the wall, δ (usually taken as proportion of ϕ')

Methods for calculating the value of K_a include those by Rankine and Coulomb. Annex C of Eurocode 7 includes both design charts and analytical procedures for determining the value of K_a using the parameters ϕ', δ and β. As the value of slope angle β increases, so does the value of K_a. Conversely, increases in the value of ϕ' or δ lead to a reduction in the value of K_a. Where a value of $\delta > 0^o$ has been used, the retained earth pressures are inclined at an angle of δ to the horizontal. The effect of this inclination is a reduction in the horizontal component of earth pressure and an increase in the vertical component of earth pressure, both of which are favourable to the stability of the wall.

In assessing the three ultimate limit states (i.e. bearing, toppling and sliding), a gravity wall is usually modelled as a single coherent mass structure, including the footing. For a wall section formed from discrete interlocking blocks, this assumption must be checked by considering the stability of the individual blocks (see Figure 2.3).

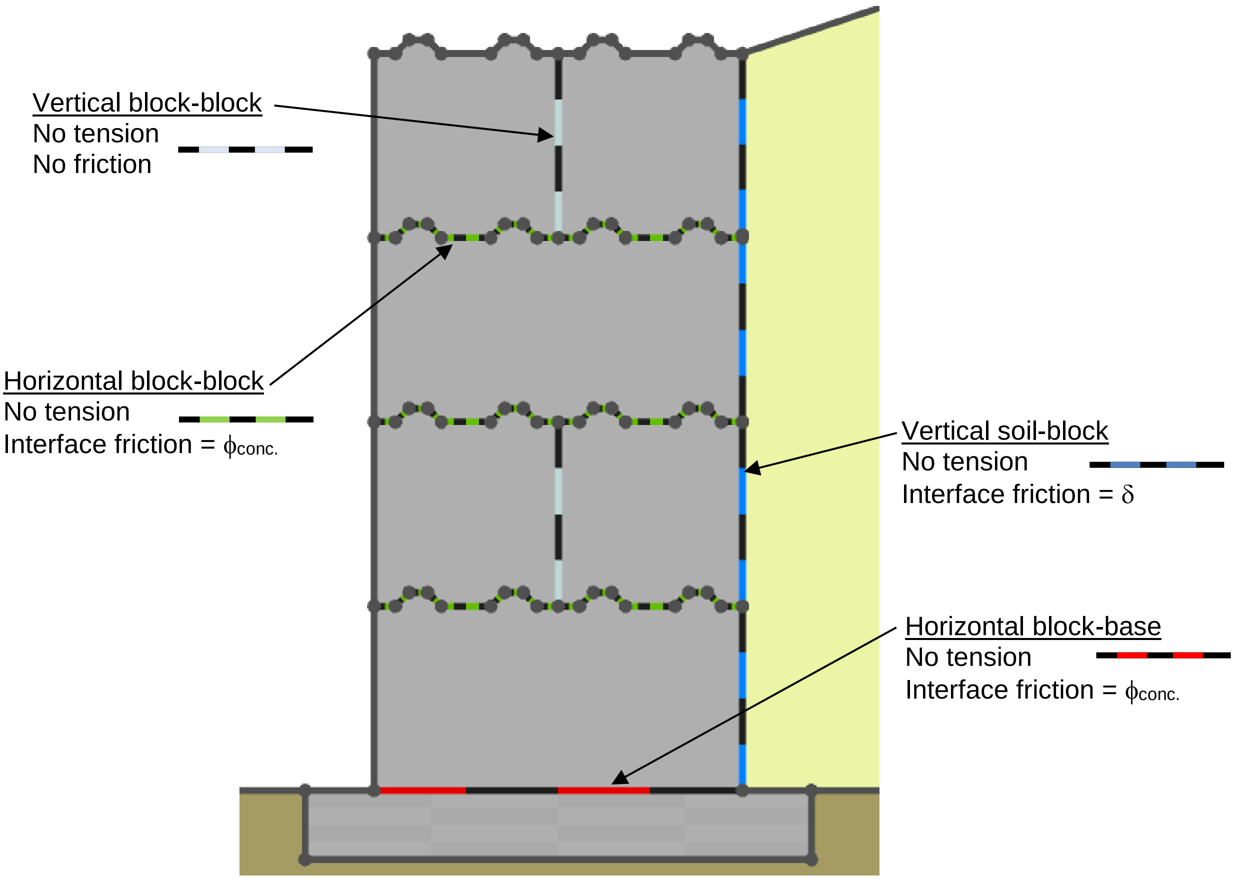
Figure 2.3 Internal stability limit states for interlocking blocks



At the interfaces between adjacent between blocks, the following conditions apply (see Figure 2.4):

- No tension between any individual blocks
- No friction along the vertical interfaces between individual blocks
- Friction occurs along the horizontal interfaces between individual blocks
- The frictional force across a horizontal interface between blocks has a limiting value based upon the shear strength of the interlocking elements (V shape channels on Vee blocks or nibs on the Duo/Legato blocks)

Figure 2.4 Interface conditions between interlocking blocks



3. Design input

Before designing a retaining structure, input data concerning the design requirements is required. Both Eurocode 7 and BS8002:2015 provide extensive lists of the data required and reference should be made to these publications. As a minimum, this data should include information on the ground conditions at the site, geometrical requirements, actions (loadings) and service requirements for the structure.

3.1. Ground conditions

The overall stability of the retaining wall can only be assessed if adequate ground investigation has been carried out. Part 2 of Eurocode 7 provides guidance on the depth and spacings of investigation points for retaining structures. For retaining wall design, the results of the ground investigation should provide information on the nature of the materials behind and beneath the structure and their strength and deformation properties. Information on groundwater levels is required as these too may significantly affect the stability of the structure.

Where ground investigation data is not available, the design of the retaining wall may be progressed on the assumption that the foundation soil is competent. This assumption would need to be confirmed before construction.

3.2. Geometrical information

The following basic geometrical information is required to enable design cross sections of the wall to be prepared:

- the location of the wall, its position relative to other structures and buried services, and the amount of construction space available;
- the necessity or otherwise to confine the support system within the site boundaries;
- the proposed height of the wall and the topography of the ground, both before and after construction;

As noted earlier, the retained height of the wall, H, and the retained slope angle, β, significantly affect the magnitude of the force acting on the retained side of the wall.

3.3. Actions

The actions, or loadings, imposed upon the structure may be categorised as permanent, variable or accidental and are defined in Eurocode 0. For the retaining wall design, information on the following actions are required:

<u>Permanent actions</u>
- Self-weight of the retained backfill material. Typical values of characteristic bulk densities, γ, for various materials may be found in BS8002:2015, Eurocode 1 and other reference sources.
- Self-weight of nearby structures supported on the retained material

<u>Variable actions</u>
- Self-weight of the stockpiled materials/items of equipment
- Traffic loading from road and rail vehicles. Typical values of characteristic vertical surcharge loads, q, for various vehicle types may be found in Tables 6 and 7 of BS8002:2015.

<u>Accidental actions</u>
- Impact loading from vehicle collisions.

