Concise Eurocodes: Geotechnical design
This book is one in a series that also includes the following:

BIP 2198, Concise Eurocodes: Design of Timber Structures – BS EN 1995: Eurocode 5
BIP 2199, Concise Eurocodes: Loadings On Structures – BS EN 1991: Eurocode 1
# Contents

6.6 Serviceability limit state design 50  
6.7 Foundations on rock; additional design considerations 53  
6.8 Structural design of spread foundations 54  
6.9 Preparation of the subsoil 55  

Section 7 Pile foundations 56  
7.1 General 56  
7.2 Limit states 57  
7.3 Actions and design situations 57  
7.4 Design methods and design considerations 57  
7.5 Pile load tests 58  
7.6 Axially loaded piles 62  
7.7 Transversely loaded piles 68  
7.8 Structural design of piles 68  
7.9 Supervision of construction 69  

Section 8 Anchorages 70  

Section 9 Retaining structures 71  
9.1 General 71  
9.2 Limit states 71  
9.3 Actions, geometrical data and design situations 72  
9.4 Design and construction considerations 74  
9.5 Determination of earth pressures 76  
9.6 Water pressures 79  
9.7 Ultimate limit state design 79  
9.8 Serviceability limit state design 85  

Section 10 Hydraulic failure 87  

Section 11 Overall stability 88  
11.1 General 88  
11.2 Limit states 88  
11.3 Actions and design situations 88  
11.4 Design and construction considerations 89  
11.5 Ultimate limit state design 90  
11.6 Serviceability limit state design 91  
11.7 Monitoring 92  

Section 12 Embankments 93
### Contents

| Annex A (normative) | Partial and correlation factors for ultimate limit states and recommended values | 94 |
| Annex B (informative) | Background information on partial factors for Design Approaches 1, 2 and 3 | 95 |
| Annex C (informative) | Sample procedures to determine earth pressures | 96 |
| Annex D (informative) | A sample analytical method for bearing resistance calculation | 102 |
| Annex E (informative) | A sample semi-empirical method for bearing resistance estimation | 106 |
| Annex F (informative) | Sample methods for settlement evaluation | 107 |
| Annex G (informative) | A sample method for deriving presumed bearing resistance for spread foundations on rock | 109 |
| Annex H (informative) | Limiting values of structural deformation and foundation movement | 111 |
| Annex J (informative) | Checklist for construction supervision and performance monitoring | 113 |
| UK National Annex to Eurocode 7: Geotechnical design – Part 1: General rules | 115 |
| Appendix 1 Figures | 129 |
| Appendix 2 – Checklist forms | 143 |
| Bibliography | 165 |
Preface

1. Purpose

This book is intended to assist geotechnical designers by providing a reduced version of BS EN 1997-1 (EC7) together with added commentary by the author (which is differentiated from the Eurocode text by means of grey shading), giving explanations where the text could be found difficult to understand or to apply. It has been developed particularly for the use of engineers who are experienced in geotechnical design but want a quicker way to understand the procedures required by EC7. It is intended to aid use of EC7, rather than to provide background explanation.

Starting from the original text of BS EN 1997-1, material that is not needed in common design situations has been omitted. Omissions are marked by ** and the headings and numbering of EC7 is retained throughout. Cross-references have been added to other Euronorms, and to other documents, including those published by BSI, quoting text or tables of values from other Euronorms where this is helpful. All additions to EC7 are shown in shaded boxes.

The text of EC7 contains many checklists. For ease of use, these have been removed to Appendix 2 and arranged as forms for practical use.

This book also contains the most commonly needed content of the United Kingdom National Annex (UKNA) to EC7. In particular, Annex A of the European (CEN) version of EC7, which provides the values of partial factors, is replaced by the equivalent annex taken from the UKNA.

Designs for common situations based on this book will generally conform to EC7. However, **full conformance to the Eurocode can only be ensured by careful use of the complete version of BS EN 1997-1 and its National Annex.**

2. Geotechnical design

The subject of EC7 is ‘Geotechnical design’. In this context, a good definition of ‘design’ is ‘the process of decisions that determines what will be built’. The Eurocodes are particularly concerned with final design, which governs safety, and not so much with scheme designs and the preliminary designs used for the purposes of costing and tendering. Thus the Eurocodes provide a series of tests that the structure that is finally to be built is required to pass.

