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

SECTION 1 SUBSTRUCTURES

PART 1

BD 41/97

REINFORCED CLAY BRICKWORK RETAINING WALLS OF POCKET-TYPE AND GROUTED-CAVITY TYPE CONSTRUCTION

SUMMARY

This Standard sets out the design and constuction requirements for pocket-type and grouted-cavity type reinforced clay brickwork retaining walls by implementing the relevant parts of BS 5628 : Part 2 : 1995. This Standard supersedes BD 41/94.

INSTRUCTIONS FOR USE

1. Insert BD 41/97 into Volume 2, Section 1.

2. Remove BD 41/94 from Volume 2, Section 1.

3. Archive this sheet as appropriate.

Note: A quarterly index with a full set of Volume Contents Pages is available separately from the Stationery Office Ltd.

THE HIGHWAYS AGENCY

THE SCOTTISH OFFICE DEVELOPMENT DEPARTMENT

THE WELSH OFFICE
Y SWYDDFA GYMREIG

THE DEPARTMENT OF THE ENVIRONMENT FOR
NORTHERN IRELAND

Reinforced Clay Brickwork Retaining Walls of Pocket-Type and Grouted-Cavity Type Construction

Summary: This Standard sets out the design and construction requirements for pocket-type and grouted-cavity type reinforced clay brickwork retaining walls by implementing the relevant parts of BS 5628 : Part 2 : 1995. Vertical retaining walls of pocket-type construction up to 5m retained height and walls of grouted-cavity type up to 2m retained height are included in the scope of this Standard.

REGISTRATION OF AMENDMENTS

Amend No	Page No	Signature & Date of incorporation of amendments	Amend No	Page No	Signature & Date of incorporation of amendments

REGISTRATION OF AMENDMENTS

Amend No	Page No	Signature & Date of incorporation of amendments	Amend No	Page No	Signature & Date of incorporation of amendments

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

SECTION 1 SUBSTRUCTURES

PART 1

BD 41/97

REINFORCED CLAY BRICKWORK RETAINING WALLS OF POCKET-TYPE AND GROUTED-CAVITY TYPE CONSTRUCTION

USE OF BS 5628: PART 2: 1995

Contents

1. INTRODUCTION

1.1 Reinforced clay brickwork walls in the form of grouted-cavity walls, where the reinforcement is placed in the middle cavity, have been in use for many years for low height retaining walls. Such walls are structurally suitable for retained heights of up to about 2m. The design and construction of these walls are covered in BS 5628 : Part 2 : 1995, 'Structural use of reinforced and prestressed masonry', which is primarily intended for the design of buildings.

1.2 In recent years, pocket-type reinforced clay brickwork retaining walls (Figure 1) have been developed for medium height (2 to 6 metres) cantilever stem walls. Design and construction of such walls are also covered in BS 5628 : Part 2 : 1995.

1.3 Reinforced clay brickwork retaining walls of pocket or grouted-cavity type may be economically viable where, for example, brickwork facing to a structure is specified for reasons of aesthetics. The purpose of this Standard is to implement the relevant parts of BS 5628 : Part 2 : 1995 and thereby make these options available for use as permanent structures on highway schemes.

Equivalence

1.4 The construction of reinforced clay brickwork retaining walls of pocket or grouted-cavity type will normally be carried out under contracts incorporating the Specification for Highway Works (MCHW 1). In such cases products conforming to equivalent standards or technical specifications of other states of the European Economic Area and tests undertaken in other states of the European Economic Area will be acceptable in accordance with the terms of the 104 and 105 Series of Clauses of that Specification. Any contract not containing these Clauses must contain suitable clauses of mutual recognition having the same effect regarding which advice should be sought.