3.4. Service requirements

The service requirements of the retaining structure may include the following:

- Service life – From short term temporary works to 120 years for permanent road/rail infrastructure projects
- Appearance – Specific aesthetic requirements
- Maintenance requirements
- The extent of acceptable ground movement during construction and in service

4. Design calculations

Design calculations are required to demonstrate that the structure has adequate stability to prevent a failure from occurring. For the ultimate limit state (i.e. collapse failure), the retaining wall must be checked as a whole and for individual block failures. The serviceability limit state is usually concerned with calculating whether excessive tilt or settlement is likely to occur. For gravity retaining walls, calculations of predicted wall movements are not routinely required. Where the magnitude of wall movement is a critical consideration, reference is made to other publications such as CIRIA Report C516 for details of appropriate calculation methods.

The calculation output for the ultimate limit states are described as follows for the external stability (i.e. the overall wall) and the internal stability (i.e. at local interfaces between blocks). In analysing retaining walls in accordance with Eurocode 7, UK users are required to use the partial factor sets from Design Approach 1, Combinations 1 and 2. Generally, the calculations are relatively simple and may be performed by hand or simple spread sheet. Alternatively, commercially available software programs may be used for the analysis.

4.1. External stability

The four external stability checks are bearing resistance failure beneath the base, sliding failure at the base, toppling failure and loss of overall stability. For stability, the calculations for each failure mechanism must satisfy the following general expression:

$E_d \leq R_d$

Where:

E_d is the design effects of the actions
R_d is the corresponding design resistance

4.1.1 Bearing resistance

For bearing resistance, stability is satisfied when:

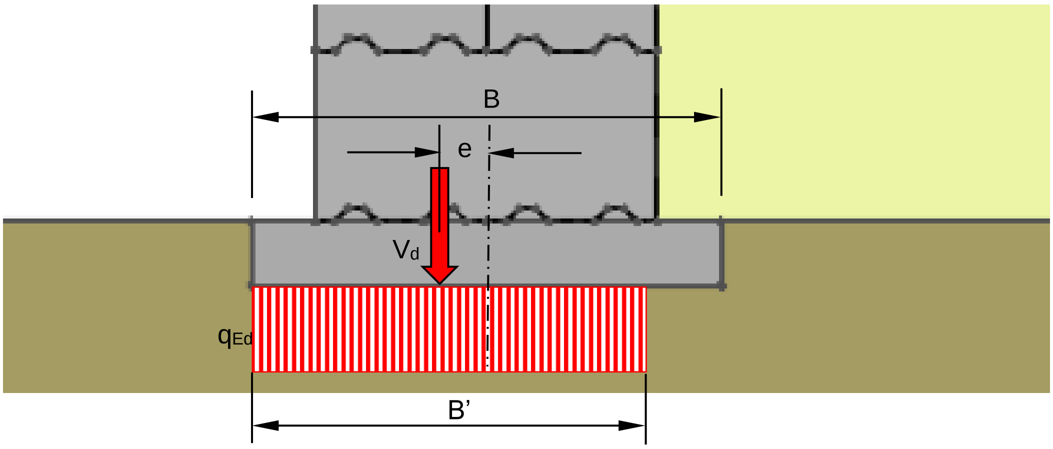
$V_d \leq R_d$

Where:

V_d is the vertical design action acting on the foundation (kN/m)
R_d is the design bearing resistance (kN/m)

The bearing pressure imposed on the underlying foundation soil must take account of eccentric loading. With reference to Meyerhof, the vertical design action, V_d, is assumed to act at the centre of a smaller foundation as shown in Figure 4.1.1.

Figure 4.1.1 Bearing area for eccentrically loaded foundations



$$B' = B - 2e$$

Where:

B' = effective width of footing (m)
B = nominal width of footing (m)
e = eccentricity from the centreline of the footing (m)

To prevent contact with the ground being lost at the edges, it is good practice to ensure that the eccentricity remains within the foundations 'middle-third' (i.e. $e \leq B/6$).

The design bearing resistance is calculated in accordance with Eurocode 7, taking account of inclined loading (i.e. the actions on the footing include vertical and horizontal components of load). The calculations take account of the characteristic density and shear strength of the underlying foundation soil and the presence of groundwater. For fine grained soils (i.e. Silts and Clays), the short term undrained condition is likely to be critical for bearing resistance. Bearing resistance in coarse grained soils (i.e. Sands and Gravels) is always based upon long term effective stress parameters.

4.1.2 Sliding resistance

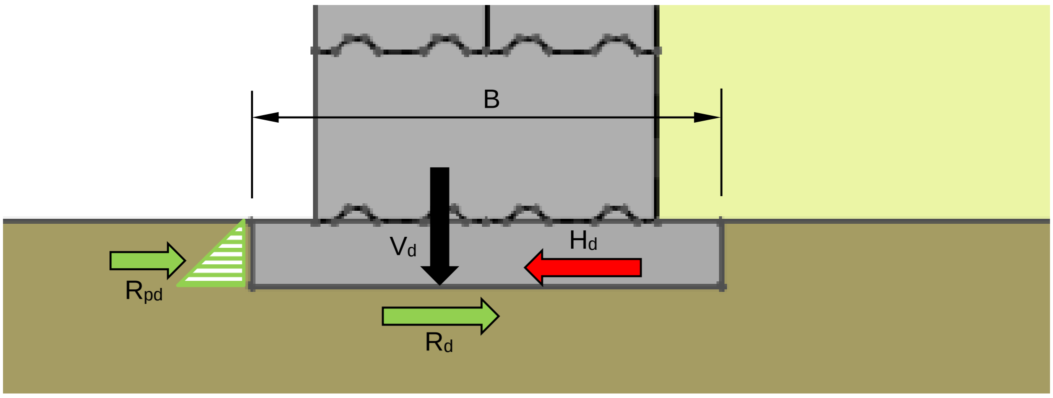
For sliding resistance, stability is satisfied when:

$$H_d \leq R_d + R_{pd}$$

Where:

H_d is the horizontal design action acting on the foundation (kN/m)
R_d is the design shear resistance (kN/m)
R_{pd} is the design passive resistance (kN/m)

Figure 4.1.2 Sliding resistance of foundation to retaining wall



The horizontal design action, H_d, is the total horizontal force applied at the base of the foundation. It comprises the retained earth pressures due to self-weight of the backfill and vertical surcharge, plus any additional horizontal actions such as impact loads.

The method for calculating the design shear resistance, R_d, depends upon whether the foundation soil is coarse grained or fine grained. For both types of soil, the drained shear resistance is calculated in terms of effective stress taking account of the vertical design action, V_d, and the angle of interface friction between the base and the ground, δ. For fine grained soils, the undrained shear resistance is also calculated based upon the width of the footing, B, and the undrained shear strength, c_u, of the foundation soil.

Drained shear resistance: $R_d = V_{d.} \times \tan \delta_{;d}$

Undrained shear resistance: $R_d = B \times c_{u;d}$

The design passive resistance, R_{pd}, is a favourable action and is calculated in a similar manner to the retained earth pressures. The main difference is that the earth pressure coefficient used in the calculation is the passive earth pressure coefficient, K_p. For relatively shallow foundation depths, the passive resistance will be small. Furthermore, the designer should consider the possibility of excavation in front of the wall that could significantly reduce any passive resistance.