3. Safety format in EC7 calculations

Like the other Eurocodes, EC7 uses the approach of limit state design, generally with the method of partial factors as its format for prescribing safety. The fundamentals and basic terminology of these can be found in BS EN 1990. The following paragraphs provide a brief introduction for geotechnical designers.

The essence of limit state design is to set up ‘design situations’, which in some cases might be quite severe, and then to show that relevant limit states would not be exceeded if those situations were to occur.
For the typical designs considered by this book, the designer is required to consider ultimate limit state (ULS) and serviceability limit state (SLS) situations.

BS EN 1990 provides the following definitions:

1.5.2.12 limit states
states beyond which the structure no longer fulfils the relevant design criteria

1.5.2.13 ultimate limit states
states associated with collapse or with other similar forms of structural failure

1.5.2.14 serviceability limit states
states that correspond to conditions beyond which specified service requirements for a structure or structural member are no longer met

These definitions are essentially non-technical. Ultimate limit states generally involve danger of casualties or severe economic loss. Serviceability limit states are less serious, involving inconvenience or disappointment, and any damage is often repairable. More detailed descriptions of ultimate and serviceability limit states are given in BS EN 1990, clauses 3.3 and 3.4. EC7 clause 2.4.7.1 notes five types of ULS relevant to geotechnical design.

Calculations for both ULS and SLS are carried out using design values of the parameters defining actions, materials, resistances and geometry. These are generally pessimistic values, incorporating all necessary factors or margins of safety, so that no further overall factor of safety is required. The design values for ULS and SLS will usually be different, generally more pessimistic for ULS since the occurrence of such a limit state would be a more serious event. The term design value as used in the Eurocodes is quite different from the traditional British usage of, for example, a design load, which would usually mean an unfactored load.

Most commonly, design values are derived by applying partial factors $\gamma$ to characteristic material strengths or resistances, and to representative actions. In principle, this applies to both ULS and SLS calculations but, generally, all the values of $\gamma$ for SLS are 1.0. Details of the application of $\gamma$ factors can be found in 2.4.6 and 2.4.7. Direct assessment of design values is also allowed, in which the designer assesses a suitably pessimistic value without the use of factoring, as discussed under 2.4.6.

Characteristic values of geotechnical parameters are discussed further under 2.4.5.2. Representative values of actions are derived from characteristic values by applying load combination factors, as explained in BS EN 1990, Section 4.

The partial factor method was originally introduced in order to provide more consistent safety for a wide range of situations in which various parameters – actions (loads) and the way they combine, material properties, geometry – could be the dominant uncertainties in terms of their effects on
overall safety. It is also thought that the method gives more opportunity for rational variation and development in situations where these uncertainties are unusually large or small.

In the author’s understanding, the purposes of the partial factors include:

- Allowance for severe variations of leading parameters.
- Allowance for variation of secondary parameters that have not been factored. These often include small geometric variations.
- Some degree of control over displacements and the degree to which material strength is mobilised, affecting strains and distortions. Although these might be thought of as serviceability aspects, the factors adopted for ULS inevitably perform this role to some extent, and since they have generally been derived by calibration to previous practice, their values are affected by this requirement.
- Although not usually stated explicitly, the factors inevitably provide some degree of protection in case of errors in design or construction. This additional role should not be overlooked in cases where reduction in factor values is allowed or where direct assessment of design values is used.

The values of partial factors have not been chosen to allow for major uncertainty or systematic inaccuracy of calculation methods. Rather, it is required that all calculation methods are either accurate or err on the side of safety [2.4.1(6) to (9)].

4. Values of partial factors

The values of partial factors, and some other numerical parameters, are termed ‘nationally determined parameters (NDP)’. The Eurocodes (as published by CEN and reprinted nationally) allow these values to be specified in national annexes but they also provide what are termed ‘recommended values’ for the partial factors. It should not be understood that these values are recommended for use in design. Rather, they are recommended by the original drafters of the Eurocodes for the consideration of national standards bodies. In this book, the ‘recommended values’ published by CEN are referred to as ‘the CEN default values’.

