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

**SECTION 1 SUBSTRUCTURES**

## PART 5

## BD 70/03

# STRENGTHENED/REINFORCED SOILS AND OTHER FILLS FOR RETAINING WALLS AND BRIDGE ABUTMENTS

## USE OF BS 8006: 1995, INCORPORATING AMENDMENT NO 1 (ISSUE 2 MARCH 1999)


### SUMMARY

This Standard implements BS 8006: 1995 for retaining walls and bridge abutments and replaces BE 3/78 (amendment 1987). This Standard introduces a method for designing base slabs for supporting vehicle paparets on retaining walls.


### INSTRUCTIONS FOR USE

1. Remove existing Contents pages for Volume 2.

2. Insert new Contents pages for Volume 2, dated May 2003.

3. Insert BD 70/03 into Volume 2. Section 1.

4. Please archive this sheet as appropriate.

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SCOTTISH EXECUTIVE DEVELOPMENT DEPARTMENT

WELSH ASSEMBLY GOVERNMENT
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THE DEPARTMENT FOR REGIONAL DEVELOPMENT
NORTHERN IRELAND

# Strengthened/Reinforced Soils and Other Fills for Retaining Walls and Bridge Abutments

# Use of BS 8006: 1995, Incorporating Amendment No 1 (Issue 2 March 1999)

Summary: This Standard implements BS 8006: 1995 for retaining walls and bridge abutments and replaces BE 3/78 (amended 1987). This Standard introduces a method for designing base slabs for supporting vehicle parapets on retaining walls.

**REGISTRATION OF AMENDMENTS**

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## USE OF BS 8006: 1995, INCORPORATING AMENDMENT NO 1 (ISSUE 2 MARCH 1999)

**Contents**

# 1. INTRODUCTION

1.1 Strengthened/reinforced soils and other fills in the form of retaining walls and bridge abutments have been in use for many years as permanent highway structures. The purpose of this Standard is to implement those parts of BS 8006 "Strengthened/reinforced soils and other fills", which apply to the design and construction of retaining walls and bridge abutments. It sets out the particular requirements for permanent highway structures with a design life of 120 years where they differ, or are more comprehensive, than provided in the British Standard.

1.2 This Standard contains a number of amendments to BS 8006: 1995 'Strengthened/reinforced soils and other fills' (incorporating Amendment No 1 (issue 2 March 1999)) by providing replacement and additional clauses, additions or deletions. The required amendments are given in Annex A and follow the clause numbering of BS 8006. This Standard is complementary to the Specification for Highway Works (MCHW 1), hereinafter referred to as the Specification.

1.3 This Standard replaces Technical Memorandum BE 3/78 (revised 1987); 'Reinforced and anchored earth retaining walls and bridge abutments for embankments'.

**Equivalence**

1.4 The construction of strengthened/reinforced soils and other fills for permanent highway structures 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.

**Scope**

1.5 This Standard gives the requirements for the design and construction of strengthened/reinforced soils and other fills in the form of retaining walls and bridge abutments for permanent structures with a design life of 120 years subject to the following limitations:

i) the Standard applies, in general, to bridge abutments and to retaining walls where the level of the fill at the back of the wall is greater than 1.5m above the finished ground level in front of the wall;

ii) walls less than 1.5m in height may be designed either on the basis of experience and qualitative geotechnical investigations, or on the basis of the requirements in this Standard;

iii) only hard facings are permitted for permanent highway structures;

iv) the design of base slabs supporting vehicle parapets is covered in clause 6.10.2 and Annex B of this Standard;

v) retaining walls and bridge abutments exceeding 10m in height are regarded as uncommon and although the approach to design will be based on the requirements of this Standard, special consideration will need to be given to accommodate the effects of differential vertical settlements between the fill, reinforcing elements and the facings arising from internal compaction of the fill due to gravitational effects;

vi) BS 8006 and this Standard outline the main considerations involved in the use of soil nailing for walls. However, the Standard does not fully address this topic and should be regarded as providing general guidance only;

vii) this Standard does not address sections 7 and 8 of BS 8006 relating to reinforced slopes and to embankments with reinforced soil foundations on poor ground and such amendments as are made in this Standard are not necessarily applicable to these uses;

viii) the document specifically excludes anchor walls with the exception of anchored earth.

1.6 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 (DMRB 1.3).

**Durability**

1.7 In addition to those requirements for durability given in BS 8006 and this Standard, the design of strengthened/reinforced soils and other fills in the form of retaining walls and bridge abutments for permanent highway structures shall take into account the requirements for durability given in BD 57 Design for durability (DMRB 1.3.7).

**Implementation**

1.8 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 its application to particular schemes with the Overseeing Organisation. Where contract documents are based on the Specification for Highway Works use of this Standard is mandatory. For use in Northern Ireland, this Standard will be applicable to those roads designated by the Overseeing Organisation.

**Mandatory Requirements**

1.9 Sections of this document which form mandatory requirements of the Overseeing Organisation are highlighted by being contained within boxes. The remainder of the document contains advice and enlargement which is commended to designers for their consideration.

# 2. REFERENCES

## 2.1 Design Manual for Roads and Bridges

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

BD 10 Design of highway structures in areas of mining subsidence (DMRB 1.3.14).

BD 13 Design of steel bridges. Use of BS 5400: Part 3 (DMRB 1.3.2).

BD 21 The assessment of highway bridges and structures (DMRB 3.4.3).

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

BD 37/88 Loads for Highway Bridges (DMRB 1.3).

BA 55 The assessment of bridge substructures and foundations (DMRB 3.4.9).

BD 57 Design for durability (DMRB 1.3.7).

BD 62 As built, operational and maintenance records for highway structures (DMRB 3.2.1).

BD 63 Inspection of highway structures (DMRB 3.1.4).

## 2.2 BSI publications

BS 5400: Part 3 1982 Code of practice for design of steel bridges.

## 2.3 Other publications

Brady K C, Watts G R A, Nagakarti A S and Greenwood J H. “Installation damage trials on geotextiles.” TRL Research Report 382, Transport Research Laboratory, Crowthorne, 1994.

Murray R T. “The development of specifications for soil nailing.” TRL Research Report 380, Transport Research Laboratory, Crowthorne, 1993.

# 3. ENQUIRIES

All technical enquiries or comments on this Standard should be sent in writing as appropriate to:

| | |
|---|---|
| Chief Highway Engineer<br>The Highways Agency<br>Room B153A<br>Romney House<br>43 Marsham Street<br>London SW1P 3HW | G CLARKE<br>Chief Highway Engineer |

| | |
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|---|---|
| Director of Engineering<br>Department for Regional Development<br>Roads Service<br>Clarence Court<br>10-18 Adelaide Street<br>Belfast BT2 8GB | G W ALLISTER<br>Director of Engineering |

# ANNEX A AMENDMENTS TO BS 8006: 1995, INCORPORATING AMENDMENT NO 1 (ISSUE 2 MARCH 1999)

| |
|---|
| The use of this annex is mandatory. |

Within BS 8006 and this document, the phrase "current BBA or equivalent certificate" shall be taken to mean "current BBA Roads and Bridges certificate or equivalent certificate".

**Section 2. Concepts and fundamental principles**

**2.1 General**
Add to end of this clause "For permanent highway structures the range of reinforcements is restricted to bars and strips of specific types of plain carbon and stainless steels given in table 6 (plain carbon steel shall be galvanised in accordance with clause 3.2.2.1) and to other forms and proprietary types with a current BBA or equivalent certificate."

**2.3 Partial factors**
In the second paragraph replace "sections 6, 7 and 8." with: "section 6." and delete ", slopes and embankment foundations respectively"

**2.5 Design strengths**
In the fourth paragraph replace "sections 6 and 7." with: "section 6."

**2.8 Soil reinforcement mechanisms in embankment foundations**
At the end of the first paragraph add " Consideration shall be given to the soil/structure interaction since measures taken to reinforce soft embankments and soft foundations could have a subsequent beneficial or harmful effect on deformations and loads imposed on reinforced soil walls and abutments."

**2.10 Soil properties to be considered**
In the second paragraph replace "sections 6, 7 and 8." with: "section 6." and delete ",slopes and embankment foundations respectively"

**2.14 Factors affecting tensile behaviour of flexible reinforcement**
In the second paragraph replace "In the case of basal ....decreases with increasing time." with: "The design life of permanent highway structures shall be 120 years. Over this design life it is anticipated that the tensile rupture strength of the reinforcement will decrease with time through various agencies of degradation. Different reinforcing materials are degraded by different agencies but all will be affected by the passage of time."
In the penultimate paragraph delete "Limits are prescribed ....over weak ground."

**Section 3. Materials**

**3.1 Soils and fills**
**3.1.1 General**
Delete last sentence "Less stringent requirements ... flatter slopes".

**3.1.2 Fill material in walls and abutments**
**3.1.2.1 Mechanical criteria**
After "Specification for Highway Works [1]." Insert "Reinforced fill shall have minimum angles of friction of 25° and 20° respectively for frictional and cohesive frictional fills. Frictional fills only are permitted with anchored earth and the minimum frictional strength of such fill shall be 30°."

**Table 2** Delete category 1 and "Argillaceous material" from category 2.

**Table 3** Delete category 1.

**3.1.2.4 Other fills and industrial waste**
**3.1.2.4.1 General**
Replace existing clause with: "Certain fills of this subclause may be used in the construction of reinforced soil walls for permanent works as listed below, provided they meet the criteria given in clauses in **3.1.2.1** and **3.1.2.2**. A greater frequency of testing shall be carried out to ensure adequate quality control."

**3.1.2.4.2 Pulverised fuel ash**
Add to the end of the first paragraph: "Special corrosion measures are required with PFA fill as detailed in **9.2.3.6.3**, and special drainage measures as in **9.2.6.3**."

**3.1.2.4.3 Colliery spoil** - delete clause.

**3.1.2.4.4 Argillaceous materials** - delete clause.

**3.1.3 Fill material in slopes** - delete clause.

**3.1.4 Fill material in foundations** - delete clause.

**Table 5** - delete table.

**3.1.5 Natural ground (for soil nailing)**
Replace existing clause with: "Soil nailing for permanent reinforced soil structures may be subject to a wide variation of natural ground conditions. The factors affecting the performance of soil nailing are identified in **2.10**. The effects of non-homogeneous ground on the stability and durability of soil nails should be evaluated for all soils outside the limits of table **4**. The suitability of particular ground conditions for soil nailing is considered in TRL Research Report 380 (Murray, 1993) and the limits of soil aggressivity for permanent structures may be selected from this Report."

**3.2 Reinforcing materials**
**3.2.1 General**
Replace NOTE and final paragraph with: "For permanent highway structures the range of reinforcements is restricted to bars and strips of specific types of plain carbon and stainless steels given in table 6 (plain carbon steel shall be galvanised in accordance with clause 3.2.2.1) and to other forms and proprietary types with a current BBA or equivalent certificate."

**3.2.2 Metallic soil reinforcements**
Paragraph 3 replace "100g/m$^2$ " with: "1000g/m$^2$ " (now covered by amendment no 1 (issue 2 March 1999)).
Add at the end: "Reinforcing elements shall not be less than 1.5 mm in thickness. Note, however, as described in **Annex F.5.1**, that special design considerations are required for reinforcing elements which are thinner than 4 mm. Anchor elements shall not be less than 16 mm in diameter, or, in the case of non-circular bar, equivalent diameter.
The dimensions and design areas of metallic soil reinforcement near holes for fasteners shall be in accordance with clause 11 of BS 5400: Part 3:1982 as implemented by BD 13 (DMRB 1.3). The rupture strength used in the design of anchored earth will be based on either the strength of any welded connection between an anchor and anchor shaft, or of the anchor shaft, whichever is the lesser. When threaded end connections are used, the cross-sectional area of the anchor shaft shall be based upon the tensile stress area."