4.1.3 Toppling resistance

For toppling resistance, stability is satisfied when:

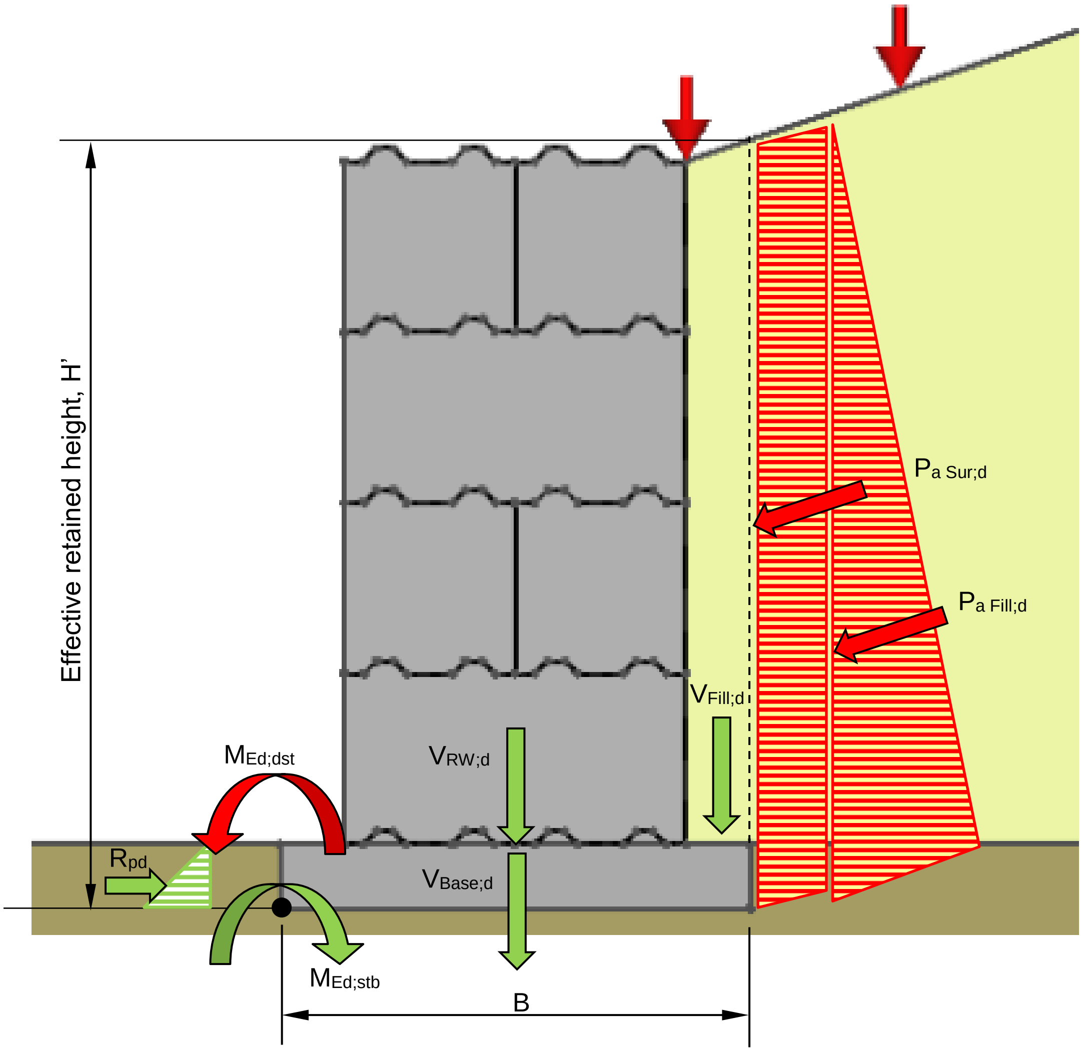
$M_{Ed;\,dst} \leq M_{Ed;\,stb}$

Where:

$M_{Ed;\,dst}$ is the destabilising design moment acting about the toe of the foundation (kNm/m)
$M_{Ed;\,stb}$ is the stabilising design moment acting about the toe of the foundation (kNm/m)

The unfavourable actions contributing to the destabilising moment are the retained earth pressures due to self-weight of the backfill and vertical surcharge. Favourable actions that contribute to the stabilising moment are the self-weight of the retaining wall, base, fill above the base and passive resistance. These actions are shown in Figure 4.1.3. As for sliding resistance, the contribution from passive resistance may be affected by excavation in front of the wall.

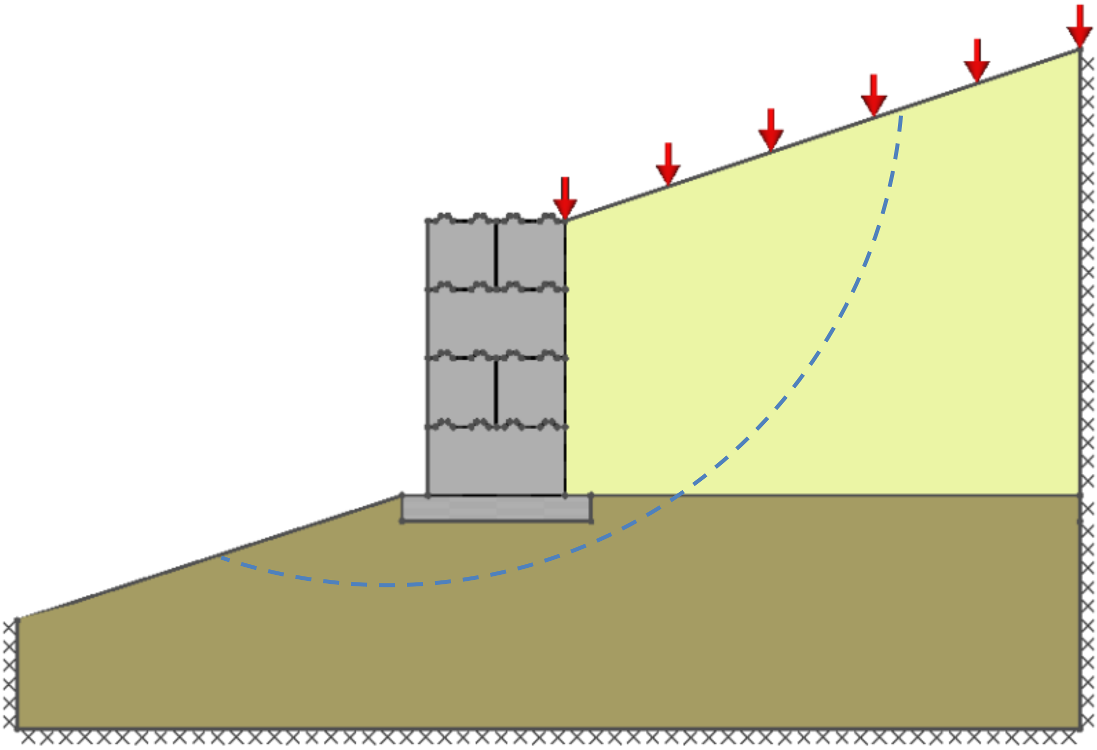
Figure 4.1.3 Toppling resistance of the retaining wall



4.1.4 Overall stability

The loss of overall stability is assessed using techniques normally associated with slope stability analysis. The critical failure surface passing beneath the base of the retaining wall is sought. The failure surface may be planar, circular or a compound surface comprising circular and linear sections. Figure 4.1.4 shows a typical circular failure surface passing beneath a retaining wall

Figure 4.1.4 Slope stability analysis with circular slip surface



The overall stability is satisfied when:

$E_d \leq R_d$

Where:

E_d is the design effects of the actions driving instability
R_d is the corresponding design resistance

Generally, the destabilising effects are due to the self-weight of the slope materials and any imposed surcharge. The resistance is derived from shear strength acting along the failure surface. In Eurocode 7, partial factors are applied to actions and material strengths to provide the required level of reliability. This approach differs from traditional UK practice whereby an appropriate 'Factor of Safety' was sought from the slope stability analysis.

