

Eurocode 7: Geotechnical design —

Part 1: General rules —

**(together with United Kingdom
National Application Document)**

Committees responsible for this Draft for Development

The preparation of the National Application Document for use in the UK with ENV 1997-1:1994 was entrusted to Technical Committee B/526, Geotechnics, upon which the following bodies were represented:

- Association of Consulting Engineers
- Association of Geotechnical Specialists
- Department of the Environment (Property and Buildings Directorate)
- Department of Transport
- Federation of Civil Engineering Contractors
- Federation of Piling Specialists
- Institution of Civil Engineers
- Institution of Structural Engineers

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National foreword

This publication comprises the English language version of ENV 1997-1:1994 *Eurocode 7: Geotechnical design — Part 1: General rules*, as published by the European Committee for Standardization (CEN) plus the National Application Document (NAD) to be used with the ENV for design of foundations and geotechnical structures to be constructed in the United Kingdom.

ENV 1997-1 results from a programme of work sponsored by the European Commission to make available a common set of rules. The full range of codes covers the basis of design and actions, the design of structures in concrete, steel, composite construction, aluminium, timber and masonry, and geotechnics and seismic design.

An ENV is made available for provisional application during a period of trial use of 3 years, but does not have the status of a fully agreed European Standard (EN). At the end of the trial period the aim is to use the experience gained to modify the ENV so that it can be approved as an EN.

The values of some of the parameters in the ENV Eurocodes may be set by member states so as to meet the requirements for safety in national regulations. The values to be used in the UK are given in clause 4 of this NAD.

The NAD contains references to alternative, supporting documents, pending the publication of relevant European Standards. These references are given in Annex A of this NAD.

The purpose of the NAD is to provide essential information, particularly in relation to safety, necessary for provisional application of the ENV and it therefore constitutes an essential part of this publication in the UK. The recommendations of the NAD take precedence in the UK over the corresponding provisions in the ENV.

Compliance with ENV 1997-1 and the NAD does not in itself confer immunity from legal obligations.

Users of this document are invited to comment on its technical content, ease of use and any ambiguities or anomalies. These comments will be taken into account when preparing the UK national response to CEN on the question of whether the ENV can be converted to an EN.

Comments should be made in writing to BSI, 389 Chiswick High Road, London W4 4AL, quoting this document, the reference to the relevant clause, and if possible, a proposed revision, within 2 years of the issue of this document.

Textual errors. When implementing the English language version of ENV 1997-1:1994 as the national prestandard, the textual errors listed below were discovered. They have been reported to CEN in a proposal to amend the text of the European Prestandard.

In line 1 of item 4 in **6.5.3** “(6.5)” should read “(6.2)”.

In line 3 of item 3 in **6.6** “(2.4.5)” should read “(2.4.6)”.

In line 4 of item 4 in **8.8.5** “pile” should read “anchorage”.

In equation G.2 of Annex G “ α ” should read “ α' ”.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the National Application Document title page, pages ii to x, the ENV title page, pages 2 to 88 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

National Application Document for use in the UK with ENV 1997-1:1994

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Introduction

This National Application Document has been prepared by Technical Committee B/526 to enable ENV 1997-1 (Eurocode 7-1) to be used for the design of geotechnical structures to be constructed in the United Kingdom. It has been developed from:

- a) a textual examination of ENV 1997-1; and
- b) trial calculations, including parametric calibration against relevant UK codes and standards, to assess its ease of use and to provide numerical factors that produce designs in general conformity with UK practice.

1 Scope

This National Application Document (NAD) provides information required to enable ENV 1997-1 to be used for most routine designs for geotechnical structures that are to be constructed in the UK.

2 References

2.1 Normative references

This National Application Document incorporates, by dated or undated reference, provisions from other publications. These normative references are made at the appropriate places in the text and the cited publications are listed on the inside back cover. For dated references, only the edition cited applies; any subsequent amendments to or revisions of the cited publication apply to this National Application Document only when incorporated in the reference by amendment or revision. For undated references, the latest edition of the cited publication applies, together with any amendments.

2.2 Informative references

This National Application Document refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on the inside back cover, but reference should be made to the latest editions.

3 Definitions

For the purposes of this National Application Document the following definitions apply.

NOTE ENV 1997-1 uses terminology that may not be wholly familiar to UK engineers, such as “action” and “execution”. Definitions of these terms may be found in ENV 1991-1 and ENV 1997-1 and are reproduced here for convenience.

3.1

action

force (load) applied to the structure (direct action); or an imposed or constrained deformation (indirect action)

NOTE For example caused by temperature changes, moisture variation or uneven settlement.

3.2

execution

activity of creating a building or civil engineering works

NOTE The term covers work on site; it may also signify the fabrication of components off site and their subsequent erection on site.

4 Values of partial factors

- a) In this clause, values of partial factors currently do not differ from those used in ENV 1997-1.

NOTE In the state of development of this NAD at July 1995, no deviations from boxed values are proposed.

- b) *Clause 2.4.2 (14) P* Table 2.1 should be replaced by Table 1 of this NAD. For accidental situations all numerical values of partial factors for actions should be 1.0.

- c) *Clause 7.6.3.2 (6) P* For the derivation of the ultimate characteristic bearing resistance of piles in compression, the factors to be used should be those given in Table 2 of this NAD, which should be substituted for Table 7.1.

- d) *Clause 7.6.3.2 (10) P* For the derivation of the design ultimate bearing resistance of piles in compression, the values of partial factors should be those given in Table 3 of this NAD, which should be substituted for Table 7.2.