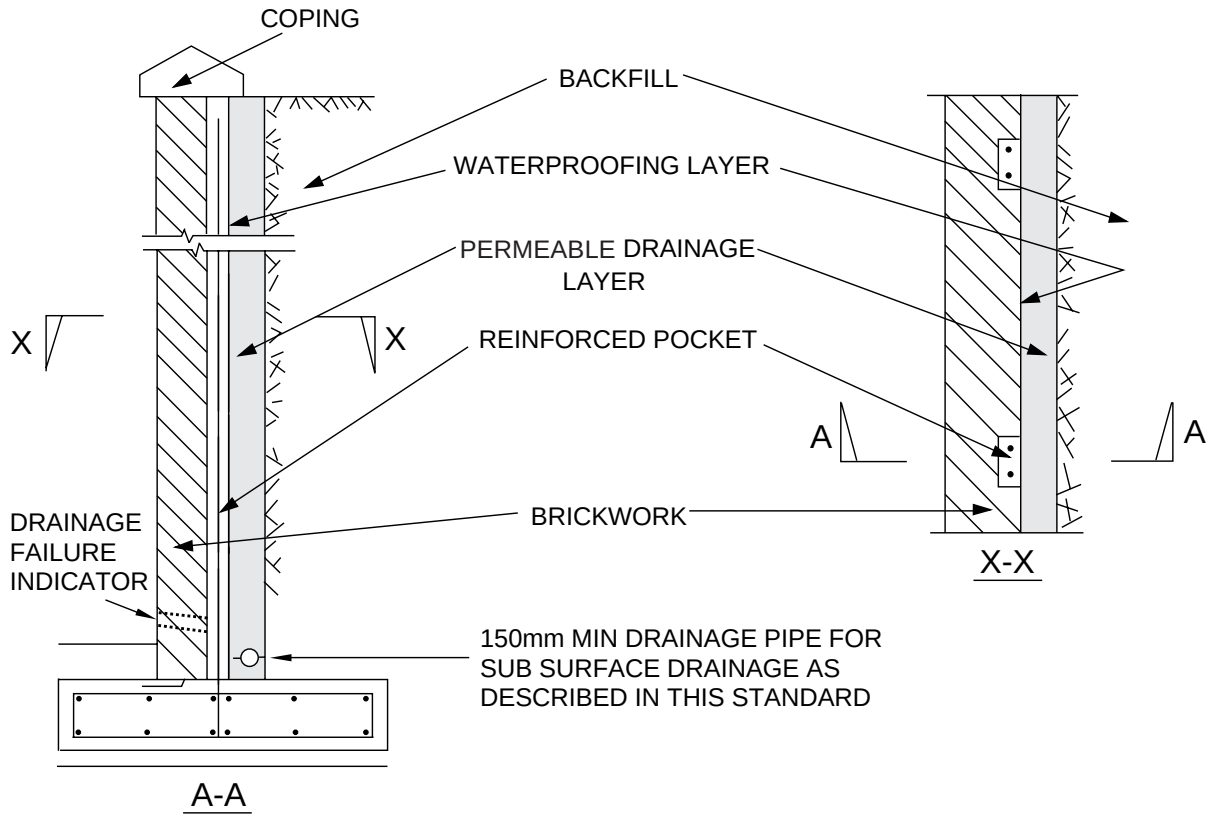

Figure 1: Pocket-type reinforced clay brickwork retaining wall

Scope

1.5 This Standard gives the requirements for the design and construction of grouted-cavity type reinforced clay brickwork retaining walls and pocket-type reinforced clay brickwork retaining walls. These types are cantilever stem walls. Prestressed construction is not covered by this Standard, nor is the use of masonry units other than clay bricks.

1.6 For the purpose of this Standard, a pocket-type reinforced clay brickwork retaining wall is one which contains vertical pockets of insitu reinforced concrete placed in the tension face of the wall. The main reinforcement also runs vertically.

1.7 This Standard covers the structures described in 1.5 and 1.6 above subject to the following limitations:

(i) Such walls shall not be used for bridge abutments, nor to retain carriageways, nor earthworks supporting carriageways. However, they can be used as wing walls to structures, so long as these do not run in such close proximity to retained carriageways that the effects of live load surcharges are significant.

(ii) The walls are vertical or near vertical with a maximum slope from the vertical of 1 in 20.

(iii) In the case of pocket-type reinforced clay brickwork retaining walls, the maximum retained height shall be 5m except for tapered wing walls where the retained height may be increased to 6m at the higher end, provided the average heights of the individual panels of a wall do not exceed 5m. The retained height is to be taken as the difference between the finished ground levels at the two faces of the wall.

(iv) In the case of grouted-cavity type reinforced clay brickwork retaining walls, the maximum retained height shall be 2m. The retained height is to be taken as the difference between the finished ground levels at the two faces of the wall.

1.8 Alternative design and construction methods and the use of materials not referred to in this Standard shall be treated as departures from standards, in accordance with Standard BD 2, Technical Approval of Highway Structures on Motorways and other Trunk Roads, Part 1 (DMRB 1.1).