Unlike bearing resistance, sliding and toppling, the assessment of overall stability is not a task well suited to simple hand calculations. Although the calculations are not especially difficult, the iteration involved in finding the critical failure surface mean that it can be a lengthy process by hand. Therefore, it is usually undertaken using a geotechnical stability computer program designed specifically for the task.

4.2. Internal stability

For each row of blocks, internal stability checks are required to ensure against sliding failure and toppling failure. The same checks are also carried out between the base and the bottom row of blocks. The calculations for each failure mechanism must satisfy the same general expression as used for external stability:

$E_d \leq R_d$

Where:

E_d is the design effects of the actions
R_d is the corresponding design resistance

4.2.1 Sliding resistance

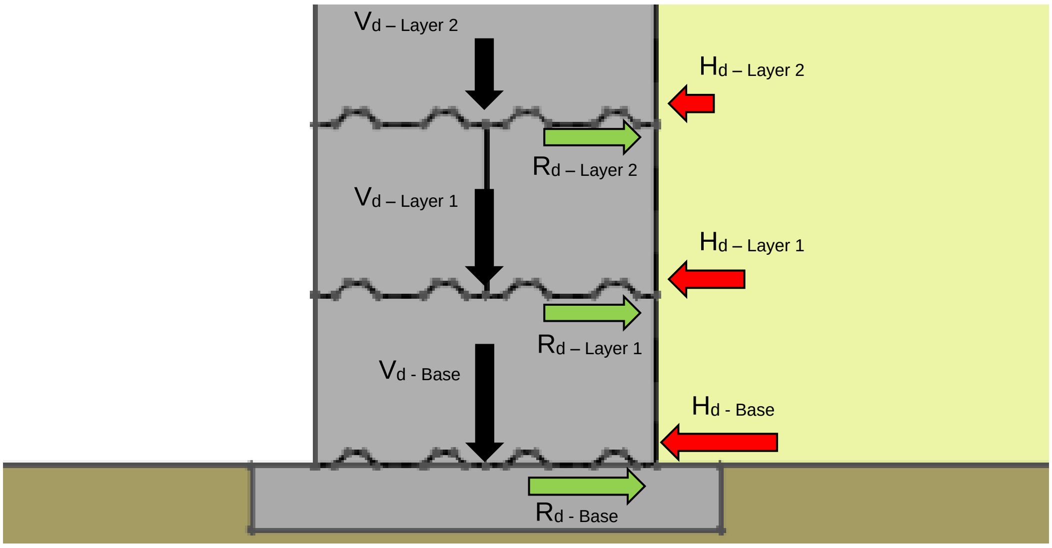
For internal sliding resistance, stability is satisfied when:

$H_d \leq R_d$

Where:

H_d is the horizontal design action acting at the base of each layer of blocks (kN/m)
R_d is the design shear resistance at the base of each layer of blocks (kN/m)

Figure 4.2.2 Sliding resistance of each layer of blocks



The horizontal design action, H_d, is the total horizontal force applied at the base of each block. It comprises the retained earth pressures due to self-weight of the backfill and vertical surcharge, plus any additional horizontal actions such as impact loads.

The design shear resistance, R_d, is calculated taking account of the vertical design action, V_d, and the angle of interface friction, δ. At the interface between the base and the bottom layer of blocks, there are no interlocking 'nibs', so δ should be based upon the friction angle between two concrete surfaces, $\phi_{;\ conc}$. For the block-block interfaces, the effect of the interlocking nibs is to increase the shear resistance. This may be expressed in terms of an enhanced friction angle along a smooth horizontal surface, $\phi_{;\ interlock}$. However, the interlocking shear resistance is limited to a maximum value, $R_{d;\ Max}$, based upon the characteristic shear strength of the concrete and the size and number of interlocking nib elements.

Base layer shear resistance: $R_{d\text{ - base}} = V_{d\text{ - base.}} \times \tan \phi_{conc;d}$

Base layer shear resistance: $R_{d\text{ – Layer } n} = (V_{d\text{ – layer } n.} \times \tan \phi_{interlock\ ;d}) \leq R_{d;\ Max}$

4.2.2 *Toppling resistance*

For internal toppling resistance, stability is satisfied when:

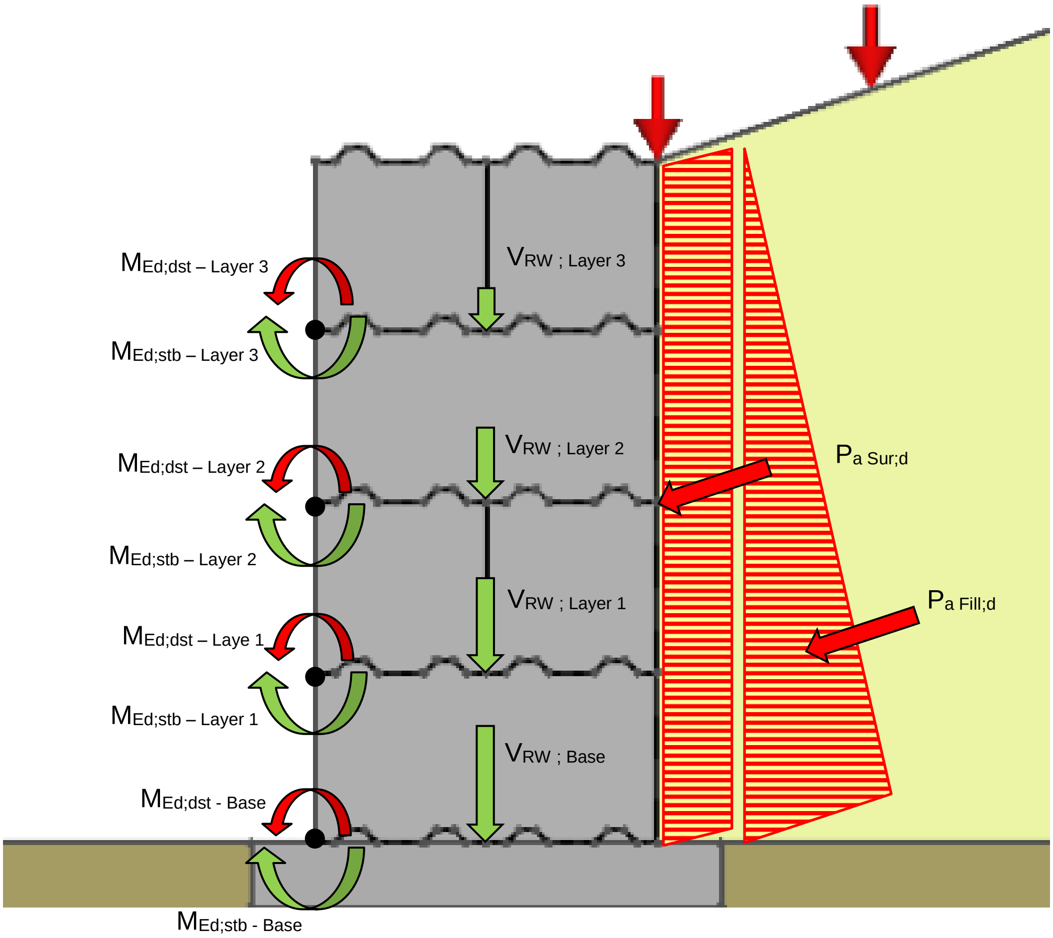
$M_{Ed;\,dst} \leq M_{Ed;\,stb}$

Where:

$M_{Ed;\,dst}$ is the destabilising design moment acting about the toe of each layer of blocks (kNm/m)
$M_{Ed;\,stb}$ is the stabilising design moment acting about the toe of each layer of blocks (kNm/m)

The unfavourable actions contributing to the destabilising moment are the retained earth pressures due to self-weight of the backfill and vertical surcharge. Favourable actions that contribute to the stabilising moment are the self-weight of all the blocks above each layer. These actions are shown in Figure 4.2.3.