- e) *Clause 7.6.3.3* The value 1.5 should be substituted for the bracketed value [1.5]

f) *Clause 7.7.2.2 (2) P* For the derivation from pile load tests of ultimate characteristic values of the resistance of piles in tension, the values of partial factors to be applied to the measured ultimate tensile resistance should be those given in Table 4 of this NAD, which should be substituted for Table 7.3.

g) *Clause 7.7.2.2 (4) P* The factor to derive the design value from the characteristic value should be 1.6.

h) *Clause 8.8.5 (4) P* For the derivation from assessment tests of the ultimate characteristic resistance of anchorages, the values of partial factors should be those given in Table 5 of this NAD, which should be substituted for Table 8.1.

i) *Clause 8.8.5 (5) P* For the derivation from characteristic resistance of the design resistance of anchorages, the value of partial factor should be 1.25 for temporary anchorages and 1.5 for permanent anchorages.

Table 1 — Partial factors — ultimate limit states in persistent and transient situations

Case	Actions			Ground properties			
	Permanent		Variable	$\tan \varphi$	c'	c_u	q_u^a
	Unfavourable	Favourable	Unfavourable				
A	1.0	0.95	1.5	1.1	1.3	1.2	1.2
B	1.35	1.0	1.5	1.0	1.0	1.0	1.0
C	1.0	1.0	1.3	1.25	1.6	1.4	1.4

^a Compressive strength of soil or rock.

Table 2 — Factors to derive the ultimate characteristic bearing resistance

	Number of load tests		
	1	2	> 2
Factor ξ on mean R_{cm}	1.5	1.35	1.3
Factor ξ on lowest R_{cm}	1.5	1.25	1.1

Table 3 — Factors to derive the ultimate design bearing resistance

Component factors	γ_b	γ_s	γ_t
Driven piles	1.3	1.3	1.3
Bored piles	1.6	1.3	1.5
CFA piles	1.45	1.3	1.4

Table 4 — Factors to derive characteristic ultimate tensile pile resistance from tests

	Number of load tests		
	1	2	> 2
Factor ξ on mean R_m	1.5	1.35	1.3
Factor ξ on lowest R_m	1.5	1.25	1.1

Table 5 — Factors to derive ultimate characteristic resistance from anchorage tests

	Number of assessment tests		
	1	2	> 2
Factor ξ on mean R_{am}	1.5	1.35	1.3
Factor ξ on lowest R_{am}	1.5	1.25	1.1

5 Reference standards

ENV 1997-1 does not call up supporting standards since none yet exist (see Annex A).

6 Additional recommendations

Annex B lists points that should be noted when designing to ENV 1997-1.

Annex A (informative)

References to supporting standards in Eurocode 7

Table A.1 provides guidance on British Standards which support clause references in EC7 on standards for site investigation and laboratory and field testing.

Table A.1 — References in EC 7 to other codes and standards

Reference location in EC7	Reference	UK equivalent document no.
3.1 (3)P	“internationally recognized standards and recommendations”	BS 5930 BS 1377-1 to BS 1377-9
3.2.3 (6)P	“standardized procedures”	BS 5930 BS 1377-1 to BS 1377-9
3.3.4 3.3.5	“standard laboratory procedures”	BS 1377-1 to BS 1377-9

Annex B (normative)

Additional recommendations

B.1 General

For the geotechnical design of trunk roads and motorways within the UK, reference should be made to the following documents of the Department of Transport, the Scottish Office Industry Department, the Welsh Office: Y Swyddfa Gymreig and the Department of the Environment for Northern Ireland:

- Design Manual for Roads and Bridges* [1];
- Manual for Contract Documents for Highway Works*, Volumes 1 and 2 [2].

B.2 Guidance on EC7

a) Clause 2.4.2

In 2.4.2 (12)P Case B, care is required particularly in the selection of the partial factor γ_F when the design of structural elements is critical. Whether earth pressures acting on the structure are considered to be favourable or unfavourable will substantially affect the outcome (for example, in the design of a cantilever retaining structure both the active and passive pressure distributions will usually be unfavourable to the design of the structural section). The application rules in 2.4.2 (17) are particularly important; the same value of γ_F (1.35 or 1.0) is applied to all earth and water pressures, depending on whether the combined effect of them all is favourable or unfavourable.

The bending moments and shear forces derived from factored earth pressures should be regarded as design values when using EC2 or other of the structural Eurocodes for the structural calculations.

If the application of $\gamma_F = 1.35$ leads to a physically unreasonable situation, then the factor (1.35) should be treated as a model factor and applied to the action effects (e.g. resultant bending moment and shear force) which are then treated as design values in EC2 or other of the structural Eurocodes.

b) Clause 5

Reference should be made to BS 6031, BS 8006¹⁾ and the forthcoming CEN documents from CEN/TC 288/WG6 *Execution of special geotechnical works — Grouting* and CEN/TC 288/WG7 *Execution of special geotechnical works — Jet grouting*.

c) Clause 6

Reference should be made to BS 8004.

d) Clause 7

Reference should be made to BS 8004, BS 5573 and to the forthcoming CEN documents from CEN/TC288/WG3 *Execution of special geotechnical works — Bored piles*, CEN/TC 288/WG4 *Execution of special geotechnical works — Sheet pile walls*, CEN/TC 288/WG5 *Execution of special geotechnical works — Displacement piling*.

¹⁾ In preparation.

e) *Clause 7.6.3.3*

The adhesion factor α provides a correlation between the results of static load tests and ground test results. If the values adopted for α and c_u are such that the resulting value of shaft adhesion $\alpha \cdot c_u$ represents the mean of the test results, then the shaft resistance will be given by:

$$q_{sik} = \alpha \cdot c_u / 1.5$$

then

$$R_{sd} = R_{sk} / \gamma_s = \Sigma q_{sik} \cdot A_{si} / \gamma_s = \Sigma \alpha \cdot c_u \cdot A_{si} / (1.5 \cdot \gamma_s).$$

With

$\gamma_s = 1.3$, the factor on $\alpha \cdot c_u \cdot A_{si}$ becomes 1.95.

f) *Clause 8*

Reference should be made to BS 8002, BS 8006 and to the forthcoming document from CEN/TC288/WG2 *Execution of special geotechnical works — Ground anchors*.

g) *Clause 9*

Reference should be made to BS 6031.

