Form 36

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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

For national standards, comments will be reviewed by the relevant UK national committee and the resulting standards published as a British Standard.

UK Vote

Please indicate whether you consider the UK should submit a negative (with supporting technical reasons) or positive vote on this draft. Please indicate if you are aware of any reason why this draft standard should not be published as a British Standard.

Submission of Comments

- **Annotated drafts are not acceptable and will be rejected.**
- All comments should be submitted online at **https://standardsdevelopment.bsigroup.com/**. You will need to register in order to comment.

Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx

1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex **(e.g. 3.1)**	Paragraph/ Figure/Table/Note	**Type of comment**	**Commend (justification for change) by the MB**	**Proposed change by the MB**	**Secretariat observations on each comment submitted**
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

DRAFT
prEN 1997-3

September 2022

ICS 91.010.30; 93.020

Will supersede EN 1997-1:2004

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 draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 250.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

This draft European Standard was established by CEN in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

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COMITÉ EUROPÉEN DE NORMALISATION
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Ref. No. prEN 1997-3:2022 E

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European foreword

This document (prEN 1997-3:2022) 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 document is currently submitted to the CEN Enquiry.

This document will partially supersede EN 1997-1:2004.

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 recognise 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.

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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 Eurocode 7

EN 1997 consists of a number of parts:

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

EN 1997 standards establish additional principles and requirements to those given in EN 1990 for the safety, serviceability, robustness, and durability of 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 prEN 1997-3

This document establishes principles and requirements for the design and verification of the following of geotechnical structures, including temporary geotechnical structures: slopes, cuttings, embankments, shallow foundation, piled foundation and retaining structures.

This document establishes principles and requirements for the design and verification of supporting elements: anchors, reinforcing element in reinforced fill structures, soil nails, rock bolts and facing.

This document establishes principles and requirements for the design and verification of groundwater control including reduction of hydraulic conductivity, dewatering and infiltration, and the use of impermeable barriers

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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 prEN 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 prEN 1997-3:2022 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 prEN 1997-3:2022 through notes to the following:

Table 4.1 (NDP)	Table 4.2 (NDP)	Table 5.1 (NDP)	Table 5.2 (NDP)
Table 5.3 (NDP)	Table 6.1 (NDP)	Table 6.2 (NDP)	Table 6.3 (NDP)
Table 6.4 (NDP)	Table 6.5 (NDP)	Table 6.6 (NDP)	Table 6.7 (NDP)
Formula (6.18)	Table 7.1 (NDP)	Table 8.1 (NDP)	Table 8.2 (NDP)
Table 8.3 (NDP)	Table 9.1 (NDP)	Table 9.2 (NDP)	Table 9.3 (NDP)
Table 10.1 (NDP)	Table 10.2 (NDP)	Table 10.3 (NDP)	Table 10.4 (NDP)
Table 10.5 (NDP)	Table 11.1 (NDP)	Table 11.2 (NDP)	Table 11.3 (NDP)
Table 11.4 (NDP)	Table 11.5 (NDP)	Table 12.1 (NDP)	A.1(1) NOTE 1
G.1(1) NOTE 1			

National choice is allowed in prEN 1997-3:2022 on the application of the following informative annexes.

Annex A	Annex B	Annex C	Annex D
Annex E	Annex F	Annex G	

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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.

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1 Scope

1.1 Scope of prEN 1997-3

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

1.2 Assumptions

(1) This document is intended to be used in conjunction with prEN 1990:2021, which establishes principles and requirements for the safety, serviceability, robustness, and durability of structures, including geotechnical structures, and other construction works.

(2) This document is intended to be used in conjunction with prEN 1997-1:2022, which provides general rules for design and verification of geotechnical structures.

(3) This document is intended to be used in conjunction with prEN 1997-2:2022, which gives provisions rules for determining ground properties from ground investigation.

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

prEN 1990:2021, *Eurocode — Basis of structural and geotechnical design*

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

prEN 1993 (all parts), *Eurocode 3 — Design of steel structures*

prEN 1993-1-1:2022, *Eurocode 3 — Design of steel structures — Part 1-1: General rules and rules for buildings*

EN 1993-5:2007, *Eurocode 3 — Design of steel structures — Part 5: Piling*

prEN 1994 (all parts), *Eurocode 4 — Design of composite steel and concrete structures*

prEN 1995 (all parts), *Eurocode 5 — Design of timber structures*

prEN 1996 (all parts), *Eurocode 6 — Design of masonry structures*

prEN 1997-1:2022, *Eurocode 7 — Geotechnical design — Part 1: General rules*

prEN 1997-2:2022, *Eurocode 7 — Geotechnical design — Part 2: Ground properties*

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EN 10025 (all parts), *Hot rolled products of structural steel*

EN 10080, *Steel for the reinforcement of concrete — Weldable reinforcing steel — General*

EN 10244-2:2009, *Steel wire and wire products — Non-ferrous metallic coatings on steel wire — Part 2: Zinc or zinc alloy coatings*

EN 10245-2, *Steel wire and wire products — Organic coatings on steel wire — Part 2: PVC finished wire*

EN 10245-3, *Steel wire and wire products — Organic coatings on steel wire — Part 3: PE coated wire*

EN 10245-4, *Steel wire and wire products — Organic coatings on steel wire — Part 4: Polyester coated wire*

EN 10245-5, *Steel wire and wire products — Organic coatings on steel wire — Part 5: Polyamide coated wire*

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

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

EN 14488-4, *Testing sprayed concrete — Part 4: Bond strength of cores by direct tension*

EN 14488-5, *Testing sprayed concrete — Part 5: Determination of energy absorption capacity of fibre reinforced slab specimens*

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

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

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

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

3 Terms, definitions, and symbols

3.1 Terms and definitions

For purposes of this document, the following terms and definitions apply.