**3.2.2.2 Corrosion allowance**
Paragraph 1 replace second sentence by "For natural soils associated with permanent soil nailed structures and other fills, a separate evaluation shall be made if such soils are more corrosive than those given in table 4."

**Table 7**
Delete rows beginning 5,10,50,60 and 70 years.
NOTE 1 delete "B black steel (ungalvanised);"
NOTE 2 delete note
Add "NOTE 5 Nailed structure in natural ground shall have the same requirements as for galvanised steel unless the natural soils are more corrosive than the materials specified in NOTE 3, in which case assessment shall be by special study based on TRL RR 380."

**3.2.4 Polymeric reinforcement joints**
**3.2.4.1 General**
Replace existing clause with: "Joints used for polymeric reinforcement in permanent structures shall be fabricated in accordance with the procedures given in a current BBA or equivalent certificate. The design tensile strength of the polymeric reinforcement element shall be based on the joint strength tested in accordance with ISO 10321: 1992."

**3.2.4.2 Overlaps** - delete clause.

**3.2.4.3 Sewing**
Replace existing clause with: "Sewn joints shall be as detailed in a current BBA or equivalent certificate"

**3.2.4.4 Bodkin joints**
Replace existing clause with: "Bodkin joints shall be as detailed in a current BBA or equivalent certificate."

**3.2.4.5 Stapling** - delete clause.

**3.2.4.6 Other jointing methods**
Replace existing clause with: "Other forms of jointing methods shall be as detailed in a current BBA or equivalent certificate."

**3.3 Facings**
**3.3.1 Hard facings**
Replace existing clause with: "Only hard facings are permitted for permanent reinforced soil retaining structures which may consist of one or more of the following:

(a) Reinforced concrete (either in situ or precast units),
(b) Galvanized carbon steel panels,
(c) Stainless steel panels,
(d) Proprietary material having a current BBA or equivalent certificate."

**3.3.2 Soft facings**
Delete clause

**3.4 Fasteners between the facing and reinforcing elements**
**3.4.1 General**
Replace the list of materials in this clause with:
"coated steel
galvanised steel
stainless steel
proprietary materials with a current BBA or equivalent certificate.
In addition to that given in tables 10 and 11, further details are given in the Specification on relevant material characteristics."
Delete the final sentence of this clause commencing, "Fasteners with all other coatings ....".

**3.5 Testing materials and components not covered by relevant specifications**
Replace existing clause with: "For permanent highway structures only those materials shall be used that are covered by the Specification, this Standard or a current BBA or equivalent certificate."

**Figure 8** - delete figure.

**Section 4. Testing for design purposes**

**4.1 General**
In the second paragraph beginning "Design parameters ...", after "fills/soils and reinforcement." delete remainder of clause.

**4.2 Fill and ground**
**4.2.1 General**
After the sentence ending "swelling characteristics of the soil." add: "These effects should not arise with the limited range of fills and manufactured materials permitted in permanent highway structures."

**4.2.8 Site damage**
In the second paragraph replace "laboratory" with "full scale".

**Table 13** delete row "9 The effects....thermal loading." (now covered by amendment no 1 (issue 2 March 1999)).

**4.3.6 Test requirements for polymeric reinforcements**
**4.3.6.2 Tensile strength and creep properties**
In first paragraph replace "The recommended minimum ..... should be 1000 hours." with: "The minimum test duration for polymeric reinforcement shall be 10,000 hours."

**4.4 Facing units**
Replace this clause with: "For permanent highway structures, facing units shall be designed to the appropriate British Standards or to a current BBA or equivalent certificate. Reinforced concrete units shall be designed in accordance with Standard BD 24 (DMRB 1.3.1). Galvanised and stainless steel units shall be designed in accordance with Standard BD 13 (DMRB 1.3.2)."

**Section 5. Principles of design**

**5.2 Service life**
Replace existing clause with: "The service life of permanent reinforced soil structures to be considered in design shall be 120 years."

**5.3 Factors of safety**
In the first paragraph, second sentence delete "for structures of various service lives ..... geometries and end use.".

**5.3.2 Economic ramifications of failure factor**
Delete "see table 3" at end of first sentence.
Replace "Factor $f_n$ will be common ....... in figures 10,11,12,13 and 14." with: "The partial factor, $f_n$, to use in considering the ramifications of failure of permanent reinforced soil structures shall be, for category 3 $f_n$= 1.1 and for category 2 $f_n$= 1.0. Examples of category 2 and 3 permanent reinforced soil structures are included in figures 11 and 13 respectively."
In final paragraph delete "or to a slope stability problem".

**5.3.3.3 Partial material factors for polymeric reinforcements"**
Paragraph 3 line 1 delete "steep slopes and embankments"; Paragraph 4 line 1 delete "and steep slopes"; line 8 delete "and **7.4.6.1** for slopes"; Paragraph 6 delete paragraph.

**5.3.4 Partial material factors for soils**
Replace "sections 6, 7 and 8." with: "section 6."

**5.3.5 Partial material factors for soil/reinforcement interaction**
Replace "sections 6, 7 and 8." with: "section 6."

**5.3.6 Partial load factors**
Replace "sections 6, 7 and 8." with: "section 6."

**5.5 Serviceability**
Delete the first sentence.
Replace “sections 6, 7 and 8.” with: “section 6.”
Replace “ in particularly sensitive .......are serious.” with: “to allow advance warning of potential problems to be obtained.”

**5.6 Design information**
**5.6.1 Site investigation**
**5.6.1.2 Initial desk and field study**
Add to the end of this clause: “An assessment shall be made to determine whether embankments or other fill to be retained by the permanent reinforced soil structure contains soluble salts which affect the durability of the reinforcements, facings and connections. Unless it can be shown that the presence of such materials do not introduce a further durability hazard, additional drainage facilities to minimise the hazard shall be incorporated into the reinforced soil structure.”

**5.6.1.3 Ground investigation**
**5.6.1.3.1 Extent of investigation**
Replace “should be obtained, particularly if deformation considerations are important as in the case of” with: “shall be obtained, as deformation considerations are particularly important for”.

**5.6.1.3.4 Data presentation and reporting**
Replace “sections 6, 7 and 8.” with: “section 6.”

**5.6.1.4 Investigation during construction**
Paragraph 2 delete “or forms a repair or stabilisation measure,” and delete “or stabilised”.

**5.6.2 Environmental considerations**
**5.6.2.1 General**
Delete “or seismic”.

**5.6.2.2 Chemical and biological considerations**
Change “both fill and reinforcement.” to “fill, reinforcement, facing and other components forming the reinforced soil system.”

**5.6.2.3 Post construction damage**
Replace “slitting of geotextiles and geogrids by vandals” by “accidental damage by utilities contractors etc., vandalism”.

**5.6.3 Load combinations**
Delete “The applications .... are considered for design.”

**Figure 10** - delete figure.
**Figure 12** - delete figure.
**Figure 14** - delete figure.

**Section 6. Design of walls and abutments**

**6.1 General**
Replace clause with: “This section considers the design aspects of reinforced soil structures employed for permanent highway applications of the types and forms shown in figure 15. These structures may be reinforced by strip elements, anchor elements or soil nails as covered in the Specification or this Standard or by other forms of reinforcement (including proprietary reinforcements) that have a current BBA or equivalent certificate. Only hard facings are permitted for permanent highway structures and examples of these are shown in figures 16 and 44. This section applies to abutments for conventional articulated bridge decks, with expansion joints, where forces from the bridge deck are transmitted, through bearings supported on the bankseat, directly into the abutment backfill as shown on figure 44A. This section may also apply to abutments for semi-integral bridges where thermally induced cyclic movements from jointless decks are accommodated by bearings supported on the bankseat. This section applies to abutments for fully integral bridges up to 18 metres in length but does not apply to fully integral bridges greater than 18 metres in length, where significant thermally induced movements of the jointless deck would be transmitted into the abutment fill.”

**6.2.2.3 Land based structures**
Add to the end of this clause: “For tiered walls (figure 15h)), when considering the stability of this structure, the influence of the loading of the upper tier on the lower tier shall be taken into account. For embedded walls (figure 15g)), reinforcement over-lapping in the central part of the structure shall be separated in plan and/or elevation, to avoid face to face contact between reinforcements. For environmental walls (figure 15j)), if the distance from the highway or any other structure exceeds 1.5 times the mechanical height, $f_n$ may be taken as 1.0.”

**6.4.2 Embedment**
Add to end “Where the embedment depth based on table 20 is less than that of drains or services adjacent to a permanent highway structure, consideration may be given to increasing the embedment to below the depth of the drains or services.”

**6.5.4.4 Differential settlement**
Add a final paragraph: “For the case of mining subsidence, reference should be made to Standard BD 10 (DMRB 1.3.14).”

**6.7 Facings**

**6.7.2 Structural form**

Replace existing text with: "The forms of facing permitted for permanent highway structures are described in 3.3. The form and construction requirements for these facings are discussed in section 9."

**6.7.3 Structural loads on facing**

Add to list of load to be designed for:
"- Horizontal impact loads caused by possible vehicle collision with the lower part of walls adjacent to highways.
- Possible longitudinal differential settlement."

After **"6.8 Connections"** insert **"6.8.1 General"** and replace from the second sentence beginning; "In the case of geotextile ..." with: "The form and construction requirements of connections permitted for permanent highway structures are discussed in section 9."

**6.10 (Additional clause) Superimposed structures and loads for highway walls and abutments**

Add new figure 44A.

**6.10.1 Superimposed structures**

Small horizontal and vertical movements of the fill and the facing are likely to occur during and after construction. Superimposed structures must therefore be designed to accommodate such movement. Experience of the behaviour of this form of construction indicates that monitoring shall be made a requirement so that the actual performance can be compared with the predicted design values of movement. The superimposed structure shall be designed such that suitable remedial measures can be taken if the design values are exceeded. The effect on the superimposed structure may be reduced by allowing sufficient time to elapse for the greater part of the total settlement to occur, possibly by using a surcharge, prior to building part or whole of the superimposed structure.

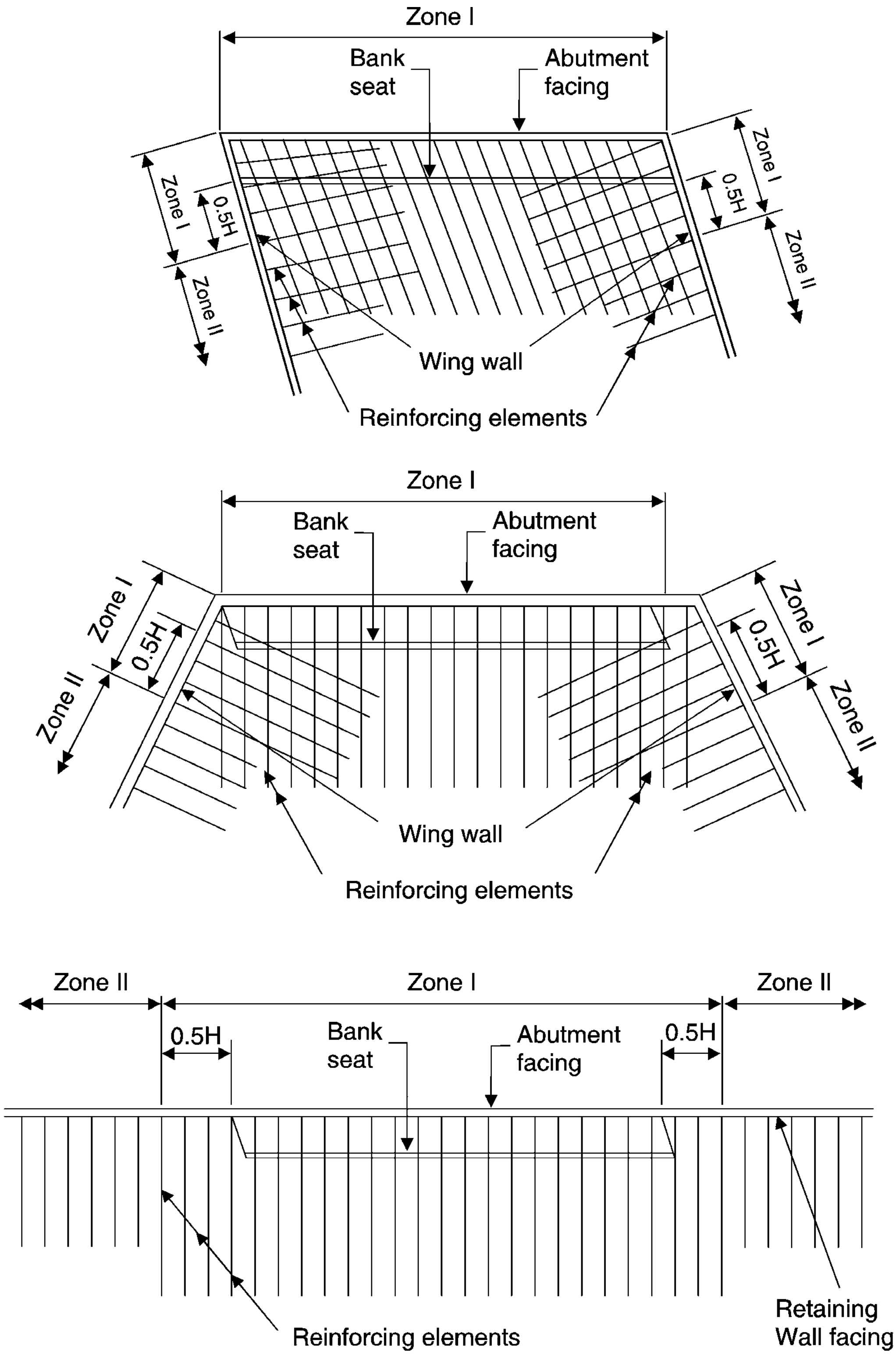
Vertical loads shall be transferred directly to the reinforced fill. Base slabs of superimposed structures must not be fully or partly supported directly by the facing.