List of references (see clause 2)

Normative references

BSI publications

BRITISH STANDARDS INSTITUTION, London

BS 5573:1978, *Code of practice for safety precautions in the construction of large diameter boreholes for piling and other purposes*.

BS 6031:1981, *Code of practice for earthworks*.

BS 8002:1994, *Code of practice for earth retaining structures*.

BS 8004:1986, *Code of practice for foundations*.

BS 8006, *Code of practice for strengthened/reinforced soils and other fills*²⁾.

Other references

[1] *Design Manual for Roads and Bridges*³⁾.

[2] *Manual for Contract Documents for Highway Works*, Vols 1 and 2³⁾.

Informative references

BSI publications

BRITISH STANDARDS INSTITUTION, London

BS 1377, *Methods of test for soils for civil engineering purposes*.

BS 1377-1:1990, *General requirements and sample preparation*.

BS 1377-2:1990, *Classification tests*.

BS 1377-3:1990, *Chemical and electro-chemical tests*.

BS 1377-4:1990, *Compaction-related tests*.

BS 1377-5:1990, *Compressibility, permeability and durability tests*.

BS 1377-6:1990, *Consolidation and permeability tests in hydraulic cells and with pore pressure measurement*.

BS 1377-7:1990, *Shear strength tests (total stress)*.

BS 1377-8:1990, *Shear strength tests (effective stress)*.

BS 1377-9:1990, *In-situ tests*.

BS 5930:1981, *Code of practice for site investigations*.

CEN publication

EUROPEAN COMMITTEE FOR STANDARDIZATION (CEN), Brussels

ENV 1991-1:1994, *Eurocode 1 — Basis of design and actions on structures — Part 1: Basis of design*.

²⁾ In preparation.

³⁾ Published by and available from HMSO.

Eurocode 7: Geotechnical design — Part 1: General rules

Eurocode 7: Calcul géotechnique —
Partie 1: Règles générales

Eurocode 7: Entwurf, Berechnung und
Bemessung in der Geotechnik —
Teil 1: Allgemeine Regeln

This European Standard (ENV) was approved by CEN on 1993-05-25 as a prospective standard for provisional application. The period of validity of this ENV is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the ENV can be converted into a European Standard.

CEN members are required to announce the existence of this ENV in the same way as for an EN and to make the ENV available promptly at national level in an appropriate form. It is permissible to keep conflicting national standards in force (in parallel to the ENV) until the final decision about the possible conversion of the ENV into an EN is reached.

CEN members are the national standards bodies of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

Foreword

1 Objectives of the Eurocodes

- (1) The structural Eurocodes comprise a group of standards for the structural and geotechnical design of buildings and civil engineering works.
- (2) They are intended to serve as reference documents for the following purposes:
 - a) As a means to prove compliance of building and civil engineering works with the essential requirements of the Construction Products Directive (CPD)
 - b) As a framework for drawing up harmonised technical specifications for construction products.
- (3) They cover execution and control only to the extent that is necessary to indicate the quality of the construction products, and the standard of the workmanship, needed to comply with the assumptions of the design rules.
- (4) Until the necessary set of harmonised technical specifications for products and for methods of testing their performance is available, some of the Structural Eurocodes cover some of these aspects in informative annexes.

2 Background to the Eurocode programme

- (1) The Commission of the European Communities (CEC) initiated the work of establishing a set of harmonised technical rules for the design of building and civil engineering works which would initially serve as an alternative to the different rules in force in the various Member States and would ultimately replace them. These technical rules became known as the "Structural Eurocodes".
- (2) In 1990, after consulting their respective Member States, the CEC transferred work of further development, issue and updates of the Structural Eurocodes to CEN and the EFTA Secretariat agreed to support the CEN work.
- (3) CEN Technical Committee CEN/TC 250 is responsible for all Structural Eurocodes.

3 Eurocode programme

- (1) Work is in hand on the following Structural Eurocodes, each generally consisting of a number of parts:

EN 1991, Eurocode 1: Basis of design and actions on structures.

EN 1992, Eurocode 2: Design of concrete structures.

EN 1993, Eurocode 3: Design of steel structures.

EN 1994, Eurocode 4: Design of composite steel and concrete structures.

EN 1995, Eurocode 5: Design of timber structures.

EN 1996, Eurocode 6: Design of masonry structures.

EN 1997, Eurocode 7: Geotechnical design.

EN 1998, Eurocode 8: Design of structures for earthquake resistance.

EN 1999, Eurocode 9: Design of aluminium alloy structures.

- (2) Separate sub-committees have been formed by CEN/TC 250 for the various Eurocodes listed above.

- (3) This part of the Structural Eurocode for Geotechnical design which had been finalised and approved for publication under the direction of CEC, is being issued by CEN as a European Prestandard (ENV) with an initial life of three years.

- (4) This Prestandard is intended for experimental practical application in the design of the building and civil engineering works covered by the scope as given in 1.1.2 and for the submission of comments.

- (5) After approximately two years CEN members will be invited to submit formal comments to be taken into account in determining future action.

- (6) Meanwhile, feedback and comments on this Prestandard should be sent to the Secretariat of sub-committee CEN/TC250/SC7 at the following address:

NNI

P.O.Box 5059

NL-2600 GB Delft

The Netherlands

or to a national standards organisation.

4 National application documents

(1) In view of the responsibilities of authorities in member countries for the safety, health and other matters covered by the essential requirements of the CPD, certain safety elements in this ENV have been assigned indicative values which are identified by []. The authorities in each member country are expected to assign definitive values to these safety elements.

