



BSI Standards Publication

Eurocode 7 — Geotechnical design

Part 3: Geotechnical structures

National foreword

This British Standard is the UK implementation of EN 1997-3:2025. Together with BS EN 1990:2023, BS EN 1997-1:2024 and BS EN 1997-2:2024, it supersedes BS EN 1997-1:2004+A1:2013 and BS EN 1997-2:2007, which will be withdrawn on 30 March 2028.

The UK participation in its preparation was entrusted to Technical Committee B/526, Geotechnics.

A list of organizations represented on this committee can be obtained on request to its committee manager.

National choice is allowed in this standard where explicitly stated within notes. The National Annex to this standard contains the national choices to be used for buildings and civil engineering works constructed in the UK.

The first generation of EN Eurocodes was published between 2002 and 2007, with conflicting British Standards withdrawn in 2010. This document forms part of the second generation of EN Eurocodes.

The second generation of EN Eurocodes is expected to be published between 2023 and 2026. These documents are being published as soon as they are available. This is being done to enable users to prepare for the transition from the first generation to second generation of EN Eurocodes.

UK adoptions of the first generation of EN Eurocodes will be withdrawn by BSI on 30 March 2028. Until that date, the first generation documents should be considered as the applicable standards for buildings and civil engineering works constructed in the UK unless otherwise specified by the relevant authority or in the specification for a particular project.

This standard is intended to be used with its National Annex and other referenced documents, including other second generation Eurocodes, as an interdependent suite of documents.

While the use of provisions in this standard in conjunction with first generation Eurocodes is not precluded, it should be undertaken with care and should only be done when users are satisfied that it will not result in a lower level of reliability than the minimum level set in the first generation Eurocodes and associated UK National Annexes.

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© The British Standards Institution 2025
Published by BSI Standards Limited 2025

ISBN 978 0 539 06278 6

ICS 91.010.30; 93.020

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 March 2025.

Amendments/corrigenda issued since publication

Date

Text affected

English Version

Eurocode 7 - Geotechnical design - Part 3: Geotechnical structures

Eurocode 7 - Calcul géotechnique - Partie 3 :
Constructions géotechniques

Eurocode 7 - Entwurf, Berechnung und Bemessung in
der Geotechnik - Teil 3: Geotechnische Bauwerke

This European Standard was approved by CEN on 29 December 2024.

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COMITÉ EUROPÉEN DE NORMALISATION
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Contents

Page

European foreword.....	7
0 Introduction	9
0.1 Introduction to the Eurocodes	9
0.2 Introduction to EN 1997 (all parts)	9
0.3 Introduction to EN 1997-3	10
0.4 Verbal forms used in the Eurocodes	10
0.5 National Annex for EN 1997-3	10
1 Scope	12
1.1 Scope of EN 1997-3	12
1.2 Assumptions.....	12
2 Normative references	12
3 Terms, definitions, and symbols.....	12
3.1 Terms and definitions	15
3.2 Symbols and abbreviations	25
4 Slopes, cuttings, and embankments	43
4.1 Scope and field of application.....	43
4.2 Basis of design	44
4.3 Materials.....	46
4.4 Groundwater.....	47
4.5 Geotechnical analysis	48
4.6 Ultimate limit states.....	51
4.7 Serviceability limit states.....	52
4.8 Implementation of design	53
4.9 Testing.....	55
4.10 Reporting	55
5 Spread foundations	55
5.1 Scope and field of application.....	55
5.2 Basis of design	55
5.3 Materials.....	60
5.4 Groundwater.....	61
5.5 Geotechnical analysis	61
5.6 Ultimate limit states.....	69
5.7 Serviceability limit states.....	76
5.8 Implementation of design	77
5.9 Testing.....	77
5.10 Reporting	78
6 Piled foundations	78
6.1 Scope and field of application.....	78
6.2 Basis of design	79
6.3 Materials.....	83
6.4 Groundwater.....	84
6.5 Geotechnical analysis	85
6.6 Ultimate limit states.....	94
6.7 Serviceability limit states.....	107
6.8 Implementation of design	107
6.9 Testing.....	109
6.10 Reporting	112

7	Retaining structures.....	112
7.1	Scope and field of application	112
7.2	Basis of design	112
7.3	Materials	116
7.4	Groundwater	117
7.5	Geotechnical analysis.....	117
7.6	Ultimate limit states	124
7.7	Serviceability limit states	129
7.8	Implementation of design.....	130
7.9	Testing.....	132
7.10	Reporting.....	132
8	Anchors	132
8.1	Scope and field of application	132
8.2	Basis of design	133
8.3	Materials	135
8.4	Groundwater	136
8.5	Geotechnical analysis.....	136
8.6	Ultimate limit states	137
8.7	Serviceability limit states	139
8.8	Implementation of design.....	142
8.9	Testing.....	142
8.10	Reporting.....	144
9	Reinforced fill structures.....	145
9.1	Scope and field of application	145
9.2	Basis of design	146
9.3	Materials	150
9.4	Groundwater	158
9.5	Geotechnical analysis.....	158
9.6	Ultimate limit states	165
9.7	Serviceability limit states	171
9.8	Implementation of design.....	171
9.9	Testing.....	172
9.10	Reporting.....	172
10	Soil nailed structures	173
10.1	Scope and field of application	173
10.2	Basis of design	173
10.3	Materials	175
10.4	Groundwater	181
10.5	Geotechnical analyses.....	181
10.6	Ultimate limit states	185
10.7	Serviceability limit states	191
10.8	Implementation of design.....	192
10.9	Testing.....	193
10.10	Reporting.....	196
11	Rock bolts and rock surface support.....	196
11.1	Scope and field of application	196
11.2	Basis of design	196
11.3	Materials	198
11.4	Groundwater	200
11.5	Geotechnical analyses.....	200
11.6	Ultimate limit states	203

11.7	Serviceability limit states.....	206
11.8	Implementation of design	206
11.9	Testing.....	206
11.10	Reporting	209
12	Ground improvement.....	209
12.1	Scope and field of application.....	209
12.2	Basis of design	211
12.3	Materials.....	216
12.4	Groundwater.....	217
12.5	Geotechnical analysis	217
12.6	Ultimate limit states.....	221
12.7	Serviceability limit states.....	224
12.8	Implementation of design	225
12.9	Testing.....	226
12.10	Reporting	228
13	Groundwater control measures.....	228
13.1	Scope and field of application.....	228
13.2	Basis of design	228
13.3	Material.....	230
13.4	Groundwater.....	231
13.5	Geotechnical analysis	231
13.6	Ultimate limit states.....	233
13.7	Serviceability limit states.....	233
13.8	Implementation of design	234
13.9	Testing.....	236
13.10	Reporting	236
Annex A	(informative) Slopes, cuttings, and embankments.....	238
A.1	Use of this annex.....	238
A.2	Scope and field of application.....	238
A.3	Calculation models for analysing the stability of soil and fill	238
A.4	Calculation models for analysing the stability of rock mass	240
Annex B	(informative) Spread foundations.....	242
B.1	Use of this annex.....	242
B.2	Scope and field of application.....	242
B.3	Checklists	242
B.4	Calculation model for bearing resistance using soil parameters	243
B.5	Calculation model for bearing resistance on ground underlain by a weaker layer	247
B.6	Calculation model for bearing resistance from Ménard pressuremeter test results	249
B.7	Calculation model for settlement evaluation based on elasticity	251
B.8	Calculation model for settlement evaluation based on the stress-strain method....	252
B.9	Calculation model for settlements without drainage	253
B.10	Calculation model for settlements caused by consolidation.....	253
B.11	Calculation model for time-settlement behaviour.....	253
B.12	Calculation model for settlement evaluation using pressuremeter test results.....	253
B.13	Calculation model for settlement evaluation using cone penetration test results ..	254
B.14	Relative stiffness of a spread foundation and subgrade modulus.....	256
B.15	Linear elastic spring stiffnesses of surface foundation	257
B.16	Calculation model for bearing resistance on rock mass based on wedge equilibrium	258

Annex C (informative) Piled foundations.....	260
C.1 Use of this annex	260
C.2 Scope and field of application	260
C.3 Pile classification	260
C.4 Pile shaft resistance based on ground parameters	262
C.5 Pile base resistance based on ground parameters.....	263
C.6 Axial pile resistance based on CPT profiles	264
C.7 Axial pile resistance from Ménard pressuremeter profiles.....	268
C.8 Axial pile resistance based on empirical tables	271
C.9 Downdrag due to vertical ground movements	273
C.10 Pile groups subject to axial tension	276
C.11 Calculation model for single pile settlement using load transfer functions	277
C.12 Calculation model for single pile lateral displacement using load transfer functions	278
C.13 Buckling and second order effects	282
C.14 Determination of axial pile resistance under cyclic loading	289
Annex D (informative) Retaining structures	291
D.1 Use of this Annex.....	291
D.2 Scope and field of application	291
D.3 Calculation model to determine limit values of earth pressures on vertical walls	291
D.4 Calculation model to determine at-rest values of earth pressure	296
D.5 Earth pressures due to compaction	297
D.6 Earth pressures caused by cyclic thermal movement for integral bridges	299
D.7 Basal heave	299
D.8 Limit equilibrium models.....	302
D.9 Beam-on-spring models	303
D.10 Calculation model to determine intermediate values of earth pressure	304
D.11 Numerical continuum models.....	306
D.12 Vertical wall stability	307
D.13 Determination of the anchor length to prevent interaction between anchors and retaining structures.....	308
Annex E (informative) Anchors	311
E.1 Use of this Annex.....	311
E.2 Scope and field of application	311
E.3 General design considerations	311
E.4 Specific design considerations.....	311
E.5 Layout of anchors	312
Annex F (informative) Reinforced fill structures.....	316
F.1 Use of this annex	316
F.2 Scope and field of application	316
F.3 Calculation models for reinforced fill structures.....	316
F.4 Calculation models for basal reinforced of embankment on weak soil.....	319
F.5 Calculation models for overbridging systems.....	320
F.6 Veneer reinforcement.....	320
F.7 Typical grades of steel used for soil reinforcement elements	321
Annex G (informative) Soil nailed structures.....	323
G.1 Use of this annex	323
G.2 Scope and field of application	323
G.3 Guidance on verification of pull-out resistance.....	323

