



BSI Standards Publication

Eurocode 7 — Geotechnical design

Part 2: Ground properties

National foreword

This British Standard is the UK implementation of EN 1997-2:2024. Together with BS EN 1997-3:—¹⁾, it supersedes BS EN 1997-2:2007, which will be withdrawn on 30 March 2028.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The first generation of EN Eurocodes was published between 2002 and 2007, with conflicting British Standards withdrawn in 2010.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UK adoptions of the first generation of EN Eurocodes will be withdrawn by BSI on 30 March 2028.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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Date	Text affected
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English Version

Eurocode 7 - Geotechnical design - Part 2: Ground properties

Eurocode 7 - Calcul géotechnique - Partie 2 : Propriétés des terrains

Eurocode 7 - Entwurf, Berechnung und Bemessung in der Geotechnik - Teil 2: Bodeneigenschaften

This European Standard was approved by CEN on 7 July 2024.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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European foreword

This document (EN 1997-2:2024) 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 2027 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 1997-3:—¹, this document supersedes EN 1997-2:2007.

EN 1997-2:2024 includes the following significant technical changes with respect to EN 1997-2:2007:

- the Scope of EN 1997-2 has been completely revised to assist the determination of ground parameters for design rather than provide a synopsis of ground investigation techniques;
- the concept of a Ground Model has been introduced to represent a site specific outline of the disposition and character of the ground and groundwater (Clause 4);
- the ground investigation process has been set out more clearly under the topics desk study (Annex C), site inspection (Annex C), preliminary and design investigations, and monitoring (Clause 5);
- rules for the minimum extent and spacing of ground investigation locations have been added (Clause 5 and Annex H);
- the description and classification of soil and rock (including discontinuities) have been described, mainly by reference to separate EN ISO standards (Clause 6);
- a new clause covering state, physical and chemical properties of the ground has been added (Clause 7);
- a new clause covering strength and stiffness parameters of the ground has been added, together with correlations linked to test data (Clauses 8 and 9 and Annexes E and F);
- a new clause covering cyclic, dynamic and seismic ground properties has been added together with correlations linked to test data (Clause 10 and Annex G);
- new clauses covering groundwater and geohydraulic properties and thermal properties have been added (Clauses 11 and 12); and
- the rules for reporting of ground investigations in the Ground Investigation Report have been revised (Annex A).

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.

¹ Under preparation. Stage at the time of publication: prEN 1997-3:2022.

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.

Any feedback and questions on this document should be directed to the user's 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 organizations 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) establishes 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 1997-2

EN 1997-2 establishes rules for obtaining information about the ground at a site, as needed for the design and execution of geotechnical structures, including temporary geotechnical structures.

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 1997-2

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

The national standard implementing EN 1997-2 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 1997-2 through notes to the following clauses:

H.3(1)

H.3(2)

National choice is allowed in EN 1997-2 on the application of the following informative annexes:

Annex A

Annex B

Annex C

Annex D

Annex E

Annex F

Annex G

Annex H

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 1997-2

- (1) This document provides rules for determining ground properties for the design and verification of geotechnical structures.
- (2) This document covers requirements and guidance for planning ground investigations, collecting information about ground properties and groundwater conditions, and preparation of the Ground Model.
- (3) This document covers requirements and guidance for the selection of field investigation and laboratory test methods to obtain derived values of ground properties.
- (4) This document covers requirements and guidance on the presentation of the results of ground investigation, including derived values of ground properties, in the Ground Investigation Report.

1.2 Assumptions

- (1) The provisions in EN 1997-2 are based on the assumptions given in EN 1990 and EN 1997-1.
- (2) This document is intended to be used in conjunction with EN 1997-1, which provides general rules for design and verification of all geotechnical structures.
- (3) This document is intended to be used in conjunction with EN 1997-3, which provides specific rules for design and verification of certain types of geotechnical structures.
- (4) This document is intended to be used in conjunction with EN 1998-1-1 which provides the requirements for the ground properties needed to define the seismic action.
- (5) This document is intended to be used in conjunction with EN 1998-5 which provides rules for the design of geotechnical structures in seismic regions.

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 1990, *Eurocode — Basis of structural and geotechnical design*

EN 1997-1:2024, *Eurocode 7 — Geotechnical design — Part 1: General rules*

EN 1998-1-1:2024, *Eurocode 8 — Design of structures for earthquake resistance — Part 1-1: General rules and seismic action*

EN 1998-5:2024, *Eurocode 8 — Design of structures for earthquake resistance — Part 5: Geotechnical aspects, foundations, retaining and underground structures*

EN ISO 14688 (all parts), *Geotechnical investigation and testing — Identification and classification of soil (ISO 14688 (all parts))*

EN ISO 14689, *Geotechnical investigation and testing — Identification, description and classification of rock (ISO 14689:2017)*

EN ISO 22475-1, *Geotechnical investigation and testing — Sampling methods and groundwater measurements — Part 1: Technical principles for the sampling of soil, rock and groundwater (ISO 22475-1)*

ISO 9276-6, *Representation of results of particle size analysis — Part 6: Descriptive and quantitative representation of particle shape and morphology*

3 Terms, definitions, and symbols

3.1 Terms and definitions

For the 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 1997-2

3.1.1.1

site

surface area or underground space where construction work or other development is undertaken

3.1.1.2

anthropogenic ground

materials placed by human activity

3.1.1.3

rockhead

boundary between materials that behave as soil and those that behave as rock

3.1.2 Terms relating to the Ground Model and derived values

3.1.2.1

state property

ground property that can change over time, such as mass density, water content and saturation, density index, or stress state

3.1.2.2

measured value of a ground property

value of a ground property recorded during a test

3.1.3 Terms relating to the content of ground investigation

3.1.3.1

ground investigation

use of non-intrusive and intrusive methods to investigate the ground and groundwater conditions beneath or around the site or zone of influence

3.1.3.2

ground investigation location

location (point, line, or area) on the site where the ground is examined and investigated by intrusive or non-intrusive methods

3.1.3.3

low-rise structure

warehouse sheds, factory buildings, or residential buildings up to three storeys high

3.1.3.4

high-rise structure

buildings and structures greater than three storeys high, including chimneys and towers

3.1.3.5

site inspection

observation and recording of features relevant to the surface and sub-surface conditions and any exposures of the ground, existing infrastructure or environment

Note 1 to entry: The inspection normally extends beyond the site boundaries.

3.1.3.6

sample

defined amount of rock, soil, or groundwater recovered from a recorded depth range

3.1.3.7

specimen

part of the sample taken for laboratory testing

3.1.3.8

sample quality class

quality class of the sample based on its degree of disturbance according to sampling technique

Note 1 to entry: Quality classes for soil samples and related sampling categories are given in Table 5.4.

Note 2 to entry: Quality classes for rock samples and related sampling categories are given in Table 5.5.