The resistance of the base slab of a superimposed structure to horizontal loads may be increased by attaching reinforcing elements. The use of base slabs attached to friction slabs or a system of ties with a ground beam or anchor blocks behind the reinforced zone is not permitted except where methods of analysis have been calibrated and approved by the Technical Approval Authority.

A reinforced soil wall may be used as a bridge abutment. For simplicity, the design of abutments may be considered in two parts, as shown in figure 44A. Zone I shall be designed assuming loading includes that of the bank seat and its applied loads. Zone II shall be designed as a retaining wall ignoring any loading derived from the bank seat.

**6.10.2 (Additional clause) Design of base slabs supporting vehicle parapets**

The design of base slabs supporting vehicle parapets shall be in accordance with Annex B of this Standard unless the parapet supporting system is incorporated in a current BBA or equivalent certificate.




Zone I: Wall designed to carry loading including bridge abutment bank seat and its applied loads

Zone II: Wall designed to carry loads other than bridge abutment bank seat and its applied loads

**Figure 44A: Bridge abutments: Typical layout plans for strengthening elements**

**Section 7. Design of reinforced slopes**
Reinforced slopes are not implemented in this Standard and all clauses, tables and figures in this section are deleted.

**Section 8. Design of embankments with reinforced soil foundations on poor ground**
Reinforced soil foundations are not implemented in this Standard and all clauses, tables and figures in this section are deleted.

**Section 9. Construction and maintenance**

**9.1 General**
Replace existing paragraph with: "The recommendations in this section apply to the construction and maintenance of permanent highway structures employing the materials permitted in the Specification, this Standard and proprietary materials covered by a current BBA or equivalent certificate. As built, operational and maintenance records for highway structures shall be provided in accordance with BD 62 (DMRB 3.2.1)."

**9.2.3.2 Placing and compaction of fill**
Replace this clause with: "Fill shall be placed and compacted in accordance with clause 622 of the Specification for Highway Works [1]."

**9.2.3.3 Restrictions on fill**
Replace first paragraph of existing clause with: "Frictional and cohesive frictional fills, as well as selected other fills and industrial wastes as defined in **3.1.2.4.5**, that are permitted for reinforced soil walls and abutments are fairly easy to compact and are relatively free draining thereby avoiding the need for special drainage measures with the exception of those required for PFA as described in **3.1.2.4.2**.
In the second paragraph, replace "**3.1.2.1** and **3.1.2.4**" with: "**3.1.2.1** to **3.1.2.4**".
Delete last paragraph "Very fine soil should not ............of the fill without compaction."

**9.2.3.4 Use of chalk fill**
Replace "should" with "shall" throughout with the exception of the sentence beginning "It is recommended that ......work proceeds, [86]."

**9.2.3.6 Use of waste materials**
**9.2.3.6.1 General**
Delete "argillaceous materials,"
Delete "and colliery spoil"
Replace the sentence "The suitability of these materials .... and connections." with: "Suitable materials complying with the requirements of the Specification and this Standard have adequate frictional strength and will provide an environment that ensures a satisfactorily durable performance from the reinforcement, facing and connections."

**9.2.3.6.2 Argillaceous materials - delete clause.**
**9.2.3.6.3 Pulverised fuel ash**
Paragraph 4 after "should be formed from stainless steel in accordance with table 6" add "unless specified differently in a current BBA or equivalent certificate."
Delete the final paragraph.

**9.2.3.6.4 Colliery spoil** - delete clause.

**9.2.4 Reinforcement elements**
Add opening sentences: "The reinforcing elements shall normally be placed at right angles to the face of the wall with the greater cross-sectional dimension in the horizontal plane. If for any reason this is not possible (eg wing wall to a skew subway) then allowances shall be made in the calculation for the divergence of the elements."

**9.2.5 Facing**
**9.2.5.1 General**
After ".... final shape of the facing." in the first sentence add: "For aesthetic reasons, the face of walls over 3 m high should be constructed with a batter as detailed in the drawings. This would normally slope at an angle of 1 in 40 from the vertical except where plan curvature of the wall renders this impractical. To ensure the final required batter is attained, it may be necessary to construct with an initially larger batter to allow for the outward facing rotation induced by the compaction plant."
In item d) insert "foundation" after "fine grain".

**9.2.5.2 Hard facing**
Replace item c) with: "c) Flexible facing. These may be as shown in figure 16c and the panels are formed of curved metal sheet."

**9.2.5.3 Soft facing**
Replace existing clause with: "Soft facing is not permitted for permanent reinforced soil structures."

**9.2.6 Drainage**
**9.2.6.3 Drainage of the wall**
Replace "In other situations a longitudinal .... rodding the pipe are necessary." with:
"To collect and dispose of water percolating through the fill, thus avoiding the development of pressure behind the facing, a continuous system of perforated or porous drainpipes not less than 150 mm diameter, complying

with clause 501.3 of the Specification, shall be provided adjacent to the facing at the level of the mass concrete strip footing. The pipe may be placed at the rear of the facing, or in front as indicated in figure 79. For the latter case, weep holes shall be located in selected facing panels at the level of the strip footing.

Alternatively, where discrete facing panels are used, the drainage path to the pipe may be more easily provided by omitting the vertical joint filler between all the panels at the base of the wall within the embedment depth, figure 79. Note that a pipe located in front of the facing allows reinforced soil construction to commence without the interruption of drain laying amongst the reinforcements. There may also be difficulty in achieving the required fall in a pipe placed to the rear of the facing because of the presence of the reinforcements. For ease of maintenance, facilities shall be included for rodding the whole length of the system from inspection manholes positioned at the foot of the wall. A pipe in front of the facing provides easier access for rodding and reduces the scale of the facilities required for maintenance purposes. Weep holes above ground level in selected facing units situated at the foot of the wall provide a visual check that the system is functioning correctly.

In addition, drainage layers complying with clause 622.5 of the Specification (excluding crushed slag) shall be provided in the following situations:

**(i) Cohesive frictional fill**
A continuous vertical drainage layer not less than 0.3 m thick shall be used adjacent to the rear of the facing. The layer shall connect with the drainage system at the base of the structure. Additionally, where the structure is founded on an impervious stratum, consideration shall be given to the use of a horizontal drainage layer at foundation level to prevent water softening the fill and possibly forming a slip surface.

**(ii) Retained soil containing injurious soluble salts**
Where it is known that the retained soil will contain soluble material that could adversely affect the durability of the reinforcing elements, a continuous vertical drainage layer not less than 0.5 m thick shall be positioned at the rear of the reinforced fill. A horizontal drainage layer of the same thickness shall be provided at foundation level to connect with the vertical layer and the drainage system at the toe of the wall.

**(iii) When PFA is used as fill**
(a) a layer of frictional fill not less than 500 mm thick shall be placed on top of the PFA and below the road formation level. This layer shall connect with the vertical drainage layer described below.

(b) A vertical drainage layer of thickness not less than 300 mm of sand with grading C or M in table 5 of BS 882 shall be provided behind the facing. The layer shall connect with the drainage system at the base of the structure.

(c) A horizontal drainage layer 450 mm thick shall be placed beneath the PFA. The top 200 mm of this layer will be sand of grading C or M in table 5 of BS 882, the remaining 250 mm will be Type B material complying with clause 505 of the Specification. This layer shall connect with the drainage system at the base of the structure. This horizontal drainage layer may be omitted if the underlying soil is sufficiently permeable to ensure the fill is adequately drained.

(d) The components of the drainage system at the base of the structure shall be resistant to the effects of sulphates.

**(iv) When chalk is used as fill**
A 300mm wide granular drainage and frost blanket or similar measure shall be used against the back face or any facing units. Where appropriate this material shall be specified as frictional fill in accordance with **3.1.2.1** and **3.1.2.2**.

Alternative proprietary methods may be adopted if covered by a current BBA or equivalent certificate."

**9.2.7 Maintenance**
After "*management and maintenance* [91]" insert "and in BD 63 Inspection of highway structures (DMRB 3.1.4)."
At the end of the first paragraph add "Assessment of reinforced soil structures should be carried out in accordance with BD 21 The assessment of highway bridges and structures (DMRB 3.4.3) and BA 55 The assessment of bridge substructures and foundations (DMRB 3.4.9)."

**9.3 Slopes**

**9.3.1 General** delete clause.

**9.3.2 Foundations** delete clause.

**9.3.3 Reinforcing elements and fill** delete clause.

**9.3.4 Facing** delete clause.

**9.3.5 Drainage** delete clause.

**9.3.6 Slope reinstatement of fill slopes** delete clause.

**9.3.7 Construction of soil nailing**
**9.3.7.1 General**
Replace "the actual configuration .... general guidelines" with: "several factors such as construction configuration, type of nailing installation, cohesion of natural soil, and climatic conditions. Further details of the construction procedure are given in the subsequent clauses and more detailed model specification clauses in TRL Research Report 380 (Murray, 1993)."

**9.3.7.2 Construction sequence**
After "see figure 84." add "The extent of excavation to specific levels shall take place consistent with the height and length of excavated face that can stand unsupported until such time as the installed nailing system stabilises the stage of excavation. The facing shall be applied within the specified time period to avoid excessive exposure of the excavated soil face."

**9.3.7.3 Excavation**
Paragraph 4 after "shotcrete facing" insert ", or proprietary facing with a current BBA or equivalent certificate,".

**9.3.7.7 Drainage**
Delete "of the slope".

**9.4 Foundations** delete clause.

**9.5 Handling, storage and placing**
**9.5.1 General**
Replace "Any component or material .... similar principles." with: "Components or materials not covered in the Specification or this Standard shall be handled and stored according to the requirements of a current BBA or equivalent certificate."

**9.5.3 Metallic reinforcement**
**9.5.3.1 General**
Replace "should be allowed ........ sections 3 and 4." with: "may be used if they hold a current BBA or equivalent certificate that conforms to the requirements of the Specification and this Standard."