Annex H (informative) Rock bolts and rock surface support.....	326
H.1 Use of this annex.....	326
H.2 Scope and field of application.....	326
H.3 Guidance on verification of pull out resistance.....	326
Annex I (informative) Ground improvement.....	328
I.1 Use of this annex.....	328
I.2 Scope and field of application.....	328
I.3 Examples of ground improvement techniques	328
I.4 Use of stress envelope to determine acceptable limit states	332
I.5 Calculation models for reinforced load transfer platform over discrete inclusions	332
I.6 Indicative range for the strength development of class II ground improved material over time	333
Annex J (informative) Groundwater control measures.....	335
J.1 Use of this annex.....	335
J.2 Scope and field of application.....	335
J.3 Examples of groundwater control measures	335
Annex K (informative) Thermoactive geostructures design	336
K.1 Introduction	336
K.2 Design principles.....	336
K.3 Ground investigation	337
K.4 Thermal design	337
K.5 Geotechnical and structural design.....	338
K.6 Execution.....	338
Bibliography.....	339

European foreword

This document (EN 1997-3:2025) has been prepared by Technical Committee CEN/TC 250 “Structural Eurocodes”, the secretariat of which is held by BSI. CEN/TC 250 is responsible for all Structural Eurocodes and has been assigned responsibility for structural and geotechnical design matters by CEN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2025, and conflicting national standards shall be withdrawn at the latest by March 2028.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

Together with EN 1990:2023, EN 1997-1:2024 and EN 1997-2:2024, this document will supersede EN 1997-1:2004 and EN 1997-2:2007.

The first generation of EN Eurocodes was published between 2002 and 2007. This document forms part of the second generation of the Eurocodes, which have been prepared under Mandate M/515 issued to CEN by the European Commission and the European Free Trade Association.

The Eurocodes have been drafted to be used in conjunction with relevant execution, material, product and test standards, and to identify requirements for execution, materials, products and testing that are relied upon by the Eurocodes.

The Eurocodes recognize the responsibility of each Member State and have safeguarded their right to determine values related to regulatory safety matters at national level through the use of National Annexes.

In comparison with the previous edition of EN 1997-1, the following main changes have been made:

- the Scope of EN 1997-3 has been extended to include geotechnical structures on/in rock (the word “ground” is now used extensively to denote soil, rock, and fill);
- new geotechnical structures have been added: pile groups and piled rafts (in Clause 6), reinforced fill structures (in Clause 9), soil nailed structures (in Clause 10), rock bolts and rock surface support (in Clause 11); ground improvement (in Clause 12) and groundwater control measures (in Clause 13);
- existing clauses on slopes, cuttings and embankments (in Clause 4), spread foundations (in Clause 5), piled foundations (in Clause 6), retaining structures (in Clause 7) and anchors (Clause 8) have been extensively revised;
- the basis of design of geotechnical structures has been aligned with EN 1990:2023;
- verification of ultimate limit state has been presented using (a) partial factors or other probabilistic methods, (b) prescriptive rules, (c) testing and (d) the Observational Method;
- durability and sustainability issues, e.g. corrosion and maintenance strategies have been addressed and an Annex K on thermoactive geostructure design introduced;
- harmonization of partial factors in ultimate limit state verification for all CEN-member states has been achieved especially for slopes and piled foundations;
- the use of numerical methods has been incorporated into the verification of limit states;
- numerous state-of-the-art calculation models have been presented in informative annexes;

- the link between design, execution and testing of geotechnical structures has been improved, with clear connections to EN execution standards and EN ISO geotechnical investigation and testing standards.

Any feedback and questions on this document should be directed to the users' national standards body. A complete listing of these bodies can be found on the CEN website.

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and the United Kingdom.

0 Introduction

0.1 Introduction to the Eurocodes

The Structural Eurocodes comprise the following standards generally consisting of a number of Parts:

- EN 1990 *Eurocode — Basis of structural and geotechnical design*
- EN 1991 *Eurocode 1 — 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 structures*
- New parts are under development, e.g. Eurocode for design of structural glass

The Eurocodes are intended for use by designers, clients, manufacturers, constructors, relevant authorities (in exercising their duties in accordance with national or international regulations), educators, software developers, and committees drafting standards for related product, testing and execution standards.

NOTE Some aspects of design are most appropriately specified by relevant authorities or, where not specified, can be agreed on a project-specific basis between relevant parties such as designers and clients. The Eurocodes identify such aspects making explicit reference to relevant authorities and relevant parties.

0.2 Introduction to EN 1997 (all parts)

EN 1997 consists of a number of parts:

- EN 1997-1 *Eurocode 7 — Geotechnical design – Part 1: General rules*
- EN 1997-2 *Eurocode 7 — Geotechnical design – Part 2: Ground properties*
- EN 1997-3 *Eurocode 7 — Geotechnical design – Part 3: Geotechnical structures*

EN 1997 (all parts) establish additional principles and requirements to those given in EN 1990 for the safety, serviceability, robustness, and durability of geotechnical structures.

EN 1997 (all parts) is intended to be used in conjunction with the other Eurocodes for the design of geotechnical structures, including temporary geotechnical structures.

Design and verification in EN 1997 (all parts) are based on the partial factor method or other reliability-based methods, prescriptive rules, testing, or the Observational Method.

0.3 Introduction to EN 1997-3

EN 1997-3 establishes principles and requirements for the design and verification of the following geotechnical structures, including temporary geotechnical structures: slopes, cuttings, embankments, shallow foundations, piled foundations, retaining structures, reinforced fill structures, soil nailed structures and ground improvement.

EN 1997-3 establishes principles and requirements for the design and verification of supporting elements: anchors, reinforcing elements in reinforced fill structures, soil nails, rock bolts and rock surface support, and ground improvement.

EN 1997-3 establishes principles and requirements for the design and verification of groundwater control measures including reduction of hydraulic conductivity, dewatering and infiltration, and the use of impermeable barriers.

0.4 Verbal forms used in the Eurocodes

The verb “shall” expresses a requirement strictly to be followed and from which no deviation is permitted in order to comply with the Eurocodes.

The verb “should” expresses a highly recommended choice or course of action. Subject to national regulation and/or any relevant contractual provisions, alternative approaches could be used/adopted where technically justified.

The verb “may” expresses a course of action permissible within the limits of the Eurocodes.

The verb “can” expresses possibility and capability; it is used for statements of fact and clarification of concepts.

0.5 National Annex for EN 1997-3

National choice is allowed in this standard where explicitly stated within notes. National choice includes the selection of values for Nationally Determined Parameters (NDPs).

The national standard implementing EN 1997-3 can have a National Annex containing all national choices to be used for the design of buildings and civil engineering works to be constructed in the relevant country.

When no national choice is given, the default choice given in this standard is to be used.

When no national choice is made and no default is given in this standard, the choice can be specified by a relevant authority or, where not specified, agreed for a specific project by appropriate parties.

National choice is allowed in EN 1997-3 through notes to the following clauses:

4.2.7.2(1)	4.3.4(1)	4.6.3(1)	5.2.7.2(1)
5.3.3(1)	5.6.1(5)	5.6.3(5)	5.6.3(7)
5.6.6(1) - 3 choices	5.6.6(3)	5.7.5(1)	6.1(2)
6.2.7.2(1)	6.3.7(1)	6.5.3.1(2)	6.5.3.3(5)
6.5.3.3(8)	6.5.3.3(10)	6.5.3.3(11)	6.5.6(3)

6.5.6(4)	6.5.8(4)	6.6.2.1(2) – 2 choices	6.6.2.4.2(1)
6.6.2.4.3(1)	6.6.3(4)	6.6.4.1(1) – 2 choices	6.6.4.2(1) – 2 choices
6.7(4)	6.9.3(6)	7.2.7.2(1)	7.3.7(1)
7.4.1(1)	7.5.3.2(2)	7.5.3.2(5)	7.6.2(6)
7.6.7(2)	7.6.9(1) – 2 choices	8.2.7.2(1)	8.3.4(1)
8.6.2(1)	8.6.2(7)	8.6.2(8)	8.6.2(9)
8.6.4(1) – 2 choices	8.7.2(4)	8.7.3(1)	8.9.1(2) – 2 choices
8.9.3(1)	9.2.7.2(1)	9.3.3(6)	9.3.4(16) – 2 choices
9.3.7(1)	9.6.2.1(1)	9.6.2.3(1)	9.6.7(1) – 2 choices
10.3.2.2(2)	10.3.8.1(11) – 2 choices	10.3.9(1)	10.6.2(2)
10.6.2(3)	10.6.2(6)	10.6.2(7)	10.6.5(3)
10.6.7(1) – 2 choices	10.9.1(4)	10.9.2(1) – 3 choices	10.9.2(8) – 2 choices
10.9.2(10) – 2 choices	11.3.3.2(3)	11.3.3.2(8)	11.3.5(1)
11.6.2(1)	11.6.3(1)	11.6.5(1)	11.9.1(4)
11.9.2(1) – 3 choices	11.9.2(4) – 2 choices	11.9.2(5) – 2 choices	11.9.3(1)
12.2.2(2)	12.2.7.2(1)	12.5.4(2) – 2 choices	12.5.4(5)
12.5.4(6) – 2 choices	12.6.1(2)	12.6.3(1)	12.6.6(1) – 2 choices
12.9.2.1(1)	12.9.2.2(2)	13.2.7.2(1)	13.3(4)
13.8.3(1)	B.5(3)	C.13.3.3(2)	C.13.3.3(4)
C.13.5.3(3) – 3 choices	C13.5.3(4)	D.8(2)	

National choice is allowed in EN 1997-3 on the application of the following informative annexes:

Annex A	Annex B	Annex C	Annex D
Annex E	Annex F	Annex G	Annex H
Annex I	Annex J	Annex K	

The National Annex can contain, directly or by reference, non-contradictory complementary information for ease of implementation, provided it does not alter any provisions of the Eurocodes.