3.1.3.9

disturbance factor

disturbance of the rock mass

3.1.3.10

mapping

process of physically going out into the field and recording information from the ground at the surface or from excavations and exposures

3.1.3.11

geological mapping

mapping to record and describe geological information and features observed in the field

Note 1 to entry: Description covers features such as morphology, lithology, hydrogeology, weathering, and any visible geological structure.

3.1.3.12

geotechnical mapping

geological mapping adapted for engineering purposes, with the addition of ground classification or geometrical features

Note 1 to entry: Geometrical features include joint sets and deformation patterns.

3.1.4 Terms relating to chemical, physical, and state properties

3.1.4.1 classification

definition of material groups and classes and assigning of materials to groups and classes with similar properties

[SOURCE: EN 16907-2:2018, 3.1.2, modified – deleted “for earthworks”]

3.1.4.2 very coarse soil

soil with particle sizes larger than 63 mm

[SOURCE: EN ISO 14688-1:2018, 5.1.1]

3.1.4.3 coarse soil

soil with particle sizes between 0,063 and 63 mm

[SOURCE: EN ISO 14688-1:2018, 5.1.1]

3.1.4.4 fine soil

soil with particle sizes smaller than 0,063 mm

[SOURCE: EN ISO 14688-1:2018, 5.1.1]

3.1.4.5 density index

ratio of the difference between the maximum void ratio and the observed void ratio to the difference between maximum and minimum void ratios

3.1.4.6 relative density

synonym for ‘density index’

3.1.4.7 consistency (Atterberg) limits

collective name for liquid, plastic, and shrinkage limits of soil

3.1.4.8 liquid limit

water content of soil at which a fine soil passes from the liquid to the plastic condition, as determined by the liquid limit test

[SOURCE: EN ISO 14688-2:2018, 3.7]

3.1.4.9 plastic limit

water content of soil at which a fine soil passes from the plastic to the semi-solid condition, as determined by the plastic limit test

[SOURCE: EN ISO 14688-2:2018, 3.9]

3.1.4.10

shrinkage limit

water content of soil below which loss of water does not result in volume reduction

3.1.4.11

activity index

ratio of the plasticity index and the clay fraction content

3.1.5 Terms relating to strength

3.1.5.1

shear strength envelope

expression that defines the boundary to failure in the material under shearing in a stress space

3.1.5.2

shear strength parameters

material parameters appearing in the expression of shear strength envelopes

3.1.5.3

shear strength in effective stresses

shear strength obtained from an envelope defined in terms of effective stress

3.1.5.4

peak shear strength

upper limit of the shear strength observed in a test

3.1.5.5

critical state shear strength

shear strength at the critical state corresponding to a state at which a soil continues to deform at constant stress and constant void ratio

3.1.5.6

residual shear strength

lower limit of the shear strength of a fine soil reached after extensive shearing and particle re-orientation or lower limit of the shear strength reached after extensive shearing of discontinuities

3.1.5.7

undrained shear strength

shear strength of water saturated soils obtained from an envelope defined in terms of total stress

3.1.5.8

peak undrained shear strength

upper limit of the undrained shear strength

3.1.5.9

remoulded undrained shear strength

undrained shear strength for totally remoulded soil

3.1.5.10

sensitivity

ratio between peak and remoulded undrained shear strengths

3.1.5.11**Geological Strength Index**

index used for rock mass classification and estimation of mechanical properties

3.1.5.12**Joint Roughness Coefficient**

number characterizing the roughness of discontinuities

3.1.5.13**joint wall compressive strength**

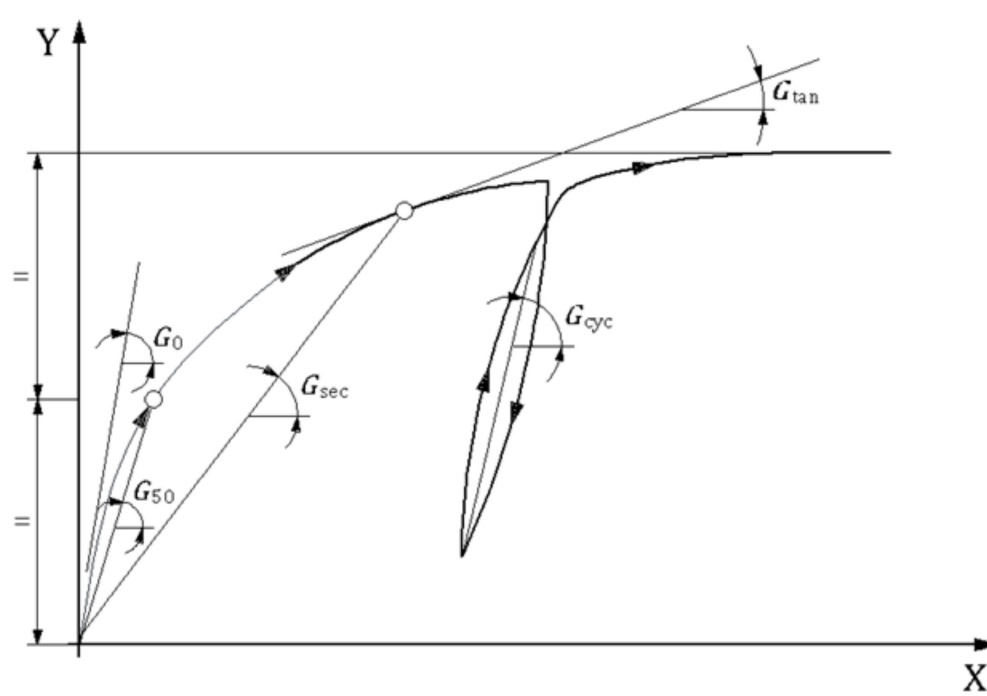
compressive strength of a discontinuity adjusted for weathering, size, width, infill and scale

3.1.5.14**rock mass strength**

strength resulting from the combination of the structural and material properties of the rock mass

3.1.6 Terms relating to stiffness and consolidation**3.1.6.1****elastic modulus**

ratio of stress increase to the corresponding increase in strain in the stress-strain relationship as shown in Figure 3.1

**Key**

X shear^a strain

Y shear^a stress

= 50 % of the maximum shear^a stress

^a For modulus of elasticity, replace the symbol G with E and substitute 'axial' instead of 'shear' in the definitions of X and Y .

Figure 3.1 — Definition of modulus on a stress-strain curve

3.1.6.2

bulk modulus

ratio between mean stress increase to a corresponding decrease in volumetric strain

3.1.6.3

shear modulus

ratio of shear stress increase to a corresponding increase in shear strain, as shown in Figure 3.1

3.1.6.4

secant modulus

ratio between stress and the corresponding strain accumulated from an initial reference state, as defined by Figure 3.1

3.1.6.5

tangent modulus

ratio between small increments of stress and strain from a given reference state, as shown in Figure 3.1

3.1.6.6

very small strain elastic modulus

value of the elastic modulus at strains $< 10^{-5}$

3.1.6.7

very small strain Poisson's ratio

value of Poisson's ratio at strains $< 10^{-5}$

3.1.6.8

oedometer (one dimensional) modulus

ratio of the variation of a principal stress by the linear strain obtained in the same direction, with the other principal strains equal to zero

Note 1 to entry: Also known as the 'constrained modulus'.