**9.5.3.4 Placing**
Replace "less than two times the reinforcement thickness" with: "less than ten times the reinforcement thickness".
Replace the end of the last sentence with: "Small areas of galvanised coating damaged during handling may be repaired within the limit of 40 $mm^2$ for each damaged area and to the procedures specified in BS 729:1986. Reinforcement damaged beyond this limit shall be rejected."

**9.5.4 Polymeric reinforcement**
**9.5.4.1 General**
Replace "Where the recommendations ............ or the manufacturer." with: "The procedures for handling, storage and placement of polymeric reinforcement shall be in accordance with the requirements of a current BBA or equivalent certificate. Some general guidance on these procedures is given in the following clauses but the methods described in the certification shall take precedence over this guidance."

**9.5.4.3 Storage**
Add to the end of the second paragraph: "Total exposure to light between manufacture and covering in the works shall not exceed the duration specified in a current BBA or equivalent certificate."

**9.5.4.4 Placing**
Delete "or slopes" through the clause.
Delete "or slope" through the clause.
Paragraph 5 delete "and **9.3** and ......... in **9.4**."
Replace "and may be connected ............ 200-300 mm should be provided." with: "and connected to hard facing."

**9.5.4.5.2 Geotextile materials**
Replace "Joints in the length ........... on site edge preparation." with: "Such joints that are permitted with proprietary reinforcing elements, shall be made in accordance with the procedures described in a current BBA or equivalent certificate."

**9.5.4.5.3 Type of seam -** delete clause.

**9.5.4.5.4 Stitch configuration -** delete clause.

**9.5.4.5.5 Stitch density -** delete clause.

**9.5.4.5.6 Sewing thread -** delete clause.

**9.5.4.5.7 Sewing machines -** delete clause.

**9.5.4.6 Jointing of geogrids**
Replace existing clause with: "Such joints that are permitted with proprietary reinforcing elements, shall be made in accordance with the procedures described in a current BBA or equivalent certificate."

**9.6 (Additional clause) Superimposed structures and services**

**9.6.1 Bridge abutment bank seat**

Where differential settlement occurring along the length of the bank seat would be detrimental to the bridge, the design should include provision for jacking the superstructure.

**9.6.2 Parapets and guard rails**

In the design of post-base connections, consideration shall be given to the need for possible re-alignment where differential settlement of the completed structure may cause undesirable visual effects.

Joints between precast capping units should be sealed where contaminated water could percolate into the reinforced fill. The units and any in situ slab should not extend beneath the nearside traffic lane of flexible carriageway construction because this may induce reflective cracking of the surfacing.

**9.6.3 Lighting columns**

Soil movements may adversely affect the alignment of lighting columns and hence the position of lanterns. The location of column foundations should therefore be carefully considered. Founding at the foot of the wall, with the column guided at capping level, may provide a suitable solution to the problem. For part height walls only, columns may be located in the embankment side slope above the reinforced zone.

**9.6.4 Services**

Owing to the multiplicity of services and their possible configurations it is not possible to give more than some general guidance for design. The possible effects arising from the presence of services in, on, over or in the vicinity of a permanent highway structure shall be examined. It is also necessary to consider the installation, maintenance and removal of services under normal and failure conditions. The appropriate authorities should be consulted at the design stage.

In full height walls, services should be carried in ducts or in a service bay above the reinforced zone, preferably incorporated in the parapet base detail. In part height walls, services should be carried in the embankment above the reinforced soil structure.

If at all possible, water mains should be sited clear of permanent highway structures. Where this is not possible, every effort should be made to avoid the disastrous effects which could be caused by a burst water main. Suitable expedients, eg sleeving or location in drained reinforced concrete service bays, should be agreed with the appropriate authority at the design stage.

**Figure 75** - delete figure.

**Figure 81** - delete figure.

**Figure 82** - delete figure.

**Figure 83** - delete figure.

**Figure 85** - delete figure.

**Figure 86** - delete figure.

**Figure 87** - delete figure.

**Figure 88** - delete figure.

**Figure 89** - delete figure.

**ANNEXES**

**Annex A (normative)**
**Assessment of partial material factors for reinforcements**

**A.1 Reinforcement design strength**

**A.1.1 General**

In the first sentence delete “In walls, slopes and certain foundation applications”.
Delete the third paragraph “A clear distinction is ........ equal or exceed the design load.”
Replace fourth paragraph “ In the case of walls .... after the end of construction.” with:
“As the design load of walls is assumed to remain constant over the required design life, the design strength to be defined is that prevailing at the end of the required design life.”

**A.3.2 Partial material factor $f_{m11}$**

**A.3.2.1 General**

In the second paragraph replace “code” with “Standard”.

**A.3.2.2 Partial material factor $f_{m111}$**

After “BS EN ISO 9002” add “in conjunction with a suitable product specification”

**A.3.2.3 Partial material factor $f_{m112}$**

Replace the second sentence “The reinforcement base strength ...... unity should be used.” with: “The reinforcement base strength shall be based upon the minimum permitted cross-section and the partial factor $f_{m112}$ shall be taken as 1.0.”

**A.3.3 Partial material factor $f_{m12}$**
**A.3.3.3 Partial material factor $f_{m122}$**
Replace the second paragraph "Real time creep tests ......10% of the design life." with: "The minimum duration of creep tests shall be 10,000 hours."

**A.4** Replace **"Partial material factor $f_{m3}$"** with **"Partial material factor $f_{m2}$"**

**A.4.2 Partial material factor $f_{m21}$**
**A.4.2.2 Metallic reinforcements**
Replace the sentences "For thinner reinforcements ....... on the basis of experience or site trials." with: "For systems employing materials not specified in clause 6.1 of this Standard or in the Specification, the value of partial factor $f_{m21}$ shall be in accordance with that given in a current BBA or equivalent certificate and shall have been determined from site damage trials following the procedures described in Annex D."

**A.4.2.3 Polymeric reinforcements**
Replace "If handling and storage ..... particularly compaction plant" with: "Handling and storage on site shall be carried out in accordance with **9.5** of this Standard. The degree of damage sustained by such handling and storage is related to the structure of the reinforcements, their method of placement, and the type of fill and the nature and use of construction plant, particularly compaction plant."
Replace the second paragraph by "For systems employing polymeric reinforcements, the value of partial factor $f_{m21}$ shall be in accordance with that given in a current BBA or equivalent certificate and shall have been determined from site damage trials following the procedures described in Annex D."

**Annex D (Normative)**
**Site damage test**
**D.1 Introduction**
In the first paragraph replace "Alternatively, other ..... following clauses." with: "Other test layouts, configurations and procedures shall only be used if prior approval in writing has been obtained or where such details comply with a current BBA or equivalent certificate."

**D.2 Test site**
In the second paragraph delete "Where the reinforcement ...... or fill slope,".
Delete third paragraph "Where the reinforcement ..... installation of the reinforcement."

**D.4 Fill materials**
In the second paragraph replace "Code" with "Standard".

**Annex G (Informative)**
**Propping forces**
Replace inequality in second paragraph with:
"height $H/2 < h_p < H$ and where ....".

In **List of references, Other references** add "Reid J.M., Czerewko M.A. and Cripps J.C., Sulfate specification for structural backfills. TRL Report 447, Crowthorne Berkshire, 2001."

**Replace "should" by "shall" throughout the following clauses:**

**3.1.2.2 Chemical and electro-chemical criteria**
**3.1.2.3 Cohesive fill**
**3.3.3 Facing unit joint filler materials**
**3.3.3.1 General**
**4.3.6.2 Tensile strength and creep properties**
**5.5 Serviceability**
**5.6.1.3.2 Methods of investigation and sampling**
**5.6.1.3.3 Ground water**
**5.6.1.3.4 Data presentation and reporting**
**5.6.1.4 Investigation during construction**
**5.6.2 Environmental considerations**
**5.6.2.1 General**
**5.6.2.2 Chemical and biological considerations**
**5.6.2.3 Post construction damage**
**5.6.2.4 Adjacent structures**
**5.6.3 Load combinations**
**5.6.4 Design record**
**6.2.2 Load factors**
**Notes to tables 17 and 18**
**6.2.3 Materials factors**
**6.4.2 Embedment**
**6.5 External stability**
**6.5.1 General**
**6.5.5 External slip surfaces**
**6.7.3 Structural loads on facing**
**6.8 Connections**
**9.2 Construction and maintenance of walls and abutments**
**9.3 Slopes**
**9.5.2 Soils and other fills**
**9.5.3.2 Handling**
**9.5.3.3 Storage**
**9.5.3.4 Placing**
**9.5.4.2 Handling**
**9.5.4.3 Storage**
**9.5.4.4 Placing**
**9.5.4.5 Sewing of geotextiles**
**9.5.4.5.1** General
**9.5.4.5.2** Geotextile materials
**A.1.2 Metallic reinforcement**
**A.1.3 Polymeric reinforcement**
**A.2 Partial material factor $f_m$**

**A.3.2.2** Partial material factor $f_{m111}$
**A.3.2.3** Partial material factor $f_{m112}$
**A.4.3 Partial material factor $f_{m22}$**
**Annex C (Normative) Determination of effective angle of internal friction (φ') and effective cohesion c' of earthworks materials**
**D.2 Test site**
**D.3 Arrangement of the reinforcement**
**D.4 Fill materials**
**D.5 Compaction plant**
**D.6 Compaction**
**D.7 Site testing**
**D.8 Recovery of the reinforcement**
**D.9 Preparation of samples**
**D.10 Visual assessment of site damage**
**D.11 Reinforcement test method**
**Annex E (Normative) Determination of coefficient of friction and adhesion between fill and reinforcing elements or anchor elements for reinforced soil and anchored earth structure.**

# ANNEX B DESIGN OF BASE SLABS SUPPORTING VEHICLE PARAPETS

**Contents**

**Chapter**

# B1. INTRODUCTION

The use of this annex is mandatory.

**General**

B1.1 This Annex gives guidance on the design of base slabs supporting vehicle and vehicle/pedestrian parapets founded on strengthened/reinforced soil structures, and also on determining the load effects to be used in the design of strengthened/reinforced soil structures which support such base slabs.

**Scope**

B1.2 This Annex covers the design of reinforced concrete base slabs to resist vehicular collision loads on the metal, concrete, and combined metal and concrete vehicle and vehicle/pedestrian parapets which they support: concrete components may be either pre-cast or cast in situ. It also covers the design of the strengthened/reinforced soil structure on which such base slabs are founded.

B1.3 This Annex is not applicable to:

(i) Parapet-supporting structures, which form an integral part of a bridge deck, bridge abutment or retaining wall - including the facing units to a strengthened/reinforced soil structure.

(ii) Base slabs which are not founded directly on a strengthened/reinforced soil structure.

(iii) Base slabs which support parapets that are not intended to contain vehicles.

Further, this Annex does not cover:

(i) The design of parapets, their attachment systems and anchorage units – refer to BD 52 (DMRB 2.3.3).

(ii) The geometrical requirements of plinths to metal parapets and to those that form part of a combined metal and concrete parapet – refer to BD 52 (DMRB 2.3.3).

**Definitions**

B1.4 The following definitions are used in addition to those given in BS 8006: 1995.

*Vehicle restraint system*: installation to provide a level of containment for an errant vehicle which may be used to limit damage or injury to users of the highway.

*Highway parapet*: a barrier at the edge of a bridge, or on top of a retaining wall or similar structure, associated with a highway.

*Vehicle parapet*: highway parapet that acts as a vehicle restraint system.

*Vehicle pedestrian parapet*: vehicle parapet with additional safety features for pedestrians and animals.

*Attachment system*: the system of attachment of the parapet to the anchorage, usually consisting of holding-down bolts.

*Anchorage*: that part contained within the parapet-supporting base slab to which the parapet is directly fixed by means of the attachment system.

**Symbols**

B1.5 The following symbols are used.