3.1.1 Common terms used in prEN 1997-3

3.1.1.1
foundation
construction for transmitting forces to the supporting ground

[SOURCE: ISO 6707-1:2020]

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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

[SOURCE: ISO 6707-1:2020]

3.1.1.4
frost heave
swelling of soil due to formation of ice within it

[SOURCE: ISO 6707-1:2020]

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
slow deformation of soil and rock mass because of prolonged pressure and stress; synonym for 'creep' in fine soils

3.1.1.7
competent rock
rock with sufficient strength and stiffness to withstand applied actions without failure or any significant permanent movement

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 excavation of the ground

3.1.2.3
cutting
earth-structure created by excavation of the ground

3.1.2.4
cut slope
slope that results from excavation

3.1.2.5
embankment
earth-structure formed by the placement of fill

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3.1.2.6
embankment slope
slope that results from the placement of fill

3.1.2.7
earthworks
civil engineering process that modifies the geometry of ground surface, by creating stable and durable earth-structures

3.1.2.8
excavation
result of removing material from the ground

3.1.2.9
levee
embankment for preventing flooding

3.1.2.10
load transfer platform
layer of coarse 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 or piles

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
footing
stepped construction that spreads the load at the foot of a wall or column

[SOURCE: ISO 6707-1:2020]

3.1.3.3
pad foundation
spread foundation with usually rectangular or circular footprint

3.1.3.4
strip foundation
long, narrow, usually horizontal foundation

[SOURCE: ISO 6707-1:2020]

3.1.3.5
raft foundation
spread foundation in the form of a continuous structural concrete slab that extends over the whole base of a structure

[SOURCE: ISO 6707-1:2020]

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3.1.3.6
adjusted elasticity method
method to evaluate the settlement of a spread foundation assuming the ground beneath the foundation is homogeneous and linear elastic

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

[SOURCE: ISO 6707-1:2020]

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

[SOURCE: ISO 6707-1:2020]

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

[SOURCE: ISO 6707-1:2020]

3.1.4.4
driven pile
displacement pile forced into the ground by hammering, vibration or static pressure

[SOURCE: modified from ISO 6707-1:2020]

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 term 'mainly' implies at least 70 % to 80 % of the compression force applied to the pile is transmitted to the ground via its base.

[SOURCE: ISO 6707-1:2020]

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 term '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.

[SOURCE: ISO 6707-1:2020]

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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

[SOURCE: ISO 6707-1:2020]

3.1.4.10
piled foundation
foundation that incorporates one or more piles

[SOURCE: ISO 6707-1:2020]

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 pile axial resistance based on a Geotechnical Design Model comprising various strata with assigned ground parameters that can be ascribed to either the whole or part of the project site area

3.1.4.14
model pile method
calculation method to determine the pile axial resistance based on a single profile of field tests with assigned ground parameters relevant just to the local profile and not to the whole project site area

3.1.4.15
downdrag (negative shaft friction)
situation where the ground surrounding a pile settles more than the pile shaft sufficient to induce a downward drag force that potentially results in drag settlement

3.1.4.16
drag force
additional axial force acting on a pile due to downdrag

3.1.4.17
drag settlement
additional settlement of a pile due to downdrag

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3.1.4.18
neutral plane
depth at which there is no relative movement between the pile and the surrounding ground

3.1.4.19
pile heave
upward movement of the ground surrounding a pile that can result in a heave force developing on the pile shaft, tension within the pile shaft, and upward movement of part or all of the pile

3.1.4.20
trial pile
pile that will not form part of the foundation, installed before the commencement of the piling works, and used to investigate the appropriateness of the chosen type of pile and method of execution and to confirm its design, dimensions, and resistance

3.1.4.21
working pile
pile that will form part of the foundation of the structure

3.1.4.22
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

3.1.4.23
ultimate control test
load test carried out on a test pile to determine its resistance at the ultimate limit state

3.1.4.24
serviceability control test
load test carried out on a test pile to determine its load-displacement behaviour and resistance at the serviceability limit state

3.1.4.25
inspection test
test used to verify acceptance of a working pile

Note 1 to entry: Pile inspection tests include non-destructive integrity tests (to confirm the as-built condition, length, and cross-sectional area of the pile shaft) and concrete or grout tests (such as cube or cylinder strength tests to confirm that the pile materials comply with acceptance criteria).

3.1.4.26
integrity test
test carried out on an installed pile for the verification of soundness of materials and of the pile geometry

3.1.4.27
pile load
axial compressive, tensile, or transverse load (or force) applied to the head of the pile

3.1.4.28
pile test proof load
maximum proposed test load which includes imposed actions from the superstructure or the ground

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3.1.4.29
temporary support load
load representing the temporary axial or transverse support from the ground to a pile under load test resulting from particular conditions of the test such as variations in groundwater, pile head level or pile head restraint that may reverse, reduce or change under service conditions

3.1.4.30
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

[SOURCE: adapted from EN ISO 22477-1:2018]

3.1.4.31
dynamic load
axial compressive impact load (or force) applied to the head of a pile by a driving hammer or drop mass

[SOURCE: EN ISO 22477-4:2018, 3.1.5]

3.1.4.32
dynamic load test
test where a pile is subjected to 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]

3.1.4.33
dynamic impact test
pile test with measurement of strain, acceleration and displacement versus time during the impact event

Note 1 to entry: Dynamic impact tests are often referred to as dynamic load tests

[SOURCE: EN ISO 22477-4:2018, 3.1.8]

3.1.4.34
rapid load test
pile load test where a pile is subjected to chosen axial rapid load at the pile head for the analysis of its capacity (compression resistance)

[SOURCE: EN ISO 22477-10:2016, 3.1.8]

3.1.4.35
bi-directional load test
static load test using an embedded jack where a section of the pile is used as reaction to load another section

Note 1 to entry: It is possible to install one or more levels of jacks in the pile shaft

3.1.4.36
ultimate resistance of a pile
corresponding state in which the piled foundation displaces significantly with negligible increase of resistance

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3.1.4.37
driving formulae
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]

3.1.4.38
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]

3.1.4.39
closed form solution
mathematical analysis of the dynamic load test data based on closed form wave analysis equations to derive a mobilised load

3.1.4.40
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]

3.1.4.41
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

3.1.4.42
pile set
permanent pile settlement after one hammer impact blow during driving

3.1.4.43
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 footing 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.

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3.1.5.3
embedded wall
relatively thin retaining structure of steel, reinforced concrete, or timber that is supported by anchors, struts 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 exists and examples include double sheet pile wall cofferdams, gabion walls, crib walls, earth structures reinforced by grouting.

Note 2 to entry: Earth structures reinforced by tendons, geotextiles, and structures with multiple rows of soil nails are considered as soil reinforcement (see 3.1.7).

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 prEN 1997-3:2022 is termed a 'ground anchor' in EN 1537.