3.1.6.9

swelling

ground volume expansion caused by physicochemical processes or by the ingress of water

3.1.6.10

undrained modulus

elastic modulus for undrained conditions

3.1.7 Terms relating to cyclic, dynamic, and seismic properties

3.1.7.1

compressional wave velocity

velocity of propagation of a compressional (primary) wave in a medium

3.1.7.2

cyclic liquefaction

transition of soil behaviour from solid-like to liquid-like due to cyclic or seismic actions

3.1.7.3

cyclic modulus

slope of the line connecting the two points of reversal in cyclic loading as shown in Figure 3.1

3.1.7.4**cyclic shear strength**

maximum value of cyclic shear stress that can be sustained for a given number of cycles without exceeding a given strain threshold

3.1.7.5**cyclic undrained shear strength**

shear stress required to develop a specified residual axial strain in a given number of load cycles

Note 1 to entry: The specified residual axial strain is normally taken as 10 %.

3.1.7.5**cyclic strain**

maximum strain attained or imposed during the application of cyclic actions

3.1.7.6**cyclic stress**

maximum stress attained or imposed during to the application of cyclic actions

3.1.7.7**damping ratio**

ratio between the energy dissipated in a cyclically loaded system and the corresponding elastic energy of deformation based on hysteresis loops of stress vs strain

3.1.7.8**cyclic degradation**

deterioration of ground properties due to repeated load cycles (similar to fatigue in structural members)

3.1.7.9**fundamental frequency**

lowest value of the frequency associated with relative maximum amplification of the seismic ground motion

3.1.7.10**post-cyclic strength**

available strength after the application of a given number of stress cycles

3.1.7.11**post-cyclic creep**

deformation associated with average constant loads after the application of a given number of stress cycles

3.1.7.12**seismic bedrock**

reference formation identified by a shear wave velocity greater than 800 m/s

3.1.7.13**shear wave velocity**

velocity of propagation of a shear (secondary) wave in a medium

3.1.8 Terms relating to groundwater and geohydraulic properties

3.1.8.1

aquitard

confining layer that retards, but does not prevent, the flow of water to or from an adjacent aquifer

3.1.8.2

aquifer

body of permeable rock or soil mass suitable for containing and transmitting groundwater

3.1.8.3

aquiclude

body of soil or rock with extremely low transmissivity, which effectively prevents the flow of water through the ground

3.1.8.4

joint water pressure

pressure of the water in the joints or discontinuities of ground

3.1.8.5

pressure head

ratio of the pore water/joint water pressure and the weight density of water above a point

[SOURCE: EN ISO 18674-4:2020, 3.3]

3.1.8.6

piezometer

field instrument system for measuring pore or joint water pressure or piezometric level, at the measuring point

Note 1 to entry: The system is either an open or closed piezometric system.

[SOURCE: EN ISO 18674-4:2020, 3.1, modified]

3.1.8.7

open system

field instrument system in which the fluid is in direct contact with the atmosphere and the piezometric level at the measuring point is measured

Note 1 to entry: Also known as an 'open piezometric system'.

[SOURCE: EN ISO 18674-4:2020, 3.6]

3.1.8.8

closed system

measuring system in which the reservoir is not in direct contact with the atmosphere and in which the pressure in the fluid is measured by a pressure measuring device

Note 1 to entry: Also known as a 'closed piezometric system'.

[SOURCE: EN ISO 18674-4:2020, 3.7]

3.1.8.9**hydraulic conductivity**

ratio of the average velocity of a fluid through a cross-sectional area (Darcy's velocity) to the applied hydraulic gradient

Note 1 to entry: Hydraulic conductivity can vary in the vertical and horizontal directions.

3.1.8.10**absolute permeability**

property that quantifies the ability of porous ground to permit the flow of fluids through its pore spaces

Note 1 to entry: Also known as intrinsic permeability or specific permeability. The terms 'hydraulic conductivity' and 'absolute permeability' are interchangeable if the ground is fully saturated.

3.1.8.11**transmissivity**

rate at which water passes through a unit width of an aquifer under unit hydraulic gradient

3.1.9 Terms relating to thermal properties of the ground**3.1.9.1****thermal conductivity**

ratio of the thermal flux through a cross-sectional area (Fourier's law) to the applied thermal gradient

3.1.9.2**heat capacity or specific heat capacity**

capacity of a material to store thermal energy

3.1.9.3**thermal diffusivity**

ratio of the thermal conductivity to the specific heat capacity

3.2 Symbols and abbreviations

For the purposes of this document, the symbols given in EN 1997-1 and the following symbols and abbreviations apply.

NOTE 1 The symbols commonly used in all Eurocodes are defined in EN 1990.

NOTE 2 The notation of the symbols used is based on ISO 3898.

3.2.1 Latin upper case letters

B	pore water pressure coefficient
C	thermal capacity per unit volume
C_c	compression index
$C_{c,PSD}$	coefficient of curvature
C_g	swelling coefficient
C_i	non-dimensional coefficient of correlation
C_{sw}	swelling index
$C_{U,PSD}$	uniformity coefficient

C_α	coefficient of secondary compression
D	disturbance factor for rock mass
D_n	particle size that n % by weight are smaller than
D_0	small strain damping ratio
D_{50}	median grain size
E'	drained modulus of elasticity
E_u	undrained modulus of elasticity
E_{BJT}	modulus of elasticity from a borehole jack test (according to EN ISO 22476-7)
E_{cyc}	cyclic modulus of elasticity
E_{DMT}	modulus of elasticity from a flat dilatometer test (according to EN ISO 22476-11)
E_{FDP}	modulus of elasticity from a full displacement pressuremeter test (according to EN ISO 22476-8)
E_{FDT}	modulus of elasticity from a Flexible Dilatometer test (according to EN ISO 22476-5)
E_i	modulus of elasticity of intact rock
E_M	modulus of elasticity from a Ménard pressuremeter test (according to EN ISO 22476-4)
E_{OED}	modulus of elasticity from an oedometer test (according to EN ISO 17892-5)
E_{PBP}	modulus of elasticity from a pre-bored pressuremeter test (according to EN ISO 22476-5)
E_{PLT}	modulus of elasticity from a plate loading test
E_{rm}	modulus of elasticity of rock mass
E_s	modulus of elasticity of soil
E_{SBP}	modulus of elasticity from a self-boring pressuremeter test (according to EN ISO 22476-6)
E_{sec}	secant modulus of elasticity
E_{tan}	tangent modulus of elasticity
E_u	undrained modulus of elasticity
G_0	shear modulus at very small strain
G_{cyc}	shear modulus from a CTxT
G_{FDT}	shear modulus from a Flexible Dilatometer test (according to EN ISO 22476-5)
G_M	shear modulus from a Ménard pre-bored pressuremeter test (according to EN ISO 22476-4)
G_{PBP}	shear modulus from a Pre-Bored Pressuremeter test (according to EN ISO 22476-5)
G_{SBP}	shear modulus from a Self-Boring Pressuremeter test (according to EN ISO 22476-6)
G_{sec}	shear modulus from a DSS
H_{800}	depth of the bedrock formation identified by a shear wave velocity vs greater than 800 m/s
I_A	activity index
I_c	soil behaviour type index
I_D	density index of coarse soil
I_{DMT}	DMT material index (according to EN ISO 22476-11)

