VOLUME 2 HIGHWAY STRUCTURES: DESIGN (SUBSTRUCTURES AND SPECIAL STRUCTURES), MATERIALS
SECTION 1 SUBSTRUCTURES

PART 4

BA 68/97

CRIB RETAINING WALLS

SUMMARY

This Advice Note complements departmental Standard BD 68/96 which sets out the design and construction requirements for crib retaining walls.

INSTRUCTIONS FOR USE

This is a new document to be inserted into the Manual.

1. Insert BA 68/97 into Volume 2 Section 1 after Part 3.

2. Archive this sheet as appropriate.

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THE HIGHWAYS AGENCY

THE SCOTTISH OFFICE DEVELOPMENT DEPARTMENT

THE WELSH OFFICE
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THE DEPARTMENT OF THE ENVIRONMENT FOR NORTHERN IRELAND

Crib Retaining Walls

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Contents

Chapter

1. INTRODUCTION

General

This Advice Note complements the Design Standard BD 68, which is hereafter referred to as the Standard. The Advice Note provides additional information using the clause numbering of the Standard. The Prefix 'A' has been attached to those clauses of the Advice Note which have no counterpart in the Standard and should be considered after the clause quoted. Likewise the Figures and Tables of the Advice Note have been prefixed, for example Figure A1.1, to distinguish between them and those given in the Standard.

1.1 The Standard follows a limit state partial factor approach to design as expressed in Eurocode 7: Geotechnical design: Part 1: General rules (BSI, 1995) and in BS 8002:1994, but there are differences in the details of application.

1.3 The Standard applies to structures for retaining earth which are built up of individual elements to form a series of box-like cells into which infill is placed to form an integral part of the structure. However, some types of crib structure are not covered by the Standard by reason of size, inclination or loading conditions, and other forms of box-like structure into which fill is placed, such as gabions and bin walls, are excluded.

For economy, the dimensions of the crib cells should be such as to induce arching of the infill between the crib elements. Cribs having a square cross-section may be a particularly efficient shape for promoting arching, but usually this arrangement is impractical. To ensure an appreciable transfer of the weight of the infill to the crib structure, the ratio of the length (a) to width (b) of the crib cells should not be greater than 2.0.

Separating terraced walls by a distance equal to the height of the lower wall should ensure that the presence of the upper wall does not substantially influence the performance of the lower wall, but this does not remove the need to check the overall stability of the whole arrangement, (Limit mode 4).

The minimum distance between the back of the top of the wall and the edge of any carriageway should ensure that the effects of live loads from traffic are small.

It is not intended that foundations to substantial structures be placed close to the back of the crib structure, but it would be too restrictive to eliminate the installation of, for example, street furniture whose foundation loads are relatively low.

Definitions

1.6 A typical arrangement of crib elements in a multi-cell wall is shown in Figure A1.1.

1.13 In most cases, there will be insufficient data to allow the characteristic values of the properties of the soils and fills to be calculated, and so these parameters may be expressed as nominal values. It is intended that the nominal and characteristic values be equivalent, but equivalence may be difficult to prove.

1.14 Design values for material properties are usually defined in terms of a characteristic or equivalent nominal value, but in some cases, such as the shear strength of soils, it may be more convenient to select the design values directly. Superimposed loads are specified in structural loading codes, such as BD37 (DMRB 1.3).