1 Scope

1.1 Scope of EN 1997-3

- (1) This document provides specific rules to be applied in the design and verification of geotechnical structures.

1.2 Assumptions

- (1) This document is intended to be used in conjunction with EN 1990, which establishes principles and requirements for the safety, serviceability, robustness, and durability of structures, including geotechnical structures, and other construction works.

NOTE Additional or amended provisions can be necessary for assessment of existing structures, see prEN 1990-2.

- (2) This document is intended to be used in conjunction with EN 1997-1, which provides general rules for the design and verification of geotechnical structures.
- (3) This document is intended to be used in conjunction with EN 1997-2, which gives provisions for determining ground properties from ground investigations.
- (4) This document is intended to be used in conjunction with the other Eurocodes for the design of geotechnical structures, including temporary geotechnical structures.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE See the Bibliography for a list of other documents cited that are not normative references, including those referenced as recommendations (i.e. in 'should' clauses), permissions ('may' clauses), possibilities ('can' clauses), and in notes.

EN 206, *Concrete — Specification, performance, production and conformity*

EN 1563, *Founding — Spheroidal graphite cast irons*

EN 771-3, *Specification for masonry units — Part 3: Aggregate concrete masonry units (Dense and lightweight aggregates)*

EN 1536, *Execution of special geotechnical work — Bored piles*

EN 1537, *Execution of special geotechnical works — Ground anchors*

EN 1538, *Execution of special geotechnical work — Diaphragm walls*

EN 1990:2023, *Eurocode — Basis of structural and geotechnical design*

EN 1991-2:2023, *Eurocode 1 — Actions on structures — Part 2: Traffic loads on bridges and other civil engineering works*

EN 1992 (all parts), *Eurocode 2 — Design of concrete structures*

- EN 1992-1-1:2023, *Eurocode 2 — Design of concrete structures — Part 1-1: General rules and rules for buildings, bridges and civil engineering structures*
- EN 1993 (all parts), *Eurocode 3 — Design of steel structures*
- EN 1993-1-1:2022, *Eurocode 3 — Design of steel structures — Part 1-1: General rules and rules for buildings*
- prEN 1993-5:2023, *Eurocode 3 — Design of steel structures — Part 5: Piling*
- EN 1994 (all parts), *Eurocode 4 — Design of composite steel and concrete structures*
- EN 1995 (all parts), *Eurocode 5 — Design of timber structures*
- EN 1996 (all parts), *Eurocode 6 — Design of masonry structures*
- EN 1997-1:2024, *Eurocode 7 — Geotechnical design — Part 1: General rules*
- EN 1997-2:2024, *Eurocode 7 — Geotechnical design — Part 2: Ground properties*
- EN 10025 (all parts), *Hot rolled products of structural steel*
- EN 10079, *Definition of steel products*
- EN 10080, *Steel for the reinforcement of concrete — Weldable reinforcing steel — General*
- EN 10218-1, *Steel wire and wire products — General — Part 1: Test methods*
- EN 10218-2, *Steel wire and wire products — General — Part 2: Wire dimensions and tolerances*
- EN 10223-3, *Steel wire and wire products for fencing and netting — Part 3: Hexagonal steel wire mesh products for civil engineering purposes*
- EN 10223-6, *Steel wire and wire products for fencing and netting — Part 6: Steel wire chain link fencing*
- EN 10223-8, *Steel wire and wire products for fencing and netting — Part 8: Welded mesh gabion products*
- EN 10244-2, *Steel wire and wire products — Non-ferrous metallic coatings on steel wire — Part 2: Zinc or zinc alloy coatings*
- EN 10245 (all parts), *Steel wire and wire products — Organic coatings on steel wire*
- EN 12063, *Execution of special geotechnical work — Sheet pile walls, combined pile walls, high modulus walls*
- EN 12699, *Execution of special geotechnical works — Displacement piles*
- EN 12715, *Execution of special geotechnical work — Grouting*
- EN 12716, *Execution of special geotechnical work — Jet grouting*
- EN 12794, *Precast concrete products — Foundation piles*

EN 13251, *Geotextiles and geotextile-related products — Characteristics required for use in earthworks, foundations and retaining structures*

EN 13438, *Paints and varnishes — Powder organic coatings for hot dip galvanised or sherardised steel products for construction purposes*

EN 13670, *Execution of concrete structures*

EN 13738, *Geotextiles and geotextile-related products — Determination of pullout resistance in soil*

EN 14199, *Execution of special geotechnical works — Micropiles*

EN 14475:2006, *Execution of special geotechnical works — Reinforced fill*

EN 14487-1, *Sprayed concrete - Part 1: Definitions, specifications and conformity*

EN 14490:2010, *Execution of special geotechnical works — Soil nailing*

EN 14679, *Execution of special geotechnical works — Deep mixing*

EN ISO 1461, *Hot dip galvanized coatings on fabricated iron and steel articles — Specifications and test methods (ISO 1461)*

EN ISO 10319, *Geosynthetics — Wide-width tensile test (ISO 10319)*

EN ISO 12957-1, *Geosynthetics — Determination of friction characteristics — Part 1: Direct shear test (ISO 12957-1)*

EN ISO 12957-2, *Geosynthetics — Determination of friction characteristics — Part 2: Inclined plane test (ISO 12957-2)*

EN ISO 22282-4, *Geotechnical investigation and testing — Geohydraulic testing — Part 4: Pumping tests (ISO 22282-4)*

EN ISO 22477-1, *Geotechnical investigation and testing — Testing of geotechnical structures — Part 1: Testing of piles: static compression load testing (ISO 22477-1)*

EN ISO 22477-2, *Geotechnical investigation and testing — Testing of geotechnical structures — Part 2: Testing of piles: static tension load testing (ISO 22477-2)*

EN ISO 22477-4, *Geotechnical investigation and testing — Testing of geotechnical structures — Part 4: Testing of piles: dynamic load testing (ISO 22477-4)*

EN ISO 22477-5:2018, *Geotechnical investigation and testing — Testing of geotechnical structures — Part 5: Testing of grouted anchors (ISO 22477-5:2018)*

EN ISO 22477-10, *Geotechnical investigation and testing — Testing of geotechnical structures — Part 10: Testing of piles: rapid load testing (ISO 22477-10)*

3 Terms, definitions, and symbols

3.1 Terms and definitions

For purposes of this document, the terms and definitions given in EN 1990, EN 1997-1 and the following apply.

3.1.1 Common terms used in EN 1997-3

3.1.1.1

foundation

construction for transmitting forces to the supporting ground

3.1.1.2

deep foundation

foundation consisting of a pile or caisson that transfers loads below the surface stratum to a deeper stratum or series of strata at a range of depths

3.1.1.3

caisson

hollow construction with substantial impervious walls that comprises one or more cells and is sunk into the ground or water to form the permanent shell of a deep foundation

3.1.1.4

frost heave

swelling of soil due to formation of ice within it

3.1.1.5

ground heave

upward movement of the ground caused by either failure in the ground or by deformations due to stress relief, creep, or swelling

3.1.1.6

secondary compression

creep (in fine soils)

slow deformation of soil and rock mass because of prolonged pressure and stress

3.1.1.7

downdrag

situation where the ground surrounding a structural element settles more than the element itself, causing a downward drag force on and potential drag settlement of the element

3.1.1.8

drag force

additional axial force acting on a structural element due to downdrag

3.1.1.9

drag settlement

additional settlement of a structural element due to downdrag

3.1.1.10

reinforcing element

structural element added to the ground or engineered fill for stabilizing slopes or retaining structures

Note 1 to entry: Examples include steel or geosynthetic reinforcement, soil nails and rock bolts.

3.1.1.11

sprayed concrete

concrete that is conveyed through a hose and pneumatically sprayed at high velocity onto a surface

3.1.1.12

wire mesh

arrangement of bidirectional interlocking metal wires with small openings spaced between them

3.1.1.13

facing element

modular precast panel embedding the connections for soil reinforcements or soil nails covering to the exposed face of a reinforced fill or soil nailed structure which retains the fill between layers of reinforcement or soil nails and protects the fill against erosion

3.1.2 Terms relating to slopes, cuttings, and embankments

3.1.2.1

earth-structure

civil engineering structure made of fill material or as a result of excavation

3.1.2.2

cut

void that results from open excavation of the ground

3.1.2.3

cutting

earth-structure created by excavation of the ground

3.1.2.4

embankment

earth-structure formed by the placement of fill

3.1.2.5

embankment slope

slope that results from the placement of fill

3.1.2.6

earthworks

civil engineering process that modifies the geometry of ground surface

3.1.2.7

excavation

result of removing material from the ground

3.1.2.8

levee

embankment for preventing flooding

3.1.2.9

load transfer platform

layer of engineered fill constructed with or without reinforcing element used to spread the load from an overlying structure such as a spread foundation, raft or embankment to improved ground

3.1.3 Terms relating to spread foundations

3.1.3.1

spread foundation

foundation that transmits forces to the ground mainly by compression on its base

3.1.3.2

strip foundation

long, narrow, usually horizontal foundation

3.1.3.3

raft foundation

spread foundation in the form of a continuous structural concrete slab that extends over the whole base of a structure

3.1.4 Terms relating to piled foundations

3.1.4.1

pile

slender structural member, substantially underground, intended to transmit forces into load-bearing strata below the surface of the ground

3.1.4.2

bored cast-in-place pile

bored pile formed by continuous or discontinuous earthwork methods where the hole is subsequently filled with concrete

3.1.4.3

displacement pile

pile which is installed in the ground without excavation of material from the ground, except for limiting heave, vibration, removal of obstructions, or to assist penetration

3.1.4.4

driven pile

displacement pile forced into the ground by hammering, vibration or static pressure

3.1.4.5

end bearing pile

pile that transmits forces to the ground mainly by compression on its base

Note 1 to entry: The word 'mainly' implies at least 70 % to 80 % of the compression force applied to the pile is transmitted to the ground via its base.