I_f	fracture spacing
I_L	liquidity index of fine soil (according to EN ISO 17892-12)
I_P	plasticity index of fine soil (according to EN ISO 17892-12)
K	hydraulic conductivity
K_{bulk}	bulk modulus
K_D	DMT horizontal stress index (as per EN ISO 22476-11)
K_0	at-rest earth pressure coefficient
K_{PMT}	calibration factor for PMT test results
L	length of test section in the thickness of aquifer
M_{DMT}	DMT modulus (according to EN ISO 22476-11)
N	number of blows to drive the penetrometer over a defined distance (as per EN ISO 22476-2)
N	number of cycles
N_{kt}	a cone factor (as per EN ISO 22476-1)
N_{min}	minimum number of field investigations
N_{WST1}	number of half rotations per 1 m penetration (as per EN ISO 22476-10)
N_{60}	SPT blow count normalized for energy (as per EN ISO 22476-3)
$(N_1)_{60}$	SPT blow count normalized for overburden pressure and energy (as per EN ISO 22476-3)
OCR	over-consolidation ratio
Q	coefficient that depends on the crushability of the material
R_f	friction ratio
T	transmissivity
$V_{S,H800}$	equivalent value of the shear wave velocity of the soil column above the depth of the bedrock formation
X_{max}	maximum distance between two field investigations

3.2.2 Latin lower case letters

a	non-dimensional material parameter in the Hoek-Brown strength envelope
c_{dis}	apparent cohesion of the discontinuity
$c'_{X,Y}$	effective cohesion measured at a condition X (p for peak, cs for critical state, r for residual) by a specific test Y (UCT, UU, TX, FVT, etc.)
c_h	coefficient of horizontal consolidation
$c_{u,X,Y}$	shear strength in total stress analysis measured at a condition X (p for peak, cs for critical state, r for residual, rmd for remoulded) by a specific test Y (DST, TXT, CU, CD, FVT etc.)
c_v	coefficient of consolidation
c_{fv}	peak shear strength of soil, derived from the maximum torque measured by field vane test (as per EN ISO 22476-9)
d_{min}	minimum depth of field investigation
e	void ratio of soil

$e_{\max}$	maximum void ratio of soil
$e_{\min}$	minimum void ratio of soil
e_0	void ratio of the prepared specimen
f	frequency of the load in Hz
f_0	fundamental frequency of a soil deposit
f_1	soil property function defining the relationship between shear strength and soil suction
f_s	sleeve resistance
h_w	pressure head
k	absolute permeability
m	coefficient that depends on the relevant shear mode to failure
m_b	non-dimensional material parameter in the Hoek-Brown strength envelope
m_i	non-dimensional material parameter in the Hoek-Brown strength envelope
m_v	one dimensional compressibility
p'	mean principal effective stress
p_1	corrected pressure at the origin of the pressuremeter modulus pressure range (see EN ISO 22476-4)
p_a	atmospheric air pressure
p_{LM}	limit pressure from Ménard pressuremeter test (according to EN ISO 22476-4)
p_{ref}	reference pressure usually equal to 100 kPa
q_c	cone tip resistance measured (as per EN ISO 22476-1)
q_n	net cone resistance ($= q_t - \sigma_{v0}$)
q_t	corrected cone resistance (as per EN ISO 22476-1)
s	non-dimensional material parameter in the Hoek-Brown strength envelope
u	groundwater pressure
u_a	pore air pressure
v_p	compressional wave velocity
v_s	shear wave velocity
w	water content
w_L	liquid limit of soil
w_P	plastic limit of soil
w_S	shrinkage limit of soil

3.2.3 Greek upper case letters

Δu_2	excess pore water pressure measured at the gap between cone tip and friction sleeve (as per EN ISO 22476-1)
Δe	change in void ratio

3.2.4 Greek lower case letters

γ	shear strain
γ	weight density of the fluid.
γ_{cyc}	cyclic shear strain
γ_e	elastic threshold strain beyond which shear modulus falls below its maximum value
γ_{ref}	reference value of engineering shear strain (at which $G_{\text{sec}}/G_0 = 0,5$)
γ_w	weight density of groundwater
δ_x	horizontal incremental displacement of a specimen in direct shear
δ_z	vertical incremental displacement of a specimen in direct shear
ε	strain
ε_g	swelling amplitude
ε_{vol}	volumetric strain ($= \Delta V/V_0$) from reconsolidation to $(\sigma'_{v0}, \sigma'_{h0})$
η	dynamic viscosity of a fluid
κ	thermal diffusivity
λ	thermal conductivity
ν	Poisson's ratio
ν_0	Poisson's ratio at very small strain
ρ	bulk mass density
$\rho_{\text{d,max}}$	reference density at optimal water content (Proctor)
σ	normal stress
σ'	effective normal stress
σ_0	In-situ total stress
σ_{ci}	uniaxial compressive strength
σ'_{h0}	in-situ horizontal effective stress
σ_n	normal stress acting on a discontinuity
σ'_p	pre-consolidation pressure
σ_t	tensile strength of soil or rock
σ_v	total vertical stress
σ_{v0}	in-situ vertical total stress
σ'_{v0}	in-situ vertical effective stress
σ_1	major principal stress
σ_3	minor principal stress
τ	shear stress
τ_{dis}	shear stress at failure along a discontinuity;
τ_p	peak shear strength of discontinuity
φ	angle of friction

φ'	effective angle of friction
φ_b	base angle of friction of a rock surface
$\varphi'_{x,y}$	effective angle of friction measured at a condition X (p for peak, cs for critical state, r for residual) by a specific test Y (DST, CU, CD, TXT, etc.)