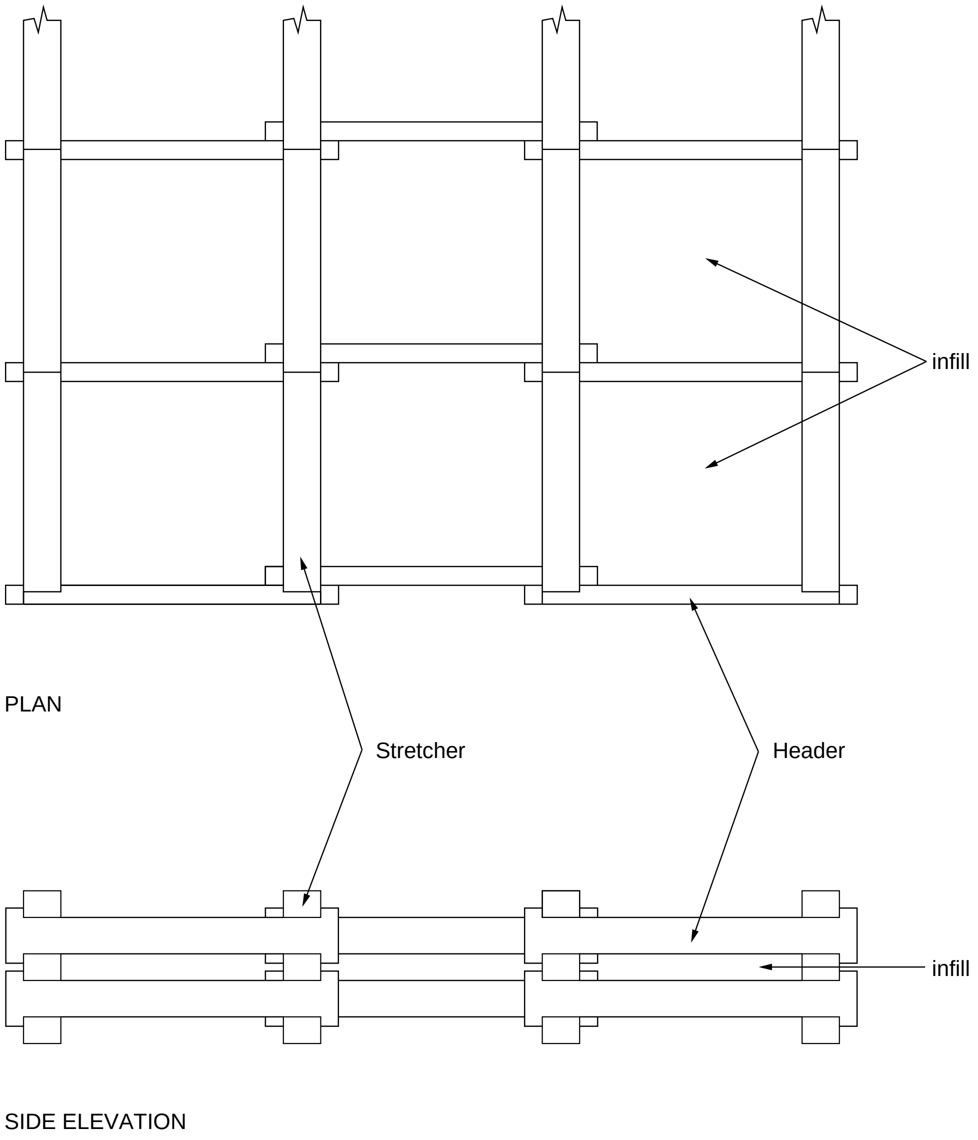

Figure A1.1 Typical arrangement of crib elements in a multi-cell wall

SYMBOLS

A	m^2	cross-sectional area
a	m	clear distance between headers
B	m	distance between centrelines of front and rear stretchers of the wall measured parallel to the headers
b	m	clear distance between front and rear stretchers of a cell measured parallel to the headers
b_{hd}	m	width of header
b_{st}	m	width of stretcher
c'	kN/m^2	effective cohesion
Cu	kN/m^2	undrained shear strength
D_e	m	embedment depth
d_{hd}	m	depth of header
d_{st}	m	depth of stretcher
E	-	$\exp(-z_i/z_0)$
e_s	m	eccentricity of joint loads acting on headers including lack of fit
e_w	m	eccentricity of resultant force
F_n	kN	shear force acting normal to axis of headers
F_t	kN	shear force acting in plane of joint
f	kN/m^2	material strength
h_s	m	height of surcharge
K	-	earth pressure coefficient
K_a	-	active earth pressure coefficient
K_0	-	at-rest earth pressure coefficient
L	m	length
M	$kN.m$	moment
N	kN	normal force at joints

n_j	-	number of joints
P_n	kN	resultant of extemal design load components acting normal to potential failure plane
p_h	kN/m^2	horizontal earth pressure
p_v	kN/m^2	vertical earth pressure
Q_k	kN	nominal load
Q^*	kN	design load
q	kN/m^2	design maximum base pressure
q_{ult}	kN/m^2	ultimate base pressure
R	kN	resultant load
R_n	kN	normal component of resultant load
R_t	kN	tangential component of resultant load
R^*	kN	design resistance
S^*	kN	design load effects
T_{hd}	kN	tension in headers
U	m	internal perimeter of crib cell
v	N/mm^2	shear stress in concrete
v_{hd}	m	clear vertical distance between headers
v_{st}	m	clear vertical distance between stretchers
W	kN	self-weight
w	kN/m	uniformly distributed load
z_b	m	depth of backfill
z_i	m	depth of infill
z_o	m	depth parameter used in calculating infill pressures

α	-	coefficient of interaction between sliding surfaces
γ	kN/m^3	unit weight
γ_{fL}	-	partial safety factor for loads
γ_{f3}	-	partial safety factor for load effects
γ_m	-	partial safety factor for material properties
Δ	-	change in quantity
δ'	°	effective angle of interface friction between different materials
δ'_1	°	angle of interface friction between infill and crib skeleton
δ'_2	°	angle of interface friction between foundation base and subsoil
δ'_3	°	angle of interface friction between crib elements and foundation base
δ'_4	°	angle of interface friction between infill and foundation base
δ'_5	°	angle of interface friction between crib elements
δ'_6	°	angle of interface friction between retained backfill and crib skeleton
σ'	kN/m^2	effective stress
ϕ'	°	effective angle of friction of soil/fill
μ	-	coefficient of friction between different materials