$\alpha$ Coefficient of frictional interaction between the base slab and the fill

$\phi'_{cv}$ Critical state angle of shearing resistance

$\phi'_{des}$ Design angle of shearing resistance

$\phi'_{p}$ Peak angle of shearing resistance

$\gamma_{f3}$ Partial safety factor for load effects

$\gamma_{fL}$ Partial safety factor for load

$\gamma_{m}$ Partial safety factor for material properties

$b$ Effective width of parapet-supporting base slab

$B$ Width of the parapet-supporting base slab

$e$ Eccentricity of resultant force

$f_{des}$ Design strength

$f_k$ Characteristic strength, or equivalent nominal value

$M$ Factor to account for partial mobilisation of strength of fill

$M_D$ Design disturbing moment

$M_R$ Design restoring moment

$P_N$ Component of design load acting normal to plane under consideration

$P_T$ Component of design load acting parallel to plane under consideration

$Q^*$ Design load

$Q_k$ Nominal load

$R^*$ Design resistance

$R^*_S$ Design sliding resistance

$S^*$ Design load effect

# B2. DESIGN OF BASE SLABS TO RESIST VEHICULAR COLLISION EFFECTS

**General**

B2.1 Base slabs supporting vehicle and vehicle/ pedestrian parapets shall be designed for vehicular collision effects on the supported parapets. The load effects to be taken into account include those due to dead loads, vehicle collision or parapet failure, associated live loads, wind and earth pressures, all in accordance with BS 8006, except where superseded by clauses in this Annex.

B2.2 To facilitate the replacement or repair of a parapet following a vehicle collision, a progressive increase in resistance shall be provided from the point of impact to the supporting base slab.

B2.3 A base slab shall be designed to resist all the loads which the parapet is capable of transmitting, up to and including failure in any mode that might be induced by a vehicle collision, without damage to the base slab or the structure upon which it is founded. The loads transmitted by a vehicle collision generate (a) 'local effects', ie acting on the supporting elements in the vicinity of the impact and (b) 'global effects' ie acting on the structure as a whole. The requirements for considering (a) and (b) vary according to the relative masses of the containment system and supporting structure because these control the degree of attenuation of the collision forces.

B2.3.1 With low and normal levels of containment parapets the design loads due to vehicle collision could be exceeded and the parapet posts are designed to achieve their full plastic moment before either the attachment system or anchorage fails, so design of the supporting base slab is based on the ultimate capacity of the parapet posts. Therefore the base slab for low and normal levels of containment parapets shall be designed to take account of loads due to 'local effects' only. The 'global effects' of vehicle collision need not be considered for low and normal levels of containment parapets.

B2.3.2 However, high level of containment parapets resist much greater design loads due to vehicle collision. Therefore the base slab for high level of containment parapets shall be designed to take account of loads due to both 'local effects' and 'global effects'.

B2.3.3 The 'local effects' of the loads resulting from a vehicle collision with a low, normal or high level of containment parapets shall be considered in the design of the elements supporting the parapet. The 'local effects' of the loads, given in B2.11.1, shall be considered for the following.

(i) Sliding of the base slab.

(i) Toppling of the base slab.

(i) Rupture of the base slab.

Note: For low and normal levels of containment parapets, it is not necessary to consider the failure of the supporting strengthened/reinforced soil structure, as given in Chapter B3, because only "local effects" need to be dealt with.

B2.3.4 The 'global effects' of the loads resulting from a vehicle collision with high level of containment parapets shall be considered in the design of the elements supporting the parapet, but such effects need not be considered for collisions with other types of parapet. The 'global effects' of the loads, given in B2.11.2, shall be considered for the following:

(i) Sliding of the base slab.

(ii) Toppling of the base slab.

(iii) Rupture of the base slab.

(iv) The failure of the supporting strengthened/ reinforced soil structure: this is dealt with in Chapter B3.

B2.3.5 'Global effect' loads shall be considered separately from 'local effect' loads.

B2.4 The recommended design sequence is summarised in Figure B2.1.

**Design life**

B2.5 The design life of a base slab to a detachable parapet shall be taken as 120 years. The design life of a base slab constructed integrally with the parapet shall be taken to be the same as for the parapet.

**Structural adequacy**

B2.6 A partial factor limit state approach to design is adopted. With this the design value of a load ($Q^*$) is determined from its nominal value ($Q_k$) by the relation,

$$Q^* = \gamma_{fL} \cdot Q_k$$

the design load effect ($S^*$) is obtained from the design load by the relation,

$$S^* = \gamma_{f3} \cdot (\textit{effects of } Q^*)$$

the design resistance ($R^*$) is defined as follows,

$$R^* = \textit{function}\ (f_{des}) = \textit{function}\ \left(\frac{f_k}{\gamma_m}\right)$$

where $f_{des}$ is the design strength, and
$f_k$ is the characteristic strength or its equivalent nominal value,

and for all appropriate combinations of load effects, the following shall be satisfied:

$$\sum R^* > \sum S^*$$

where $\sum R^*$ and $\sum S^*$ are the summed design resistances and load effects respectively.

**Limit states**

B2.7 To ensure both an adequate degree of safety and serviceability, parapet-supporting base slabs shall be designed for both the ultimate and serviceability limit states.

For the *ultimate limit state (ULS)*, design shall ensure that the structure is sufficiently strong and stable to withstand the design load effects, taking due account of the possibility of toppling, sliding and rupture.

For the *serviceability limit state (SLS)*, design shall ensure that under normal service conditions the structure will not suffer damage that would reduce its intended service life or incur excessive maintenance costs. Due account shall be taken of the possibility of excessive movements induced by vehicular collision on the supported parapet.

**Partial factors**

B2.8 The following partial factors are used:

(i) $\gamma_{fL}$ - the load factor whose value should take account of the possibility of an unfavourable deviation of a load from its nominal value, and of the reduced probability that various loads acting together will attain their nominal values simultaneously.

Values of $\gamma_{fL}$ for various loads are given in BD 37 (DMRB 1.3): values applicable to the loads generated on a parapet through a vehicle collision are given in Clause B2.11 for ULS and Clause B2.18 for SLS.

(ii) $\gamma_{f3}$ - the load effect factor whose value should take account of the inaccurate assessment of the effects of loading, unforeseen stress distribution within the structure, and variations in the dimensional accuracy achieved in construction.

Values of $\gamma_{f3}$ for various cases are given in BD 24 (DMRB 1.3.1): values applicable to the design of a parapet-supporting base slab are given in Clauses B2.15 and B2.18.

(iii) $\gamma_m$ - the material factor whose value should cover for possible reductions in the strength of the materials in the structure as a whole, compared with the characteristic or nominal value deduced from control test specimens, and possible weaknesses in the structure due to, for example, manufacturing tolerances and compaction operations.

Values of $\gamma_m$ for concrete components are given in BD 24 (DMRB 1.3.1).

**Loads**

B2.9 The nominal value of a load shall be appropriate to a return period equal to the design life of the base slab: appropriate values for various loads for a return period of 120 years are given in BD 37 (DMRB 1.3). The nominal loads arising from a vehicle collision with a parapet are given in Clause B2.11.

B2.10 The combinations of load to be considered in design, and the values of $\gamma_{fL}$ for each combination, shall be in accordance with BD 37 (DMRB 1.3) except where superseded by this Annex. Where the combined dead load of the self weight of the base slab and fill on top of the base slab have a disturbing effect, the value of $\gamma_{fL}$ applied to the dead load shall be increased to 1.5 in accordance with the recommendations of BS 8006 as implemented by BD 70 (DMRB 2.1.5).

**Loads due to vehicle collision with parapets**

B2.11 Clause 6.7 of BD 37 (DMRB 1.3.1) shall be superseded by the following:

B2.11.1 Loads due to vehicle collision with low, normal and high levels of containment parapets for determining ‘local effects’:

B2.11.1.1 Nominal collision loads: in the design of a parapet-supporting base slab and the strengthened/ reinforced soil structure on which the base slab is founded, the following nominal collision loads resulting from a vehicle collision with a parapet shall be considered.

For concrete parapets (high and normal levels of containment) - the calculated ultimate design moment of resistance and the calculated ultimate design shear resistance of any 4.5 m length of parapet applied uniformly over that length (ie with $\gamma_m$=1).

For metal parapets (low, normal and high levels of containment) – the nominal collision loads are the more critical of (i) or (ii) below.

(i) the calculated ultimate design moment of resistance of a post applied at each base of up to three adjacent posts combined with a shear force which is the lesser of:

  (a) the calculated force from ultimate design moment of resistance of a parapet post, ie with $\gamma_m$=1, divided by the height of the centroid of all the effective longitudinal members above the base of the parapet applied at each base of up to any three adjacent parapet posts, or,

  (b) the calculated ultimate design shear resistance of a parapet post, ie with $\gamma_m$=1, applied at each base of up to any three adjacent parapet posts.

(ii) the calculated ultimate design moment of resistance of a post applied at the base of a single post combined with a shear force which is the lesser of:

  (a) the calculated ultimate design moment of resistance of the parapet post, ie with $\gamma_m$=1, divided by the height of the centroid of the lowest effective longitudinal member above the base of the parapet applied at the base of the post, or

  (b) the calculated ultimate design shear resistance of a parapet post, ie with $\gamma_m$=1, applied at the base of the post.

In the case of all high level of containment parapets, an additional single vertical load of 175kN shall be applied uniformly over a length of 3m at the top of the front face of the parapet. The loaded length shall be in that position which will produce the most severe effect on the member under consideration.

B2.11.1.2 Associated nominal primary live load: where it has an adverse effect, the nominal primary live load shall be represented by the HA surcharge load of 10 kN/m$^2$ and shall be considered to act in combination with the loads arising from a vehicle collision with a parapet. The associated nominal primary live load may be taken to act only on the plinth base slab and not on any surfaces adjacent to the plinth base slab. The associated nominal primary live load shall be ignored where it has a relieving effect.

B2.11.1.3 Load combination: the loads arising from a vehicle collision with a parapet shall be considered in combination 4 only, as defined in Table 1 of BD 37 (DMRB 1.3), and need not be taken to coexist with other secondary live loads.

B2.11.1.4 Design load: the values of $\gamma_{fL}$ to be applied to the nominal collision loads and the associated nominal primary live load shall be as follows:

| **Loading** | **$\gamma_{fL}$ values for the ultimate limit state** | |
|---|---|---|
| | **Low and normal levels of containment parapets** | **High level of containment parapet** |
| Loads arising from a vehicle collision with a parapet | 1.50 | 1.40 |
| Adverse associated primary live load | 1.30 | 1.30 |

B2.11.2 Loads due to vehicle collision with high level of containment parapets for determining 'global effects'

B2.11.2.1 Nominal collision loads: in the design of the base slab and the supporting strengthened/reinforced soil structure, the following nominal collision loads shall be applied at the top of the traffic face of a high level of containment parapet.

(i) a horizontal transverse load of 500 kN,

(ii) a horizontal longitudinal load of 100 kN,

(iii) a vertical load of 175 kN.

The loads shall be applied uniformly over a length of 3 m measured along the line of the parapet. The position of the loaded length shall be such that it produces the most severe effect on the part of the structure under consideration.

B2.11.2.2 Associated nominal primary live load: where it has an adverse effect, the nominal primary live load shall be represented by the HA surcharge load of 10 $kN/m^2$ and shall be considered to act in combination with the loads arising from a vehicle collision with a high level of containment parapet. The associated nominal primary live load may be taken to act only on the plinth base slab and not on any surfaces adjacent to the plinth base slab. This load shall be applied so that it will have the most severe effect on the element under consideration. However the nominal primary live load shall be ignored where it has a relieving effect.

B2.11.2.3 Load combination: the loads arising from a vehicle collision with a parapet shall be considered in combination 4 only, as defined in Table 1 of BD 37 (DMRB 1.3), and need not be taken to coexist with other secondary live loads.