3.2.5 Abbreviations

BDP	Borehole Dynamic Penetration (test)
BE	Bender Element
BJT	Borehole Jack Test
BST	Borehole Shear Test
CBR	California Bearing Ratio
CDSS	Cyclic Direct Simple Shear
CD	Consolidated Drained (triaxial test)
CPT	Cone Penetration Test
CPTU	Cone Penetration Test with pore water pressure measurement (piezocone test)
CRS	Constant Rate of Strain
CTS	Cyclic Torsional Shear
CTxT	Cyclic Triaxial Test
CU	Consolidated Undrained (triaxial test)
DMT	Flat Dilatometer Test (also known as Marchetti Dilatometer Test)
DP	Dynamic Penetration (Test)
DSS	Direct Simple Shear (Test)
DST	Direct Shear Test
FDP	Full Displacement Pressuremeter
FDT	Flexible Dilatometer Test
FVT	Field Vane Test
GIR	Ground Investigation Report
GSI	Geological Strength Index
IL	Incremental loading oedometer test
IST	Interface Shear Test
JCS	Joint Compressive Strength of a discontinuity
JRC	Joint Roughness Coefficient
MBV	Methylene Blue Value
MPM	Ménard Pressuremeter (Test)
MQC	Minimum Quality Class of sample suitable for a test (see 5.4.5)
MR	Modulus Ratio
MWD	Measuring While Drilling

OCR	Over-Consolidation Ratio
OED	Oedometer (Test)
OMC	Organic Matter Content
PBP	Pre-Bored Pressuremeter (Test)
PLT	Plate Loading Test
PMT	Pressuremeter Test
RC	Resonant Column (Test)
RQD	Rock Quality Designation
SBP	Self-boring Pressuremeter (Test)
SCPT	Seismic Cone Penetration Test
SCR	Solid Core Recovery
SDMT	Seismic Dilatometer Test
SPT	Standard Penetration Test
TCR	Total Core Recovery
TxT	Triaxial Test
UCS	Uniaxial Compressive Strength
UCT	Unconfined Compression Test
UU	Unconsolidated Undrained (Triaxial Test)
WST	Weight Sounding Test

4 Ground Model and derived values

4.1 Ground Model

- (1) A Ground Model shall comprise the geological, hydrogeological, and geotechnical conditions at the site, based on the ground investigation results.

NOTE 1 Geological conditions include, for example, the description of the site geomorphology, the lithology of the geotechnical units, the potential presence and level of a rockhead, geometrical and geotechnical properties of discontinuities and weathered zones.

NOTE 2 Hydrogeological conditions address surface, groundwater, and piezometric levels, including their potential variation with time, potential water flows and the presence of other fluids or gases affecting the site.

NOTE 3 Geotechnical conditions include, for example, the disposition of the geotechnical units and the mechanical behaviour of the ground described by the properties of the geotechnical units.

- (2) Variability and uncertainty of geological, hydrogeological and geotechnical conditions and properties shall be included in the Ground Model.

- (3) The detail and the extent of the Ground Model shall be consistent with the Geotechnical Category and the zone of influence.

NOTE Guidance on Geotechnical Category and zone of influence is given in EN 1997-1:2024, 4.1.2.

- (4) The Ground Model shall be progressively developed and updated based on potential new information.

NOTE The Ground Model and the Ground Investigation Report are the main output of the Ground Investigation and form the basis for the development of the Geotechnical Design Model (see EN 1997-1:2024, 4.2.3).

- (5) The Ground Model shall reference the derived values of ground properties for encountered geotechnical units.

NOTE Guidance on derived values is given in 4.2.

- (6) The Ground Model should be documented in the Ground Investigation Report.

- (7) As an alternative to (6), the Ground Model may be documented in the Geotechnical Design Report.

4.2 Derived values

- (1) Derived values of the properties of a geotechnical unit shall be established from data gathered during the desk study, site inspection, preliminary and design investigations, and monitoring of the ground and structures.
- (2) Empirical correlations and theories used to obtain the derived values shall be documented in the Ground Investigation Report.
- (3) The Ground Investigation Report shall record whether empirical correlations and theories used in parameter derivation are intended to provide average, superior, or inferior values.
- (4) The information given for each correlation should specify either directly or through reference:
- the materials to which they apply, specified by their description according to EN ISO 14688-1 and classification according to EN ISO 14688-2 and EN ISO 14689, or their intrinsic and chemical properties;
 - the database that supports the correlation; and
 - the estimated transformation errors.
- (5) Site-specific data should be used to support generic correlations.

NOTE Site specific data generally results in smaller transformations errors.

- (6) Derived values of ground mass properties that are determined from test results on samples should be adjusted for scale effects.

5 Ground investigation

5.1 General

- (1) The ground investigation shall be planned so that it collects the information needed to define the geotechnical units that influence the anticipated design situations.

NOTE 1 Guidance on suitable ground investigation techniques is given in Annex B.

NOTE 2 The geotechnical units include soil layers, rock masses and any fill in place prior to the investigation works.

- (2) The ground investigation should determine potential obstacles, hidden objects, and locally adverse properties in the ground, that could influence the geotechnical structure and its' execution.

NOTE Examples are existing underground infrastructure, cables, pipes, cavities, unexploded devices, historical, archaeological, and cultural objects, local absence or presence of critical layers or zones.

- (3) The scope, level of detail, and accuracy of the ground properties to be obtained during the ground investigation shall be defined before the start of the investigation.

NOTE 1 The extent of ground investigation and the required sample quality classes affect the precision of the determined ground properties.

NOTE 2 Guidance on the confidence levels of the results from different tests is given in Annex B.

- (4) The ground investigation should be carried out in phases to progressively increase knowledge and reduce uncertainty of the information about the ground.

- (5) The ground investigation shall identify the ground materials and groundwater conditions within the zone of influence.

- (6) The ground investigation should determine potential obstacles for the execution of the geotechnical structure, including but not limited to:

- obstructions to drilling and boring;
- drivability of the ground;
- abrasivity;
- borehole stability;
- potential flow of groundwater in or out of a borehole;
- geometrical properties of discontinuities and weakness zones;
- borehole axis deviations; and
- potential loss of grout from the borehole.

- (7) The ground investigation should identify rockhead, transition zones between geotechnical units and weathered zones where present.

NOTE A distinct rockhead can be difficult to define in cases with transition or weathered zones between soil and rock materials.

- (8) The minimum amount of ground investigation should be specified according to the Geotechnical Category, as given in Table 5.1.

Table 5.1 — Criteria for ground investigation for different Geotechnical Categories

Geotechnical Category	Criteria for ground investigation
GC3 ^a	The items given below for GC2 and, in addition: — sufficient ground investigations to capture the relevant variabilities of the ground; — sufficient ground investigations to capture the properties for relevant geotechnical units using more than one ground investigation method; — sufficient ground investigations to capture the scatter of the relevant properties of each geotechnical unit.
GC2	The items given below for GC1 and, in addition: — sufficient ground investigations to identify relevant geotechnical units in the zone of influence; — determination of relevant ground properties by field and laboratory testing and by monitoring.
GC1	All items given below: — desk study of the site, review of comparable experience; — site inspection; — design investigation, if necessary.
^a GC3 is assumed unless a different category has been determined by the desk study or by preliminary or design investigation.	

- (9) If there is sufficient information from the desk study and site inspection to justify classification as GC1, additional design investigation may be omitted.

NOTE Guidance on the content of a Desk Study is given in 5.2.2.

- (10) Ground investigations may also include other laboratory or field investigation tests than are specified in this document, using methods adapted to the local conditions.