3.1.4.6

friction pile

pile transmitting forces to the ground mainly by friction between the surface of the pile and the adjacent ground

Note 1 to entry: The word 'mainly' implies at least 70 % to 80 % of the compression or tension force applied to the pile is transmitted to the ground by friction between the pile shaft and the ground.

3.1.4.7

replacement pile

pile installed in the ground after excavation of material

3.1.4.8

tension pile

vertical or inclined pile used to transfer axial tension force by friction between the surface of the pile and the adjacent ground

3.1.4.9

pile cap

construction at the head of one or more piles that transmits forces from a structure to one or several piles

3.1.4.10

piled foundation

foundation that incorporates one or more piles

3.1.4.11

pile group

foundation that incorporates piles arranged in a grid

3.1.4.12

piled raft

combined foundation that incorporates a ground bearing raft foundation and a pile group

3.1.4.13

Ground Model Method

calculation method to determine the axial resistance of a single pile based on ground properties determined from field or laboratory tests, accounting for horizontal variability of the ground in the piled area

3.1.4.14

Model Pile Method

calculation method to determine the axial resistance of a single pile based on individual pile resistance profiles determined from correlations with field test results or ground properties from field or laboratory tests

3.1.4.15

neutral plane

depth at which there is no relative movement between the pile and the surrounding ground due to down drag

3.1.4.16

trial pile

pile that does not form part of the foundation, installed before the commencement of the piling works, that is used to investigate the appropriateness of the chosen pile type and method of execution and to confirm its design, dimensions, and resistance

3.1.4.17

working pile

pile that does form part of the foundation of the structure

3.1.4.18

test pile

trial pile or working pile to which loads are applied to determine the load-displacement behaviour of the pile and the surrounding ground at the time of construction

3.1.4.19**ultimate pile load test**

load test carried out on a test pile to determine its resistance at the ultimate limit state

3.1.4.20**serviceability pile load test**

load test carried out on a test pile to determine its load-displacement behaviour and resistance at the serviceability limit state

3.1.4.21**integrity test**

test carried out on an installed pile for the verification of soundness of materials and of the pile geometry

3.1.4.22**pile load**

axial compressive, tensile, or transverse load (or force) applied to the head of the pile

3.1.4.23**proof load (in a pile load test)**

maximum proposed test load in a pile load test

3.1.4.24**temporary support force**

temporary force arising from axial or transverse support from the ground to a pile during a pile load test resulting from variations in groundwater, pile head level or pile head restraint that can reverse, reduce or change under service conditions

3.1.4.25**static load test**

load test in which a single pile is subject to a series of static loads in order to define its load-displacement behaviour

3.1.4.26**dynamic load test**

test where a pile is subjected to a chosen axial dynamic load at the pile head to allow the determination of its compressive resistance

[SOURCE: EN ISO 22477-4:2018, 3.1.7]

3.1.4.27**rapid load test**

load test where a pile is subjected to a chosen axial rapid load at the pile head for the analysis of its compression resistance

[SOURCE: EN ISO 22477-10:2016, 3.1.7, modified]

3.1.4.28**ultimate resistance of a pile**

corresponding state in which the pile displaces significantly with negligible increase of resistance

3.1.4.29**driving formula**

formula that relates impact hammer energy and number of blows for a unit distance or permanent set for a single blow to pile compressive resistance

[SOURCE: EN ISO 22477-4:2018, 3.1.9]

3.1.4.30

wave equation analysis

analysis of a dynamically loaded pile by a mathematical model that can represent the dynamic behaviour of the pile by the progression of stress waves in the pile and the resulting response of the ground

[SOURCE: EN ISO 22477-4:2018, 3.1.10]

3.1.4.31

closed form solution

mathematical analysis of the dynamic load test data based on closed form wave analysis equations to derive a mobilized load

3.1.4.32

signal matching

numerical analysis to evaluate the shaft and base resistance of the test pile by modelling the pile and ground with assumed parameters to closely match the measured signals of pile head strain, displacement and acceleration obtained during a dynamic load test

[SOURCE: EN ISO 22477-4:2018, 3.1.11]

3.1.4.33

re-driving

process of re-initiating movement of a driven pile carried out some time after pile installation, used to check or determine any change in pile set or resistance

3.1.4.34

pile set

permanent pile settlement after one hammer impact blow during driving

3.1.4.35

pile set-up

time-dependent increase in pile resistance

3.1.5 Terms relating to retaining structures

3.1.5.1

retaining structure

structure that provides lateral support to the ground or that resists pressure from a mass of other material

3.1.5.2

gravity wall

retaining structure of stone or plain or reinforced concrete having a base spread foundation with or without a heel, ledge or buttress

Note 1 to entry: The weight of the wall itself, sometimes including stabilizing masses of soil, rock or backfill, plays a dominant role in the support of the retained material.

3.1.5.3

embedded wall

relatively thin retaining structure of steel, reinforced concrete, or timber that is supported by anchors, struts and/or passive earth pressure

Note 1 to entry: The bending stiffness of such walls plays a significant role in the support of the retained material while the role of the weight of the wall is insignificant.

Note 2 to entry: This definition includes structures that do not reach below the final excavation level, even if they cannot formally be considered as embedded.

3.1.5.4

composite retaining structure

retaining structure composed of elements of gravity and embedded walls

Note 1 to entry: A large variety of such structures exist and examples include double sheet pile wall cofferdams, gabion walls, crib walls, earth structures reinforced by grouting.

Note 2 to entry: Retaining structures reinforced by geosynthetics, steel strips, or wire meshes are considered as reinforced fill structures (see 3.1.7.2).

Note 3 to entry: Retaining structures reinforced by soil nails are considered as soil nailed structures (see 3.1.8.3).

3.1.5.5

combined wall

embedded wall composed of primary and secondary steel elements, placed in the ground before excavation begins

3.1.6 Terms relating to anchors

3.1.6.1

anchor

structural element capable of transmitting an applied tensile load from the anchor head through a free anchor length to a resisting element and finally into the ground

3.1.6.2

grouted anchor

anchor that uses a bonded length formed of cement grout, resin or similar material to transmit the tensile force to the ground

Note 1 to entry: A 'grouted anchor' in this document is termed a 'ground anchor' in EN 1537.

3.1.6.3

permanent anchor

anchor with a design service life greater than two years

3.1.6.4

temporary anchor

anchor with a design service life of two years or less

3.1.6.5

tendon

part of an anchor that is capable of transmitting the tensile load from the anchor head to the resisting element in the ground

3.1.6.6

fixed anchor length

designed length of an anchor over which the load is transmitted to the surrounding ground through a resisting element

3.1.6.7

free anchor length

distance between the proximal end of the fixed anchor length and the tendon anchorage point at the anchor head

3.1.6.8

tendon bond length

(for grouted anchors only) length of the tendon that is bonded directly to the grout and capable of transmitting the applied tensile load

3.1.6.9

tendon free length

length of the tendon between the anchorage point at the anchor head and the proximal end of the tendon bond length

3.1.6.10

apparent tendon free length

(for grouted anchors only) length of tendon which is estimated to be fully decoupled from the surrounding grout and is determined from the load-elastic displacement data following testing

3.1.6.11

lock-off load

load with which pre-stressable anchors are fixed to realize an active force to limit deformation

3.1.6.12

Test Method 1

test in which the anchor is loaded stepwise by one or more load cycles increasing from the datum load to the proof load

Note 1 to entry: At each load step the displacement of the tendon end is measured during a fixed time period.

[SOURCE: EN ISO 22477-5:2018, Test Method 1]

3.1.6.13

Test Method 3

test in which the anchor is loaded in incremental steps from a datum load to a maximum load

Note 1 to entry: The displacement of the tendon end is measured under maintained load at each loading step.

[SOURCE: EN ISO 22477-5:2018, Test Method 3]

3.1.6.14

proof load (in anchor test)

maximum test load to which an anchor is subjected in a particular load test

[SOURCE: EN ISO 22477-5:2018, 3.1.8]

3.1.7 Terms relating to reinforced fill structures

3.1.7.1

reinforced fill structures

structure that incorporates discrete layers of soil reinforcement within engineered fill

Note 1 to entry: The reinforcement layers are generally placed horizontally, between successive layers of fill during construction.

3.1.7.2**basal reinforcement to embankments**

fill structures incorporating at their base level at least one layer of soil reinforcements, commonly used for fills founded on weak or soft soils and fills founded on inclusion networks, or for fills overbridging voids

3.1.7.3**soil veneer reinforcement**

use of soil reinforcement to prevent the sliding of the cover soil layer over a landfill lining or cover system, or any other low friction interface

3.1.7.4**isochronous creep curves**

load/strain creep curves plotted at fixed times for geosynthetic reinforcement elements

Note 1 to entry: The load at which there is a specified difference in strain for a specified time interval can then be defined. The procedure how to generate the isochronous creep curves is given in ISO/TS 20432.

3.1.7.5**equivalent constant in-soil temperature**

temperature that causes the same rate of reinforcing element degradation during one year as the actual in-soil temperature variation at the location of the reinforcing element

3.1.7.6**external failure mechanism**

failure mechanism for a reinforced fill structure that does not intersect the structure

3.1.7.7**compound failure mechanism**

failure mechanism for a reinforced fill structure that intersects the structure

3.1.7.8**internal failure mechanism**

failure mechanism for a reinforced fill structure that occurs solely within the structure

3.1.8 Terms relating to soil nailed structures**3.1.8.1****soil nail**

reinforcing element installed into the ground that mobilises resistance with the ground along its entire length, working mainly in tension, but with shearing/bending forces as a potential but negligible secondary effect

Note 1 to entry: Soil nails are usually driven or bored into the ground.

3.1.8.2**soil nailed structure**

cutting, slope, or existing structure reinforced with soil nails, that are installed into the ground, usually at a sub-horizontal angle

Note 1 to entry: Soil nails form part of a composite structure which usually includes facing elements (head plates, sprayed concrete, wire mesh, or other facing elements). The facing retains the ground between the soil nails that would otherwise be left unsupported.