B2.11.2.4 Design loads: the values of $\gamma_{fL}$ to be applied to the nominal collision loads and the associated nominal primary live load shall be as follows:

| **Loading** | **$\gamma_{fL}$ values for the ultimate limit state** |
|---|---|
| Loads arising from a vehicle collision with a high level of containment parapet | 1.40 |
| Adverse associated primary live load | 1.25 |

**Earth pressures**

B2.12 The magnitude and distribution of earth pressures shall be calculated in accordance with the principles of soil mechanics.

**Pore water pressures**

B2.13 Where necessary account shall be taken of pore water pressures, but the stabilising effect of negative pore water pressures shall be ignored.

**Dispersal of load**

B2.14 It may be assumed that the load effects are dispersed vertically through any upstand plinth to the base slab as well as longitudinally through the base slab at a length-to-depth ratio of 1 longitudinally to 1 vertically and a length-to-width ratio of 1 longitudinally to 1 transversely, as shown in Figure B2.2. Longitudinal dispersal shall not be assumed to occur across a transverse joint in the base slab unless adequate shear connection is provided.

**Ultimate limit states of base slab foundation**

B2.15 For the design of the foundation for those load arrangements associated with the collapse of a parapet, which may or may not include the associated primary live load, $\gamma_{f3}$ shall be taken as 1.0. For all other load combinations $\gamma_{f3}$ shall be taken as 1.1 for the ULS, and 1.0 for the SLS. (Note: see clause B2.17 for values of $\gamma_{f3}$ for structural design.)

(i) Toppling of base slab: the potential for rotation about the toe of the base slab shall be checked, with the following condition being satisfied for all appropriate combinations of load:

$$\sum M_R > \gamma_{f3} \cdot \sum M_D$$

where $\sum M_R$ is the sum of the design restoring moments, and

$\sum M_D$ is the sum of the design disturbing moments.

Note that sizing a base slab by considering toppling alone may lead to high bearing pressures at the toe of the base slab, and the dimensions of a base slab may be governed by the requirements to limit settlement of the base slab – see Clause B2.18 below – and the pressures acting on the supporting structure beneath it - see Chapter B3.

(ii) Sliding of base slab: the potential for sliding between the base slab and the founding strengthened/reinforced soil structure shall be checked, with the following condition being satisfied for all appropriate combinations of load:

$$\sum R^*_S > \gamma_{f3} \cdot \sum P_T$$

where $\sum R^*_S$ is the sum of the design sliding resistances generated along the potential failure plane, and

$\sum P_T$ is the sum of the design load components acting parallel to the potential failure plane.

The design sliding resistance at the soil/concrete interface shall be assessed, using effective stress parameters, through the relation:

$$R^*_S = P_N \alpha(\tan \phi_p) / f_{ms}$$

where $P_N$ is the design value of the normal component of the resultant force acting on the interface,

$\alpha$ may be assumed to have a value of 1.0 for cast in situ base slabs and 0.75 for pre-cast base slabs, but different values may be used where they are supported by measurements, and

$\phi'_p$ is the peak angle of shearing resistance of the fill beneath the base slab,

$f_{ms}$ is a partial factor against sliding, which shall be taken as 1.2.

The effects of effective cohesion shall be ignored.

**Serviceability limit state of base slab foundation**

B2.16 Differential settlement of base slab under collision loading: excessive tilting of the base slab may lead to spalling of concrete around the junction of the base slab and uppermost facing panel. Permanent deflection may affect the appearance due to a poor line along the stringcourse, make it difficult to realign the replacement parapet, and perhaps lead to cracking of the road pavement at the end of the slab. The dimensions of a base slab may therefore be governed by the requirement to limit the settlement of the slab.

Transient, and perhaps also permanent, deflection of a base slab might be generated by concentrated traffic loads acting on the base slab and by a vehicle collision on the parapet. Thus differential settlement can be assessed by considering the effects of the design traffic load and of vehicle collision loading acting independently of the other loads.

***Load model***

For convenience, the primary traffic load can be modeled using the Type HA surcharge load, which is a uniformly distributed load of 10 $kN/m^2$.

***Limiting deflection***

Whilst it is difficult to establish a limiting deflection for all situations, in most cases it would be appropriate to limit the effect of loads (other than dead loads) to the generation of a settlement of 5 mm at the toe of the slab.

***Method of analysis***

There are a number of problems in calculating the deflection of a base slab, not least the possible interaction of the slab and the upper part of the wall: deflection at the toe of the slab might well be increased by any outward movement of the wall. Furthermore, in general, a static analysis will be carried out to represent a dynamic event. A number of options are available including the use of complex methods of analysis, such as finite elements, and 'elastic' stress equations, as given in texts such as Poulos and Davis (1974). In most cases a complex method would not be justified for this limit mode.

When determining the bearing capacity of a base slab, it is essential that the inclination of the applied load be taken into account. A number of methods are available including the following:

(i) That due to Meyerhof where the pressure distribution beneath a base slab is assumed to be uniform over an effective width b as shown in Figure B2.3 and given by;

$$b = B - 2e$$

where $B$ is the width of the base slab, and

$e$ is the eccentricity of the resultant design load acting at the interface.

(This approach is also described in Clause 6.5.2 of BS 8006: 1995).

(ii) From equations given in standard texts and Standards, such as Appendix D of the draft BS EN 1997-1 (CEN, 1999).

***Partial safety factors***

There will be some uncertainty in the method of analysis used to estimate settlement. The reliance that can be placed on the results of any of the methods is best assessed by the designer: in this case it would be inappropriate to substitute engineering judgement by a fixed value of $\gamma_{f3.}$

Similarly, the appropriate value of $\gamma_m$ to be applied to the measure of 'stiffness' will vary widely according to its derivation. For the sake of simplicity and economy in design, a value of $\gamma_m$ of unity should be used in combination with a reasonably cautious estimate of 'mean stiffness' of the backfill over the appropriate stress range.

The partial factors for the loads to be considered shall be as follows:

| **Loading** | **$\gamma_{fL}$ values for the serviceability limit state** | |
|---|---|---|
| | **Low and normal levels of containment parapet** | **High level of containment parapet** |
| Dead load of base slab | 1.0 | 1.0 |
| Dead load of fill on top of the base slab | 1.0 | 1.0 |
| Loads arising from vehicle collision with a parapet | 1.20 | 1.15 |
| Associated primary type HA traffic loading | 1.10 | 1.10 |

***Input data***

All the methods of analysis require some measure of the stiffness of the backfill. This could be assessed from the results of laboratory or field tests on the material, or be based on published data tempered by experience. It should be appreciated that the stiffness of a soil under a dynamic load can be substantially higher than under a static load.

Stiffness may be derived from the results of a one-dimensional compression test or a plate bearing test – and expressed for example as an 'E' or $M^*$ value (see, for example, BD 12 (DMRB 2.2.6)). It is difficult to ensure that the in situ characteristics of the material are reproduced by the laboratory test specimens. The results of plate bearing tests would also have to be extrapolated to the dimensions of the base slab.

**Structural design of base slab**

B2.17 Base slabs shall be designed in accordance with BD 24 (DMRB 1.3.1) except as noted in Clauses B2.18 and B2.19.

B2.18 Only load combinations 1 and 4 at the ULS, as given in Table 1 of BD 37 (DMRB 1.3), shall be considered.

B2.19 When a parapet is designed to be monolithic with its foundation slab, the parapet shall be designed with a predetermined failure section, ideally within the stem of the parapet and which is clearly visible to allow identification after an impact. Failure within the base slab should not be an option. Also when parapets are constructed monolithic with their foundations, consideration must be made to the practicality of repair or replacement of the parapet.

B2.20 For convenience, the live load surcharges shall be in accordance with Clause 5.8.2.1 of BD 37 (DMRB 1.3), ie Type HA load is a uniformly distributed load of 10 $kN/m^2$ ; Type HB load is a uniformly distributed load where 45 units HB = 20 $kN/m^2$, 30 units HB = 12 $kN/m^2$ and intermediate values are obtained by interpolation.

**Durability**

B2.21 Concrete cover to reinforcement shall be in accordance with BD 57 (DMRB 1.3.7).

B2.22 To prevent excessive cracking in concrete components due to shrinkage and thermal movements, reinforcement shall be provided in accordance with BD 28 (DMRB 1.3).