- (11) The results of the ground investigation should be presented together with statements on any limitations, discrepancies, uncertainties, or gaps in the data, as well as if any deviation has been made from standard procedures for the investigation.

5.2 Contents of ground investigation

5.2.1 General

- (1) Ground investigation shall include:

- a desk study (5.2.2);
- site inspection (5.2.3); and
- for GC2 and GC3, design investigations (5.2.5).

- (2) Ground investigation for GC2 and GC3 should also include:

- preliminary investigation (5.2.4);

— monitoring (5.2.6).

NOTE Guidance on information to be obtained from the ground investigation is given in Annex D.

5.2.2 Desk study

(1) A desk study shall be carried out.

NOTE Guidance on the desk study is given in Annex C.

(2) A desk study should include factual information of the site details, site history, and site geology, including any previous GIR in the vicinity of the site and previous experience related to the site.

(3) The desk study should be carried out at an early stage of the ground investigation.

(4) The desk study should identify potential hazards in the ground.

(5) The desk study should identify the presence of any existing structure that can influence or can be affected by the new structure.

NOTE This includes hidden structures, e.g. foundations, cables, pipes, tunnels, and potential archaeological finds.

(6) The desk study shall determine a preliminary zone of influence.

5.2.3 Site inspection

(1) The site shall be visited and inspected before preliminary or design investigations are conducted.

NOTE 1 Guidance on site inspection is given in Annex C.

NOTE 2 See EN 1997-1:2024, 10.3, for inspection during execution and EN 1997-1:2024, 10.6, for inspection as part of the Observational Method.

(2) The findings of the site inspection should be confirmed by comparison with the information gathered by the desk study.

(3) The site inspection should cover the entire surface area of the zone of influence.

(4) Inspection and geotechnical mapping of visible ground surfaces should be included in the site inspection.

(5) The findings of the site inspection shall be recorded in the Ground Investigation Report.

5.2.4 Preliminary investigation

(1) Preliminary investigations should be performed to identify key issues that need to be addressed by design investigation.

NOTE 1 Geophysical investigations can be performed in the preliminary investigation to identify these key issues.

NOTE 2 Further guidance on the ground investigation is given in Annex D, including geotechnical hazards.

NOTE 3 Light footprint screening techniques can be used to optimize subsequent phases of ground investigation and the resulting ground and geotechnical models.

(2) Preliminary investigations should enable determination of:

- groundwater conditions, including aquifers, aquitards, or aquicludes;
- geotechnical hazards present at the site, including landslide and seismic hazards;
- valuable or historical constructions;
- suitable positioning of the structure;
- preliminary design of the geotechnical and related structures;
- stability of any excavations or underground openings;
- potential impacts of the proposed construction on the surroundings, including neighbouring buildings, structures, and sites;
- potential need for and suitability of different ground improvement methods; and
- sources of construction materials.

(3) Preliminary investigation should provide information concerning:

- material types and their disposition;
- rockhead within the zone of influence;
- discontinuities and their geometry;
- piezometric levels and groundwater pressures;
- preliminary values of the strength and stiffness properties of the geotechnical units; and
- potential occurrence of natural or anthropogenic contamination in the ground or groundwater.

5.2.5 Design investigation

(1) Design investigations shall provide values of ground properties needed to verify all limit states in any applicable design situations.

(2) Design investigations should identify ground and groundwater conditions that could influence the behaviour and execution of the structure or adversely affect its durability.

(3) In addition to (1) and (2), design investigations should provide, as relevant:

- data for a description and classification of the geotechnical units;
- values of state, physical and chemical ground and groundwater properties;
- values of strength properties of the ground;
- values of stiffness, compressibility and consolidation properties of the ground;
- values of cyclic, dynamic, and seismic properties of ground;

- groundwater conditions and ground hydraulic properties; and
- values of thermal properties of the ground.

(4) The information on groundwater conditions should include, as relevant:

- the depth, thickness, and extent of water-bearing geotechnical units in the ground;
- the groundwater pressure distribution;
- piezometric levels and their variation over time;
- the hydraulic conductivity and its possible anisotropy for each geotechnical unit; and
- the chemical composition and temperature of groundwater.

5.2.6 Monitoring

(1) Monitoring should be used to obtain information on ground behaviour and on groundwater conditions for design.

NOTE See EN 1997-1:2024, 10.4.

5.3 Ground investigation techniques

5.3.1 Site inspection techniques

(1) Site inspection should be performed using one or more of the following techniques:

- visual observation;
- topographic mapping;
- photogrammetric mapping;
- airborne and on-ground video tools;
- geological mapping; and
- geotechnical mapping.

5.3.2 Preliminary or design investigation techniques

5.3.2.1 Exploratory holes and openings

(1) Ground and groundwater conditions should be determined using one or more of the following techniques:

- test pits, shafts, and exploratory headings;
- percussive and rotary boreholes;
- logging of borehole walls, excavations, and exposures; and
- probing.

(2) Exploratory activities should include sampling and groundwater measurements.

5.3.2.2 Field investigation techniques

(1) Field investigation tests should be performed in accordance with the standards given in Table 5.2.

Table 5.2 — Field investigation tests and corresponding standards

Type of test	Test standard
Field testing	EN ISO 22476 (all parts)
Geophysical testing	See Note ^a
Geohydraulic testing	EN ISO 22282 (all parts)
Geothermal testing	EN ISO 17628 (all parts)
Testing of geotechnical structures	EN ISO 22477 (all parts)
In-situ stress measurements	ISRM Suggested Methods (all parts)
^a ISO/TC 182/WG 12 is preparing a standard. Information is also available in ISO 19901-10.	

(2) Field investigation tests other than those given in Table 5.2 may also be carried out, provided the test standard used is recorded in the Ground Investigation Report.

(3) Geophysical tests should be used to identify:

- ground conditions (including stratification and any lateral variations, weathered or fractured zones, faulting, presence of cavities);
- buried objects (including utilities, services, existing foundations and basement structures, artefacts, archaeological structures and unexploded ordnance) that could interfere with the construction works;
- groundwater conditions; and
- parameters for the estimation of porosity, hydraulic conductivity and stiffness.

NOTE Guidance on utilization of geophysical methods in site characterization can be found in Medhus, A.B. and Klinkby, L. (2022).

(4) Disposition of geotechnical units identified using geophysical testing shall be compared with the results of direct ground investigation techniques and adjusted accordingly.

NOTE Geophysical testing can be carried out ahead of intrusive investigation to optimize the scope of the investigation.

5.3.2.3 Laboratory testing

(1) Laboratory tests should be performed in accordance with the standards given in Table 5.3.

Table 5.3 — Laboratory test standards

Type of test	Test standard
Laboratory testing of soil	EN ISO 17892 (all parts)
Laboratory testing of rock	ISRM Suggested Methods

(2) Laboratory tests other than those given in Table 5.3 may also be carried out, provided the test standard used is recorded in the Ground Investigation Report.