Note 2 to entry: Soil nails are typically arranged in rows. For cut-faced applications, the rows are usually installed sequentially in a top-down sequence as the face of the structure is progressively excavated.

3.1.9 Terms relating to rock bolts and rock surface support

3.1.9.1

rock bolt

reinforcing element for stabilizing rock excavations and slopes, transferring load from the unstable exterior to the confined interior of the rock mass including doweling to prevent shear failure through discontinuities

Note 1 to entry: Rock bolts consist of different types of reinforcement of the rock mass, and generally consist of a bar (solid, hollow or flexible) or cable, fixed in place by either mechanical expansion or by grout, or resin.

3.1.9.2

rock surface support

support given to a rock mass to prevent potential rock falls and ravelling of the rock surface

Note 1 to entry: Rock surface support is non-structural and includes wire mesh and sprayed concrete

3.1.10 Terms relating to ground improvement

3.1.10.1

ground improvement

modification of the ground to provide better performance at ultimate and or serviceability limit states

Note 1 to entry: Ground modification includes changes of one or more properties, typically by means of compaction, consolidation, replacement or mixing with binders, or installation of inclusions within the ground improvement zone.

3.1.10.2

ground improvement zone

volume of ground within which ground improvement is installed and results in modified ground properties

3.1.10.3

inclusion

elements installed in the ground with defined geometry and material properties sufficiently different from the surrounding ground so as to modify the distribution of load, stress and groundwater flow within the ground improvement zone

3.1.10.4

rigid inclusion

inclusions with stiffness and strength that are significantly higher than the ground in which they are installed

3.1.10.5

discrete ground improvement

ground improvement zone comprising inclusions created in the ground with properties differing from the surrounding ground

3.1.10.6

diffused ground improvement

ground improvement where the ground improvement zone is be modelled with a single set of parameters

3.1.10.7**structural connection**

mechanical connection between the ground improvement and the structure, capable of transferring compressive, tensile, shear, and bending actions directly

3.1.10.8**contact**

physical contact between the ground improvement and the structure, capable of transferring only compressive and limited shear loads

Note 1 to entry: The transferable shear load typically depends on the size of the compressive load and the activated friction.

3.1.10.9**load distribution**

subdivision of the total load into the share transferred by the inclusion and the part transferred by the soil

Note 1 to entry: The load distribution is determined by calculation and is an integral part of the design of discrete ground improvement.

3.2 Symbols and abbreviations

For the purposes of this document, the following symbols and abbreviations apply.

Note 1 to entry: The symbols commonly used in all Eurocodes are defined in EN 1990.

Note 2 to entry: Further symbols commonly used in Eurocode 7 are defined in EN 1997-1.

Note 3 to entry: The notation used for the symbols used is based on ISO 3898.

3.2.1 Symbols*Latin upper-case letters*

A	plan area of the foundation base
A	loss of metal (including zinc) per face over the first year (in reinforcement elements)
A'	effective plan area of the foundation
A_0	initial cross-sectional area of steel reinforcement
$A_{0,con}$	initial cross-sectional area of steel reinforcement at a connection
A_b, A_s	area of the pile base and shaft, respectively
$A'_{gs,d}$	design value of the effective adhesion between the ground and geosynthetic reinforcement (also covers apparent adhesion caused by interlocking mechanism)
A_r	reduced cross-sectional area of steel reinforcement, taking account of the maximum anticipated loss of steel during the design service life of the structure
$A_{r,con}$	reduced cross-sectional area of steel reinforcement at a connection, taking account of the maximum anticipated loss of steel along the design service life of the structure

A_{red}	plan area of the foundation base not including any area where there is no positive contact pressure between the foundation and the underlying ground
A_{ru}	reduced cross-sectional area of the reinforcing element at ultimate resistance, allowing for the effects of potential corrosion
A_{ry}	reduced cross-sectional area of the reinforcing element at yield, allowing for the effects of potential corrosion
$A'_{\text{sn,d}}$	design value of the effective adhesion between the ground and a soil nail
$A'_{\text{st,d}}$	design value of the effective adhesion between the ground and steel reinforcement
B	foundation width (shorter dimension on plan)
B	breadth of the reinforcing element
B'	effective foundation width
B_b, B_s	base and shaft width (for square piles), respectively
$B_{\text{n,eq}}$	equivalent pile base size equal to B_b (for square piles), D_b (for circular piles), or p_b/π (for other shaped piles)
B_{nom}	nominal width of the rectangular foundation
B'_{eq}	effective width of an equivalent rectangular foundation
B_{gi}	smaller plan dimension of a rectangle circumscribing the ground improvement zone, limited to the depth of the zone of influence (in ground improvement)
B_{ri}	diameter of an inclusion
B_{ref}	reference diameter of an inclusion
$B_{\text{s,eq}}$	equivalent pile shaft size equal to B_s (for square piles) or D_s (for circular piles)
C	subgrade reaction modulus
C_a	cohesive resistance along the slip surface of an active wedge
$C_{\text{ad,SLS}}$	serviceability limit state criterion for non-grouted anchors
$C_{\text{d,SLS,min}}, C_{\text{d,SLS,max}}$	minimum and maximum design value of the relevant serviceability criterion for the considered geotechnical structure within the zone of influence
C_p	cohesive resistance along the slip surface of a passive wedge
D	diameter of circular foundation, reinforcing bar
D_b	base diameter (for circular piles) in pile foundations
D_{ds}	diameter of depression at the surface

D_d	design drag force due to moving ground in pile foundations
D_f	embedment depth
D_{nom}	nominal diameter of the circular foundation
D_{rep}	representative drag force due to moving ground in pile foundations
D_s	shaft diameter (for circular piles) in pile foundations
D_{supp}	representative vertical or transverse temporary support force
D_y	diameter of the void
E_d	design value of the effects of actions at the ultimate limit state
$E_{d,SLS}$	design value of the maximum anchor force, including the lock-off load, and sufficient to prevent the serviceability limit state in the anchored structure
$(EI)_d$	design value of bending (flexural) stiffness
EI	bending (flexural) stiffness
E_i	initial tangent modulus
$E_{m,rep}$	Representative value of the ground elasticity modulus
E_{ur}	unloading-reloading modulus
EI	bending stiffness
F_{cd}	design axial compression force applied to the pile including an allowance for any potential drag force
$F_{cd,SLS}$	design axial compression load applied to the pile at the serviceability limit state, including potential drag forces
$F_{d,SLS}$	design value of an action to prevent a serviceability limit state
$F_{d,ULS}$	design value of the action that the supporting element shall provide to prevent an ultimate limit state of the supported structure or the design action at the ultimate limit state for piles
$F_{group,d}$	design action applied to the pile group or piled raft
$F_{rep,SLS}$	representative value of the action that the supporting element shall provide to prevent a serviceability limit state of the supported structure
$F_{rep,ULS}$	representative value of the action that the supporting element shall provide to prevent an ultimate limit state of the supported structure
F_{td}	design axial tension load applied to the pile

$F_{\text{tot},k}$	characteristic value of the load on a raft
$F_{\text{tr},d}$	design transverse force applied to the pile including an allowance for any potential transverse force due to moving ground
H	embankment height
H_e	excavation depth
H_{ret}	height of supported ground
H_s	height of material above a geosynthetic layer
H_v	height above a void
I	second moment of area (geometric moment of inertia)
I_s	influence factor for foundation shape
$I_{z,\text{max}}$	maximum value of vertical strain influence factor for spread foundation
K_0	at-rest earth pressure coefficient
K_a	active pressure coefficient
K_{ay}, K_{aq}, K_{ac}	active earth pressure coefficients
$K_{ac,u}$	active earth pressure coefficient for undrained conditions
K_{py}, K_{pq}, K_{pc}	passive earth pressure coefficients
$K_{pc,u}$	passive earth pressure coefficient for undrained conditions
K_s	relative stiffness between the foundation and the ground
K_u	corrosion heterogeneity factor at the ultimate stress (in reinforcement elements)
K_y	corrosion heterogeneity factor at yield (in reinforcement elements)
L	foundation length
L'	effective foundation length
L_b	grouted length of steel bar
L_{bd}	design value of buckling length
L_{db}	debonded length of the soil nail
L_{dd}	depth of the neutral plane corresponding to the point where the pile settlement equals the ground settlement
L_{ds}	total length of the reinforcing element along which direct shear stresses are mobilized

L'_{eq}	effective length of an equivalent rectangular foundation
L_{int}	mobilized interface length
L_j	length of the j^{th} layer of reinforcement
L_n	nail length
L_{po}	total length of the reinforcing element beyond the failure surface (or line of maximum tension) where pull-out stresses are mobilized (for reinforcement elements)
L_{ps}	total length of the reinforcing element beyond the failure surface (or line of maximum tension) where punching shear stresses are mobilized
N	normal component of the resulting force acting on the foundation base
N_a	component of the total action acting normal to the slip surface of an active wedge
N_c	non-dimensional bearing resistance factor for the influence of the ground's effective cohesion
N_{cr}	critical buckling pile load
N_{cu}	non-dimensional bearing resistance factor for the influence of the ground's undrained shear strength
N_d	design value of N
N'_d	design value of the effective action acting normal to the foundation base
N_{Ed}	design axial pile load
N_{rep}	representative value of N
N_p	component of the total action acting normal to the slip surface of a passive wedge
N_q	non-dimensional bearing resistance factor for overburden pressure
N_{Rd}	structural design resistance of the pile
N_s	shape factor depending on the length and the width of the excavation
N_γ	non-dimensional bearing resistance factor for the influence of the ground's weight density
$N_{\gamma u}$	non-dimensional bearing resistance factor for the influence of the ground's weight density in undrained conditions
P	percentage of test results passing the required characteristic value (in ground improvement)
P	length of the perimeter of a reinforcing element