Eurocodes are implemented as standards by national standards bodies. When using them, it is therefore important to use the appropriate national annex, which will usually be the national annex of the nation in which the construction site is located. Alternatively, the national annex to be used could be specified by contracts, depending on the legal constraints of each nation. The United Kingdom National Annex, published by BSI, will be referred to as the UKNA.

For the UK, a letter sent by the Department for Communities and Local Government to building control offices and others can be seen at http://www.communities.gov.uk/documents/planningandbuilding/pdf/1454859.pdf. This gives formal notification that Eurocodes are available for building control purposes and that the UKNA is to be used for construction in the UK. The letter also announces that some British Standards are withdrawn from 31 March 2010. Annex A states correctly that BS 8002 and BS 8004 are withdrawn but also states that BS 8006 and BS 8081 are withdrawn, which is not correct. The term ‘withdrawn’ means that BS 8002 and BS 8004 are no longer current British Standards and they will not be maintained further. It does not prevent their use in design but this could be open to the objection that they are no longer current.
If Eurocodes are used in non-European countries, it is important to establish which national annex is to be applied. Use of the CEN ‘recommended values’ (CEN default values) is strongly discouraged, especially for pile design, for which more conservative values have been specified by most countries.

5. Structural design in geotechnical situations

EC7 interfaces with other Eurocodes that give provision for design of structural elements of concrete or steel including foundations, retaining structures, pre-stressed members such as anchors, etc. The Eurocodes have been written so that the same partial factors on actions and on ground properties and resistances are applied to both geotechnical and structural design, consistently in EC7 and in the other Eurocodes. A further note relevant to the UK use of ‘Design Approach 1’ is provided under 2.4.7.3.4.2.
Foreword to EN 1997-1

In common with other Eurocodes, EC7 starts with a Foreword explaining the background to the Eurocode programme and how the Eurocodes relate to other documents including the National Annexes. Only a small part of the Foreword is retained in this book.

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The Foreword notes the purpose and history of the development of the Eurocodes. Its purpose is essentially to achieve harmonisation of rules in Europe, so that trade can be carried out on a fair and clear basis. Changing, or improving, levels of safety and serviceability achieved in construction was not the European Commission’s main motivation in developing the Eurocodes. However, individual teams developing the codes have been concerned to achieve this.

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The Eurocode standards provide common structural design rules for everyday use for the design of whole structures and component products of both a traditional and an innovative nature. Unusual forms of construction or design conditions are not specifically covered and additional expert consideration will be required by the designer in such cases.

National Standards implementing Eurocodes

The National Standards implementing Eurocodes will comprise the full text of the Eurocode (including any annexes), as published by CEN, which may be preceded by a National title page and National foreword, and may be followed by a National annex.

The National annex may only contain information on those parameters, which are left open in the Eurocode for national choice, known as Nationally Determined Parameters, to be used for the design of buildings and civil engineering works to be constructed in the country concerned, i.e.:

— values and/or classes where alternatives are given in the Eurocode,
— values to be used where a symbol only is given in the Eurocode,
— country specific data (geographical, climatic), e.g. snow map,
— the procedure to be used where alternative procedures are given in the Eurocode.

It may also contain:

— decisions on the application of informative annexes,
— references to non-contradictory complementary information to assist the user to apply the Eurocode.

**
Section 1 General

1.1 Scope

1.1.1 Scope of EN 1997

(1) EN 1997 is intended to be used in conjunction with EN 1990:2002, which establishes the principles and requirements for safety and serviceability, describes the basis of design and verification and gives guidelines for related aspects of structural reliability.

(2) EN 1997 is intended to be applied to the geotechnical aspects of the design of buildings and civil engineering works.

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1.1.2 Scope of EN 1997-1

(1) EN 1997-1 is intended to be used as a general basis for the geotechnical aspects of the design of buildings and civil engineering works.