(2) Many of the supporting standards, including those giving values for actions to be taken into account and measures required for fire protection, will not be available by the time this Prestandard is issued. It is therefore anticipated that a National Application Document giving definitive values for safety elements, referencing compatible supporting standards and giving national guidance on the application of this Prestandard will be issued by each Member State or its Standard Organisation. This Prestandard should be used in conjunction with the National Application Document valid in the country where the building and civil engineering works is to be constructed.

It is intended that this Prestandard is used in conjunction with the NAD valid in the country where the building or civil engineering works are located.

5 Matters specific to this prestandard

(1) The scope of eurocode 7 is defined in 1.1.1 and the scope of this Part of eurocode 7 is defined in 1.1.2. Additional Parts of Eurocode 7 which are planned are indicated in 1.1.3; these will cover additional technologies or applications, and will complement and supplement this Part.

(2) In using this Prestandard in practice, particular regard should be paid to the underlying assumptions and conditions given in 1.3.

(3) The nine chapters of this Prestandard are complemented by seven annexes which have informative status.

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Section 1. General

1.1 Scope

1.1.1 Scope of Eurocode 7

(1)P This prestandard applies to the geotechnical aspects of the design of buildings and civil engineering works. It is subdivided into various separate parts. See 1.1.2 and 1.1.3.

(2)P This prestandard is concerned with the requirements for strength, stability, serviceability and durability of the structures. Other requirements, e.g. concerning thermal or sound insulation, are not considered.

(3)P This prestandard shall be used in conjunction with ENV 1991-1 “Basis of Design” of Eurocode 1 “Basis of Design and Actions on Structures” which establishes the principles and requirements for safety and serviceability, describes the basis for design and verification and gives guidelines for related aspects of structural reliability.

(4)P This prestandard gives the rules to calculate actions originating from the ground such as earth pressures. Numerical values of actions on buildings and civil engineering works to be taken into account in the design are provided in ENV 1991 Eurocode 1 “Basis of Design and Actions on Structures” applicable to the various types of construction.

(5)P In this prestandard execution is covered to the extent that is necessary to indicate the quality of the construction materials and products which should be used and the standard of workmanship on site needed to comply with the assumptions of the design rules. Generally, the rules related to execution and workmanship are to be considered as minimum requirements which may have to be further developed for particular types of buildings or civil engineering works and methods of construction.

(6)P This prestandard does not cover the special requirements of seismic design. Eurocode 8, “Design provisions for earthquake resistance of structures” provides additional rules for seismic design which complete or adapt the rules of this prestandard.

1.1.2 Scope of ENV 1997-1

(1)P This prestandard gives a general basis for the geotechnical aspects of the design of buildings and civil engineering works.

(2)P The following subjects are dealt with in ENV 1997-1 Eurocode 7: “Geotechnical design”.

- *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: Retaining Structures;*
- *Section 9: Embankments and Slopes.*

1.1.3 Further Parts of Eurocode 7

(1)P This prestandard will be supplemented by further Parts which will complete or adapt it for particular aspects of special types of buildings and civil engineering works, special methods of construction and certain other aspects of design which are of general practical importance.

1.2 References

This European Prestandard incorporates by dated or undated reference, provisions from other standards. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this Prestandard only when incorporated in it by amendment or revision.

ISO 1000:1981, *SI-units and Recommendations for the use of their multiples and of certain other units.*

ISO 3898:1987, *Bases for design of structures. Notations. General symbols.*

1.3 Distinction between, Principles and Application Rules

(1)P Depending on the character of the individual clauses, distinction is made in this prestandard between Principles and Application Rules.

(2)P The Principles comprise:

- general statements and definitions for which there is no alternative, as well as;
- requirements and analytical models for which no alternative is permitted unless specifically stated.

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

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

(5)P It is permissible to use alternative rules different from the Application Rules given in this Eurocode, provided it is shown that the alternative rules accord with the relevant Principles.

1.4 Assumptions

(1)P The following assumptions apply:

- data required for design are collected, recorded and interpreted;
- structures are designed by appropriately qualified and experienced personnel;
- adequate continuity and communication exist between the personnel involved in data- collection, design and construction;
- adequate supervision and quality control is provided in factories, in plants, and on site;
- execution is carried out according to the relevant standards and specifications by personnel having the appropriate skill and experience;
- construction materials and products are used as specified in this Eurocode or in the relevant material or product specifications;
- the structure will be adequately maintained;
- the structure will be used in accordance with the purpose defined for the design.

1.5 Definitions

1.5.1 Terms common to all Eurocodes

(1)P The terms used in common for all Eurocodes are defined in ENV 1991-1 Basis of design.

1.5.2 Special terms used in ENV 1997-1

(1)P The following terms are used in ENV 1997-1 with the following meanings:

- **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;
- **ground**: soil, rock and fill existing in place prior to the execution of the construction works;
- **structure**: as defined in ENV 1991-1 “Basis of design”, including fill placed during execution of the construction works;

1.6 S.I. units

(1)P S.I. units shall be used in accordance with ISO 1000.

(2) For geotechnical calculations, the following units are recommended:

- | | |
|-------------------------------------|---|
| — forces | kN, MN |
| — moments | kNm |
| — mass density | kg/m ³ , Mg/m ³ , (t/m ³) |
| — unit weight | kN/m ³ |
| — stresses, pressures and strengths | kN/m ² (kPa) |
| — stiffness | MN/m ² (MPa) |

— coefficient of permeability	m/s, (m/year)
— coefficient of consolidation	m ² /s, (m ² /year)

1.7 Symbols common to all Eurocodes

(1)P The symbols used in common for all Eurocodes are defined in ENV 1991-1 “Basis of design”.

1.8 Symbols used in Eurocode 7

(1)P The symbols commonly used in ENV 1997-1 are defined in the following sections. Other symbols are defined where they are used locally in the text. The notation of the symbols used is based on ISO 3898:1987.