P_c	critical creep load determined in Test Method 3 of EN ISO 22477-5:2018
P_o	lock-off load
P_p	proof load
R	radius of a circular foundation
$R_{ad,SLS}$	design value of an anchor's geotechnical resistance at the serviceability limit state
$R_{ad,ULS}$	design value of an anchor's geotechnical resistance at the ultimate limit state
$R_{ak,SLS}$	characteristic value of an anchor's geotechnical resistance at the serviceability limit state
$R_{ak,ULS}$	characteristic value of an anchor's geotechnical resistance at the ultimate limit state
R_{am}	measured value of an anchor's geotechnical resistance
$R_{am,SLS}$	measured value of an anchor's geotechnical resistance at the serviceability limit state
$R_{am,ULS}$	measured value of an anchor's geotechnical resistance at the ultimate limit state
$R_{am,\alpha SLS}$	measured value of an anchor's geotechnical resistance complying with its serviceability limit state criterion α_{SLS}
$R_{am,\alpha ULS}$	measured value of an anchor's geotechnical resistance complying with its ultimate limit state criterion α_{ULS}
$R_{am,CadSLS}$	measured value of the anchor's geotechnical resistance complying with $C_{ad,SLS}$
$R_{am,CadULS}$	measured value of the anchor's geotechnical resistance complying with $C_{ad,ULS}$
$(R_{am,ULS})_{min}$	minimum value of $R_{am,ULS}$ in a number of tests
$(R_{am,SLS})_{min}$	minimum value of $R_{am,SLS}$ in a number of tests
R_{block}	ultimate vertical resistance of the block of ground bounded by the perimeter of the pile group
R_b, R_s, R_{st}	resistance of pile base, shaft, and shaft in tension, respectively
$R_{b,rep}$	pile's representative base resistance in axial compression
$R_{calc,mean}$	mean calculated pile resistance for a set of profiles of field or laboratory test results
$R_{calc,min}$	minimum calculated pile resistance for a set of profiles of field or laboratory test results
R_c, R_t, R_{tr}	pile resistance to compression, tension, and transverse actions, respectively
$R_{c,rep}$	pile's representative total resistance in axial compression
$R_{con,x,rep}$	representative tensile resistance at the connection of component 'x', where 'el' denotes the reinforcing element at the connection to the facing; 'c' denotes the connector (steel

	plates and bolts, steel rods, polymeric bodkins, combs, pins, polymeric loops and toggles, etc.) at the connection; and 'f' denotes the facing element at the connection
R_g	resistance of the ground supporting the load transfer platform in the net area between the columns mobilized at a settlement that is compatible with the settlement of the ground improvement system
R_{group}	ultimate compressive resistance of a pile group
$R_{\text{group,d}}$	design resistance of the pile group or piled raft
$R_{\text{group,rep}}$	representative ultimate vertical resistance of the pile group
$R_{\text{gs,int,d}}$	design tensile strength of the interface with a geosynthetic reinforcing element
R_i	ultimate axial resistance of the i -th pile in the pile group, taking full account of the effects of pile interaction
$R_{\text{k,com}}$	characteristic resistance to direct shear of a reinforcing element
$R_{\text{k,ds}}$	characteristic tensile resistance of a connection (of a reinforcing element)
$R_{\text{m,sn,pul}}$	measured pull-out force for a soil nail
R_N	drained bearing resistance normal to the base of a spread foundation
R_{Nd}	design bearing resistance normal to the base of a spread foundation
R_{Nu}	undrained bearing resistance normal to the base of a spread foundation
R_{pd}	design value of the resisting force caused by earth pressure on the foundation side
$R_{\text{piled-raft}}$	ultimate compressive resistance of a piled raft
$R_{\text{piled-raft,d}}$	design resistance of the piled raft
$R_{\text{piled-raft,rep}}$	representative ultimate compressive resistance of a piled raft
$R_{\text{po,d}}$	design value of interface resistance between the fill and the reinforcing element
$R_{\text{po,rep}}$	representative pull-out resistance of a reinforcing element
R_{raft}	additional bearing resistance from the raft
$R_{\text{raft,net}}$	additional bearing resistance from the raft, considering the net area of the raft
$R_{\text{rep,SLS}}$	representative value of the pile's serviceability resistance
$R_{\text{rep,ULS}}$	representative value of the pile's ultimate resistance
$R_{\text{ri}}, R_{\text{ro}}$	pick-up and anchoring resistance for rock bolts
$R_{\text{ri,i}}$	resistance of a rigid inclusion depending on its position within a group of inclusions

$R_{s,rep}$	pile's representative shaft resistance in axial compression
$R_{sn,int,d}$	design tensile strength of the interface with a soil nail element
$R_{st,int,d}$	design tensile strength of the interface with a steel reinforcing element
$R_{sys,rep}$	representative value of the total resistance of the ground improvement system with rigid inclusions
R_{td}	design value of the axial tensile resistance of a pile or a structural element
$R_{t,el,rep}$	representative tensile resistance of the reinforcing element
$R_{t,rep}$	representative axial tensile resistance of a pile
$R_{t,wm,rep}$	representative tensile resistance of the wire mesh
$R_{T,base}$	sliding resistance of a foundation along its base
$R_{T,face}$	resistance from earth pressure on the front of the foundation
$R_{t,el,rep}$	representative tensile resistance of a reinforcing element
$R_{test,mean}$	mean pile resistance measured in a set of load tests
$R_{test,min}$	minimum pile resistance measured in a set of load tests
$R_{tr,d}$	design transverse resistance of a pile
$R_{Tu,base}$	undrained sliding resistance of a foundation along its base
R_{xd}	design resistance of a pile (where x is one of b for base, c for compression, s for shaft, t for tension or tr for transverse)
R_{xm}	measured resistance of a pile (where x is one of b for base, c for compression, s for shaft, t for tension or tr for transverse)
$R_{x,rep}$	representative resistance of a pile (where x is one of b for base, c for compression, s for shaft, t for tension or tr for transverse)
S_t	sensitivity of fine soil
S_v	vertical spacing of reinforcement
T	component of the total action acting transverse (parallel) to the foundation base
T	age of the structure (in reinforcement elements)
T_d	design value of the applied force acting parallel to the foundation base, including any thrust caused by earth pressure acting on the foundation
$T_{f,j}$	tensile force due to any horizontal loads
$T_{gs,k}$	characteristic tensile strength of geosynthetic reinforcement

T_k	characteristic tensile strength of a reinforcing element
$T_{k,cr}$	characteristic tensile strength of a reinforcing element allowing for creep and limiting elongation
$T_{p,j}$	tensile force per metre width due to the vertical loads of self-weight and surcharge
T_{rep}	representative value of T
$T_{s,j}$	tensile force due to any strip loading
T_{ven}	tensile force to hold a veneer system on a dry slope
U	uplift force due to groundwater pressure on the foundation base
V_{norm}	coefficient of variation based on a normal distribution of strength values
W	wedge weight load
W_s	surcharge load
W_T	vertical uniformly distributed (wedge) load on the reinforcement
W_v	resultant vertical load excluding external strip loads on a reinforcement layer

Latin lower-case letters

a	adhesion between the wall and the ground
a_d	design value of a geometrical property
a_{nom}	nominal value of a geometrical property
b	base width of an embankment
b	width of a strip element (in reinforcement elements)
$b_\alpha, b_\varphi, b_\gamma$	non-dimensional factors accounting for base inclination
b_{cu}	non-dimensional factor accounting for base inclination, undrained
b_{gs}	width of reinforcement per unit width
b_{st}	width of strip reinforcement per unit width
c'	soil's or fill's effective cohesion
$c_{min,dur}$	minimum concrete cover required for durability
c_u	undrained shear strength of soil or fill
c_{ud}	design value of the undrained shear strength of soil or fill

$c_{u,ref}$	reference undrained shear strength
$c_{u,rep}$	representative value of the undrained shear strength of soil or fill
d_{avg}	average horizontal spacing between the test profiles
d_c, d_q, d_γ	non-dimensional factors accounting for the embedment depth and resistance above the base of the foundation
d_{cu}	non-dimensional factor accounting for embedment depth and resistance above the base of the foundation, undrained
d_{min}	minimum depth of field investigation
d_{ref}	reference horizontal spacing for the Model Pile Method
d_s	rock discontinuity spacing between a pair of immediately adjacent discontinuities
e	eccentricity of the applied or resultant action
e	centre to centre spacing of inclusions
e_{0d}	maximum transverse deformation of the initial curvature over the buckling length, design value
e_B	eccentricity of the applied load in the direction of B
e_d	design eccentricity of the resultant action
e_j	eccentricity of the resultant vertical load at the level of the j^{th} layer of reinforcement
e_L	eccentricity of the applied load in the direction of L
e_z	initial zinc thickness of coating (for steel reinforcement elements)
f_{ds}	direct shear factor determined from direct shear tests or comparable experience (for reinforcing elements)
f_{e0d}	factor accounting for that initial deflection of pile is not measurable
f_{md}	design value of the unconfined compressive strength of improved ground
f_s	reduction factor to allow for uncertainty in the extrapolation of data for a given design service life
f_{ud}	design tensile strength of steel reinforcement
f_{uk}	characteristic ultimate tensile strength of steel reinforcement
f_{yk}	characteristic yield strength of steel reinforcement
g_c, g_q, g_γ	non-dimensional factors accounting for ground surface inclination
g_{cu}	non-dimensional factor accounting for ground surface inclination, undrained