Figure 4.2.3 Toppling resistance of each layer of blocks



5. Other design considerations

There are a number of other important considerations that may affect the retaining wall design. Some of these considerations are outlined in the following sections.

5.1 Drainage

Water levels within the ground and the retained fill can have a significant effect on the stability of a retaining wall. The design needs to consider the likely range of water levels and account for the associated water pressures in the calculation of retained pressures acting on the rear face of the wall. The need for and requirements of adequate drainage are addressed in Eurocode 7. Commentary in BS8002-2015 states:

Provision of suitable drainage is vital to ensure the acceptable performance of an earth retaining structure.

Drainage measures to control the water level within the retained fill include provision of weep holes or slotted drain pipes at the heel of the wall. For low permeability backfills, a drainage layer should be provided at the rear face of the wall. For further details of drainage measures, reference should be made to BS8002-2015.

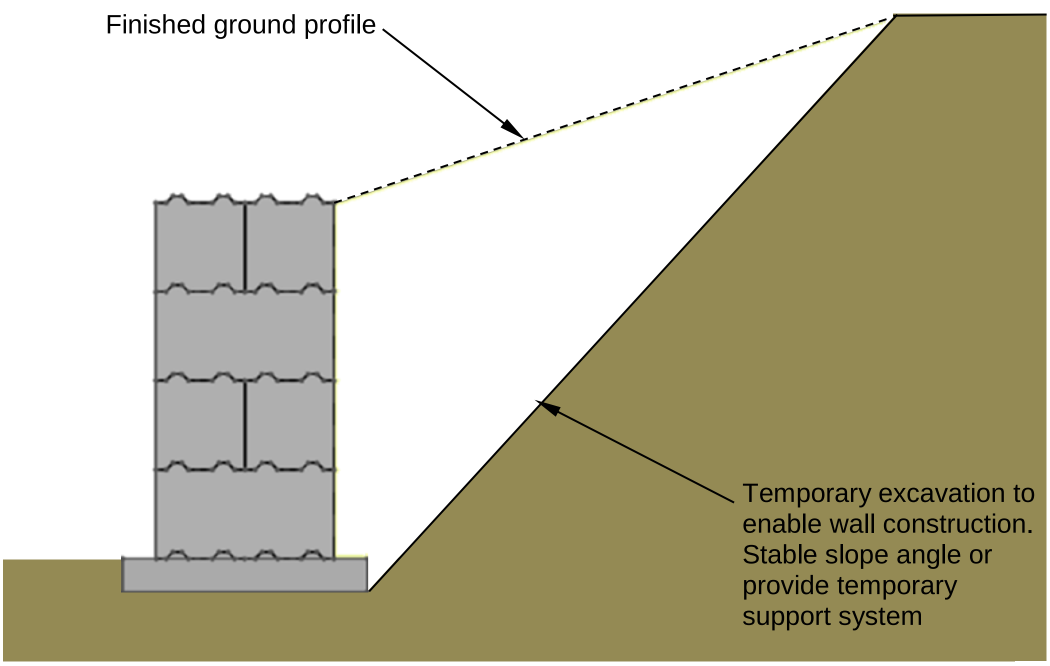
5.2 Flooding

Where applicable, the design flood level should be considered. In assessing the stability of the retaining wall, buoyant densities for materials below flood level should be used.

5.3 Temporary works

In some situations, excavation may be necessary to provide adequate width for the retaining wall. This is particularly relevant when installing a wall to support an existing slope. In this case, attention should be given to providing a stable excavation which may entail the use of temporary support measures (see Figure 5.3.1)

Figure 5.3.1 Temporary excavation for retaining wall construction



5.4 Construction loading

During the backfilling process, actions from construction plant and equipment may affect the stability of the wall. The effects of these actions should be considered, especially where equipment is required to operate close to the rear face of the wall (such as compaction plant). Actions from construction equipment are generally applied over relatively small areas (i.e. the contact area of a tyre or track). The effect of these concentrated loads on a retaining wall may be assessed following the methods in PD6694. Limitations on the weight of compaction equipment within 2m of the face of the wall are given in the earthworks section of the Specification for Highway Works (Series 600 of SHW).

5.5 Parapets and handrails

To reduce the risk of falls from height, edge protection is often required at the top of a retaining wall structure. This protection usually takes the form of a handrail, parapet or fence. The edge protection may be fixed directly to the wall structure or embedded in the backfill behind the wall. The primary action on the edge protection is usually accidental impact load, values of which may be found in structural Eurocode 1. Where a solid form of edge protection is provided, wind loading may be significant. The actions on the edge protection are generally applied in a horizontal direction and should be taken into consideration in the design of the retaining wall.

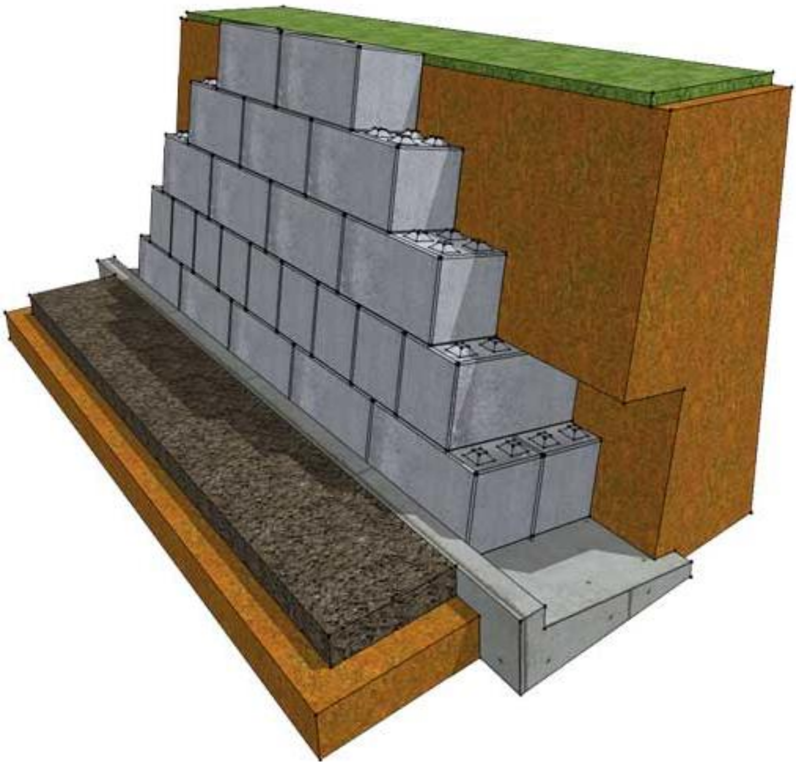
5.6 Front face batter

These types of gravity retaining structure may be constructed with a vertical or a sloping front face. Where a vertical front face is proposed, clause 5.3.1 of BS8002-2015 recommends the following:

> *To avoid the illusion of tilting forward, the front face of a mass concrete retaining wall should be battered backwards at no less than 1 in 50.*

Achieving this backwards batter may be achieved by inclining the upper surface of the foundation base. It is emphasised that the stability of the wall is improved as the backwards batter slope increases. However, this benefit must be considered in relation to the space available for the wall installation. Figure 5.6.1 shows a typical layout for a wall constructed with an inclined front face.