(3) Laboratory testing should be carried out shortly after sampling.

NOTE This is particularly important when stiffness properties are to be determined.

(4) Preservation and storage of samples for laboratory testing should comply with EN ISO 22475-1.

5.3.3 Instrumentation for monitoring

(1) Geotechnical monitoring by field instrumentation should comply with EN ISO 18674 (all parts).

(2) Instruments shall be maintained throughout the period identified in the Monitoring Plan specified in EN 1997-1:2024, 10.4.

5.3.4 Back analysis

(1) Monitoring results may be obtained during execution or from existing, trial, or failed geotechnical structures.

(2) Information on the behaviour of the ground may be gathered from back-analysis of monitoring results.

(3) Best estimate values of parameters for calculation models may be determined from back-analysis of monitoring results.

5.4 Planning of preliminary and design investigations

5.4.1 General

(1) The planning of preliminary and design investigations shall be appropriate for the purpose of the investigation and the anticipated geotechnical units.

(2) The planning of preliminary and design investigations shall provide:

- positioning and depth of field investigation and sampling locations;
- field investigation techniques to be used at each location;
- required sample quality and therefore the samplers to be used (see Clauses 7 to 10 and EN ISO 22475-1);
- laboratory testing to be carried out;
- measurements of groundwater pressures and piezometric levels to be made;
- details of instrumentation to be installed; and

- standards to be applied to all aspects of the works.
- (3) The type and extent of the techniques to be used in the investigation shall be based on the results of the desk study, the site inspection, previous knowledge of the geotechnical structure to be designed, the Geotechnical Category, and the zone of influence.
- (4) The extent of investigations shall cover the:
 - zone of influence of the structure;
 - zone of influence of temporary works elements;
 - depth of effect of any dewatering works on groundwater conditions;
 - depth for calculation of the seismic response as specified in EN 1998-1-1:2024, Clause 5 and EN 1998-5:2024, Clause 6 when prescribed; and
 - presence of any destabilizing features in the ground on or around the site.

NOTE The zone of influence under cyclic, dynamic or seismic actions can be different from that under static loading.

5.4.2 Number of investigation locations and laboratory tests

- (1) The number of investigation locations and laboratory tests in a geotechnical unit shall be determined from:
 - the variability of the ground;
 - previous documented experience in ground with the same variability; and
 - the Geotechnical Category.
- (2) The number of investigation locations and laboratory tests should be appropriate for the ground investigation techniques used and typical uncertainty levels of the test results.

NOTE 1 The use of more than one ground investigation technique can reduce uncertainty in derived values.

NOTE 2 Guidance on the suitability and applicability of different ground investigation techniques is given in Annex B.

- (3) The number and type of samples for laboratory tests should be appropriate for the material to be sampled and potential sample disturbance.

5.4.3 Minimum extent of field investigation and spacing of investigation locations

- (1) The depth and horizontal extent of the field investigation shall be sufficient to determine the ground conditions within the zone of influence.

NOTE Guidance on the minimum depth $d_{\min}$ of field investigation is given in EN 1997-3 for specific structures.

- (2) Groundwater and piezometric levels shall be determined to assess whether they could influence the stability or displacements or drainage of the geotechnical structure or any adjacent structures or utilities or their execution.

- (3) The value of $d_{\min}$ should be increased in the case of unfavourable ground conditions.
- (4) The value of $d_{\min}$ may be reduced in competent ground, if sufficient comparable experience exists to allow its properties to be predicted throughout the zone of influence.

NOTE Depending on the level of loading, examples of competent ground include medium strong rock masses or stronger, very dense coarse soil and fine soil with very high shear strength.

- (5) The spacing of investigation locations shall be appropriate for the:

- variation of the ground conditions;
- variation of the geotechnical units;
- variation of the groundwater conditions;
- critical elements of the structure; and
- the geotechnical category.

- (6) The spacing of investigation locations on plan should be no greater than $X_{\max}$.

NOTE Guidance on $X_{\max}$ is given in Annex H.

- (7) The number of investigation locations should be no less than $N_{\min}$.

NOTE Guidance on $N_{\min}$ is given in Annex H.

- (8) For structures in Geotechnical Category 3, the maximum spacing of investigation locations should be less than $X_{\max}$ and the minimum number of investigation locations should be greater than $N_{\min}$.

- (9) Where documented previous knowledge, local experience, or the results of preliminary investigations indicate that ground properties are highly variable, closer spacing and more investigation locations than given in (6) and (7) should be used.

NOTE 1 Further guidance on the extent of ground investigation for specific geotechnical structures is given in EN 1997-3.

NOTE 2 Geophysical techniques can supplement the information between intrusive investigation locations.

- (10) In cases where more than one type of investigation technique is planned, the investigation locations shall be separated by sufficient distance to avoid any interference.

- (11) For structures in Geotechnical Category 1, the maximum spacing of investigation locations may be greater than $X_{\max}$ and the minimum number of investigation locations may be less than $N_{\min}$.

- (12) Where documented previous knowledge, local experience or the results of preliminary investigations indicate that ground properties are sufficiently uniform across the site, a wider spacing or fewer investigation locations than given in (6) and (7) may be used, provided the reduced intensity is justified in the Ground Investigation Report.

5.4.4 Positioning of investigation locations

- (1) The depth and positioning of investigation locations shall be sufficient to identify the disposition of geotechnical units and their properties within the zone of influence.

NOTE The zone of influence for the different geotechnical structures is specified in EN 1997-3.

- (2) The positioning of investigation locations should be based on the results of the desk study, site inspection and results of any preliminary investigations and according to the:
- presence of critical locations relative to the shape, structural behaviour, and expected load distribution of the structure;
 - stability of slopes or cuttings and steps in the ground;
 - necessity of investigation locations outside the site so that the stability of the slopes or cuttings can be assessed;
 - preventing hazards to the structure, its execution, or the surroundings;
 - requirements for groundwater and monitoring instruments; and
 - potential monitoring during and after execution.
- (3) The position and elevation of investigation locations shall be recorded in the Ground Investigation Report, together with details of the grid reference system and geodetic reference datum used.

5.4.5 Sampling and laboratory testing

- (1) Samples should be taken from all geotechnical units.
- (2) Sampling shall comply with EN ISO 22475-1.
- (3) Groundwater measurements should comply with EN ISO 18674-4.
- (4) Planning of the sampling and selection of the equipment for taking each sample shall be appropriate for the:
- parameters to be measured;
 - tests to be carried out;
 - minimum sample quality class;
 - material to be sampled;
 - required diameter and mass of the sample; and
 - chosen sampler.
- (5) A specific sampling category, defined according to EN ISO 22475-1, shall be selected according to Tables 5.4 and 5.5 to obtain a required minimum quality class (MQC).
- (6) Samples of lower quality class may be used for testing, if the design acknowledges that test results and resulting design parameters have a larger uncertainty and not necessarily accurately reflect in situ conditions/behaviour.