Subscripts

b	backfill
c	crib cell
cv	constant volume or critical state value
des	design value
f	front (joint)
fb	foundation
h	horizontal

hd	header
i	infill
j	joint
k	characteristic or equivalent nominal value
m	middle (joint)
pk	peak value
rv	residual value
r	rear (joint)
s	surcharge
st	stretcher
v	vertical

2. DESIGN PRINCIPLES AND OBJECTIVES

General

2.1 A limit state partial factor approach to design is adopted whereby the structure is shown to satisfy performance requirements through the application of partial safety factors to cover for uncertainties in the applied loads (γ_{fL}), material strengths (γ_m) and model of analysis (γ_{f3}).

2.2 The assumption of a design life does not necessarily mean that the structure will no longer be fit for its purpose at the end of that period, or that it will continue to be serviceable for that length of time without regular inspection and adequate maintenance.

Limit states

2.3 For the ultimate limit state, calculations will almost certainly be required to confirm stability. However calculations may not be necessary for the serviceability limit state, and the requirements may be satisfied by inspection, by reference to published data for similar structures, and by good detailing and construction practice.

Limit modes

2.7 The six limit modes specified in 2.8 to 2.13 of the Standard represent the modes of behaviour which are acknowledged as being capable of leading to the failure of crib retaining walls. Limit modes 1 to 6 must be considered in the design, although other limit modes may be appropriate in certain circumstances and should be checked accordingly.

2.8 In most cases, limit modes 1 and 2 will determine the overall dimensions of the crib structure.

2.12 The crib elements may fail in tension, compression, shear, bending and torsion, or by any combination of these. The designer must ensure that the most onerous combination of design load effects is checked.

Partial factors

2.14 The intention is that uncertainties in the applied loads, the method of analysis, and the material properties are covered by γ_{fL}, γ_{f3} and γ_m respectively. The first and last are applied to characteristic or equivalent nominal values. Whilst the application of values of γ_m to manufactured products such as steel is widely accepted, its application to soils is much less so - principally because of the difficulties of defining their characteristic strengths. The value of γ_{f3} may not be quantifiable by analysis, as to some extent it reflects the level of confidence in the calculation method for the limit mode under consideration. Thus the values of γ_{f3} given in the Standard may change in the light of experience.

Additional partial factors are defined in other Design Standards and Codes of Practice, for example in Eurocode 7: Geotechnical design: Part 1: General rules (BSI, 1995) to cover for the ramifications of failure. Furthermore, the partial factors used in the Standard are subdivided in other Standards and Codes, for example γ_m into γ_{m1} and γ_{m2} components in BS 5400 Part 1: 1988. In general the increased complication associated with the use of additional factors and component factors is thought unnecessary in the design of crib walls. Having said that, in some cases the uncertainty in the dimensions of structural components may be better dealt with in terms of a geometric (γ_g) rather than a proportional (γ_m) partial safety factor.

Loads

2.16 Earth pressure coefficients are tabulated in BS 8002:1994.

A2.18 Where appropriate the following sources of load should be considered:

(i) three dimensional effects generated on structures curved in plan,

(ii) cyclic loading,

(iii) flooding from nearby structures and/or services,

(iv) those generated by adjacent construction operations such as pile-driving, excavation, and pumping operations.

Design values and structural adequacy

A2.22 The approach to design used for the crib wall may not be applicable for assessing, for example, the stability of a supported slope to the structure. Although the disturbing effect of such a slope must be considered when assessing the stability of a crib wall, the stability of the slope may be assessed using other Standards, Codes or Advice Notes: for example HA44 (DMRB 4.1.1). Similarly, different values of the partial safety factors to those given in the Standard may be warranted when considering the stability of a potential failure plane far removed from the crib structure.

3. LOADS

Superimposed loads

3.2 Loads from superimposed structures must be set back by a minimum distance of 1 metre from the rear of the crib wall to prevent localised overstressing of the crib elements.

Vertical earth pressures

3.3 The vertical pressure within the crib cells is determined using an approach derived for silos, see Masterton et al (1995).

Horizontal earth pressures

3.5 The magnitude and distribution of lateral earth pressures acting on a structure may be calculated using methods based on Rankine or Coulomb. It is an implicit assumption of Rankine's theory that there is no wall friction, but such effects may be considered in Coulomb's method.

The wall friction mobilised will depend on *inter alia* the size of the crib cements and the spacing between them, and the relative movement between the wall and the retained backfill. Since these parameters are not easily determined it is usually necessary to assume the magnitude of the wall friction. The designer must use his discretion to select an appropriate value for the mobilized angle of wall friction (δ') for each structure, taking due cognisance of all the factors involved; for example, where there is a possibility of the wall moving downwards due to poor foundations, a reduced value of δ' should be used. The direction in which wall friction acts greatly influences the stability against overturning and sliding.