Implementation

1.9 This Standard should be used forthwith on all schemes for the construction and improvement of trunk roads, including motorways, currently being prepared, provided that, in the opinion of the Overseeing Organisation, this would not result in significant additional expense or delay progress. Design Organisations should confirm their application to particular schemes with the Overseeing Organisation. In Northern Ireland, this Standard will be applicable to those roads designated by the Overseeing Organisation.

2. DESIGN

2.1 Design for the ultimate limit state of overall stability of the soil/structure shall be in accordance with Annex B, as shall the corresponding serviceability limit state of deformation. Annex B also covers the methods for calculating the earth pressures to be used and the soil parameters required for these calculations.

2.2 The detailed structural design of all pocket-type or grouted-cavity type reinforced clay brickwork retaining walls at both ultimate and serviceability limit states shall be carried out in accordance with BS 5628 : Part 2 : 1995 as amended by this Standard. The required amendments are given in Annex A and are listed under the relevant clause numbers of BS 5628 : Part 2 : 1995. The earth pressures to be applied shall be calculated as described in Annex B.

2.3 Parts of BS 5628 : Parts 1 and 3 referred to by BS 5628 : Part 2 : 1995, shall be considered as applicable for the purposes of this Standard.

2.4 Any reference to prestressed brickwork or to masonry units other than clay bricks in BS 5628 : Part 2 : 1995 shall be considered as not applicable for the purposes of this Standard.

2.5 Only clay bricks to BS 3921 : 1985 (as amended 1995) are to be used. (See clause 1.4)

3. ADDITIONAL REQUIREMENTS

3.1 Materials and workmanship for the construction of reinforced clay brickwork retaining walls and the requirements for backfilling, drainage and waterproofing shall comply with the Specification for Highway Works, MCHW 1, Clause 2503. (Although the title of Clause 2503 refers to the pocket-type form of construction, its requirements apply equally to grouted-cavity walls.)

4. REFERENCES

1. Design Manual for Roads and Bridges: Stationery Office Ltd

Volume 1: Section 1 Approval Procedures

BD 2 Technical approval of Highway Structures on Motorways and other Trunk Roads. Part 1 (DMRB 1.1).

Volume 1: Section 3 General Design

BD 15 General Principles for the Design and Construction of Concrete Bridges. Use of BS 5400 : Part 1 (DMRB 1.3.2).

BD 24 Design of Concrete Bridges. Use of BS 5400 : Part 4 (DMRB 1.3.1).

BD 37 Loads for Highway Bridges. Use of BS 5400 : Part 2 (DMRB 1.3).

BD 57 Design for Durability (DMRB 1.3.7).

2. Manual of Contract Documents for Highway Works: Stationery Office Ltd

Volume 1: Specification for Highway Works 1993 (MCHW 1)

3. BSI Standards Publications: British Standards Institution, London

BS 5400 : Steel, Concrete and Composite Bridges.

Part 1 : 1988. General Statement.

Part 2 : 1978. Specification for Loads.

Part 4 : 1990. Code of Practice for Design of Concrete Bridges.

BS 5628 : Use of Masonry.

Part 1 : 1992. Structural use of unreinforced masonry.

Part 2 : 1995. Structural use of reinforced and prestressed masonry.

Part 3 : 1985. Materials and components, design and workmanship.

BS 8002 : 1994. Code of Practice for Earth Retaining Structures.

BS 3921 : 1985. Specification for Clay Bricks. (As amended 1995).

BS 882 : 1992. Specification for Aggregates from Natural Sources for Concrete.

5. ENQUIRIES

Approval of this document for publication is given by the undersigned:

The Quality Services Director
The Highways Agency
St Christopher House
Southwark Street
London SE1 0TE

T A ROCHESTER
Quality Services Director

The Deputy Chief Engineer
The Scottish Office Development Department
National Roads Directorate
Victoria Quay
Edinburgh
EH6 6QQ

N B MACKENZIE
Deputy Chief Engineer

The Director of Highways
Welsh Office
Y Swyddfa Gymreig
Crown Buildings
Cathays Park
Cardiff
CF1 3NQ

K J THOMAS
Director of Highways

TheTechnical Director
Department of the Environment for
Northern Ireland
Roads Service
Clarence Court
10-18 Adelaide Street
Belfast
BT2 8GB

V CRAWFORD
Technical Director

All technical enquiries or comments on this document should be sent in writing as appropriate to the above.