1.8.1 Latin upper case letters

B	width
D	diameter
F	axial or transverse load on pile
H	horizontal action or force
K	earth pressure coefficient
N	bearing resistance factor
R	vertical resistance (in units of force) of a foundation element
V	vertical action or force

1.8.2 Latin lower case letters

a	adhesion
c'	cohesion intercept in terms of effective stress
c_u	undrained shear strength
i	hydraulic gradient
k	permeability
q	overburden or surcharge pressure
s	settlement
u	pore water pressure

1.8.3 Greek lower case letters

γ	unit weight
δ	angle of shearing resistance between ground and structure
σ	total normal stress
σ'	effective normal stress
τ	shear stress
ϕ	angle of shearing resistance
ϕ'	angle of shearing resistance in terms of effective stress

1.8.4 Subscripts

a	active earth pressure
a	anchor
b	base of pile
c	compression
d	design value
k	characteristic value
p	passive earth pressure
s	shaft of pile
t	tensile
t	total
tr	transverse
w	water
o	at rest or initial condition

Section 2. Basis of geotechnical design

2.1 Design requirements

(1)P A structure shall be designed in compliance with the general design principles given in ENV 1991-1 Eurocode 1 “Basis of Design”.

(2)P In order to establish minimum requirements for the extent and quality of geotechnical investigations, calculations and construction control checks, the complexity of each geotechnical design shall be identified together with the risks to property and life. In particular, a distinction shall be made between:

- light and simple structures and small earthworks for which it is possible to ensure that the fundamental requirements will be satisfied on the basis of experience and qualitative geotechnical investigations, with negligible risk for property and life;
- other geotechnical structures.

(3) For projects of low geotechnical complexity and risk, such as defined above, simplified design procedures are acceptable.

(4)P The following factors shall be taken into consideration when determining the geotechnical design requirements:

- nature and size of the structure and its elements, including any special requirements;
- conditions with regard to its surroundings (neighbouring structures, traffic, utilities, vegetation, hazardous chemicals, etc.);
- ground conditions;
- groundwater situation;
- regional seismicity;
- influence of the environment (hydrology, surface water, subsidence, seasonal changes of moisture).

(5) To establish geotechnical design requirements three Geotechnical Categories, 1, 2 and 3, may be introduced.

A preliminary classification of a structure according to geotechnical category should normally be performed prior to the geotechnical investigations. This category may later be changed. The category should be checked and eventually changed at each stage of the design and construction process.

The various design aspects of a project may require treatment in different geotechnical categories. It is not necessary to treat the whole of the project according to the highest of these categories.

The procedures of higher categories may be used to justify more economic designs, or where the designer considers them to be appropriate.

Geotechnical Category 1

This category only includes small and relatively simple structures:

- for which it is possible to ensure that the fundamental requirements will be satisfied on the basis of experience and qualitative geotechnical investigations;
- with negligible risk for property and life.

Geotechnical Category 1 procedures will only be sufficient in ground conditions which are known from comparable experience to be sufficiently straight-forward that routine methods may be used for foundation design and construction.

Geotechnical Category 1 procedures will be sufficient only if there is no excavation below the water table or if comparable local experience indicates that a proposed excavation below the water table will be straight-forward.

The following are examples of structures or parts of structures complying with Geotechnical Category 1:

- simple 1 and 2 storey houses and agricultural buildings with a maximum design column load of 250 kN and 100 kN/m for walls and using conventional types of spread and piled foundations;
- retaining walls and excavation supports where the difference in ground levels does not exceed 2m;
- small excavations for drainage works, pipe-laying, etc.

Geotechnical Category 2

This category includes conventional types of structures and foundations with no abnormal risks or unusual or exceptionally difficult ground or loading conditions. Structures in Geotechnical Category 2 require quantitative geotechnical data and analysis to ensure that the fundamental requirements will be satisfied, but routine procedures for field and laboratory testing and for design and execution may be used.

The following are examples of structures or parts of structures complying with Geotechnical Category 2:

Conventional types of:

- spread foundations;
- raft foundations;
- piled foundations;
- walls and other structures retaining or supporting soil or water;
- excavations;
- bridge piers and abutments;
- embankments and earthworks;
- ground anchors and other tie-back systems;
- tunnels in hard, non-fractured rock and not subjected to special water tightness or other requirements.

Geotechnical Category 3

This category includes structures or parts of structures which do not fall within the limits of Geotechnical Categories 1 and 2.

Geotechnical Category 3 includes very large or unusual structures, structures involving abnormal risks, or unusual or exceptionally difficult ground or loading conditions and structures in highly seismic areas.

(6)P For each geotechnical design situation it shall be verified that no relevant limit state is exceeded.

(7) This design requirement may be achieved by:

- use of calculations as described in **2.4**;
- adoption of prescriptive measures, as described in **2.5**;
- experimental models and load tests, as described in **2.6**;
- an observational method, as described in **2.7**.

These four approaches may be used in combination. In practice experience will often show which type of limit state will govern the design, and the avoidance of other limit states may be verified by a control check.

(8)P The interaction between structure and ground shall be considered.

(9) Compatibility of strains in the materials involved at a limit state should be considered, especially for materials which are brittle or which have strain-softening properties. Examples include over-reinforced concrete, dense granular soils, cemented soils and clays which exhibit low residual strength. Detailed analysis, allowing for the relative stiffness of structure and ground, may be needed in cases where a combined failure of structural members and the ground could occur. Examples include raft foundations, laterally loaded piles and flexible retaining walls.

(10)P Buildings shall be protected against the penetration of groundwater or the transmission of vapour or gases to the inner surfaces.

(11)P When possible the design results shall be checked against comparable experience.