3.1.6.3
permanent anchor
anchor with a design service life which is in excess of 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

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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
investigation test
load test to establish the geotechnical ultimate load resistance of an anchor at the interface of the resisting element and the ground and to determine the characteristics of the anchor in the working load range

[SOURCE: EN ISO 22477-5:2018, 3.1.6]

3.1.6.12
suitability test
load test to confirm that a particular anchor design will be adequate in particular ground conditions

[SOURCE: EN ISO 22477-5:2018, 3.1.9]

3.1.6.13
acceptance test
load test to confirm that an individual anchor conforms with its acceptance criteria

[SOURCE: EN ISO 22477-5:2018, 3.1.1]

3.1.6.14
lock-off load
load with which pre-stressible anchors are fixed to realise an active force to limit deformation

3.1.6.15
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

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

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3.1.6.16
test method 2
test in which the anchor is loaded stepwise by load cycles increasing from a datum load to the proof load

Note 1 to entry: At each load step the load loss in the anchor is measured during a fixed time period.

[SOURCE: EN ISO 22477-5:2018, Test Method 2]

3.1.6.17
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]

3.1.7 Terms relating to reinforced fill structures

3.1.7.1
reinforced fill structures
engineered fill incorporating discrete layers of soil reinforcement, generally placed horizontally, which are arranged between successive layers of fill during construction

3.1.7.2
soil nailed structures
engineered cut-faced or existing structures incorporating layers of soil reinforcements which are installed into the ground, usually at a sub-horizontal angle, and that mobilise resistance with the soil along their entire length

Note 1 to entry: They are typically arranged in rows. For cut-faced applications the rows are usually placed between successive passes of soil excavation in front of one face of the structure.

3.1.7.3
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

3.1.7.4
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

3.1.7.5
tie back wedge method
method of analysis of reinforced soil structures that follows basic design principles currently employed for classical or anchored retaining walls

3.1.7.6
coherent gravity method
method of analysis of reinforced soil structures based on the monitored behaviour of a large number of structures using inextensible reinforcements, corroborated by theoretical analysis

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3.1.7.7
isochronous creep curves
load/strain creep curves plotted at fixed times (0,1 h, 1 h, 10 h, etc.)

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 TR 20432.

3.1.7.8
equivalent constant in-soil temperature
temperature that causes, during one year, the same rate of reinforcing element degradation as the actual in-soil temperature variation at the location of the reinforcing element

3.1.8 Terms relating to ground reinforcing element

3.1.8.1
rock bolt
rock reinforcing element for stabilizing rock excavations, transferring load from the unstable exterior to the confined interior of the rock mass

3.1.8.2
rock anchor
rock reinforcing element capable of imposing a pre-tensile load via the anchor from the unstable exterior to the confined interior of the rock mass to enhance the shear capacity of potential slip surfaces inside the rock mass

Note 1 to entry: A rock anchor differs from a “regular” anchor, that it is not transmitting external loads into the ground from e.g. retaining walls, but to impose internal pretension load to stabilize the rock itself. Many of the anchor characteristics may be the same or similar, such as an anchor head, grouting, anchor length.

3.1.8.3
soil nails
soil reinforcing element to treat unstable natural soil slopes or as a construction technique that allows the safe over-steepening of soil slopes

3.1.8.4
sprayed concrete
concrete that is conveyed through a hose and pneumatically sprayed at high velocity onto a surface

3.1.8.5
wire mesh
arrangement of bidirectional interlocking metal wires with spaced, small openings between

3.1.8.6
facing element
modular precast panel embedding the connections for soil reinforcements

3.1.9 Terms relating to ground improvement

3.1.9.1
ground improvement
modification of the ground or its hydraulic conductivity in order to bring the effects of actions within ultimate and serviceability requirements

Note 1 to entry: Ground improvement can be achieved by reducing or increasing hydraulic conductivity, binding or densifying the ground, filling voids, or creating inclusions in the ground.

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3.1.9.2
ground improvement zone
volume of ground within which ground improvement is installed and results in modified ground properties

3.1.9.3
inclusion
elements installed in the ground with defined geometry and material properties sufficiently different from the surrounding ground as to modify the distribution of load, stress and groundwater flow within the ground improvement zone

3.1.9.4
rigid inclusion
inclusions with higher stiffness and a measurable unconfined compressive strength

3.1.9.5
discrete ground improvement
ground improvement zone comprising inclusions created in the ground with properties differing from the surrounding ground

3.1.9.6
diffused ground improvement
ground improvement where the ground improvement zone is be modelled with a single set of parameters

3.1.9.7
structural connection
mechanical connection between the ground improvement and the structure, capable of transferring compressive, tensile, shear, and bending actions directly

3.1.9.8
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.

3.1.9.9
load distribution
subdivision of the total load into the share transferred by the inclusion and the share 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.

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3.2 Symbols and abbreviations

The symbols in prEN 1997-1:2022 and the following apply to this document.

3.2.1 Latin upper-case letters

A	plan area of the foundation base; and
A	loss of metal (incl. zinc) per face over the first year (in reinforcement elements)
A'	effective foundation area (= B' x L')
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	cross sectional 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 ($A_r = A_0 - \Delta_{Ar}$)
$A_{r,con}$	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 ($A_{r,con} = A_{0,con} - \Delta A_{r,con}$)
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.
$A'_{sn,d}$	design value of the effective adhesion between the ground and a soil nail
$A'_{st,d}$	design value of the effective adhesion between the ground and steel reinforcement
B	foundation width (shorter dimension on plan); and
B	breadth of the reinforcing element
B'	effective foundation width
B_b, B_s	base and shaft width (for square piles), respectively
$B_{b,eq}$	equivalent pile base size equal to B_b (for square piles), D_b (for circular piles) or p/π (for other shaped piles)
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)

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$B_{s,eq}$	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_p	Cohesive resistance along the slip surface of a passive wedge
D	bar diameter
D	embedment depth
D_{add}	representative vertical or transverse temporary support force
D_b	base diameter (for circular piles) in pile foundations
D_{ds}	Diameter of depression at the surface
D_{rep}	representative drag force due to moving ground in pile foundations
D_d	design 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_dI	Flexural stiffness of the pile, design value
E_i	initial tangent modulus in at-rest conditions
E_{ur}	unloading-reloading modulus
$F_{ad,SLS}$	design value of the maximum anchor force, including the effect of lock off load, and sufficient to prevent a serviceability limit state in the supported structure
$F_{ak,SLS}$	characteristic value of the maximum anchor force, including the effect of lock-off load, sufficient to prevent a serviceability limit state in the supported structure
$F_{d,SLS}$	design value of an action to prevent a SLS
$F_{d,ULS}$	Design value of an action to prevent an ULS
F_{ax}	axial action applied to the pile
$F_{cd,SLS}$	design axial compression applied to the pile at the serviceability limit state, including potential down drag forces
$F_{d,group}$	design action applied to the pile group or piled raft
F_{td}	design axial tension applied to the pile
$F_{tr,d}$	design transverse force applied to the pile including an allowance for any potential