NOTE An example is water content in cohesive material that can be determined from quality class 4 instead of 3 if the increased uncertainty is accounted for in the design parameters.

Table 5.4 — Quality classes of soil samples and sampling categories

Soil properties	Quality classes of soil samples for laboratory testing				
Unchanged soil properties	1	2	3	4	5
soil type	*	*	*	*	*
particle size	*	*	*	*	
water content	*	*	*		
density, density index, hydraulic conductivity	*	*			
compressibility, shear strength, stiffness	*				
Properties that can be determined					
sequence of layers	*	*	*	*	*
boundaries of strata – broad	*	*	*	*	
boundaries of strata – fine	*	*			
Atterberg limits, particle density, organic content	*	*	*	*	
water content	*	*	*		
density, density index, porosity, hydraulic conductivity	*	*			
compressibility, shear strength, stiffness	*				
Sampling categories	A				
		B			
			C		
				D	
					E

Table 5.5 — Quality classes of rock samples and sampling categories

Rock properties	Quality classes of rock samples for laboratory testing				
	1	2	3	4	5
Unchanged properties					
identification of rock type	*	*	*	*	*
particle shape and mineralogy	*	*	*	*	*
dimensions of all particles	*	*	*	*	
texture	*	*			
particle size	*	*	*	*	
density, porosity, hydraulic conductivity	*	*			
strength and deformation	*				
Properties that can be determined					
boundaries of strata – coarse definition	*	*	*	*	*
boundaries of strata- fine definition	*	*	*	*	
weathering	*	*	*		
discontinuity description	*	*	*		
discontinuity properties	*	*			
overall fracture state (including RQD)	*	*			
atterberg limits, particle density, organic content	*	*	*	*	
water content	*	*	*		
sensity, porosity, hydraulic conductivity	*	*			
strength, deformation, stiffness	*				
Sampling categories	A				
		B			
			C		
				D	
					E

(7) Before taking specimens for testing, the quality of recovered samples should be reported in the Ground Investigation Report.

NOTE See Table F.1 for guidance on verifying sample quality for low to medium OCR clays.

(8) Soil samples obtained using Category A samplers (as defined in EN ISO 22475-1) shall be handled to avoid deformation, desaturation, or swelling of samples during transport and storage.

(9) Reconstituted or reconsolidated specimens may be used to determine ground properties.

- (10) Reconstituted specimens of coarse soils should have approximately the same composition, bulk mass density, and water content as the in-situ material.
- (11) The procedure used to reconstitute soil specimens shall be reported in the Ground Investigation Report.
- (12) Planning of laboratory testing shall consider:
- the selection of test samples;
 - the conditions of storage before testing;
 - maximum allowed time between sampling and laboratory testing;
 - whether desiccated samples are to be re-saturated and by which technique;
 - the number of tests required per geotechnical unit; and
 - whether parallel tests are to be run on the same geotechnical unit.

6 Description and classification of the ground

6.1 General

- (1) Natural exposures, artificial exposures created as part of the investigation and all samples recovered in the investigation shall be inspected and described.
- (2) The description and classification of soils shall comply with EN ISO 14688 (all parts).
- (3) The description and classification of rock and its weathered profile shall comply with EN ISO 14689.
- NOTE Particular care is needed in describing the transition between soil and rock at rockhead.
- (4) Rock mass classification systems may be used for placing a rock mass into groups or classes and assigning unique descriptions (or values) on the basis of similar properties or characteristics.
- (5) Rock mass classification systems may be used to determine the rock mass strength parameters in accordance with 8.1.
- (6) Rock mass classification systems may be used to estimate the rock mass stiffness in accordance with 9.1.
- (7) Classification of a site for seismic purposes shall comply with EN 1998-1-1.
- (8) Classification of materials and fill for earthworks should comply with EN 16907-2.
- (9) The classification of materials should be adjusted in accordance with results from different test types and comparable experience.

NOTE Indirect classification or an indication of ground type can be derived from field tests.

- (10) Anisotropy of the ground and corresponding properties should be described.

6.2 Discontinuities and weathered zones

- (1) Potential foliation of rock and of hard soils should be identified.
- (2) Discontinuities and weathered zones shall be defined by geometrical and geotechnical properties.
- (3) Geotechnical properties of discontinuities and weathered zones shall include, but not be limited to, state and physical properties.

NOTE Examples of state and physical properties are apertures, interlocking, infill, thickness, roughness, smoothness, weathering, and alteration.

- (4) State and physical properties affecting strength of the discontinuities and weathered zones shall be defined and described as specified in Clauses 7 and 8.
- (5) Discontinuities may be grouped into sets that have similar dip and strike (or dip direction).
- (6) The presence of groundwater in discontinuities and possible freeze-thaw conditions shall be determined.
- (7) Groundwater pressures in discontinuities should be determined according to Clause 11 and EN 1997-1:2024, Clause 6.
- (8) The properties of any infill and hydraulic conductivity in discontinuities and weathered zones shall be determined according to Clauses 7 and 11.

NOTE 1 Typical infill properties of discontinuities are organic matter content, swelling potential and presence of crushed material.

NOTE 2 See E.6 for guidance on determining the Geological Strength Index.

7 State, physical, and chemical properties

7.1 State properties

7.1.1 General

- (1) State properties should be determined according to one or more of the standards given in Table 7.1.

NOTE Table B.5 gives examples of applicable national standards, in the absence of EN and ISO standards.

- (2) State properties should be determined on specimens representing each soil or rock type in the sample.

Table 7.1 — Field and laboratory tests to determine state properties

Property	Test	Test standard	MQC	Comments on suitability and interpretation
Bulk mass density (ρ)	Linear measurement method; immersion in fluid method; fluid displacement method	EN ISO 17892-2	2	Testing method used considering soil type and possible sample disturbance Density of a coarse soil is generally only approximate
	Water absorption coefficient by capillarity	EN 1925	2	-
	Immersion in fluid method; fluid displacement method	EN 1936	2	Determination of real density and apparent density, and of total and open porosity
	Sand replacement method	ISO 11272	-	In situ test
	Loose bulk density and voids	EN 1097-3	3	Suitable for coarse soils and aggregates
	Nuclear gauge	See Note ^a	-	Presence of nuclear source as a hazard
	Electrical density method	See Note ^a	-	-
	Dynamic probing Cone penetration test Flat dilatometer test	EN ISO 22476-2 EN ISO 22476-1 EN ISO 22476-11	-	Use correlations
Water content (w)	Oven drying	EN ISO 17892-1	3	Check storage method of samples Standard oven-drying method. For gypsum, organic soil and soil with closed pores filled with water; precautions are needed Report presence of gypsum, organic soil
	Water content	See Note ^a	2	For rock
	Oven drying in a ventilated oven	EN 1097-5	3	Suitable for aggregates
	Neutron depth probe method	ISO 10573	-	Determination of water content in the unsaturated zone