2.2 Design situations

(1)P In geotechnical design the detailed specifications of design situations shall include, as appropriate:

- the general suitability of the ground on which the structure is located;
- the disposition and classification of the various zones of soil, rock and elements of construction which are involved in the calculation model;
- dipping bedding planes;
- mine workings, caves or other underground structures;

- in the case of structures resting on or near rock, the following shall be included:
- interbedded hard and soft strata;
- faults, joints and fissures;
- solution cavities, such as swallow holes or fissures filled with soft material, and continuing solution processes;
- the actions, their combinations and load cases;
- the nature of the environment within which the design is set, including the following:
 - effects of scour, erosion and excavation, leading to changes in the geometry of the ground surface;
 - effects of chemical corrosion;
 - effects of weathering;
 - effects of freezing;
- variations in groundwater levels, including the effects of dewatering, possible flooding, failure of drainage systems, etc.;
- the presence of gases emerging from the ground;
- other effects of time and environment on the strength and other properties of materials; e.g. the effect of holes created by animal activities;
- earthquakes;
- subsidence due to mining or other causes;
- the tolerance of the structure to deformations;
- the effect of the new structure on existing structures or services.

2.3 Durability

(1)P In geotechnical design the internal and external environmental conditions shall be estimated at the design stage to assess their significance in relation to durability and to enable provisions to be made for the protection or adequate resistance of the materials.

- (2) In designing for durability of materials used in the ground, the following should be considered:
- for concrete: aggressive agents, such as acidic conditions or sulphate salts, in the ground water;
 - for steel: chemical attack where foundation elements are buried in ground that is sufficiently permeable to allow the percolation of groundwater and oxygen; corrosion on the faces of sheet pile walls exposed to free water, particularly in the mean water level zone; pitting type of corrosive attack to steel embedded in fissured or porous concrete, particularly for rolled steel where the mill scale, acting as a cathode, promotes electrolytic action with the scale free surface acting, as an anode;
 - for timber: fungi and aerobic bacteria in the presence of oxygen;
 - for synthetic fabrics: the aging effects of UV exposure or ozone degradation or the combined effects of temperature and stress, secondary effects due to chemical degradation.

2.4 Geotechnical design by calculation

2.4.1 Introduction

(1)P Design by calculation shall be in accordance with section 9 “Verification by the partial factor method” in ENV 1991-1 Eurocode 1 “Basis of Design”. This method involves:

- calculations models;
- actions, which may be either imposed loads or imposed displacements;
- properties of soils, rocks and other materials;
- geometrical data;
- limiting values of deformations, crackwidth, vibrations etc.

(2) In geotechnical engineering knowledge of the ground conditions depends on the extent and quality of the geotechnical investigations. Such knowledge and the control of workmanship are more significant to fulfilling the fundamental requirements than is precision in the calculation models and partial factors.

- (3)P The calculation model shall describe the behaviour of the ground for the limit state under consideration.
- (4) Limit states involving the formation of a mechanism in the ground are readily checked using this approach. For limit states defined by deformation considerations, the deformations should be calculated or otherwise assessed if this approach is used.
- (5)P Calculation models shall consist of:
- a method of analysis, often based on an analytical model including simplifications;
 - if needed, a modification to the results of the analysis to ensure that the results of the design calculation model are either accurate or err on the side of safety.
- (6) The modification to the results of the analysis should take account of the following factors:
- the range of uncertainty in the results of the method of analysis on which the design calculation model is based;
 - any systematic errors known to be associated with the method of analysis.
- (7)P When no reliable calculation model is available for a specific limit state, analysis of the other limit states shall be carried out using factors to ensure that this limit state is sufficiently improbable.
- (8)P Whenever possible, the calculation model shall be correlated with field observations of previous designs, model tests or more reliable analyses.
- (9) The calculation model may consist of an empirical relationship between test results and design requirements, used in place of an analytical model. In this case the empirical relationship shall be clearly established for the relevant ground conditions.

2.4.2 Actions in geotechnical design

- (1)P For any calculation the values of actions are known quantities. Actions are not unknowns in the calculation model.
- (2)P Before any calculation is carried out, the designer shall choose the forces and imposed displacements which will be treated as actions in that calculation. Some forces and imposed displacements shall be treated as actions in certain calculations and not in others. Downdrag (negative skin friction) and earth pressures are examples of such forces.
- (3) For loads applied to foundations by structures, an analysis of the interaction between the structure and the ground may be needed in order to determine the actions to be adopted in the design of foundations.
- (4)P In geotechnical analyses, the following shall be considered for inclusion as actions:
- the weights of soil, rock and water;
 - in situ stresses in the ground;
 - free water pressures;
 - ground water pressures;
 - seepage forces;
 - dead, imposed and environmental loads from structures;
 - surcharges;
 - mooring forces;
 - removal of load or excavation of ground;
 - traffic loads;
 - movements caused by mining;
 - swelling and shrinkage caused by vegetation, climate or moisture changes;
 - movements due to creeping or sliding soil masses;
 - movements due to degradation, decomposition, self-compaction and solution;
 - movements and accelerations caused by earthquakes, explosions, vibrations and dynamic loads;
 - temperature effects, including frost heave;
 - ice loading;
 - imposed prestress in ground anchors, or struts.

(5)P The duration of actions shall be considered with reference to time effects in the material properties of the soil, especially the drainage properties and compressibility of fine grained soils.

(6)P Actions which are applied repeatedly and actions with variable intensity shall be identified for special consideration with regard to continued movements, liquefaction of soils, change of ground stiffness, etc.

(7)P Actions which are applied cyclically with high frequency shall be identified for special consideration with regard to dynamic effects.

(8)P Special consideration shall be given to the safety evaluation of a geotechnical structure where hydrostatic forces are the predominant forces. This is due to the fact that deformations, fissuring and variable permeability with inherent risk of erosion may give rise to changes in the level of the water table which could be vitally important to the safety.