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	transverse force due to moving ground
H	Maximum height of the embankment
H_e	height (depth) of the excavation
H_s	height of material above the geosynthetic layer
H_v	height above the void
I	second moment of area (geometric moment of inertia)
K	earth pressure coefficient averaging the pressure around the whole circumference, K = (1 + K_0)/2
K_0	at-rest earth pressure coefficient
K_a	active pressure coefficient
$K_{a\gamma}$, K_{aq}, K_{ac}	normal active earth pressure coefficients
$K_{ac,u}$	normal active earth pressure coefficients for undrained conditions
K_M	consequence factor applied to material properties
$K_{p\gamma}$, K_{pq}, K_{pc}	normal passive earth pressure coefficients
$K_{pc,u}$	normal passive earth pressure coefficients for undrained conditions
K_s	relative stiffness between the foundation and the ground
K_u	corrosion heterogeneity factor for ultimate (in reinforcement elements)
K_y	corrosion heterogeneity factor for yield (in reinforcement elements)
L	foundation length
L'	effective foundation length
L_{bd}	Buckling length, design value
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_{int}	mobilized interface length
L_j	Length of the j^{th} layer of reinforcement
L_n	nail length

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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 length of the reinforcing element beyond the failure surface (or line of maximum tension) where punching shear stresses are mobilized
M1, M2,	independent sets of partial factors on material
N	component of the total action acting normal to 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
N_{cu}	non-dimensional bearing resistance factor for undrained conditions
N_d	design value of N
N'_d	design value of the effective action acting normal to the foundation base
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 the influence of the overburden pressure
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, for undrained conditions
P	percentage of test results passing the required characteristic value (in ground improvement); and
P	length of the perimeter of the reinforcing element
P_c	critical creep load determined in Test Method 3
P_o	lock-off load
P_P	proof load
$R_{ad,SLS}$	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

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$R_{am,SLS}$	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}
$(R_{am,ULS})_{min}$	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_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 test results
$(R_{calc})_{min}$	minimum calculated pile resistance for a set of profiles of field 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
$R_{d,group}$	design resistance of the pile group or piled raft
$R_{d,gs,int}$	design tensile strength of the interface with the geosynthetic reinforcing element
$R_{d,st,int}$	design tensile strength of the interface with a steel reinforcing element
$R_{d,sn,int}$	design tensile strength of the interface with a soil nail element
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
$R_{k,com}$	characteristic resistance to direct shear of the reinforcing element
$R_{k,ds}$	characteristic tensile resistance of the connection (of the reinforcing element)
$R_{m,sn,pul}$	measured pull-out force
R_{pd}	design value of the resisting force caused by earth pressure on the foundation side
R_{Nd}	design bearing resistance normal to the base of a spread foundation
$R_{rep,po}$	representative pull-out resistance of the reinforcing element
$R_{rep,raft}$	representative ultimate vertical compressive resistance of the raft
$R_{ri,i}$	resistance of a rigid inclusion i, depending on its position within the group

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$R_{s,rep}$	pile's representative shaft resistance (in axial compression)
$R_{sys,rep}$	representative value of the total resistance of the ground improvement system with rigid inclusions
R_{td}	design value of pile's design axial tensile resistance; and
R_{td}	design value of the tensile resistance of the structural elements of an anchor
$(R_{test})_{mean}$	mean calculated pile resistance measured in a set of load tests
$(R_{test})_{min}$	minimum calculated pile resistance measured in a set of load tests
$R_{tr,d}$	pile's design transverse resistance
$R_{t,rep}$	pile's representative axial tensile resistance
$R_{t,rep,el}$	representative tensile resistance of the reinforcing element
$R_{x,d}$	design resistance of a pile (where x = b, c, s, st, t, or tr, as above)
$R_{x,m}$	measured resistance of a pile (where x = b, c, s, st, t, or tr, as above)
$R_{x,rep}$	representative resistance of a pile (where x = b, c, s, st, t, or tr, as above)
S_t	sensitivity of fine soil
S_v	vertical spacing of the reinforcements
T	component of the total action acting transverse (parallel) to the foundation base; and
T	age of the structure (in reinforcement elements) in years
T_d	design value of T;
$T_{f,j}$	is the tensile force per meter width due to any horizontal loads
$T_{gs,k}$	characteristic tensile strength of geosynthetic reinforcement
T_k	characteristic tensile strength of the reinforcing element
$T_{k,cr}$	characteristic tensile strength of the 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
$T_{s,j}$	is the tensile force per metre width due to any strip loading
T_{ven}	tensile force to hold the veneer system on the slope without water
V_{norm}	coefficient of variation based on a normal distribution of strength values

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W	wedge load
W_a	wedge load of an active wedge
W_p	wedge load of a passive wedge
W_s	surcharge load
W_T	vertical uniformly distributed (wedge) load on the reinforcement
W_v	resultant vertical load excluding external strip loads on the layer of reinforcement

3.2.2 Latin lower-case letters

a	adhesion between layers or of ground to a construction
a_d	design value of the geometrical property
a_{nom}	nominal value of the geometrical property
b	base width of the embankment; and
b	width of the strip element (in reinforcement elements)
b_c, b_q, b_γ	factors accounting for base inclination
b_{cu}	factor accounting for base inclination, undrained
b_{gs}	width of reinforcement per unit width (b_{gs} = 1 for continuous sheets)
b_{st}	width of strip reinforcement per unit width (b_{st} = 1 for grids)
$c_{min,dur}$	minimum concrete cover required for environmental conditions
c_u	soil undrained shear strength
$c_{u,d}$	design undrained shear strength of the soft foundation soil (in reinforcing elements)
$c_{u,rep}$	representative undrained shear strength of the soft foundation soil (in reinforcing elements)
d_c, d_q, d_γ	factors accounting for the depth of foundation embedment
d_{min}	minimum depth of field investigation
d_s	rock discontinuity spacing between a pair of immediately adjacent discontinuities
d_{cu}	factor accounting for depth, undrained
e	eccentricity of the applied or resultant action

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e_{0d} maximum transversal 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)