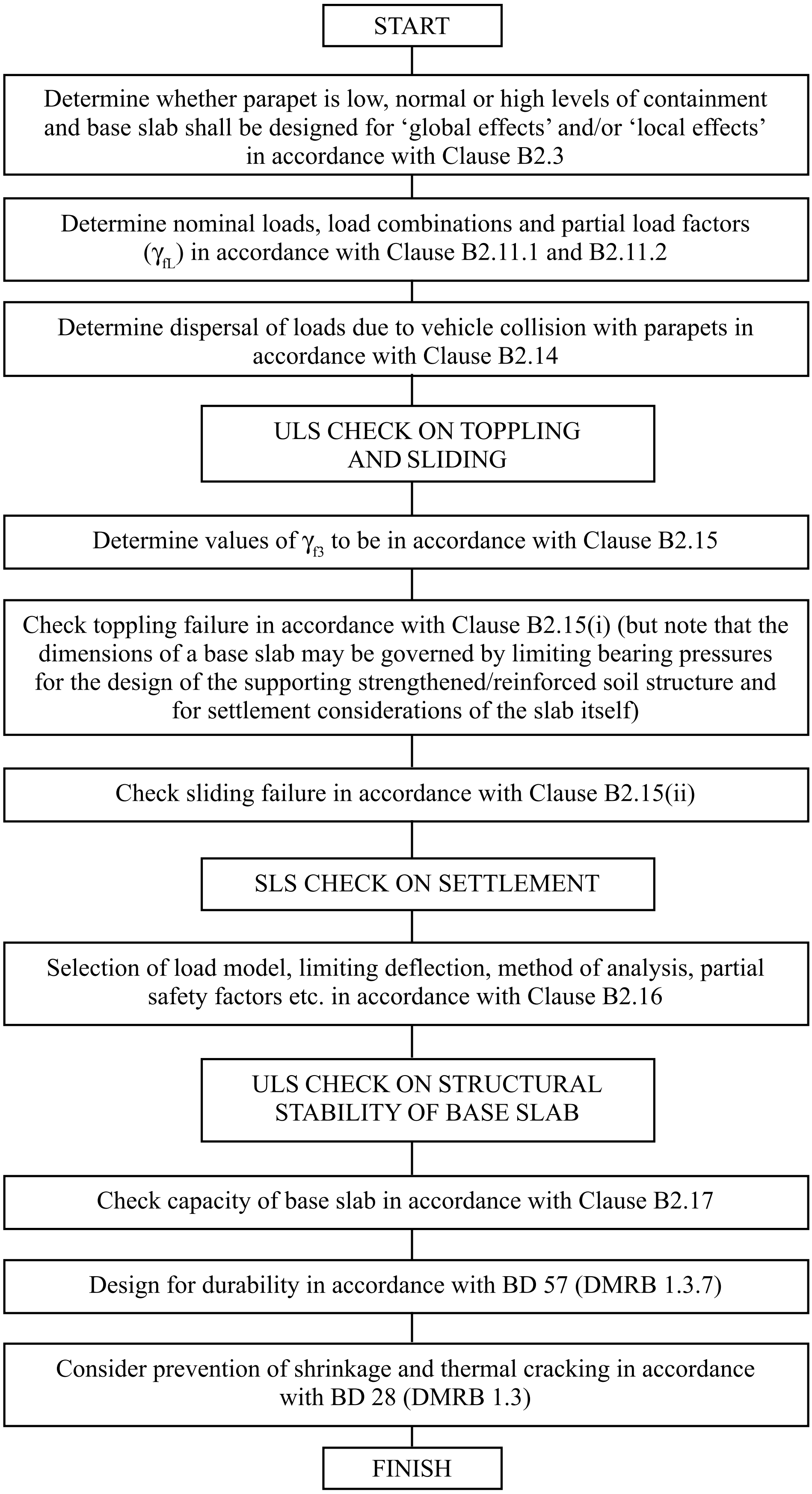



**Figure B2.1 Design sequence for parapet-supporting base slabs on strengthened/reinforced soil structures**

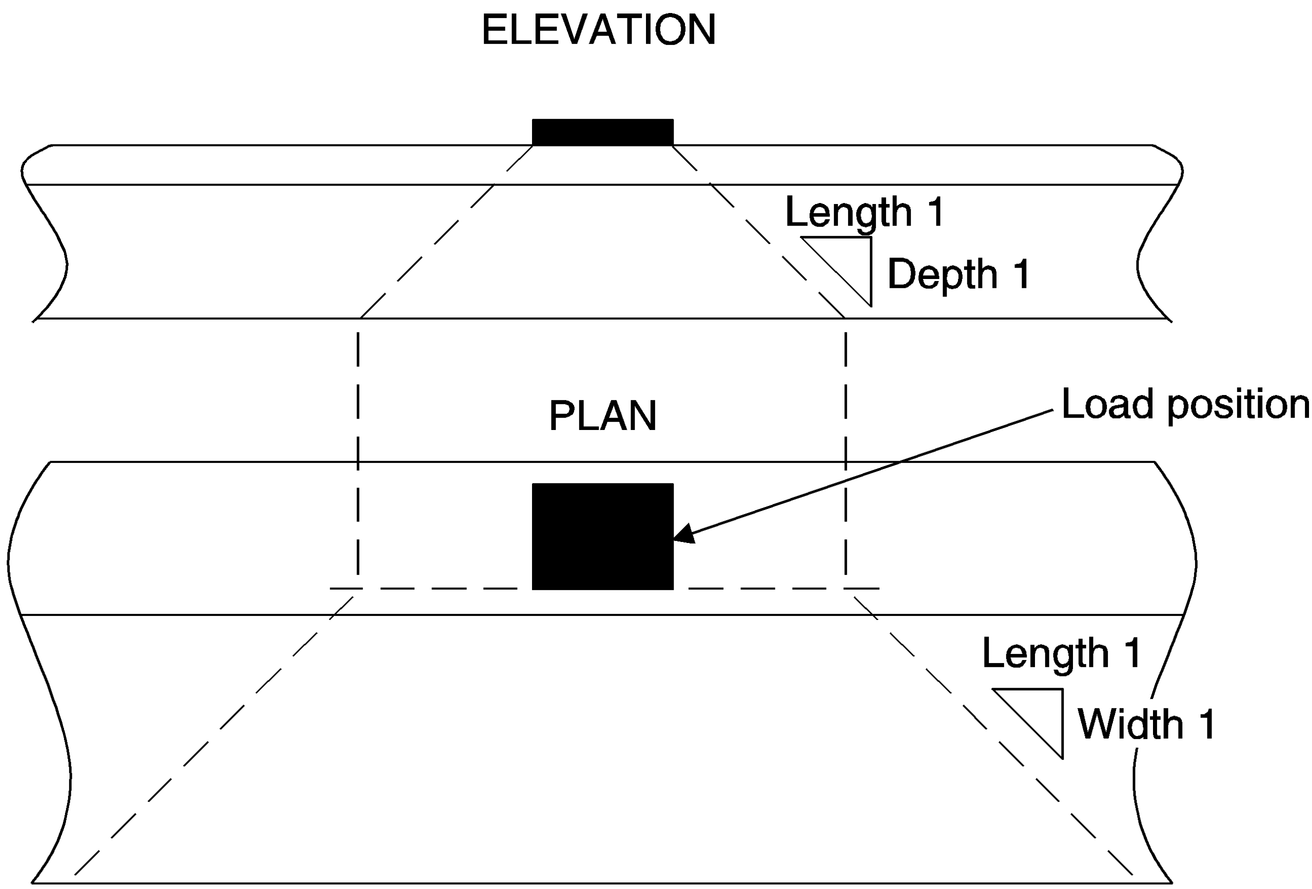



**Figure B2.2 Dispersal of load effects through a base slab**

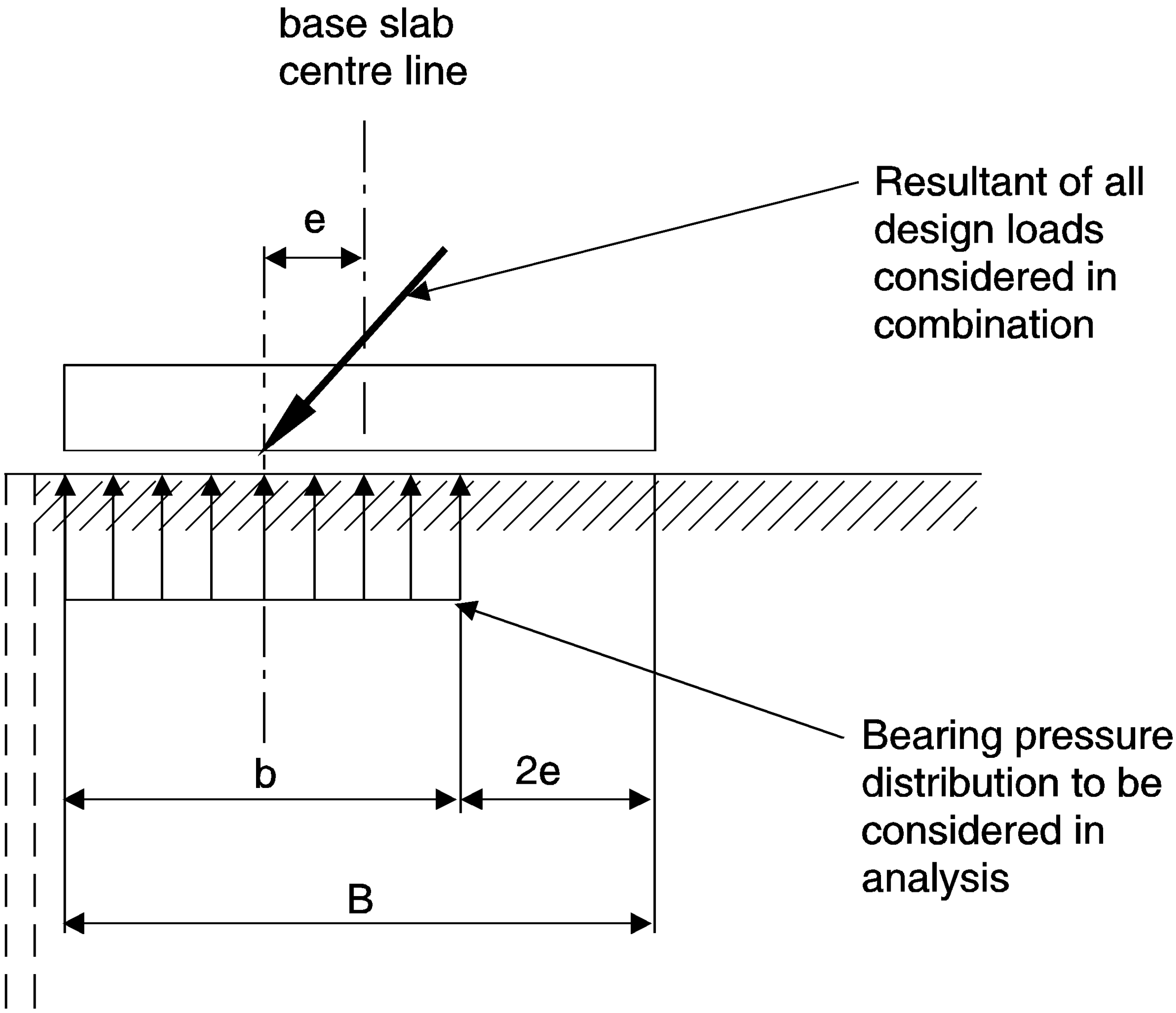



**Figure B2.3 Distribution of pressure beneath a base slab**

# B3. DESIGN OF STRENGTHENED/REINFORCED SOIL STRUCTURES SUPPORTING BASE SLABS TO HIGH LEVEL OF CONTAINMENT PARAPETS

**General**

B3.1 In addition to the requirements of BD 70 (DMRB 2.1.5), a strengthened/reinforced soil structure which supports a base slab to a high level of containment parapet shall be designed to resist the load effects resulting from a vehicle collision with the high level of containment parapet and an associated HA load. The load effects resulting from vehicle collisions with high level of containment parapets shall be determined in accordance with this Chapter.

Note: This section is not to be applied to strengthened/reinforced soil structures which support base slabs to parapets of low and normal levels of containment.

B3.2 The recommended design sequence is summarised in Figure B3.1.

**Design approach**

B3.3 A limit state approach to design shall be followed in accordance with Chapter 2 of BD 70 (DMRB 2.1.5). The values of the partial factors adopted shall be in accordance with Clause 2.3 of BD 70 (DMRB 2.1.5).

**Design life**

B3.4 The design life of a strengthened/reinforced soil structure supporting the base slab to a high level of containment parapet shall be in accordance with Clause 5.2 of BD 70 (DMRB 2.1.5).

**Loads**

B3.5 The loads on the strengthened/reinforced soil structure on which the base slab to a high level of containment parapet is founded shall be determined in accordance with BD 70 (DMRB 2.1.5) except where superseded by Clause B3.6.

B3.6 Loads arising from a vehicle collision with a high level of containment parapet shall be in accordance with Clauses B2.3 and B2.11.

B3.7 The horizontal and vertical load effects on a strengthened/reinforced soil structure arising from a vehicle collision with a high level of containment parapet shall be uniformly applied to an effective width determined according to Clause B2.14 and as shown in Figure B2.2. The horizontal and vertical load effects shall be dispersed within the reinforced soil structure in accordance with BS 8006 as implemented by BD 70 (DMRB 2.1.5).

B3.8 The pressure distribution beneath a base slab shall be assumed to be uniform over an effective width $b$ as given in Clause B2.16 and shown in Figure B2.3.

**Load combinations and partial load factors**

B3.9 The combinations of loads and partial load factors for each combination shall be in accordance with Clause 6.2 of BD 70 (DMRB 2.1.5). In addition, application of the collision load effects on the strengthened/reinforced soil structure due to the base slab of a high level of containment parapet shall be in accordance with Clauses B2.3 and B2.11.