ANNEX A

AMENDMENTS TO BS 5628 : PART 2 : 1995

Clause

1.3 Both Clause 1.3.3.2 and 1.3.3.4 should refer to figure 6, not figure 7.

1.4 Delete definition of f_b and insert the following:
'f_b Ultimate anchorage bond strength between concrete infill and steel (in N/mm^2)'

2.1 Add the following after 'BS 5628 : Part 3', 'and the Specification for Highway Works.' Delete 'or BS 5390'.

2.2 Delete clause, insert the following:

'2.2 Structural units
Bricks intended for use in reinforced masonry shall comply with Specification for Highway Works. MCHW 1 : Clause 2503.2.

Selection of bricks shall follow the recommendations contained in BS 5628 : Part 3 in respect of durability and other considerations.

The tables and graphs in this part of BS 5628 cover masonry units of compressive strength 7N/mm^2 or more. (Based on the gross area of bed for clay bricks.)

Second hand masonry units or calcium silicate bricks shall not be used in reinforced brickwork for highway structures.'

2.3 Delete clause.

2.4 Delete clause, insert the following:

'2.4 Damp-proof courses
Damp-proof courses shall be incorporated at just above ground level and shall consist of a minimum of two bonded courses of either DPC1 or DPC2 type bricks as defined in table 4 of BS 3921 : 1985 (1995). Class A and B clay engineering bricks to BS 3921 : 1985 (1995) provide equivalent damp-proof course performance to DPC1 and DPC2 bricks respectively. Facing and other bricks with equivalent water absorption properties can also be used to form damp-proof courses. Bricks for damp-proof courses shall be laid in a designation (i) mortar as given in BS 5628. Particular requirements are given in Specification for Highway Works. MCHW 1 : Appendix 25/3.'

2.6 Delete clause, insert the following:

'2.6 Cements, aggregates, water and mortars
Cements, aggregates, water and mortars intended for use in reinforced brickwork shall comply with the Specification for Highway Works. MCHW 1 : Clause 2503. Masonry cement or high aluminia cement shall not be used.'

2.7 Delete clause.

2.8 Delete clause.

2.9 Delete clause, insert the following:

'2.9 Concrete infill
Concrete infill for reinforced brickwork shall comply with the Specification for Highway Works. MCHW 1 : Clause 2503.

The grade of concrete and cover to reinforcement shall comply with Table 13 of BS 5400 : Part 4 : 1990 as implemented by BD 57 Design for Durability (DMRB 1.3.7).'

3.1.1.2 Delete 'BS 8110 : Part 1' and replace with 'BS 5400 : Part 4 : 1990 as implemented by BD 24 (DMRB 1.3.1).'

3.1.2.2.1 Delete clause, insert the following:

'3.1.2.2.1 Deflection
The deflection of the structure shall not adversely affect its performance. The final deflection (including the effects of temperature, creep and moisture movement) of the wall shall not exceed height of wall above base/125. In any calculation of deflection (see Appendix C) the design loads and the design properties of materials shall be those recommended for the serviceability limit state in clauses 3.3 to 3.5.'

3.1.2.2.2. Add the following at the end of paragraph 1:

'Cracking of concrete shall conform to clause 4.1.1.1 of BS 5400 : Part 4 : 1990 as implemented by BD 24 (DMRB 1.3.1) and BD 57 (DMRB 1.3.7).'

3.2.1 Delete paragraphs 3 and 5. Add the following before paragraph 4:

'Jointing is preferable to pointing and shall be used unless there is a specific need to point.'

Add the following after paragraph 4:

'The choice of DPC shall not reduce the bending or shear capacity of the wall.'

3.2.2 Delete paragraphs 1 and 2, insert the following:

'The overall dimensions and stability of earth retaining and foundation structures, eg the area of pad footings, shall be determined in accordance with Annex B of this Standard.'

3.2.3 Delete clause.

3.3 Delete clause, insert the following:

'3.3 Loads
All loads applied to the structure shall be derived from BS 5400 : Part 2 as implemented by BD 37 (DMRB 1.3), and using the earth pressures given in Annex B of BD 41 (DMRB 2.1.1).'