$f_{m,d}$ design value of the unconfined compressive strength of the improved ground

f_s reduction factor to allow for extrapolation uncertainty for given design service life

f_{uk} characteristic ultimate tensile strength of steel reinforcement

f_{yk} characteristic yield strength of steel reinforcement

g_c, g_q, g_γ factors accounting for ground inclination

h maximum depth or maximum height of a cutting, excavation or embankment

i load inclination factor; and

i numbering of strata with i from 1 to n

i_c, i_q, i_γ factors accounting for load inclination

i_{cu} load inclination factor, undrained

j index number of layers or strata with j from 1 to n

k subgrade modulus; and

k horizontal subgrade reaction coefficient

$k_{a\gamma}$, k_{aq}, k_{ac} inclined active earth pressure coefficients

$k_{ac,u}$ inclined active earth pressure coefficients for undrained conditions

$k_{p\gamma}$, k_{pq}, k_{pc} inclined passive earth pressure coefficients

$k_{pc,u}$ inclined passive earth pressure coefficients for undrained conditions

k_{cu} reduction factor on c_u

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$k_n\{P\}$	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
$k_{\tan\varphi}$	reduction factor on $\tan\varphi$
k_δ	constant depending on the roughness of the ground structure interface and local disturbance during installation: $k_\delta = a/c$
m	exponent in bearing resistance formulae for the load inclination factor i
m_y	mean of the measured values of $\log(q_{u,field})$ (in ground improvement)
n	number of rigid inclusions; and
n	exponent (factor covering reduction in corrosion rate in time for reinforcement elements)
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
$p_{a,min}$	minimum value of p_a to the retaining wall face
p_{fd}	design value of the ultimate transversal ground resistance pressure
p_{group}	smaller dimension of a rectangle circumscribing a group of piles
$p_{max,d}$	presumed maximum design bearing pressure
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 at the level of the foundation base

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q_o	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	end bearing or base stress
$q_{m,sn,pul}$	measured interface unit strength
q_p	permanent vertical surcharge applied at formation level (on the passive side of the retaining wall)
q_s	surface load
$q_{s,i}$	shaft friction in the various strata i
q_{sk}	characteristic skin friction along the soil nail (reinforcement element)
$q_{u,field}$	unconfined compressive strength measured in unconfined compressive tests on field samples
$q_{uk,imp}$	characteristic value of the unconfined compressive strength of the improved ground
$q_{u,rep}$	representative value of the unconfined compressive strength of the 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	factors accounting for the shape of the foundation base
s_{cu}	factor accounting for shape, undrained
s_{ground}	ground strata settlement profile (at any particular time)
s_p	centre to centre spacing of the inclusions
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_0	time / date of installation or construction
u	groundwater pressure at a point in the ground
u_a	groundwater pressure acting at depth z on the active side of the retaining wall
w_s	surcharge of the geosynthetic layer
x	distance along the length of the reinforcing element

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y transversal deflection of the pile

y_f relative deformation between the pile and the supporting soil where p_f is obtained

z depth below ground surface

z_a depth of zone of influence; and

z_a depth at the active side of the retaining wall

z_c depth of the foundation soil when the depth is limited and c_u is constant throughout

$z_{e,e}$ equivalent embedment depth

z_{emb} embedment depth of the foundation

z_f foundation depth (thickness)

z_p depth at the passive side of the retaining wall

z_w groundwater level at a depth

z_{zoi} depth of zone of influence

3.2.3 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 is a width deviation

Δc_{dev} allowance in design for deviation of the concrete cover

Δe oss of thickness caused by corrosion in the ground

3.2.4 Greek lower-case letters

α angle of inclination of the foundation base to the horizontal; and

α angle of inclination of the 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} is a soil/reinforcement interaction coefficient for undrained conditions (for reinforcing elements)

α_{SLS} creep rate defining the geotechnical resistance of an anchor at the serviceability limit state (determined from the displacement per log cycle of time at constant anchor load as defined in EN ISO 22477-5)

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α_{ULS} creep rate defining the geotechnical resistance of an anchor at the ultimate limit state (determined from the displacement per log cycle of time at constant anchor load as defined in EN ISO 22477-5)

β inclination of the ground surface

γ unit weight density of the ground

γ_a average weight density of the ground (on active side of the 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 the 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'_d design effective weight density of the ground below the foundation level

γ_E partial factor on effect-of-actions

γ_F partial factor on actions

$\gamma_{F,drag}$ partial factor on a drag force due to moving ground in pile foundations

$\gamma_{F,SLS}$ partial factor on the anchor force at the serviceability limit state

γ_{gs} partial material factor for geosynthetic reinforcement

$\gamma_{gs,int}$ partial resistance factor on 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 material factor, applied to ground properties

γ_{M0}, γ_{M2} partial factors for steel (in reinforcing elements) whose values are specified in prEN 1993-1-1

$\gamma_{M,gs}$ partial factor for geosynthetic reinforcing elements

$\gamma_{M,pwm}$ partial factor for polymer steel woven wire mesh reinforcing elements

γ_p average weight density of the ground (on passive side of the retaining wall) above depth z_p

γ_R partial resistance factor, applied to ground resistance

γ_{Rb}, γ_{Rs} resistance factors in pile foundations

γ_{Rc} resistance factor for an individual pile axial compressive resistance

γ_{Rst} resistance factor

γ_{Rd} partial factor associated with the uncertainty of the resistance model / model factor in pile

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foundations; and

γ_{Rd} model factor accounting for additional uncertainty owing to extrapolation of measured strengths to the design service life (of reinforcing elements)

$\gamma_{Rd,0}$, $\gamma_{Rd,2}$ model factors that take account of the degree to which the strength of the steel reinforcing element is mobilized in a reinforced ground structure

$\gamma_{Rd,sys}$ model factor on overall system resistance

γ_{Re} passive earth resistance factor (on retaining walls)

γ_{Rst} resistance factor

$\gamma_{Rd,group}$ model factor for the pile group or piled raft

$\gamma_{R,group}$ resistance factor for the pile group axial compressive resistance

γ_{Rh} partial factor for sliding resistance

γ_{RN} partial factor for bearing resistance

$\gamma_{R,ds}$ partial factor to direct shear of the reinforcing element

$\gamma_{R,po}$ partial factor for pull-out resistance of the reinforcing element

$\gamma_{R,raft}$ resistance factor for the raft

γ_{Rst} partial factor of shaft resistance in pile foundations

$\gamma_{R,sys}$ partial resistance factor for the rigid inclusion system

γ_{RT} partial factor for sliding resistance

γ_{Rtr} partial factor of transversal resistance in pile foundations

γ_{SLS} partial factor for pile shaft resistance in the serviceability limit state

$\gamma_{tan\varphi,cv}$ partial factor on the coefficient of internal friction of the ground under constant-volume conditions

$\gamma_{tan\varphi,res}$ partial factor on the coefficient of friction of the ground along a residual slip surface

δ ground/structure interface friction angle; and

δ angle of inclination of the earth pressure

δ_d design value of δ

δ_{ep} angle of inclination of the earth pressure

δ_{rep} representative value of δ

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ε_l limiting strain in the 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 the element at the design temperature