(9)P The following features which may affect the water pressures shall be considered:

- the level of the free water surface or the groundwater table;
- the favourable or unfavourable effects of drainage, both natural and artificial, taking account of its future maintenance;
- the supply of water by rain, flood, burst water mains or other means;
- changes of water pressures due to the growth or removal of vegetation.

(10)P For limit states with severe consequences (generally ultimate limit states), design values for water pressures and seepage forces shall represent the most unfavourable values which could occur in extreme circumstances. For limit states with less severe consequences (generally serviceability limit states), design values shall be the most unfavourable values which could occur in normal circumstances.

(11) The risk of unfavourable water levels may be caused by changes in the water catchment, and reduced drainage possibilities (owing to blockage or freezing), etc. should be considered.

Unless the adequacy of the drainage system can be demonstrated and its maintenance ensured, it will often be necessary to assume that the groundwater table could rise to ground level in extreme circumstances. In some cases this could be considered as an accidental action.

(12)P The design shall be verified for each of the three Cases, A, B and C separately as relevant.

(13) Cases A, B and C have been introduced in order to ensure stability and adequate strength in the structure and in the ground in accordance with Table 9.2 of ENV 1991-1, Eurocode 1 Basis of Design.

(14)P The values of partial factors for Permanent and variable actions given in Table 2.1 shall generally be used for verification of ultimate limit states of conventional types of structures and foundations in persistent and transient situations. More severe values shall be considered in cases of abnormally great risk or unusual or exceptionally difficult ground or loading conditions. Where it can be justified on the basis of the possible consequences, less severe values may be used for temporary structures or transient situations. For accidental situations all numerical values of partial factors for actions shall be taken equal to [1,0].

Table 2.1 — Partial factors — ultimate limit states in persistent and transient situations

Case	Actions			Ground Properties			
	Permanent		Variable	$\tan \phi$	c'	c_u	q_u^a
	Unfavourable	Favourable	Unfavourable				
Case A	[1.00]	[0.95]	[1.50]	[1.1]	[1.3]	[1.2]	[1.2]
Case B	[1.35]	[1.00]	[1.50]	[1.0]	[1.0]	[1.0]	[1.0]
Case C	[1.00]	[1.00]	[1.30]	[1.25]	[1.6]	[1.4]	[1.4]

^a Compressive strength of soil or rock.

(15) For ground properties, different partial material factors are to be used with Cases A, B and C, (see 2.4.3 and Table 2.1)

Where it is clear that one of the three cases is most critical to the design, it will not be necessary to carry out calculations for other cases. However, different cases may be critical to different aspects of a design.

In this prestandard, Case A is only relevant to buoyancy problems, where hydrostatic forces comprise the main unfavourable action. The values given in Table 2.1 are only valid for such situations. For buoyancy problems it is often more appropriate to use a structural solution (e.g. overflow arrangements) associated with partial factor values close to unity, rather than to rely on larger values which are less appropriate.

Case B is often critical to the design of the strength of structural elements involved in foundations or retaining structures. Where there is no strength of structural materials involved, Case B is irrelevant.

Case C is generally critical in cases, such as slope stability problems, where there is no strength of structural elements involved. Case C is often critical to the sizing of structural elements involved in foundations or retaining structures, and sometimes to the strength of structural elements. Where there is no strength of ground involved in the verification, Case C is irrelevant.

The design strengths of the structural materials and the ground will not necessarily both be fully mobilised in the same case.

In structural design of elements such as footings, piles, retaining walls, etc., a model factor γ_{sd} may be introduced as relevant.

(16)P Permanent actions shall include self weight of structural and non-structural components and those actions caused by ground, groundwater and free water.

(17) In calculation of design earth pressures for Case B, the partial factors given in Table 2.1 are applied to characteristic earth pressures. Characteristic earth pressures comprise characteristic water pressures together with stresses which are admissible in relation to the characteristic ground properties and characteristic surface loads.

All permanent characteristic earth pressures on both sides of a wall are multiplied by [1.35] if the total resulting action is unfavourable and by [1.00] if the total resulting action effect is favourable. Thus, all characteristic earth pressures are treated as being derived from a single source as defined in ENV 1991-1.

In some situations, the application of partial factors to characteristic earth pressures could lead to design values which are unreasonable or even physically impossible. In these situations, the partial factors for actions given in Table 2.1 may be treated as model factors. They are then applied directly to the action effects (i.e. internal structural forces and bending moments) derived from characteristic earth pressures.

In calculation of design earth pressures for Case C, the partial factors given in Table 2.1 are applied to the characteristic strength of the ground and to the characteristic surface loads.

(18)P For the verification of serviceability limit states, partial factors of unity shall be used for all permanent and variable actions except where specified otherwise.

(19)P Design values of actions due to ground and groundwater may also be derived by methods other than the use of partial factors. The partial factors set out in Table 2.1 indicate the level of safety considered appropriate for conventional design in most circumstances. These shall be used as a guide to the required level of safety when the method of partial factors is not used.

(20) Where design values for ultimate limit state calculations are assessed directly, they should be selected such that a more adverse value is extremely unlikely to affect the occurrence of the limit state.

Direct assessment of design values is particularly appropriate for actions or combinations of actions for which values derived using Table 2.1 are clearly impossible.

2.4.3 Ground properties

(1)P Design values of ground properties, X_d , shall either be derived from characteristic values, X_k , using the equation:

$$X_d = X_k / \gamma_m \quad (2.1)$$

where:

γ_m is the safety factor for the ground property or shall be assessed directly.

(2)P The selection of characteristic values for soil and rock properties shall be based on the results of laboratory and field tests. Account shall be taken of the possible differences between the properties measured in the tests and the soil and rock properties governing the behaviour of the geotechnical structure due to factors such as:

- presence of fissures, which may play a different role in the test and in the geotechnical structure;
- time effects;
- the brittleness or ductility of the soil and rock tested.