h	maximum depth or maximum height of a cutting, excavation or embankment
h_{com}	depth to the bottom of a compressible soil layer or the zone of influence
h_{ref}	reference thickness of a soil layer
h_s	distance between the lowest support and excavation level at each construction stage
i	index from 1 to n
i_c, i_q, i_γ	non-dimensional factors accounting for load inclination
i_{cu}	non-dimensional factor accounting for load inclination, undrained
j	index number of layers or strata with j from 1 to n
k	subgrade reaction modulus
k_{cc}	corrosion concentration factor, accounting for concentrated areas of corrosion and depending on the steel manufacturing process
k_{cu}	reduction factor depending on the foundation material, execution method and soil or fill disturbance
k_d	design value of the subgrade reaction modulus
$k_{\text{interface}}$	reduction factor depending on the foundation material, execution method and soil or fill disturbance
$k_n\{P\}$	acceptance value for the sample distribution in terms of P
k_{po}	pull-out factor determined in laboratory pull-out tests in representative conditions, from comparable experience, or from field tests (for reinforcement elements)
k_{sn}	soil nail (reinforcement element) pull-out factor determined from field pull-out tests or from comparable experience
k_{subgrade}	coefficient of horizontal subgrade reaction
k_t	calibration factor accounting for the influence of the termination on the measured breaking strength of the element
$k_{\tan\varphi}$	reduction factor applied to $\tan\varphi$
$k_{\tan\delta}$	reduction factor depending on the foundation material and execution method
m	exponent in bearing resistance formulae for the load inclination factor i
m_y	mean of the measured values of $\log(q_{u,\text{field}})$ (in ground improvement)
n	number of rigid inclusions or piles
n	exponent (factor covering reduction in corrosion rate in time for reinforcement

	elements)
n	number of geotechnical units providing resistance
n_{test}	number and type of site-specific pile load tests
n_{total}	total number of piles in similar ground conditions
p	pile perimeter
p_0	total at-rest earth pressure
p'_0	effective at-rest earth pressure
p_a	component of the total active earth pressure normal to the retaining wall face
p'_a	component of the effective active earth pressure normal to the retaining wall face
$p_{a,\text{min}}$	minimum value of p_a to the retaining wall face
p_{fd}	design value of the ultimate transverse ground resistance pressure
$p_{\text{f,rep}}$	representative value of the ultimate transverse ground resistance pressure
p_{group}	smaller dimension of a rectangle circumscribing the group of piles forming the foundation
p_p	component of the total passive earth pressure normal to the retaining wall face
p'_p	component of the effective passive earth pressure normal to the retaining wall face
p_{ps}	resistance to punching through the ground or fill (of a reinforcing element)
p_{re}	perimeter of the reinforcing element
p_{sn}	representative perimeter of the failure surface enclosing the soil nail per unit length, where pull-out resistance is mobilized
q	overburden or vertical surcharge pressure at given level
q'	effective overburden pressure in ground outside the foundation base at the level of the base
q_0	overburden pressure applied to the ground outside the foundation
q_a	vertical surcharge applied at the ground surface (on the active side of the retaining wall)
q_b	unit base resistance
q_p	permanent (or unfavourable variable) vertical surcharge applied at ground surface on the passive side
q_s	surface load

$q_{s,i}$	unit shaft resistance the i -th geotechnical unit
q_{sk}	characteristic skin friction along the soil nail (reinforcement element)
$q_{s,rep}$	representative value of unit shaft resistance
$q_{st,i}$	unit shaft resistance in tension in the i -th geotechnical unit
$q_{u,field}$	unconfined compressive strength measured in unconfined compressive tests on field samples
$q_{u,imp,k}$	characteristic value of the unconfined compressive strength of improved ground
$q_{u,imp,nom}$	nominal value of the unconfined compressive strength of the Class II ground improvement material
$q_{u,rep}$	representative value of the unconfined compressive strength of improved ground
s_0	settlement caused by undrained shear
s_1	settlement caused by consolidation
s_2	settlement caused by creep
s_c, s_q, s_γ	non-dimensional factors accounting for the shape of the foundation
s_{cu}	non-dimensional factor accounting for shape of the foundation, undrained
s_{ground}	ground strata settlement profile (at any particular time)
s_{pile}	pile settlement with depth
s_y	standard deviation of the measured values of $\log(q_{u,field})$ (in ground improvement)
t	time in days (since t_0)
t_f	thickness of foundation
t_0	time / date of installation or construction
u	groundwater pressure at a point in the ground
u_a	groundwater pressure acting on the active side of a retaining wall
u_p	groundwater pressure acting on the passive side of the wall
v_a	horizontal wall movement required to mobilize full active earth pressure
v_p	horizontal wall movement required to mobilize full passive earth pressure
w_s	surcharge on a geosynthetic layer
x	distance along the length of a reinforcing element

y	transverse deflection of a pile
y_f	transverse deflection of the pile at ground failure
z	depth below ground surface
z_a	depth on the active side of a retaining wall
$z_{c,max}$	maximum depth at which p'_c applies
$z_{c,min}$	minimum depth at which p'_c applies
z_{min}	minimum horizontal extent of field investigation for anchors
z_p	depth on the passive side of a retaining wall

Greek upper-case letters

Δa	deviation in a geometrical property
ΔA_r	maximum anticipated loss of steel area during the design service life of the structure
ΔB	deviation in width
Δc_{dev}	allowance in design for deviation of concrete cover
ΔD	deviation in diameter
Δe	loss of thickness caused by corrosion in the ground

Greek lower-case letters

α	angle of inclination of a foundation base to the horizontal
α	angle defining the width of the foundation area
α	angle of inclination of a surcharge
α_1	limit value of the creep rate in Test Method 1
α_3	limit value of the creep rate in Test Method 3
α_{ds}	soil/reinforcement interaction coefficient for undrained conditions (for reinforcing elements)
α_{SLS}	creep rate that defines the geotechnical resistance of an anchor at the serviceability limit state
α_{ULS}	creep rate that defines the geotechnical resistance of an anchor at the ultimate limit state
β	inclination of the ground surface from the horizontal, measured downwards from the edge of the foundation

$\tan \varphi$	coefficient of friction of the ground
γ	unit weight density of the ground
γ^*	relevant weight density below foundation base depend on on the ground water level
γ_a	average weight density of the ground (on the active side of a retaining wall) above depth z_a
$\gamma_{a,SLS}$	partial factor on an anchor's geotechnical resistance at the serviceability limit state
$\gamma_{a,SLS,test}$	partial factor on an anchor resistance at the serviceability limit state in acceptance tests
$\gamma_{a,ULS}$	partial factor on an anchor's geotechnical resistance at the ultimate limit state
γ_{cu}	partial factor on undrained shear strength
γ'_d	design effective weight density of the ground below foundation level
γ_E	partial factor on the effect of actions
γ_F	partial factor on an action
$\gamma_{F,drag}$	partial factor on the drag force on a pile due to moving ground
$\gamma_{F,SLS}$	partial factor on an anchor force at the serviceability limit state
γ_{gs}	partial factor on the strength of geosynthetic reinforcement
$\gamma_{gs,int}$	partial factor on the interface strength of geosynthetic reinforcement
$\gamma_{gs,d}$	design value of the effective angle of shearing resistance between the ground and geosynthetic reinforcement
γ_M	partial factor on a material property
γ_{M0}, γ_{M2}	partial factors for steel (see EN 1993-1-1)
$\gamma_{M,gs}$	partial material factor for geosynthetic reinforcing element
$\gamma_{M,pwm}$	partial material factor for a polymeric steel woven wire mesh reinforcing element
γ_p	average weight density of the ground (on the passive side of a retaining wall) above depth z_p
γ_{pf}	partial factor on transverse ground resistance pressure
γ_R	partial factor on resistance
$\gamma_{Ra,SLS}$	partial factor on the anchor's geotechnical resistance at the serviceability limit state
$\gamma_{Ra,ULS}$	partial factor on the anchor's geotechnical resistance at the ultimate limit state

$\gamma_{Ra,SLs,test}$	partial factor on the anchor's geotechnical resistance at the serviceability limit state
γ_{Rb}	partial factor on the base resistance of a single pile
γ_{Rc}	partial factor on the axial compressive resistance of a single pile
$\gamma_{Rd,bolt}$	model factor accounting for uncertainty in the interface model for rock bolts
$\gamma_{Rd,group}$	model factor accounting for uncertainty in the resistance model for a pile group
$\gamma_{Rd,nail}$	model factor accounting for uncertainty in the pull-out resistance of soil nails
$\gamma_{Rd,pile}$	model factor accounting for uncertainty in the resistance model for a piled foundation
$\gamma_{Rd,piled-raft}$	model factor accounting for uncertainty in the resistance model for a piled raft
$\gamma_{Rd,retain}$	model factor accounting for uncertainty in the resistance model for a retaining structure
$\gamma_{Rd,sys}$	model factor on overall system resistance
$\gamma_{Rd,wm}$	model factor accounting for additional uncertainty owing to extrapolation of measured strengths to the design service life of reinforcing elements
γ_{Re}	partial factor on passive earth resistance
$\gamma_{R,group}$	partial factor on the axial resistance of a pile group
γ_{Rh}	partial factor on the sliding resistance of a spread foundation
γ_{RN}	partial factor on the bearing resistance of a spread foundation
$\gamma_{R,ds}$	partial factor on the direct shear resistance of a reinforcing element
$\gamma_{R,po}$	partial factor on the pull-out resistance of a reinforcing element
$\gamma_{R,piled-raft}$	partial factor on the compressive resistance of a piled raft
γ_{Rs}	partial factor on the shaft resistance of a single pile loaded in compression
$\gamma_{R,st}$	partial factor on the shaft resistance of a single pile loaded in tension
$\gamma_{R,sys}$	partial factor on the compressive resistance of a rigid inclusion system
γ_{RT}	partial factor on sliding resistance
$\gamma_{RT,face}$	partial factor on passive resistance contributing to sliding resistance
γ_{Rtr}	partial factor on the transverse resistance of a single pile
$\gamma_{\tan\delta}$	partial factor on interface friction
$\tan \delta$	coefficient of friction between the foundation and the ground