The distribution of horizontal earth pressure on the back of stepped multi-cell crib walls needs careful consideration. A recommended distribution for a double cell wall is shown in Figure A3.1.

In situations where the retained fill forms a steep slope, (i.e. where the angle of the slope approaches ϕ'), or where the backfill zone is restricted, the classical earth pressure theories may be unreliable.

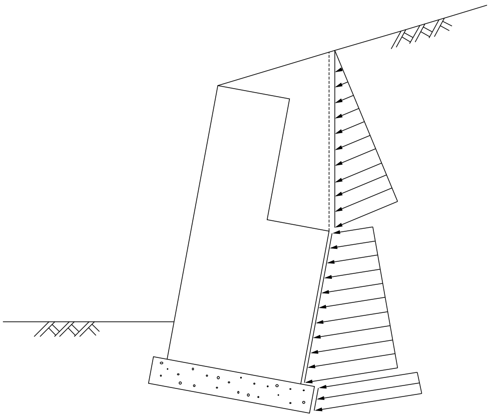

Figure A3.1 Earth pressure on the back of a stepped double cell wall

3.6 Design values of lateral earth pressure can be derived from the design soil strength, which for effective stress calculations is characterized by the values of ϕ'_{des} and c'_{des}, although the latter is often assumed to be zero. The lateral earth pressures are a function of the movements within the soil, and so the value of K_{des} may vary according to the limit mode being considered. For natural soils the minimum and maximum values of lateral earth pressure are associated with active (K_a) and passive (K_p) conditions respectively, but at-rest (K_0) conditions may be assumed to apply where movements are small. Values of K_a and K_p are provided in BS 8002:1994.

Because the tangent of the design angle of friction is used to define soil strength, the value of ϕ'_{des} used to calculate K_{des} may be defined as
$\tan^{-1}(\tan \phi'_{des})$.

Other factors that may affect the selection of K_{des} include:

(i) the possibility of swelling pressures developing in clayey soils,

(ii) the generation of compaction pressures in fill materials.

Pore water pressures

3.8 The definition of a characteristic (or nominal) pore water pressure is problematical, and it also would seem inappropriate to multiply the unit weight of water by a γ_{fl} value of other then unity. Direct selection of the design values of pore water pressure may therefore be preferred. The possibility of flooding of the site and its effects on construction operations and on the in-service structure should be considered.

Combination of loads

3.9 When considering sliding, both the disturbing and resisting forces are a function of the weight of the sliding mass. In this, and other similar situations, it may be appropriate to effectively cancel out the term from the equilibrium equation or adopt the same value of γ_{fl} for both sides of the equation.

3.10 For limit modes 1 to 5, the most critical levels within the wall will typically occur at changes of section and at the base of the structure.

4. STRENGTH OF COMPONENTS

General

A4.1 The selected design values of the parameter(s) governing strength should provide a reasonably conservative estimate of the in situ strength. Selection should take into account:

(i) differences between in situ conditions and those applied in field or laboratory tests,

(ii) the likely variability of in situ strength,

(iii) the effects of construction activities,

(iv) time related effects such as weathering,

(v) the mode of failure being considered,

(vi) the effects of workmanship,

(vii) variations in the ground water level, both during construction and in-service.

The application of statistical methods to define the characteristic strength of natural materials is problematical; thus it is difficult to quantify the level of safety associated with the term ‘reasonably conservative’ (or any other similar term such as ‘worst credible’). For consistency with the approach adopted for manufactured materials, the design values for strength have been defined in the Standard in terms of the characteristic value and a value of γ_m. However for some parameters, such as the angle of friction of soils and the shear strength of an interface, it may be more appropriate to select the design value directly from the available test data with reference to published information and previous experience.

Shear strength of soils and fills

4.2 With granular soils, the stress/strain curve for shear typically takes the form shown in Figure A4.1. Initially, soil behaviour may be approximated by a linear elastic model until a point of yield is reached; beyond this the soil undergoes a process of ‘work hardening’ until a peak shear strength is reached. As strains increase further the shear strength reduces (‘work softening’) until a ‘critical state’, or constant volume, condition is attained.

Simply stated:

$$\phi'_{pk} = \phi'_{cv} + \phi'_{d}$$

where ϕ'_{pk} is the peak angle of friction,

ϕ'_{cv} is the critical, or constant volume, angle of friction,

ϕ'_{d} is the component derived from the dilation of the soil; it is a function primarily of the density of the soil, but it is also influenced by the angularity and grading of the soil particles.

Other relations have also been proposed, notably by Bolton (1986).