η_{con} conversion factor accounting for the reduction of resistance (of a reinforcing element) due to the connection

η_{cov} conversion factor allowing for the relationship between the log normal and normal characteristic strength 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 the structure at the design temperature

η_{dmg} conversion factor accounting for the adverse effects of mechanical damage during execution

η_{dyn} conversion factor accounting for the adverse effects of intense and repeated loading over the design service life of the structure

$\eta_{el,con}$ conversion factor accounting for anticipated loss of strength with time and from other influences at the connection (with reinforcing elements)

η_{gs} conversion factor for geosynthetic reinforcement accounting for potential loss of strength with time and other influences

η_{pwm} conversion factor for reinforcement polymer 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 (typically 28 days) and when the improved ground is exposed to the 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 of the retaining wall

μ_{norm} mean normal strength of field samples

μ_{po} coefficient of interface friction determined in laboratory pull-out tests in representative conditions or from field tests (for reinforcement elements)

$\xi_{a,SLS,test}$ correlation factor for serviceability limit state verification taking account of the number of suitability tests

$\xi_{a,ULS,test}$ correlation factor for ultimate limit state verification taking account of the number of suitability tests

ξ_{mean} correlation factor for mean values / for the mean of the calculated values

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ξ_{min} correlation factor for minimum values/ for the minimum of the calculated 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 or comparable experience (in reinforcement elements)

ξ_{ULS} correlation factor for ultimate limit state verification

σ'_n normal effective stress acting on the reinforcing element at the distance x

σ'_v effective vertical stress acting on the reinforcing element on the anchorage length

τ_{ds} resistance (in units of stress) against direct shear along the ground / grout / reinforcement interface(for reinforcing elements)

τ_n action effect of down drag (negative shaft friction)

$\tau_{n,rep}$ representative action effect of down drag (negative shaft friction)

τ_{po} representative shear resistance (in units of stress) against pull-out along the ground/grout/reinforcement interface (for reinforcing elements)

$\varphi_{cv,k}$ characteristic value of the angle of internal friction of the ground under constant-volume conditions

$\varphi_{res,k}$ characteristic value of the angle of friction of the ground along a residual slip surface

$\varphi_{sn,d}$ design value of the effective angle of shearing resistance between the ground and a soil nail

$\varphi'_{st,d}$ design value of the effective angle of shearing resistance between the ground and steel reinforcement

ω_α intermediate variable on the angle of inclination of the surcharge

ω_δ intermediate variable on the angle of inclination of the earth pressure

3.2.5 Abbreviations

AI, AII diffused ground improvement classes

BI, BII discrete ground improvement classes

CPT Cone Penetration Test

EFA Effects Factoring Approach

EI flexural stiffness product (bending stiffness)

GC Geotechnical Category

MFA Material Factor Approach

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NDP	National Determined Parameter
OCR	overconsolidation ratio of the soil
PMT	Pressure meter Test
PWM	Polymer Steel Woven Wire Mesh
RFA	Resistance Factor Approach
SLS	Serviceability Limit State
SPT	Standard Penetration Test
ULS	Ultimate Limit State
VC	Verification Case
XA1 to XA3	Exposure classes for risk of chemical attack

4 Slopes, cuttings, and embankments

4.1 Scope and field of application

(1) This clause shall apply to cuttings, embankments and slopes within the zone of influence of construction works.

NOTE 1 Cuttings cover all type of transient and permanent excavations with an appointed design service life.

NOTE 2 EN 16907 (all parts) applies to the execution of earthworks projects (including cutting and embankments) and their planning.

(2) This clause shall apply to overall stability, local stability, and displacement of nearby structures and infrastructure within the zone of influence.

(3) 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.

(4) This clause shall apply to the overall stability of the following geotechnical structures:

- retaining structures;
- ground reinforcing elements and improved ground structures;
- structures, infrastructure and foundation on or near slopes and cuttings; and
- existing slope within the zone of influence of planned construction works.

4.2 Basis of design

4.2.1 Design situations

(1) prEN 1997-1:2022, 4.2.2 shall apply to slopes, cuttings, and embankments.

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4.2.2 Geometrical properties

4.2.2.1 General

(1) prEN 1997-1:2022, 4.3.3 shall apply to slopes, cuttings, and embankments.

4.2.3 Zone of influence

(1) prEN 1997-1:2022 4.1.2.1 shall apply to slopes, cuttings, and embankments.

4.2.4 Actions and environmental influences

4.2.4.1 General

(1) prEN 1997-1:2022, 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 include permanent and variable actions determined using the quasi-permanent combination of actions specified in prEN 1990:2021, 8.4.3.4.

(2) Design situation for cuttings shall include redistribution of initial in-situ stress due to excavation.

(3) Traffic load shall be included in the verifications of slopes, cuttings and embankments.

NOTE Guidance on traffic loads on geotechnical structures is given in prEN 1991-2:2022, 6.9 and prEN 1992-1-1:2021, 8.10

4.2.4.3 Cyclic and dynamic actions

(1) prEN 1997-1:2022, 4.3.1.3 shall apply to slopes, cuttings, and embankments.

4.2.4.4 Environmental influences

(1) prEN 1997-1:2022, 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 prEN 1997-1:2022, 8.1, the following 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 the impact of 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 in ground caused by surface or internal erosion, or scour;

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- 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 prEN 1997-1:2022, 9, the following serviceability limit states shall be verified for all slopes, cuttings, and embankments:

- settlement of embankments;
- horizontal ground movements of slopes, cuttings ad 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) prEN 1997-1:2022, 4.1.4 shall apply for slope, cuttings, and embankments.

4.2.7 Ground investigation

4.2.7.1 General

(1) prEN 1997-2:2022, 5 shall apply for slope, 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) The depth and horizontal extent of the field investigation shall be sufficient to determine the ground conditions within the zone of influence in accordance with prEN 1997-1:2022, 4.1.2.1.

(2) The minimum depth of field investigation (d_{min}) should be determined as follows:

- For cuttings: 1.4 h (where h is the maximum depth of excavation);
- For embankments: 1.2 H or 1.0 B, whichever is the larger (where H is the maximum height of the embankment and B is its foundation width i.e. shorter dimension on plan);
- For embankments: at least, down to the bottom of the deepest fine soil layer (or layer of high compressibility) that could undergo consolidation settlement, depending on the depth of influence.

(3) If a layer of high strength is encountered, d_{min}, may be reduced to the depth corresponding to the top of that layer.