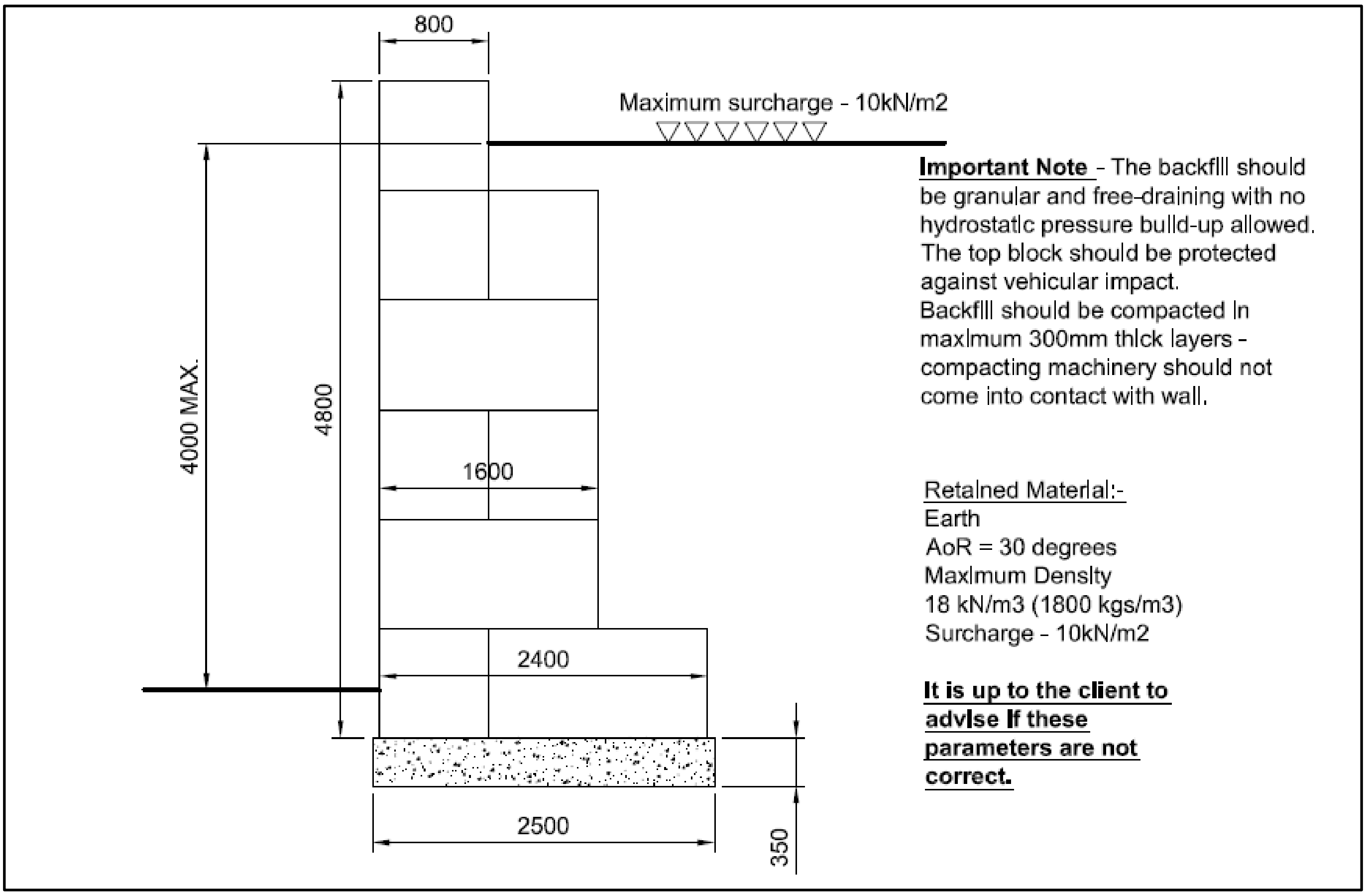
Figure 5.6.1 Legato block wall constructed with inclined front face



6. Design example

For the three interlocking concrete block systems, CPL Structures Ltd have prepared a number of example designs. For each design, a drawing has been prepared showing the layout of the blocks in cross section and the limitations of the design in terms of retained height, slope angle, backfill density, internal friction angle and allowable surcharge load. Figure 6.1 shows an extract from one such example for a 4.8m high Legato™ wall retaining 4m of fill material.

Figure 6.1 Retaining wall design example – 4m retained height Legato™ interlocking concrete block wall (Extract from CPL drawing 516-06)



These example designs have been based upon the following criteria:

- Retained earth pressures calculated using Rankine's method. This method assumes a frictional interface, $\delta = 0^{o}$ between the wall and the retained fill
- Overall sliding of the wall assumes a 'friction factor' of 0.5 at the base of the wall. This friction factor is equivalent to an interface friction angle of 26.6º (i.e. $\delta = \tan^{-1}(0.5)$)
- A minimum factor of safety of 1.5 is required to resist sliding and toppling of each block and the wall as a whole
- The designs assume a competent foundation. Bearing resistance and overall stability have not been assessed, although the calculated bearing pressures beneath the wall and the foundation base are provided.

For comparative purposes, the design example shown in Figure 6.1 has been analysed in accordance with Eurocode 7, using the program LimitState GEO v3.4. In this program, the user specifies which loads are driving the system to an ultimate limit state (or collapse state) and the program increases these loads until a failure occurs. The solution is expressed in terms of an 'Adequacy Factor' and is similar to a factor of safety on load. Partial load and material factors are applied to the materials and imposed loads prior to the application of the adequacy factor. The problem is safe against collapse if the adequacy factor is in excess of 1.0. The program is well suited to geotechnical problems designed to limit state codes such as Eurocode 7. The programme incorporates the EC7 partial factor sets for Design Approach 1-1 and 1-2 in the analysis options.

For the design of a gravity retaining wall, the principal force driving the system to collapse is the earth pressure from the retained fill. This earth pressure is mainly derived from the self-weight of the backfill material and any applied surcharges on the horizontal surface behind at the top of the wall. Therefore, the adequacy factor is applied to these actions until a collapse condition is reached.

Because the program searches for the most likely collapse mechanism, there is no specific requirement to undertake separate checks for sliding, bearing and toppling (although separate checks may be modelled). Provided the critical collapse mode generates an adequacy factor in excess of 1.0, then the other modes of failure also have an adequacy factor in excess of 1.0 (and are therefore safe against collapse).