3.4.1.1.3 Delete paragraph 2 and sub-clauses (a) to (h), insert the following:

'The value of f_K shall be taken from Table 3(A) and Figure 1(a), which apply to masonry built with bricks or other structural units with a ratio of height to least horizontal dimension of 0.6.

Note: This table is intended to cover standard format bricks which have an aspect ratio of 0.63.'

3.4.1.3.1b Delete '2.9.1' and insert '2.9 as modified by this Standard'.

3.4.1.6 Heading, line 1
Delete 'Characteristic anchorage bond strength, f_b.'
Insert 'Ultimate anchorage bond strength, f_b.'

3.4.1.6 Paragraphs 1 and 2.
Delete paragraphs, insert the following:

'The ultimate anchorage bond strength f_b between concrete infill and steel in tension or compression shall be obtained from Table 15 of BS 5400 : Part 4 : 1990, as implemented by BD 24 (DMRB 1.3.1).'

3.5.1 Delete paragraphs 2 and 3, insert the following:

'The design load effects shall be derived in accordance with BS 5400 : Part 1 as implemented by BD 15 (DMRB 1.3.2). The values of γ_{fL} to be used are those listed in BS 5400 : Part 2, as implemented by BD 37 (DMRB 1.3).'

γ_{f3} shall be taken as:

(a) 1.0 at serviceability limit state,
(b) 1.10 at ultimate limit state.'

3.5.2.1 Delete clause, insert the following:

'3.5.2.1 Combination of loads.
Design load effects for ultimate limit state shall be derived using load combinations set out in BS 5400 : Part 2, as implemented by BD 37 (DMRB 1.3). Each element and structure shall be examined under the effects of loads that can coexist in each combination.'

3.5.2.2 Delete the following symbol: 'γ_{mb} for bond strength between infill concrete or mortar and steel (see table 7);'

3.5.2.2 Title and content of table 7.
Delete 'γ_{mb}' from title.
Delete 'Bond strength between concrete infill or mortar and steel, γ_{mb} - 1.5'.

3.5.2.2 Paragraph 4 (below table 7).
Delete paragraph.

3.5.3.1 Delete clause, insert the following:

'3.5.3.1 Combination of Loads.
Design load effects for serviceability limit state shall be derived using load combinations set out in BS 5400 : Part 2, as implemented by BD 37 (DMRB 1.3). Each element and structure shall be examined under the effects of loads that can coexist in each combination.'

3.5.4 Delete clause.

4.6.6 Delete clause, insert the following:

'4.6.6 Anchorage bond
To prevent bond failure, the tension or compression in any bar due to design loads shall be developed on each side of the section by the appropriate ultimate anchorage strength given in clause 3.4.1.6. as modified by this Standard.'

5.1 to 5.5 Delete all.

Table 13 Column 2 Note: Only austenitic stainless steel reinforcement shall be used in bed joints.

6.1.2.5 Delete clause, insert the following:

'Concrete infill for reinforced masonry shall conform with clause 2.9 of BS 5628 : Part 2, as modified by this Standard.'

6.1.2.6 Paragraph 4, line 3.
At the end of paragraph, add the following:

'Reference shall be made to Table 13 of BS 5400 : Part 4 : 1990 as implemented by BD 57 (DMRB 1.3.7), for recommended nominal cover.'

6.1.2.6 Figure 6(a)
Delete 'in Table 14,' insert 'in Table 13 of BS 5400 : Part 4 : 1990 as implemented by BD 57 (DMRB 1.3.7).'

6.1.2.7 Delete clause.

6.1.2.8 Delete clause, insert the following:

'6.1.2.8 Wall ties and bed-joint reinforcement.
Wall ties and bed-joint reinforcement shall comply with the requirements of clauses 2410 and 2411 of the Specification for Highway Works (MCHW 1), with the exception that only 316 S 31 or 316 S 33 wire or bars shall be used. Bed-joint reinforcement shall not exceed 6mm diameter.

Only austenitic stainless steel bed-joint reinforcement shall be used. No contact with other steels shall be permitted to avoid the possibility of bi-metallic corrosion. Bed-joint reinforcement shall have a 15mm minimum of mortar cover to each masonary face and shall not be laid dry on a bed face, but shall be embedded within the mortar bed thickness.'

6.2 Delete clause, insert 'clause 6.2 - not used'.

6.3 Paragraph 1, lines 4 to 8.
Delete sentence from line 4 starting at 'Where contraction ...' to line 8 '... intervals of 30m.'