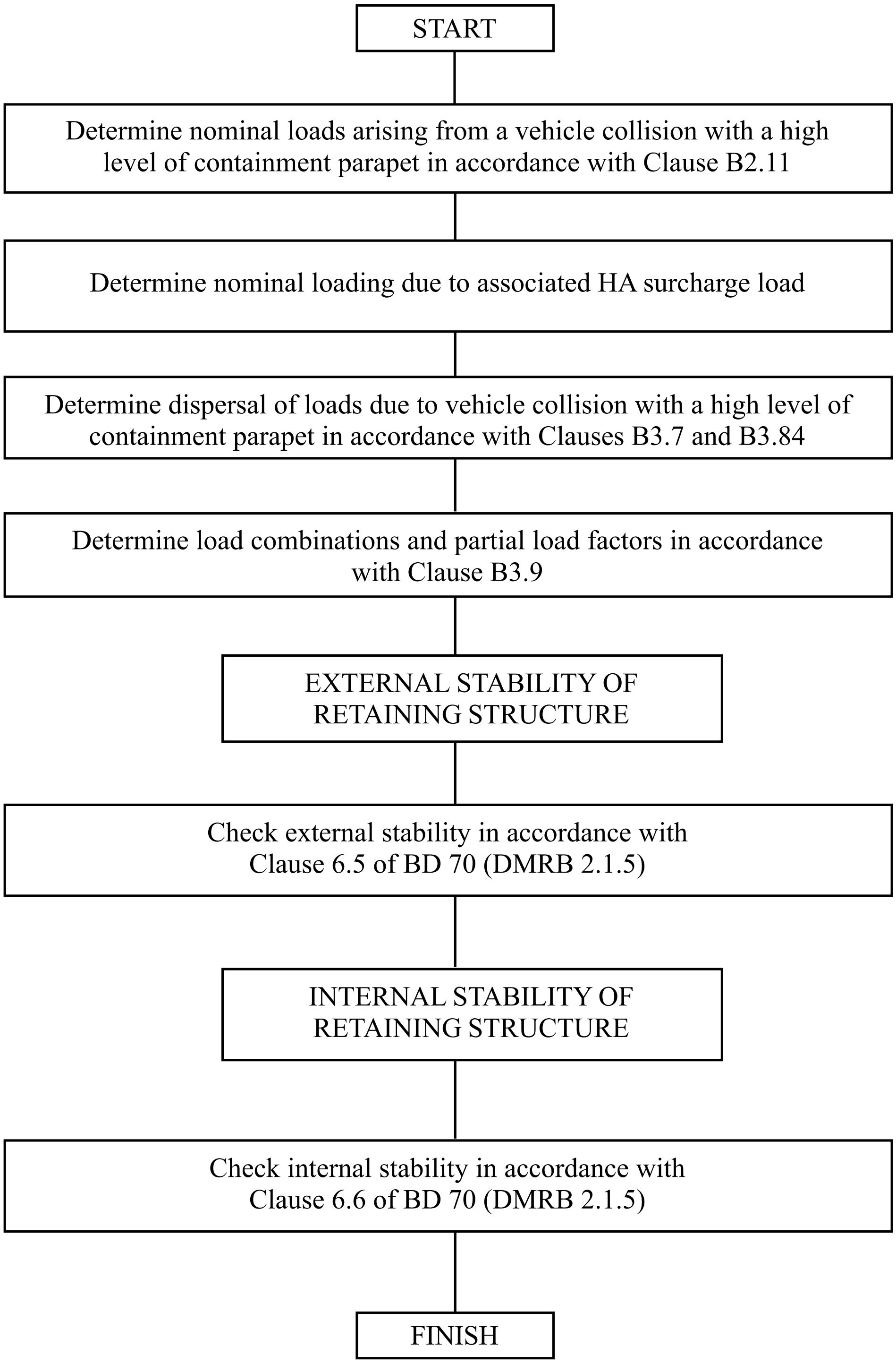



**Figure B3.1 Design sequence for a strengthened/reinforced soil structure that supports the base slab to a high level of containment parapet**

# B4. MATERIALS AND CONSTRUCTION

**General**

B4.1 Structural concrete shall meet the requirements of the 1700 Series of Clauses of the Specification, and shall be not less than Grade 30.

B4.2 To prevent corrosion of the reinforcement, promoted for example by the action of de-icing salts, all exposed surfaces adjacent to the carriageway shall be protected in accordance with BD 43 (DMRB 2.4) and the 1700 Series of Clauses of the Specification.

B4.3 The buried upper surface of a slab shall be finished and waterproofed with a Permitted Waterproofing System in accordance with BD 47 (DMRB 2.3.4) and the 2000 Series of Clauses of the Specification. All other buried surfaces shall be waterproofed in accordance with the 2000 Series of Clauses of the Specification.

**Construction details**

B4.4 Typical construction details for parapet-supporting base slabs on strengthened/reinforced soil walls are presented in Figures B4.1 and B4.2.

B4.5 The minimum dimensions of the space between the parapet base slab and the facing unit shall be:

Vertical ($d_V$ on Figure B4.1): 20 mm

Horizontal ($d_H$ on Figure B4.1): 10 mm

**Compressible Filler**

B4.6 The thickness and compressibility of the filler should be chosen to avoid loads being transferred from the parapet base to the facing units.

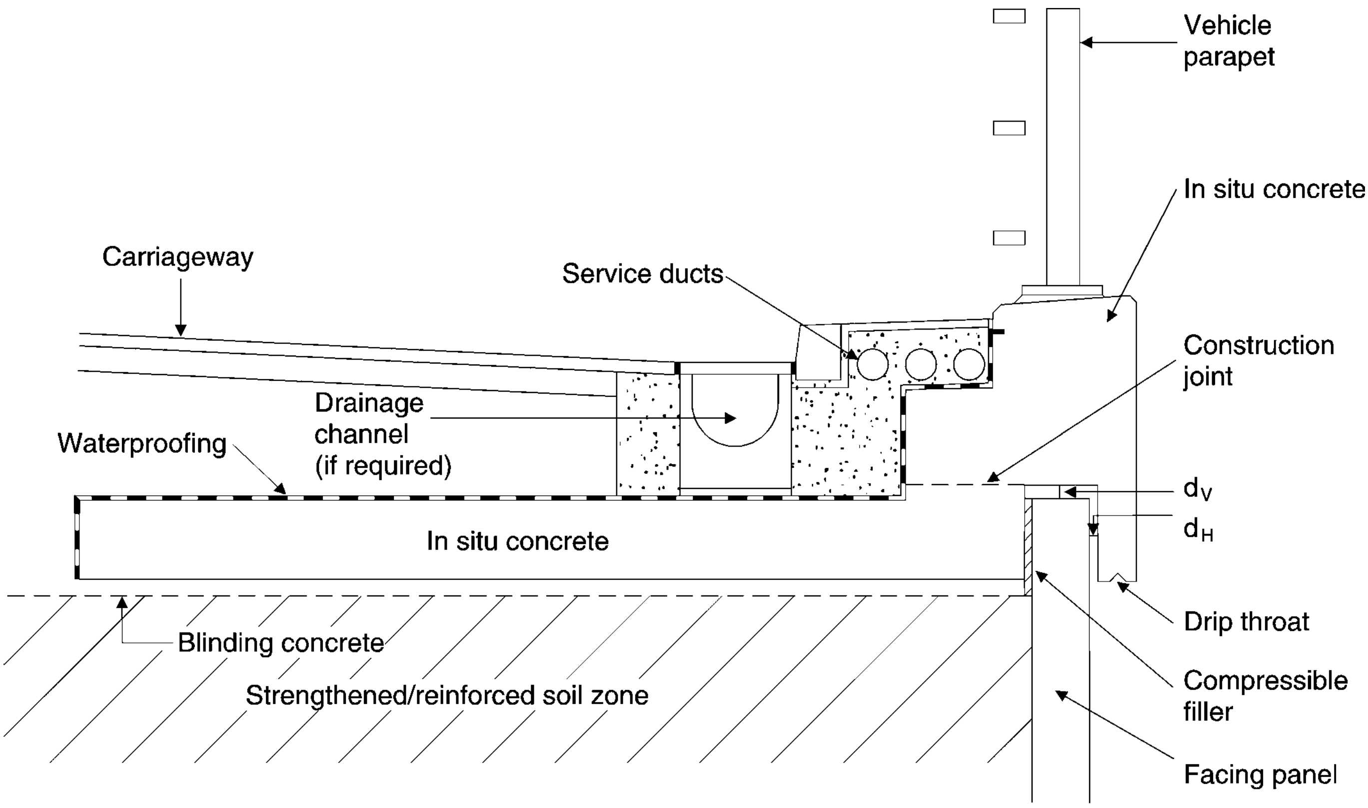



**Figure B4.1 Typical detail of a parapet-supporting base slab at the top of a strengthened/reinforced soil wall with in situ concrete coping**

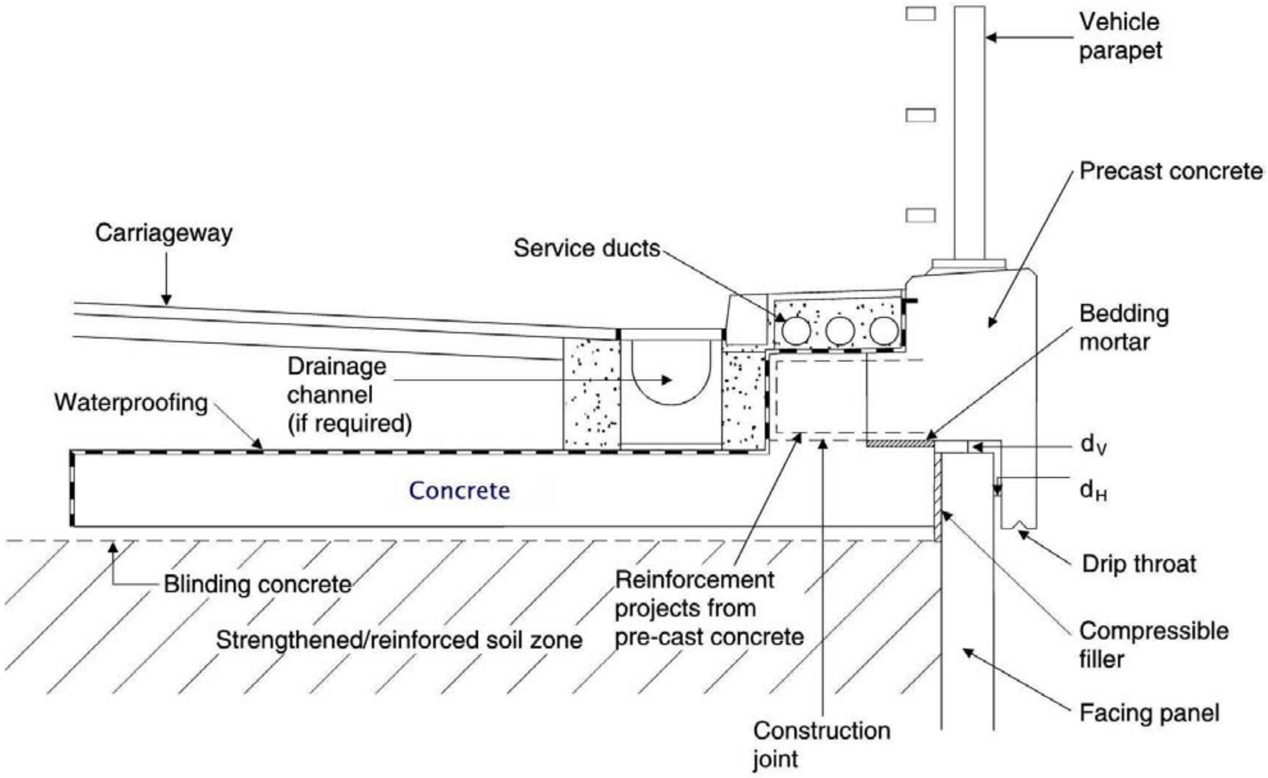



**Figure B4.2 Typical detail of a parapet-supporting base slab at the top of a strengthened/reinforced soil wall with pre-cast concrete coping**

# B5. REFERENCES

B5.1 **Design Manual for Roads and Bridges (DMRB): The Stationery Office, London**

BD 12 Design of corrugated steel buried structures with spans not exceeding 8 m (including circular arches) (DMRB 2.2.6)

BD 24 Design of concrete bridges. Use of BS 5400: Part 4: 1990 (DMRB 1.3.1)

BD 28 Early thermal cracking of concrete (DMRB 1.3)

BD 37 Loads for highway bridges (DMRB 1.3)

BD 43 Criteria and materials for the impregnation of concrete highway structures (DMRB 2.4)

BD 47 Waterproofing and surfacing of concrete bridge decks (DMRB 2.3.4)

BD 52 The design of highway bridge parapets (DMRB 2.3.3)

BD 57 Design for durability (DMRB 1.3.7)

BD 70 Strengthened/reinforced soils and other fills for retaining walls and bridge abutments. Use of BS 8006: 1995 (DMRB 2.1.5)

B5.2 **Manual of Contract Documents for Highway Work (MCHW): The Stationery Office, London**

Volume 1: Specification for Highway Works

B5.3 **Other**

British Standards Institution (1995). BS 8006: Code of practice for strengthened/reinforced soils and other fills.

CEN (1999). Preliminary draft BS EN 1997-1. Eurocode 7: Geotechnical engineering, Part 1: General rules.

Meyerhof G G (1965). Shallow foundations. ASCE, JSMFD, 91, SM2, pp21-31.

Poulos H G and Davis E H (1974). Elastic solutions for soil and rock mechanics. John Wiley & Sons, Inc.