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(4) Groundwater and piezometric levels shall be determined if they could influence the stability or settlement of the geotechnical structure or any adjacent structures or services.

4.2.8 Geotechnical reliability

(1) prEN 1997-1:2022, 4.1.2 shall apply to slopes, cuttings, and embankments.

4.3 Materials

4.3.1 Ground properties

(1) prEN 1997-2:2022, 7-12 shall apply to slopes, cuttings, and embankments.

NOTE For fill properties see prEN 1997-1:2022, 5.

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

NOTE For example, anisotropic ground strength is of special importance for cuttings in fine soils due to the unloading and rotation of the principal stresses.

(3) Potential reduction in ground strength properties caused by exposure to weather conditions during or after execution should be considered.

NOTE Examples include desiccation and saturation of the ground and thawing of frozen ground.

(4) Slopes, cuttings, and embankments may be verified using effective stress or total stress ground properties.

(5) The determination of properties of discontinuities shall comply with prEN 1997-2:2022, 6.2.

(6) For unstable, slowly moving slopes, ground properties may be derived from back analyses using prEN 1997-1:2022, 4.3.2 (12) and prEN 1997-2:2022, 5.3.6.

4.3.2 Properties of improved ground

(1) The determination of the representative values of improved ground properties shall comply with Clause 11.

4.4 Groundwater

4.4.1 General

(1) prEN 1997-1:2022, 6 shall apply to slopes, cuttings, and embankments.

(2) Measures shall be taken to prevent the adverse effects of potential scour leading to erosion of soil around an earth-structure or internal erosion of soil within or around an earth structure.

(3) Groundwater pressure at interfaces and in discontinuities shall be determined.

(4) groundwater flow through interfaces and discontinuities shall be determined.

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4.4.2 Groundwater control systems

(1) Groundwater control systems may be provided to ensure that design groundwater and piezometric pressures are not exceeded due to unforeseen circumstances.

NOTE 1 Guidance on verification of groundwater control systems is given in Clause 12.

NOTE 2 Examples of drainage for cuttings and embankments are given in EN 16907-1.

(2) If a groundwater control system is not provided, then the design shall be verified to withstand potential increase of groundwater pressures.

(3) It shall be verified that an Accidental Limit State is not exceeded if the groundwater control system fails.

(4) Where the safety and serviceability of the geotechnical structure depend on the successful performance of a groundwater control system, one or more of the following measures should be taken:

- inspection and maintenance of the system, which should be specified in the Maintenance Plan, see prEN 1997-1:2022, 5;
- installing a drainage system that will perform according to specification without maintenance; and
- installing a secondary ("backup") system.

4.5 Geotechnical analysis

4.5.1 General

(1) prEN 1997-1:2022, 7 shall apply to slopes, cuttings, and embankments.

(2) In addition to prEN 1997-1:2022, 4.3.1, the design of slopes, cuttings, and embankments subject to cyclic and dynamic loading should consider the following:

- degradation of ground strength and stiffness;
- accumulated ground movement or settlement;
- build-up of excess groundwater pressures;
- amplification of loads or displacements owing to resonance; and
- potential liquefaction of the ground.

NOTE For seismic design see EN 1998-5.

(3) The resistance of pre-existing sliding surfaces should be determined using residual strength properties.

(4) If the reliability according to prEN 1990 is not obtained in the design verification, potential necessity of stabilizing measures shall be considered.

(5) When verifying overall stability, all potential failure mechanisms shall be verified.

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4.5.2 Analysis of slopes and cuttings

4.5.2.1 Stability in soils and fills

(1) The stability of slopes shall be determined using at least one of the following calculation models:

- limit-equilibrium methods;
- numerical models according to prEN 1997-1:2022, 7.1.4;
- limit analysis.

NOTE 1 Calculation models for overall stability of soil and fill slopes are given in A.3.

NOTE 2 Calculation models for stability of rock slopes are given in Annex A.4.

(2) In layered soils with significant differences in shear strength or subjected to high external loads, the stability of both circular and non-circular failure surfaces intersecting the layers with the lowest shear strength shall be verified.

(3) When it is not obvious which condition (drained or undrained) governs overall stability in any particular geotechnical unit, a calculation using a combination of drained or undrained conditions should be used in which the most unfavourable combination of drainage conditions is chosen.

(4) The weight density of a geotechnical unit should be a superior (upper) value if it has an unfavourable effect on the stability of the slope, or an inferior (lower) value if it has a favourable effect.

(5) The stabilizing effect from capillary action in the unsaturated zone may be used in transient design situations, provided its effect can be verified by comparable experience, groundwater pressure measurements or monitoring.

NOTE The stabilizing effect is also referred to as apparent cohesion and can be significantly reduced with an increase or decrease in moisture content. A common approach is to assume zero groundwater pressure above the piezometric level.

(6) Potential development of tension cracks in cohesive soils shall be considered in the verification of limit state.

(7) Potential instability along soil-rock interfaces shall be considered in verification of limit state.

4.5.2.2 Stability in rock mass

(1) The verification of rock mass stability shall consider, but is not limited to:

- the rock excavation technique and sequence;
- damaging effects of excavation by blasting;
- influence of rock wedges within slopes and cuttings on the local stability;
- effect of possible local instability on the overall stability.

NOTE Calculation models for stability of rock slopes are given in A.4.

(2) The verification of limit states shall be based on geotechnical mapping and documentation of the rock conditions.

(3) Scaling of rock surfaces shall be specified into the design.

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4.5.3 Analysis of embankments

(1) For the analysis of the stability of embankments, the rules given in 4.5.2.1 shall apply.

(2) Analysis of embankments should adopt strength and stiffness properties that have been determined at compatible strains for the different materials in the embankment and ground.

(3) Potential uplift due to buoyancy shall be considered as an Ultimate Limit State.

(4) Additional calculation models for bearing resistance and settlement analysis given in Clause 5 may be used to verify that embankments do not exceed limit states.

(5) For embankments on low strength fine soils and organic soils, resistance to punching failure and plastic extrusion failure of the underlying soil should be verified.

NOTE 1 A calculation model for extrusion resistance of reinforces embankments is give in F.4.

NOTE 2 Calculation models for embankments subject to punching shear are given in B.5.

4.5.4 Supporting elements

(1) In cases where a combined failure of supporting elements and the ground could occur, ground-structure interaction shall be considered allowing for the difference in strength and stiffness of the ground and that of the supporting element.

NOTE Cases include failure surfaces intersecting supporting elements such as walls, piles, anchors, discrete ground improvement, and reinforcement elements and walls.