6.5 Delete clause, insert the following:

'6.5 Drainage and waterproofing
Drainage and waterproofing of reinforced brickwork retaining wall structures shall be in accordance with the Specification for Highway Works (MCHW 1) and as detailed here.

Sub-surface drainage is important for an earth retaining structure and must be shown in detail on the

contract documents. Surface drainage should be provided to drain surface water away from the retaining wall and the backfill.

The design shall take into account the influence of ground water on the wall, both during construction and permanently, and the effect of any changes in ground water level.

In order to collect and dispose of any water percolating through the fill, a continuous system of porous or perforated drainpipes not less than 150mm diameter shall be provided adjacent to, and at the rear of, the vertical stem of the wall at the level of the top of the footing.

For ease of maintenance, facilities should be included for rodding the whole length of the system from inspection manholes positioned at the foot of the wall. Weep holes located just above ground level can provide a useful check that the system is functioning correctly, and will limit the rise in water level in the event of a drainage failure. If used, weep holes should not be allowed to drain freely onto footways or carriageways. For selected granular backfill a vertical permeable layer shall be provided at the back of the wall consisting of the following materials as described in the Specification for Highway Works (MCHW1) Clause 513:

(a) Granular drainage layer;
(b) Cast in-situ porous no fines concrete;
(c) Precast hollow concrete blocks.

When drainage material type (a) is used, it must satisfy Clause 513 of the Specification for Highway Works (MCHW 1).

When drainage materials of the types (b) and (c) above are used, they shall be capable of withstanding any horizontal pressure likely to be exerted through the backfill. These drainage materials are not recommended when the backfill contains materials susceptible to piping such as chalk or PFA.

The vertical drainage layer should connect with the drainage pipes.

When selected cohesive material, PFA or chalk are used as backfill, the following provisions shall be made:

(a) A layer of granular fill not less than 500mm thick shall be placed on top of the fill and below any paved surfaces. This layer shall connect with the vertical drainage layer described below.

(b) A vertical drainage layer of thickness not less than 300mm of fine aggregate of grading C or M complying with Table 5 of BS 882 shall be provided behind the wall. The layer shall connect with the drainage system at the base of the structure.

(c) A horizontal drainage layer 450mm thick shall be placed beneath the fill. The top 200mm of this layer will be of fine aggregate of grading C or M complying with Table 5 of BS 882, the remaining 250mm will be of Type B filter material complying with Clause 505 of the Specification for Highway Works (MCHW1). This layer shall connect with the drainage system at the base of the structure. This layer can be omitted if the underlying soil is highly permeable.

Proprietary drainage materials can be used as permeable backing provided they have a current British Board of Agrément Roads and Bridges Certificate or equivalent certificate.

When PFA is used as a backfilling material, there is a danger that it may turn into a slurry as a result of accidental flooding forming voids in the mass of the backfill. This can happen during construction

as well as afterwards. Due precaution should therefore be taken at the design stage to reduce the likelihood of water leakage in the vicinity of the PFA fill by specifying leak-proof joints in any drains and if necessary rerouting any water mains.'

6.6 Delete clause, insert the following:

'D.p.cs shall comply with the requirements of clause 8 and the Specification for Highway Works MCHW 1 Clause 2503. Copings shall either be of brick, block, cast stone, cast concrete or natural stone, conforming to Table 4 of BS 5628 : Part 3 : 1985. Consideration shall be given to the likelihood of copings being displaced by lateral impact and the possibility of vandalism. 'L' shaped copings and clip over copings may be used to prevent displacement by lateral loads. Copings shall be dowelled, joggle jointed or suitably fixed down. Movement joints in copings shall coincide with wall movement joints.'

7.2.8 Add the following:

'Jointing is preferable to pointing and shall be used unless there is a specific need for pointing. Joints shall be tooled as the work progresses to either a flush or bucket handle profile.'

7.3.2.2 Delete clause, insert the following:

'Clay masonry units of suction rate greater than 1.5kg/(m^2. min) shall not be used in highway structures.'

ANNEX B

OVERALL RETAINING WALL DESIGN

B.1 Introduction

B.1.1 This Annex outlines the principles to be used for the overall limit state design of a backfilled cantilever retaining wall and describes the methods to be used for determining the horizontal earth pressures on the wall and the soil parameters to be used in the calculations. The detailed structural design of the walls covered by this Standard is set out in the main text and Annex A to this Standard. Highway live loading will not normally apply to any of the limit states.