δ	ground/structure interface friction angle
δ	angle of inclination of earth pressure
δ_d	design value of δ
δ_{ep}	angle of inclination of earth pressure
δ_{rep}	representative value of δ
ε_l	limiting strain in reinforcement
ε_r	reinforcement strain
η_c	conversion factor accounting for long term effects in ground improvement
η_{ch}	conversion factor accounting for the adverse effects of chemical and biological degradation of a reinforcing element at its design temperature
η_{con}	reduction factor accounting for anticipated loss of strength with time and from other influences at a connection
$\eta_{con,dmg}$	reduction factor accounting for the reduction of resistance due to damage of the connection
η_{cor}	is a reduction factor accounting for the adverse effects of degradation of the wire mesh by corrosion over the design service life of the structure
η_{cov}	conversion factor allowing for the relationship between log normal and normal characteristic strengths based on field test results
η_{cr}	conversion factor accounting for the adverse effect of tensile creep due to sustained static load over the design service life of a structure at its design temperature
η_{dmg}	conversion factor accounting for the adverse effects of mechanical damage on reinforcing element or wire mesh during transportation, installation and execution
η_{dyn}	conversion factor accounting for the adverse effects of intense and repeated loading over the design service life of the structure
η_{gs}	reduction factor for geosynthetic reinforcement accounting for potential loss of strength with time and other influences
η_{pwm}	conversion factor for reinforcement polymeric steel woven wire mesh accounting for potential loss of strength with time and other influences
η_t	conversion factor accounting for the difference in time between testing and when improved ground is exposed to designed stresses
η_w	conversion factor accounting for the adverse effects of weathering
θ	angle on plan between the L axis and the direction of T

λ	inclination to the vertical of a retaining wall
λ	slenderness ratio of a pile
μ_{norm}	mean normal strength of field samples
μ_{po}	coefficient of interface friction determined in laboratory pull-out tests on reinforcement elements in representative conditions or from field tests or comparable experience
$\xi_{\text{a,SLS,test}}$	correlation factor for serviceability limit state verification taking account of the number of suitability tests
$\xi_{\text{a,ULS,test}}$	correlation factor for ultimate limit state verification taking account of the number of suitability tests
ξ_{mean}	correlation factor applied to the mean of calculated or test values
ξ_{min}	correlation factor applied to the minimum of calculated or test values
ξ_{n}	correlation factor based on the number of tests and selected value of measured force
ξ_{sn}	correlation factor accounting for the number of field pull-out tests performed on or comparable experience of reinforcement elements
ξ_{ULS}	correlation factor for ultimate limit state verification
σ_{an}	normal component of the total active earth pressure acting on the wall face
σ_{pn}	normal component of the total passive earth pressure acting on the wall face
σ'_{an}	normal component of the effective active earth pressure acting on the wall face
σ'_{pn}	normal component of the effective passive earth pressure acting on the wall face
σ'_{n}	normal effective stress acting on a reinforcing element
σ'_{v}	effective vertical stress acting on the anchorage length of a reinforcing element
σ'_{va}	vertical stress (excluding surcharge pressure) acting on the active side of the wall
σ'_{r}	radial effective stress
$\tau_{\text{a}}, \tau_{\text{p}}$	shear component of the active and passive earth pressure, respectively
τ_{ds}	resistance against direct shear along the ground/grout/reinforcement interface of a reinforcing element
τ_{f}	interface resistance along the soil nail, soil nail-grout, soil nail-soil, or grout-soil interface
τ_{s}	shaft friction mobilized to equilibrate the vertical anchor force
$\tau_{\text{s,dd}}$	unit shaft friction causing downdrag
τ_{po}	representative shear resistance against pull-out of a reinforcing element along the ground/grout/reinforcement interface

$\varphi_{\text{sn,d}}$	design value of the effective angle of shearing resistance between the ground and a soil nail
$\varphi'_{\text{st,d}}$	design value of the effective angle of shearing resistance between the ground and steel reinforcement
ω_{α}	intermediate variable depending on the angle of inclination of a surcharge
ω_{δ}	intermediate variable depending on the angle of inclination of earth pressure

3.2.2 Abbreviations

AI, AII	diffused ground improvement classes
BI, BII	discrete ground improvement classes
CPT	cone penetration test
GC	Geotechnical Category
MPM	Ménard pressuremeter test
NDP	Nationally Determined Parameter
OCR	overconsolidation ratio of soil
PMT	pressuremeter test
PWM	polymeric steel woven wire mesh
SPLT	serviceability pile load test
SPT	standard penetration test
UPLT	ultimate pile load test
VC	Verification Case

4 Slopes, cuttings, and embankments

4.1 Scope and field of application

- (1) This clause shall apply to overall stability, local stability, and displacement of slopes, cuttings and embankments.

NOTE 1 EN 16907 (all parts) gives definitions, principles and general rules for the planning, design, and specification of earthworks.

NOTE 2 The stability of existing slopes can be assessed using reliability levels for existing structures according to EN 1990.

- (2) This clause shall apply to dams and levees but excludes the verification of water retention of those structures.

NOTE The provisions in this clause do not entirely cover design rules needed for dams and levees classified in CC3 and CC4. For these structures, additional provisions can be needed.

(3) This clause shall apply to the overall stability of the following:

- slopes and cuttings supporting nearby structures, infrastructure or foundations;
- existing slopes within the zone of influence of the construction works;
- retaining structures (see Clause 7);
- slopes and cuttings supported by anchors (see Clause 8);
- reinforced fill structures (see Clause 9);
- soil nailed structures (see Clause 10);
- slopes and cuttings supported by rock bolts or rock surface support (see Clause 11); and
- embankments on improved ground (see Clause 12).

4.2 Basis of design

4.2.1 Design situations

(1) EN 1997-1:2024, 4.2.2 shall apply to slopes, cuttings, and embankments.

4.2.2 Geometrical properties

(1) EN 1997-1:2024, 4.3.3 shall apply to slopes, cuttings, and embankments.

4.2.3 Zone of influence

(1) EN 1997-1:2024, 4.1.2.1 and 4.2.5 shall apply to slopes, cuttings, and embankments.

4.2.4 Actions and environmental influences

4.2.4.1 General

(1) EN 1997-1:2024, 4.3.1 shall apply to slopes, cuttings, and embankments.

4.2.4.2 Permanent and variable actions

(1) Design situations involving long-term settlement and movement should be verified according to EN 1997-1:2024, 9.1(5).

(2) Traffic load on slopes, cuttings and embankments shall comply with EN 1991-2:2023, 6.9 and 8.10, as appropriate.

4.2.4.3 Cyclic and dynamic actions

(1) EN 1997-1:2024, 4.3.1.3 shall apply to slopes, cuttings, and embankments.

4.2.4.4 Environmental influences

(1) EN 1997-1:2024, 4.3.1.4 shall apply to slopes, cuttings, and embankments.

4.2.5 Limit states

4.2.5.1 Ultimate limit states

- (1) In addition to EN 1997-1:2024, 8.1, the following potential ultimate limit states shall be verified for all slopes, cuttings, and embankments:
- loss of overall and local stability of the ground and structures within the zone of influence;
 - failure due to gradual degradation of ground strength;
 - failure along discontinuities;
 - failure due to rock fall;
 - loss of bearing resistance of embankments;
 - structural failure of the face or surface of the slope, cutting or embankment and parts of it;
 - structural failure of stabilizing measures;
 - adverse hydraulic effects as a result of failure of drains, filters or seals;
 - rapid drawdown of surface water levels causing excess pore water pressure;
 - failure of the ground caused by surface or internal erosion, or scour; and
 - structural failure in structures, roads, railway lines, or utilities due to movements in the ground in the zone of influence.
- (2) Potential ultimate limit states other than those given in (1) should be verified.

4.2.5.2 Serviceability limit states

- (1) In addition to EN 1997-1:2024, Clause 9, the following potential serviceability limit states shall be verified for all slopes, cuttings, and embankments:
- settlement of embankments;
 - horizontal ground movements of slopes, cuttings, and embankments;
 - creep in soil and fill during the freezing and thawing period;
 - loss of serviceability in neighbouring structures, roads or services due to movements in the ground or due to changes in groundwater conditions;
 - deformation of the structure, which can cause serviceability limit states of existing nearby structures;
 - movements in the ground due to shear deformations, settlement, vibration or heave; and
 - accumulated ground movement or settlement due to creep.

NOTE Excavation below groundwater level can cause severe reduction in ground strength, hydraulic heave, groundwater flow, internal erosion, piping or surface erosion.

- (2) Potential serviceability limit states other than those given in (1) should be verified.

4.2.6 Robustness

(1) EN 1997-1:2024, 4.1.4 shall apply for slopes, cuttings, and embankments.

4.2.7 Ground investigation

4.2.7.1 General

(1) EN 1997-2:2024, Clause 5 shall apply for slopes, cuttings, and embankments.

NOTE Specific ground investigations for earthworks are given in EN 16907-1 and EN 16907-5.

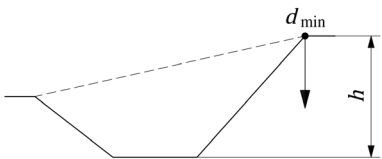
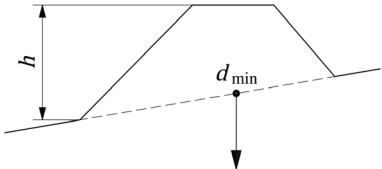
4.2.7.2 Minimum extent of field investigation

(1) In addition to EN 1997-2:2024, 5.4.3, the minimum depth of field investigation for slopes, cuttings, and embankments shall be determined.

NOTE 1 The minimum depth d_{min} of field investigation is given in Table 4.1 (NDP) unless the National Annex gives another value.

NOTE 2 EN 1997-2:2024, 5.4.3(3) and (4) give provisions for increasing or decreasing d_{min} depending on the ground conditions.

Table 4.1 (NDP) — Minimum depth of field investigation of slopes, cuttings, and embankments

Application	Minimum depth	Illustration
Cuttings	$d_{min} = 1,4 h$	
Embankments ^a	$d_{min} = \max\{1,2 h; h_{com} + 2 \text{ m}\}$	
^a h_{com} is the depth to the bottom of a compressible soil layer or of the zone of influence. h_{com} is measured from the same position as d_{min} .		

4.2.8 Geotechnical reliability

(1) EN 1997-1:2024, 4.1.2 shall apply to slopes, cuttings, and embankments.

4.3 Materials

4.3.1 Ground

(1) EN 1997-2:2024, Clauses 7 to 12 shall apply to slopes, cuttings, and embankments.

NOTE For fill properties see EN 1997-1:2024, Clause 5.

(2) Anisotropic properties should be determined if they have the potential to influence ground behaviour.