For this example, the model shown in Figure 6.2 has been analysed to check for compliance with GEO Design Approach 1, Combinations 1 and 2 (DA1/1 and DA1/2). To enable direct comparison with the approach taken on drawing 516-06, an additional combination using partial factors set to unity has been performed.

The foundation soil has been modelled assuming a fine-grained material (Clay) with undrained shear strength, c_u. Initially, a high value of c_u was assumed to represent a competent foundation (see Figure 6.3). This was then reduced until a critical failure mechanism occurred beneath the base of the wall (see Figure 6.4).

Figure 6.2 LimitState GEO model for 4m retained height Legato™ interlocking concrete block wall

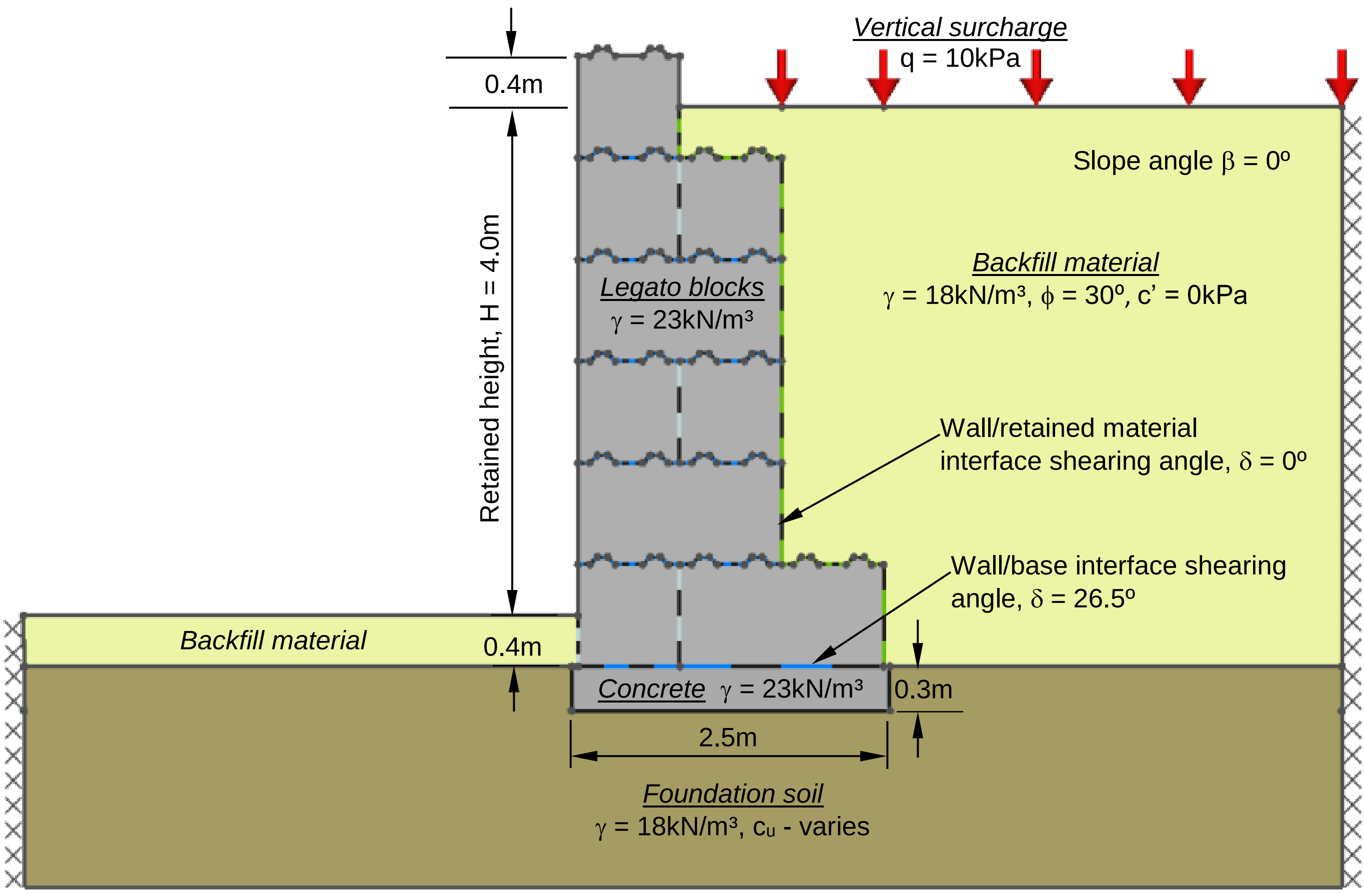


Figure 6.3 Critical failure mechanism for a competent foundation soil

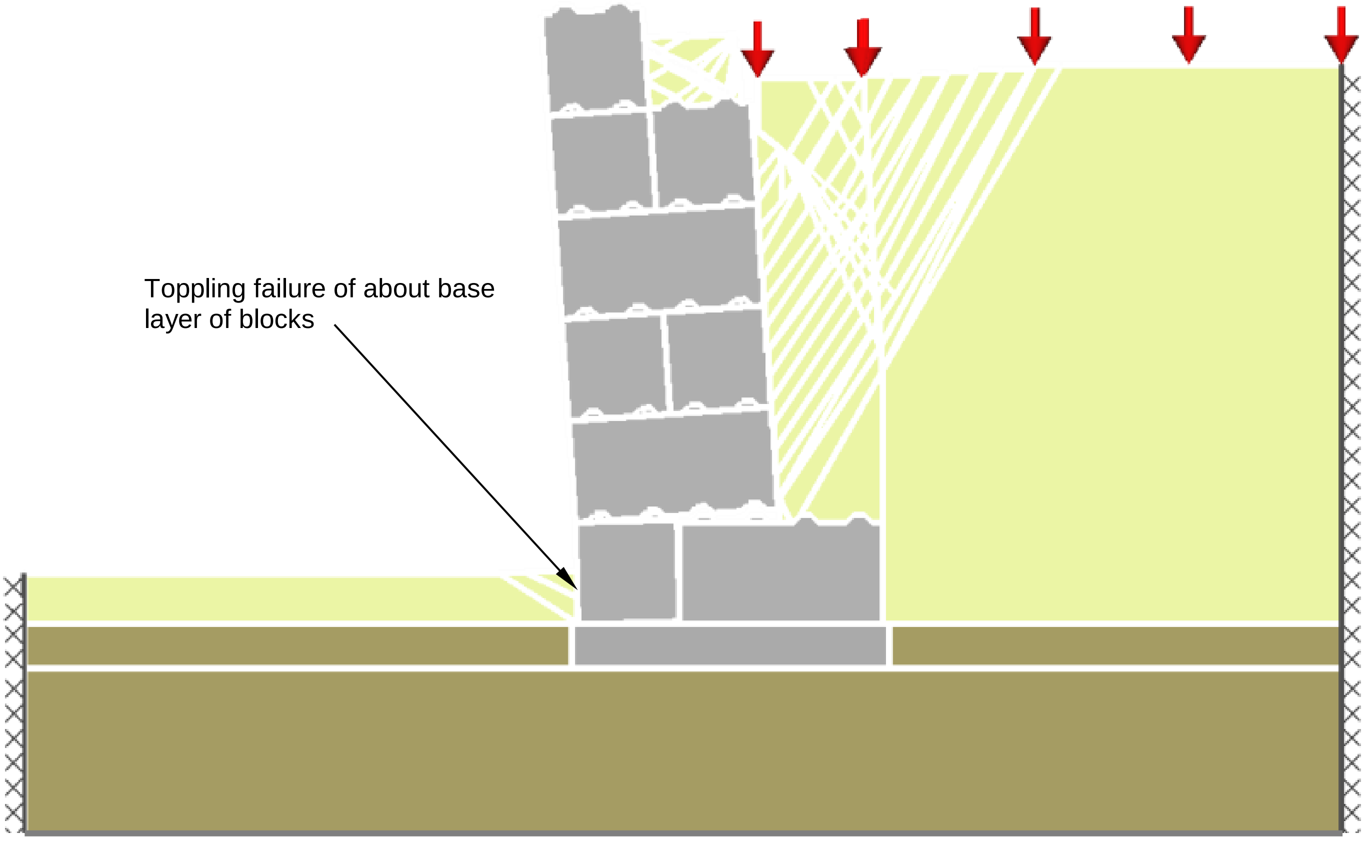
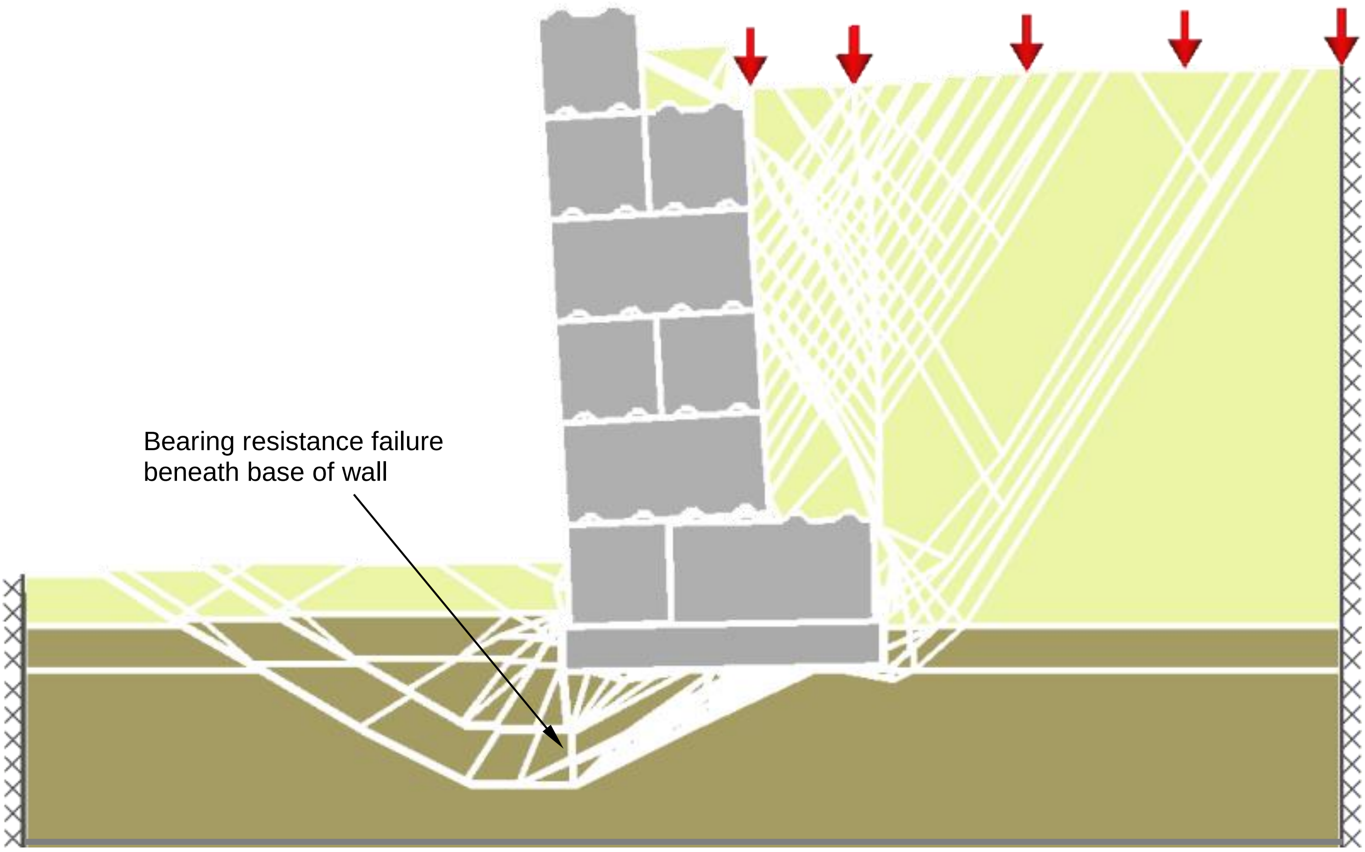


Figure 6.4 Critical failure mechanism through the foundation soil



The results of the LimitState GEO stability analysis are summarised in Table 6.1.

Table 6.1 - Summary of GEO stability analyses

Design condition	***Adequacy Factor (AF)/ Failure mechanism***		
	Unity	***DA1-1***	***DA1-2***
Foundation soil c_u = 43kPa	1.47 Toppling	1.06 Toppling	1.00 Bearing

Based upon the results in Table 6.1, the retaining wall geometry provides sufficient resistance to ensure compliance with the requirements of Eurocode 7. The critical failure mechanisms are toppling of the blocks and bearing failure beneath the base of the wall. The 'Unity' combination produced a minimum adequacy factor of 1.47 for toppling at the base of the blocks. This is equivalent to a 'Factor of Safety' against toppling of approximately 1.5 and is consistent with the design approach described on drawing 516-06.