B.2 Limit States

B.2.1 The structure and the surrounding soil must be designed to perform satisfactorily for both the ultimate and the serviceability limit states. The four limit states which are to be considered in the design are:

(i) Ultimate Limit State of the Structural Elements
(ii) Serviceability Limit State of the Structural Elements
(iii) Ultimate Limit State of Overall Stability of Soil/Structure
(iv) Serviceability Limit State for Deformation of Soil/Structure

Limit states (i) and (ii) for the walls covered by this Standard, are dealt with in the main text of this Standard and in Annex A. The requirements for limit states (iii) and (iv) are the subject of this Annex B.

B.2.2 Ultimate Limit State of Soil/Structure

(i) This limit state corresponds with the following failure modes of the surrounding soil and the soil-structure interface:

- Sliding
- Overturning
- Failure of the foundation soil
- Slip failure of the surrounding soil

(ii) Design for this limit state shall be based on the design procedures given in BS 8002 : Code of Practice for Earth Retaining Structures as implemented by the Overseeing Organisation. Nominal values of the relevant loads given in BS 5400 : Part 2, implemented by BD 37 (DMRB 1.3), shall be used in the calculations. Load factors are to be taken as those given in BD 37 unless changed by this Standard.

Note: The overturning design criterion given in BS 5400 : Part 2 is not applicable to this limit state.

B.2.3 Serviceability Limit State of Soil/Structure

(i) The adoption of recommended allowable net bearing pressures for the foundation design shall avoid undesirable settlements and tilting of the structure. If required, such movements can be calculated from a displacement or consolidation analysis and taken into account in the overall design of the structure.

(ii) The factor of safety for this limit state shall be taken as 1. Nominal values of the relevant loads given in BS 5400 : Part 2, implemented by BD 37 (DMRB 1.3), shall be used in the calculations. Load factors are to be taken as those given in BD 37 unless changed by this Standard.

B.3 Earth Pressures for Design

B.3.1 In all limit states of design, earth pressures generating from the retained fill will need to be considered. Methods for calculating these earth pressures and the corresponding partial load factors applicable to them are given below. For low permeability backfill (Classes 7A and 7B, Series 600 Earthworks, Specification for Highway Works MCHW 1), it is necessary in design to assess separately the earth pressures acting in the short term and those acting in the long term when full porewater pressure equilibrium has occurred. In clay fills the short term earth pressures are determined using the undrained shear strength (c_u) whereas for the long term earth pressures the effective stress strength parameters (c'. Ø') are used.

B.3.2 For the ultimate limit state of the structural elements, 'at rest' earth pressure shall be used in the design. The partial load factor γ_{fL} for earth pressure generated by the backfill itself shall be taken as 1.2 (0.67 for relieving effects).

B.3.3 For the serviceability limit state of the structural elements, 'at rest' earth pressure shall be used in the design. The partial load factor γ_{fL} for earth pressure generated by the backfill itself shall be taken as 1.0.

B.3.4 For the ultimate and serviceability limit states of the soil/structure, 'active' earth pressure shall be used in the design in accordance with BS 8002 Code of Practice for Earth Retaining Structures.

B.3.5 For all states γ_{fL} for water pressure shall be taken as 1.2.

B.4 Backfill Soil Parameters

B.4.1 Where the design uses assumed soil parameters, such as soil density γ, effective cohesion c' and the effective angle of shearing resistance Ø', checks shall confirm that the properties of the fill material to be used in the actual construction are not inferior to those used in the design.

B.4.2 All combinations of design situations, such as the presence of hydrostatic pressure, etc, shall be considered when applicable. The possibility of burst water mains in the vicinity of the structure shall be taken into account.

B.4.3 When PFA (Class 7B) is used, the value of the effective angle of internal friction Ø' for the PFA can be taken as 30^o, but must be confirmed by tests for final design. The value of c' for PFA shall be established by test but must not be taken to be greater than 5 kN/m^2 for design purposes. The properties of PFA can vary considerably from one source of supply to another. For this reason only PFA from a single source shall be used.

B.4.4 Cohesive fill materials other than PFA shall be placed at moisture conditions close to their long term equilibrium states which shall be specified in the Contract. Otherwise problems associated with volume change, such as increased earth pressure, can arise afterwards.