In service, the mobilized shear strength will be below the peak shear strength. Deformations will increase as collapse is approached and, following the attainment of the peak shear strength, the soil will dilate to approach its critical state strength. Note that the adoption of the critical state strength will cater for strength changes due to the effects of progressive failure and non-uniform densities within the soil deposit (whether by nature or by inadequate compaction). However it must be appreciated that the deformation required to attain the critical state strength is sufficient to lead to a serviceability failure and so it does not relieve any obligation to ensure good construction practice.

4.3 For a low plasticity clay, i.e. PI < 25 per cent, the behaviour during shear could be expected to approximate to that of a granular soil.

For a high plasticity clay, i.e. PI > 25 per cent, the behaviour beyond the peak strength may be markedly different to that of a granular soil. As the shear strength falls from its peak value, the clay in a narrow zone adjacent to the failure plane will soften and reach the constant volume or 'critical state' condition. However, because of non-uniform straining, the point on the stress/strain curve corresponding to the critical state will be ill-defined. With continuing displacement the shear strength will continue to fall below the critical state value to eventually reach a residual value at a large displacement. The displacement required to mobilize the residual strength would usually be well in excess of that which a retaining structure could withstand. However where a structure is sited on ground which has previously experienced movements, the parent soil may contain relic shear planes along which the strength may approach the residual value. In such cases, and where appropriate, design should be based on the residual strength; for example when considering base sliding and deep seated slip failures.

4.4 **Effective cohesion**. Some soils may exhibit an additional component to frictional shear strength, namely effective cohesion, but as soil is sheared beyond its peak strength this component is usually assumed to tend to zero. Values of *c'* usually derive from linear curve fitting of strength envelopes, as shown in Figure A4.2, and

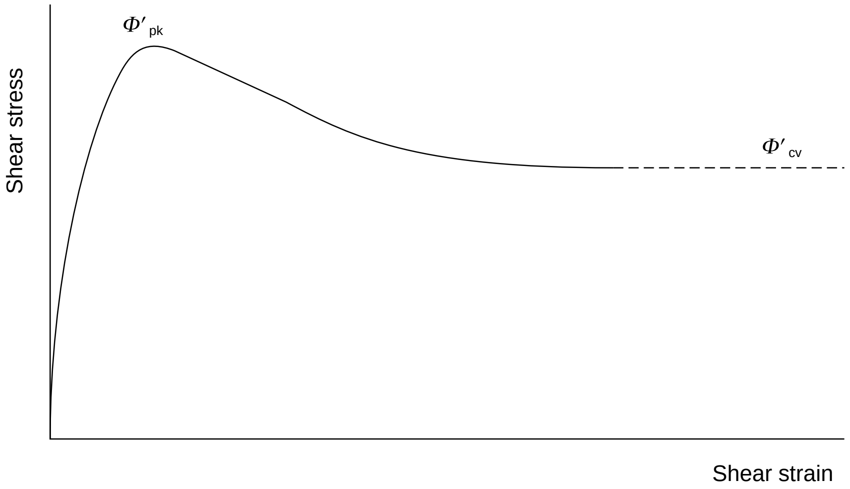

Figure A4.1 A typical stress/strain curve for a dense granular soil

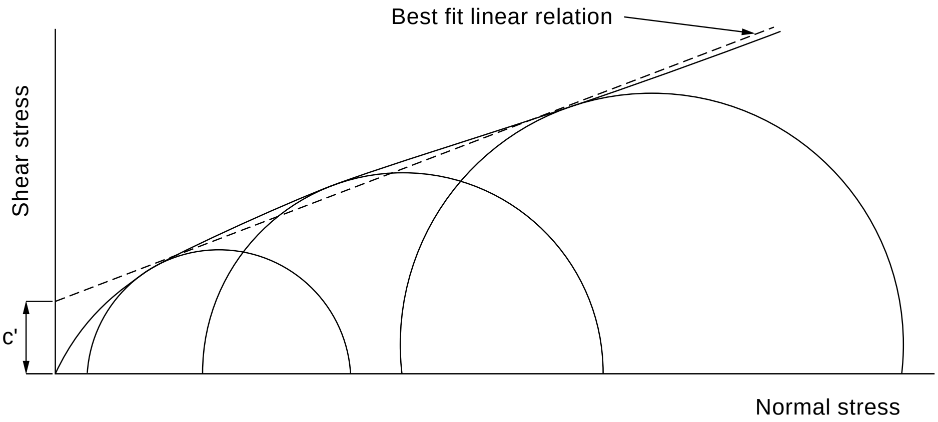

Figure A4.2 Linear curve fitting of shear strength evelope

sometimes may only result from the variability in the test data - this is common where the test specimens are not fully saturated.

4.5 **Undrained shear strength**. Undrained shear strength is not a fundamental property of soils; its value varies with the method of measurement. Current practice is to derive values of *Cu* from triaxial compression tests, this being consistent with the development of active earth conditions. The influence of the method of measurement, including procedures for sampling and preparation of test specimens, and anisotropy should be considered when deriving the design value.