For this example, the minimum undrained shear strength to prevent a bearing failure is 43kPa, which is equivalent to a medium strength (Firm) clay.

7. Conclusions

The interlocking concrete block systems manufactured by Elite Precast Concrete may be used for the design of retaining walls. These structures are designed as gravity walls, relying on their self-weight to support the retained ground. The design should conform with the requirements of current standards, which in the UK are defined in the structural Eurocodes. Specifically, BS EN1997-1, referred to as Eurocode 7, addresses the geotechnical design of structures including retaining walls.

To ensure the structure is safe, stability checks are required to prevent failure by toppling, sliding, bearing and overall stability. These stability checks apply to the structure as a whole and the stability of the individual blocks. Generally, the stability checks are simple equilibrium calculations and may be performed by hand or using a spread sheet. However, for more complex design cases and for overall stability checks, the use of a geotechnical stability program is recommended.

A number of example designs have been prepared on behalf of Elite Precast Concrete Ltd by CPL Structures Ltd. These designs provide a useful illustration of the block arrangements required for specific applications and load conditions. The limitations of these example designs are listed on the drawings and should be adhered to. Where the design deviates from these limitations, a design check should be undertaken by a suitably qualified professional engineer.

There are many items to consider when designing a retaining wall. The aim of this guidance document has been to highlight those considered to be of most significance to these types of structure in typical UK applications. For more complete guidance, reference should be made to the listed publications, especially BS8002:2015 and Eurocode 7.