(3) A conversion factor shall be applied where necessary to convert the laboratory and field test results into values which can be assumed to represent the behaviour of the soil and rock in the ground.

(4)P Selection of characteristic values of soil and rock properties shall take account of the following:

- geological and other background information, such as data from previous projects;
- the variabilities of the property values;
- the extent of the zone of ground governing the behaviour of the geotechnical structure at the limit state being considered;
- the influence of workmanship on artificially placed or improved soils;
- the effect of construction activities on the properties of in-situ ground.

(5)P The characteristic value of a soil or rock parameter shall be selected as a cautious estimate of the value affecting the occurrence of the limit state.

(6) The extent of the zone of ground governing the behaviour of a geotechnical structure at a limit state is usually much larger than the extent of the zone in a soil or rock test and consequently the governing parameter is often a mean value over a certain surface or volume of the ground. The characteristic value is a cautious estimate of this mean value.

The governing zone of ground may also depend on the behaviour of the supported structure. For instance, when considering a bearing resistance ultimate limit state for a building resting on several footings, the governing parameter is the mean strength over each individual zone of ground under a footing, if the building is unable to resist a local failure. If instead the building is stiff and strong enough, the governing parameter may be the mean of these mean values over the entire zone or part of the zone of ground under the building.

Statistical methods may be employed in the selection of characteristic values for ground properties. Such methods should allow apriori knowledge of comparable experience with ground properties to be taken into account for example by means of Bayesian statistical methods.

If statistical methods are used, the characteristic value should be derived such that the calculated probability of a worse value governing the occurrence of a limit state is not greater than 5 %.

(7)P Characteristic values may be lower values, which are less than the most probable values, or upper values, which are greater. For each calculation, the most unfavourable combination of lower and upper values for independent parameters shall be used.

(8)P The selection of characteristic values shall take account of the uncertainties in geometrical data and in the calculation model unless they are allowed for directly or in the calculation model.

(9)P For verification in persistent and transient situations of ultimate limit states the numerical values of partial factors for ground properties given in Table 2.1 for the cases A, B and C are generally appropriate to be used with the partial factors for actions for the same cases for conventional design situations. For accidental situations all numerical values of partial factors shall be taken equal to [1,0].

(10)P For ultimate limit states in which soil strength acts in an unfavourable manner, the value of γ_m adopted shall be less than [1,0].

(11) The degree to which soil strength will be mobilised at the limit state may be taken into account by adopting design values which are less than the upper characteristic values divided by factors γ_m less than [1,0].

(12)P The partial factors for the resistance of a pile or an anchorage, determined on the basis of soil strength parameters, pile driving formulae or load tests, or anchorage tests are given in sections 7 and 8.

(13)P For serviceability limit states all values of γ_m are equal to [1,0].

(14)P Design values of ground properties may also be derived by methods other than the use of partial factors. The partial factors set out in the Table 2.1 indicate the level of safety considered appropriate for conventional designs. These shall be used as guidance to the required level of safety when the method of partial factors is not used.

(15) Where design values for ultimate limit state calculations are assessed directly, they should be selected such that a more adverse value is extremely unlikely to affect the occurrence of the limit state.

2.4.4 Design strength of structural materials

(1)P The design strength properties of structural materials and the design resistance of structural elements shall be calculated in accordance with the ENV's 1992 to 1996 and 1999.

2.4.5 Geometrical data

(1)P Geometrical data include the level and slope of the ground surface, water levels, levels of interfaces between strata, excavation levels, the shape of the foundation, etc.

(2)P In cases where variations of the geometrical data are not important, they shall be allowed for in the selection of design values for material properties or actions. In other cases it is generally advisable to allow for these uncertainties directly.

(3)P For limit states with severe consequences, design values for geometrical data shall represent the most unfavourable values which could occur in practice.

2.4.6 Limiting values for movements

(1)P A limiting value for a particular deformation is the value at which an ultimate or serviceability limit state is deemed to occur.

(2)P In foundation design limiting values shall be established for the foundation movements.

(3) The components of foundation movement which may need to be considered include settlement, relative (or differential) settlement, rotation, tilt, relative deflection, relative rotation, horizontal displacement and vibration.

(4)P The design values for the limiting movements shall be agreed with the designer of the supported structure.

(5)P The selection of design values for limiting movements shall take account of the following:

- the confidence with which the acceptable value of the movement can be specified;
- the type of structure;
- the type of construction material;
- the type of foundation;
- the type of ground;
- the mode of deformation;
- the proposed use of the structure.

(6)P The differential settlements and relative rotations for foundations shall be estimated to ensure that these do not lead to the occurrence of an ultimate limit state or a serviceability limit state, such as unacceptable cracking or the jamming of doors, in the supported structure.

(7) The maximum acceptable relative rotations for open frames, infilled frames and load bearing or continuous brick walls are unlikely to be the same but are likely to range from about 1/2 000 to about 1/300 to prevent the occurrence of a serviceability limit state in the structure. A maximum relative rotation of 1/500 is acceptable for many structures. The relative rotation likely to cause an ultimate limit state is about 1/150.

For normal structures with isolated foundations, total settlements up to 50 mm and differential settlements between adjacent columns up to 20 mm are often acceptable. Larger total and differential settlements may be acceptable provided the relative rotations remain within acceptable limits and provided the total settlements do not cause problems with the services entering the structure or cause tilting, etc.

The above guides concerning limiting settlements apply to normal routine structures. They should not be applied to buildings or structures which are out of the ordinary or for which the loading intensity is markedly non-uniform.

(8)P Calculations of differential settlement shall take account of:

- random or systematic variations in ground properties;
- the loading distribution;
- the construction method;
- the stiffness of the structure.

(9) For the majority of ground conditions, including alluvia, silts, loess, fills, peat and residual soils, consideration should be given to the possibility of a component of differential settlement due to variation in the ground properties across the site.