(2) If supporting elements are used to increase overall stability, their structural resistance shall be verified for the combined effects of action from the ground and the structure for all relevant design situations.

(3) Supporting elements used to improve overall or local stability, bearing resistance, or settlement performance shall be verified in accordance with clauses 6-10.

NOTE Actions in the supporting elements can include axial forces, shear forces or bending moments depending on the types of interaction between the ground and the supporting elements.

(4) It shall be verified that the design resistance of the supporting element equals or exceeds the design effect of actions given by Formula (4.1):

$$E_{\mathrm{d}} = \max\left(F_{d,ULS};\ \gamma_F F_{d,SLS}\right) \tag{4.1}$$

where

$F_{\mathrm{d,ULS}}$ is the design value of the action that the supporting element shall provide to prevent an ultimate limit state of the slope, cutting or embankment;

$F_{\mathrm{d,SLS}}$ is the design value of the action that the supporting element shall provide to prevent a serviceability limit state of the slope, cutting or embankment;

γ_{F} is a factor to convert a SLS value into an ULS value (using DC4).

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4.5.5 Ground displacement and settlement of embankments

(1) In addition to prEN 1997-1:2022, 4.3.1 potential ground displacement due to the following causes should be considered:

- change of stresses in the ground due self-weight or application and removal of external actions;
- change in groundwater conditions and corresponding groundwater pressures;
- ongoing creep;
- volume loss of soluble strata or due to internal erosion;
- shrinkage and swelling of ground due to change in water content;
- freeze and thaw effects; and
- presence of cavities in the ground.

(2) The following components of settlement should be considered for soils and fill beneath and within the embankment:

- immediate settlement;
- settlement caused by consolidation; and
- settlement caused by creep.

NOTE Consolidation and creep can occur simultaneously, particularly in thick soil layers of low hydraulic conductivity.

(3) Immediate settlement and settlement below an embankment during execution should be included in the calculation of total settlement if it affects the final structure or utilities.

(4) Settlement within and below the embankment after execution due to external actions, self-weight, or delayed compaction effects should be included in the total settlement.

4.6 Ultimate limit states

4.6.1 Verification by the partial factor method

(1) prEN 1997-1:2022, 4.4 shall apply for slopes, cuttings, and embankments.

4.6.2 Verification by prescriptive rules

(1) prEN 1997-1:2022, 4.5 shall apply for slopes, cuttings, and embankments.

4.6.3 Verification by testing

(1) prEN 1997-1:2022, 4.6 shall apply for slopes, cuttings, and embankments.

(1) Staged construction or trial embankments excavations or cuttings may be used to verify limit states.

4.6.4 Verification by the Observational Method

(1) prEN 1997-1:2022, 4.7 shall apply for slopes, cuttings, and embankments.

4.6.5 Partial factors

(1) Partial factors for the verification of slopes, cuttings, and embankments at the ultimate limit states shall be determined according to prEN 1997-1:2022, 4.4.1 using the Material Factor Approach.

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NOTE 2 Values of the partial factors are given in Table 4.1 (NDP) for persistent and transient design situations and in Table 4.2 (NDP) for accidental design situations, unless the National Annex gives different values.

Table 4.1 — (NDP) Partial factors for the verification of ground resistance of slopes, cuttings, and embankments for fundamental (persistent and transient) design situations

Verification of	Partial factor on	Symbol	Material factor approach (MFA)[a,b]
Overall stability	Actions and effects-of-actions	γ_F and γ_E	VC3
	Ground properties[c]	γ_M	M2[b]
Bearing resistance	see Clause 5		

a Values of the partial factors for Verification Case 3, (VC3) are given in prEN 1990 :2021 Annex A.

b Values of the partial factors for Sets M2 are given in prEN 1997-1:2022, 4.4.1.3.

c Also includes ground properties of Class AI ground improvement (Clause 11)

Table 4.2 — (NDP) Partial factors for the verification of ground resistance of slopes, cuttings, and embankments for accidental design situations

Verification of	Partial factor on	Symbol	Material factor approach (MFA)[a]
Overall stability	Actions and effects-of-actions	γ_F and γ_E	Not factored
	Ground properties[b]	γ_M	M2
Bearing resistance	see Clause 5		

a Values of the partial factors for Set M2 are given in prEN 1997-1:2022 Annex A.

b Also includes ground properties of Class AI ground improvement (Clause 11).

4.7 Serviceability limit states

4.7.1 General

(1) prEN 1997-1:2022, 9 shall apply to slopes, cuttings, and embankments.

(2) It shall be verified that deformation of the ground within the zone of influence of a slope, cutting, or embankment does not cause a serviceability limit state in nearby structures or civil engineering works.

(3) Serviceability limit states for embankments shall be verified for deformations caused by freezing and thawing.

4.7.2 Displacement of slopes and cuttings

(1) In accordance with prEN 1990:2021, 5.1(2), if there are no explicit serviceability criteria, then the verification of serviceability limit states of slopes may be omitted provided ultimate limit states are verified.

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4.7.3 Settlement of embankments

(1) It shall be verified that differential settlement caused by the variability of ground stiffness and thickness does not cause a serviceability limit state to be exceeded.

(2) When verifying the settlement of an embankment, any decrease in effective stress in the ground should be considered.

4.8 Implementation of design

4.8.1 General

(1) prEN 1997-1:2022, 10 shall apply to slopes, cuttings, and embankments.

NOTE For earthworks see EN 16907-3.

4.8.2 Inspection

(1) prEN 1997-1:2022, 10.3 shall apply to slopes, cuttings, and embankments.

(2) Quality control of earthworks should comply with EN 16907-5.

4.8.3 Monitoring

4.8.3.1 General

(1) prEN 1997-1:2022, 10.4 shall apply to slopes, cuttings, and embankments.

(1) In addition to prEN 1997-1:2022, 10.4, a Monitoring Plan should be prepared for slopes, cuttings, and embankments in GC 2 and GC3 for the following situations:

- when existing slopes show permanently or repeatedly ongoing displacement;
- where the stability is sensitive to the groundwater pressure distribution in and beneath the embankment;
- when utilizing the stabilising effect from capillary action; and
- to measure effects on structures.

4.8.3.2 Monitoring of slopes and cuttings

(1) The Monitoring Plan for slopes and cuttings should include, but is not limited to, measurement of the following:

- horizontal and vertical ground displacements with time;
- groundwater levels or groundwater pressures with time as needed;
- location and geometrical properties of the sliding surface in a developed slide, to derive the ground strength parameters from back analysis for the design of remedial works; and
- displacement and visible damage of structures and infrastructures within the zone of influence.

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