Shear strength of interfaces between different materials

4.6 The interfaces to be considered in design are:

(i) along potential sliding surfaces at the boundaries of the crib structure, such as the foundation base and subsoil, and between different soils, fills and rocks,

(ii) between the back of the crib structure and the retained backfill.

The forces generated at these interfaces may be defined using an effective stress or a total stress analysis. The presence of drainage materials and the potential for tension cracks will usually dictate that an effective stress analysis is appropriate for determining the shear forces generated between the back of a crib structure and the retained soil.

4.7 The angle of interface friction (δ') between two materials can be derived from the results of direct shear box tests, but in many cases values of δ' will be based on published information and previous usage. As with ϕ', it may be more convenient and appropriate to select the value of δ'_{des} directly rather than through the use of a factored characteristic value. Frictional resistance may be expressed in terms of a coefficient of friction (μ) rather than in terms of an angle: where $\mu = \tan \delta'$.

4.8 In the absence of test data, the values of $\tan \delta'$ ($= \mu$) given in Table A4.1 may be used for preliminary design purposes.

Bearing capacity of soils and fills

4.9 Guidance on bearing capacity of soils and fills is given in BS 8004: 1986 Foundations.

Lower load-accepting element	**Upper load-bearing element**		
	pre-cast concrete*	**softwood timber**	**hardwood timber**
precast concrete*	0.4	0.5	0.3
softwood timber	0.4	0.4	0.3
hardwood timber	0.3	0.3	0.1
granular soil	0.3	0.3	0.3

* The actual value for precast concrete is dependent on the finish applied to the elements.

Table A4.1 Values of $\tan \delta'$ for use in preliminary designs

5. DESIGN

Limit Mode 1: Overturning failure

5.2 In stepped multi-cell walls the changes of cross-section are likely to be critical and should be checked for overturning failure about the front joints.

Limit Mode 2: Sliding failure

5.4 In stepped multi-cell walls the changes of cross-section are likely to be critical and the wall should be checked for sliding failure at these levels. The resistance of the wall to sliding failure is increased by tilting the wall into the retained slope. Likewise, resistance to base sliding can be increased by introducing a shear key to the base of the foundation.

5.8 Where packers, shims or bedding material are used at the contact points between crib elements, the correct coefficient of friction must be used in design. A mortar pad/concrete interface may be taken as having the same coefficient of friction as a concrete/concrete interface.

The resistance of the wall to sliding on failure planes passing through the wall parallel to the headers is the sum of the resistances due to friction between the elements and within the fill. Consequently the resistance to sliding is dependent on the proportion of the infill weight which is transferred to the crib structure.

Interlocking devices between elements are provided to aid construction and should not be relied upon to provide any resistance to sliding failure. Horizontal movements between units may damage such devices. The devices could be designed to withstand the sliding forces, and this in turn may improve the stability of the wall against sliding failure but the use of robust interlocking devices may promote brittle and relatively sudden failures.

Limit Mode 3: Bearing failure of the foundation

5.9 Usually the partial factor for materials (γ_m) is applied to the shear strength of the soil, but because bearing capacity is a function of shear strength, γ_m may be applied to the ultimate bearing capacity derived from soil tests: whichever route is taken, γ_m should not be applied more than once.

A5.10 The inclusion of wall friction in this limit mode has the effect of reducing the bearing pressure at the toe of the structure, thereby giving a more uniform pressure distribution which is believed to be more representative of that present in structures.

Limit Mode 4: Slip failure of the soil

5.11 A slip failure may take the form of a translational or rotational slide, and be limited to the surface layers or be deeper seated. The failure mechanism will be a function of a number of variables including *inter alia*, the geometry of the structure, the properties of the fill and the parent soil, and the applied loading. A number of established techniques exist for assessing the stability, but the suitability of a particular method to a problem is often site specific, and the analysis model and parameters used must be appropriate for the site conditions. Bromhead (1986) describes a range of techniques for analysing stability and provides guidance on their applicability to various situations.

5.13 Where the parent soil contains relic shear surfaces generated by ground movements the design resistance should be based on the residual strength of the soil.

Limit Mode 5: Failure of the headers and stretchers

5.16 The distribution of mean vertical cell pressure, p_{vi}, with depth is shown in Figure A5.1. The maximum mean vertical cell pressure is given by:

$$\overline{P}_{vi\,max} = \gamma_{ik} \cdot z_0$$

where γ_{ik} is the unit weight of the infill, and
z_0 is as defined in 3.3

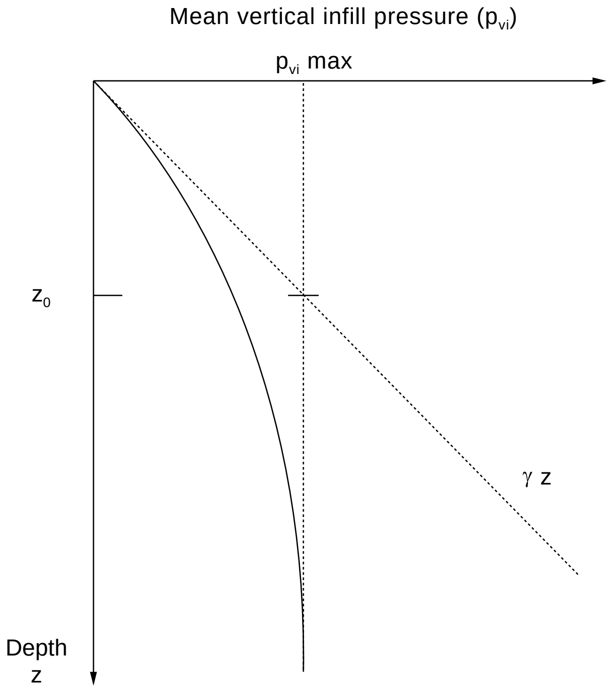

Figure A5.1 Distribution of mean vertical infill pressure with depth

The backward inclination of a wall may reduce the pressures within the crib cells and thereby the loading on all the elements except possibly the rear stretchers but, for simplicity, the cell pressures could be derived assuming that the wall is vertical. Account should be taken of the effects of surcharges, multi-cell wall sections and stepped crib cells; the distribution of mean vertical infill pressure in a stepped crib cell is shown in Figure A5.2. A surcharge on the top of a cell will increase the pressures local to the top, but the soil pressures at depth will not be much affected.

The effective angle of friction between the crib elements and the infill, δ'_1, is dependent on many factors, including the relative movement between the infill and the crib structure, the particle size of the fill, and the shape of the elements. A lower value of δ'_1 should be used if settlement of the crib structure relative to the infill is likely; however this may be prevented by providing a continuous slab foundation.

The loading on the rear stretchers is a function of the difference between the infill pressures and the backfill pressures.

Soil arching between the crib elements will occur to a degree which is dependent upon the ratio of the depth of the elements and the distance between them. Maximum load transfer to the elements will occur with full arching, when the full backfill or infill soil pressure is transferred to the elements.

Infill pressures acting on the stretchers will induce a tensile force in the headers, but backfill pressures acting on the rear of the wall will induce a compressive force in the headers. Headers near the top of the wall will generally have a net tensile force, whilst those further down the wall may have a net compressive force, the magnitude and sense of the resultant force being dependent on the distribution of horizontal shear force between front and rear joints. The equation for header tension given in 5.16 will give an upper bound value for all levels in the wall.

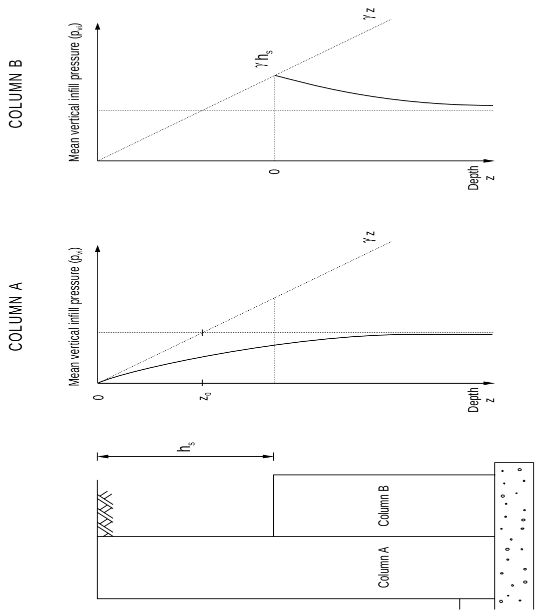

Figure A5.2 Distribution of mean vertical infill pressure in a stepped crib cell

Figure A5.2 Distribution of mean vertical infill pressure in a stepped crib cell

5.17 The application of monolith theory to determine joint forces will ensure conservative results. Usually the joints at the front of the wall will be more highly stressed than those at the rear, but in walls where the inclination from the vertical is significant the combination of the self weight of the wall and friction acting on the back of the wall may reverse this.

Limit Mode 6: Deformation

5.19 The deformation generated during construction is dependent upon the sequence of construction, and the requirements of the Standard should be followed. Figure A5.3 shows comparable deformations for walls backfilled during and after crib construction.

A5.20 Crib walls are frequently described by manufacturers as having an 'inherent flexibility', but it is important to note that this relates to their potential to be fitted to suit particular applications requiring changes in height, direction or curvature. A crib wall must be designed and constructed to take account of differential movements, otherwise it will not tolerate them.

The values in Table A5.1 may be used as a guide to specifying end of construction tolerances.