(2) The following subjects are dealt with in EN 1997-1:

Section 1: General
Section 2: Basis of geotechnical design
Section 3: Geotechnical data
Section 4: Supervision of construction, monitoring and maintenance
Section 5: Fill, dewatering, ground improvement and reinforcement
Section 6: Spread foundations
Section 7: Pile foundations
Section 8: Anchorages
Section 9: Retaining structures
Section 10: Hydraulic failure
Section 11: Overall stability
Section 12: Embankments

(3) EN 1997-1 is accompanied by Annexes A to J, which provide:

— in A: recommended partial factor values; different values of the partial factors may be set by the National annex;
— in B to J: supplementary informative guidance such as internationally applied calculation methods.
1.1.3 Further Parts of EN 1997

(1) EN 1997-1 is supplemented by EN 1997-2 that provides requirements for the performance and evaluation of field and laboratory testing.

1.2 Normative references

This clause provides references to the other Eurocodes and some of the geotechnical execution standards.

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1.3 Assumptions

The Eurocodes assume that data collection, design, construction and maintenance will all be carried out consistently with good practice. The codes do not state who carries responsibility for each of these aspects but it should be noted that they are addressed to designers. Adequate documentation of all these aspects is essential to good practice.

It is clearly impossible for designers to control construction and maintenance. However, besides ensuring that design is undertaken ‘by appropriately qualified and experienced personnel’, designers should demand that data collection is adequately carried out, which, in the geotechnical context, includes ground investigation. Guidance on investigations is provided by BS EN 1997-2 and by Uff and Clayton (1986, 1991).

Designers should also take responsibility for adequate specification of construction and the preparation and communication of manuals and other documents related to maintenance.

It is assumed that ‘adequate continuity and communication exist between the personnel involved in data-collection, design and construction’. This can be challenging in situations in which structural and geotechnical design are carried out by different individuals or different companies. For example, clear communication of the actions to be applied to foundations is essential, requiring that all the engineers involved in the design understand and comply with the Eurocode system.

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1.4 Distinction between Principles and Application Rules

(1) Depending on the character of the individual clauses, distinction is made in EN 1997-1 between Principles and Application Rules.
(2) The Principles comprise:
— general statements and definitions for which there is no alternative;
— requirements and analytical models for which no alternative is permitted unless specifically stated.

(3) The Principles are preceded by the letter P.

(4) The Application Rules are examples of generally recognised rules, which follow the Principles and satisfy their requirements.

The Principles in EC7 are, in general, statements of essential good practice, on which the Application Rules expand.

**

1.5 Definitions

1.5.1 Definitions common to all Eurocodes

(1) The definitions common to all Eurocodes are given in EN 1990:2002, 1.5.

1.5.2 Definitions specific for EN 1997-1

1.5.2.1
groundwater action

action transmitted to the structure by the ground, fill, standing water or ground-water

The meaning of the term ‘action’ in the context of geotechnical design has been much debated. See comments in 2.4.2 for further information.

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1.5.2.2
comparable experience

documented or other clearly established information related to the ground being considered in design, involving the same types of soil and rock and for which similar geotechnical behaviour is expected, and involving similar structures. Information gained locally is considered to be particularly relevant.
Section 1 General

Geotechnical design depends critically on the proper use of accumulated experience. However, this can become an impenetrable and irrational black box, sometimes termed ‘engineering judgement’. EC7 attempts to define ‘comparable experience’ so as to distinguish experience that is of genuine relevance and also recorded in an objective fashion, so that it can be scrutinised and applied in an appropriate manner.

1.5.2.3

ground

soil, rock and fill in place prior to the execution of the construction works;

1.5.2.4

structure

organised combination of connected parts, including fill placed during execution of the construction works, designed to carry loads and provide adequate rigidity

Generally, the term ‘structure’ has to be understood in its context. This definition shows that it may include structural fill as, for example, in an embankment.

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1.5.2.5

derived value

value of a geotechnical parameter obtained by theory, correlation or empiricism from test results

1.5.2.6

stiffness

material resistance against deformation

1.5.2.7

resistance

The term ‘resistance’ is used to denote the capacity of a component or cross-section, such as bending resistance, buckling resistance, bearing resistance (or bearing capacity), pile resistance/capacity or passive resistance. It should be seen as distinct from the strength of material. Partial factors are applied either to the strength of material or to ‘resistance’, depending on the approach adopted.

**
1.6 Symbols

In this text, symbols and abbreviations will be defined in context as they are needed. For the full list, see BS EN 1997-1.