Location of plane of structure	**± 50mm**
Variation in front batter slope from design slope	**± 5mm per metre height**
Bulging (vertical) and Bowing (horizontal)	**± 20mm in 4.5m template**
Steps at joints	**± 5mm**
Alignment along top and bottom	**± 15mm from reference alignment**

Table A5.1 Proposed end of construction tolerances for typical applications

Longitudinal and transverse differential settlement may lead to a serviceability failure. The tolerance of a wall to differential settlement is dependent upon the particular crib walling system adopted.

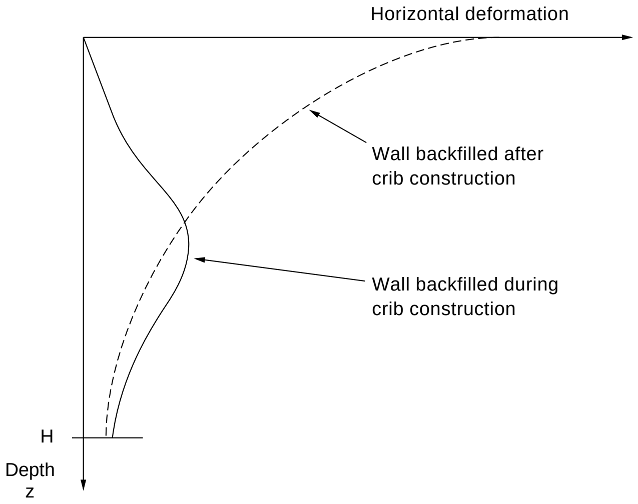

Figure A5.3 Variation in end of construction deformation with construction method

6. MATERIALS AND CONSTRUCTION DETAILS

Materials

6.2 The minimum permeability coefficient should ensure that infill is effectively 'free draining'.

6.3 The durability of timber crib elements is extended by the use of preservatives, but some difficulty may be experienced in demonstrating a 120 year design life for such elements.

6.4 Depending on exposure conditions, the use of air-entrained concrete may be necessary, especially for sites adjacent to live carriageways where the crib elements may be exposed to de-icing salts.

If any of the crib elements are found to require shear reinforcement, it would be prudent to specify shear reinforcement for all the elements to a structure. Otherwise it will be necessary to check shear reinforcement requirements for all the levels of elements and joints within the structure. Furthermore, there remains the practical problems of distinguishing on site between those elements that contain shear reinforcement and those that do not.

Construction procedure

6.10 The rules given in the Standard are intended to limit the movements of the crib wall during construction. Furthermore, headers are not usually designed to withstand lateral loads and thus they may not be able to support a large differential in the height of infill in adjacent cells during construction.

To avoid damage and disturbance of the crib elements, heavy compaction equipment should not be used near the wall. Compaction of the fill within the crib cells is difficult, but care should be taken to eliminate voids around the elements. A small plate compactor or a hand tool could be used to compact fill close to the back of the crib structure.

It should be appreciated that the performance of a crib wall can be heavily influenced by the quality of workmanship.

Foundations

6.11 The foundation can be formed either by constructing a concrete slab or by laying the first few courses of the crib structure, with enclosed reinforcement if necessary, and then placing concrete to engulf the bottom one or two courses.

A template should be used to obtain the specified batter for the foundation. Careful and accurate setting out and laying of the units at the base of the wall is necessary to avoid construction difficulties higher up the wall.

A layer of mortar can be used to ensure an even bedding for the elements on the foundation thereby preventing local failure due to irregularities on the foundation surface. Alternatively, the first course of elements can be laid directly onto fresh concrete.

Crib elements

6.13 Crib elements should be sufficiently robust to withstand construction operations.

6.16 To prevent errors in construction the crib elements should be symmetrical and interchangeable between front and rear faces. If a non-symmetrical design is necessary the elements should be clearly non-symmetric. See also 6.4.

Timber systems are well suited to sites with many changes in direction as the elements are easily cut to size, facilitating construction of corners and small radius curves. If penetration of preservatives is incomplete, treatment of the cut ends will be necessary. Alternatively, elements could be trimmed as necessary before treatment with preservatives. Concrete elements can also be cut to size on site using a disc cutter or similar equipment but exposed reinforcement will require protection using, for example, epoxy mortar. Some walling systems may be able to accommodate curves without the trimming of elements, thus eliminating corners and producing savings in construction time and cost.

Planting

6.20 To prevent contamination of the infill, the topsoil required for plant growth can be contained in geosynthetic grow-bags, but the provision of water to the plants is problematical. Backwards inclination of the wall will expose the front face of the wall to precipitation but this may be insufficient to sustain a healthy plant growth. Pockets of topsoil, whether enclosed in geotextile bags or not, may adversely affect the stability of the wall, especially if located at regular intervals along the wall and at a constant level. Plants should be chosen to suit the environment in which the wall is situated, with consideration being given to, amongst other aspects, altitude, precipitation, exposure, atmosphere, and de-icing salts. Maintenance requirements should be kept to a minimum.

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