



BSI Standards Publication

## **Eurocode — Basis of structural and geotechnical design**

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## National foreword

This British Standard is the UK implementation of EN 1990:2023. It supersedes BS EN 1990:2002+A1:2005 and BS EN 1997-1:2004+A1:2013, which will be withdrawn on 30 March 2028.

The UK participation in its preparation was entrusted to Technical Committee B/525/1, Actions (loadings) and basis of design.

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The first generation of EN Eurocodes was published between 2002 and 2007, with conflicting British Standards withdrawn in 2010.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UK adoptions of the first generation of EN Eurocodes will be withdrawn by BSI on 30 March 2028.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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**Amendments/corrigenda issued since publication**

Date

Text affected

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English Version

## Eurocode - Basis of structural and geotechnical design

Eurocodes - Bases des calculs structuraux et  
géotechniques

Eurocode - Grundlagen der Planung von Tragwerken  
und geotechnischen Bauwerken

This European Standard was approved by CEN on 2 January 2023.

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. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists 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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COMITÉ EUROPÉEN DE NORMALISATION  
EUROPÄISCHES KOMITEE FÜR NORMUNG

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## **European foreword**

This document (EN 1990:2023) 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.

This document supersedes EN 1990:2002 and its amendments and corrigenda.

In comparison with the previous edition, the following main changes have been made:

- extension of scope to include provisions for bearings;
- improved approach for ULS verification;
- improved provisions on robustness;
- improved provisions on fatigue verification;
- improved provisions for basis of design for geotechnical structures in alignment with EN 1997;
- inclusion of provisions for sustainability;
- improved guidance on reliability analysis and code calibration;
- improved guidance for SLS verification of buildings related to deflection limits, vibrations and foundation movements;
- improved guidance on management of structural reliability of construction works;
- inclusion of guidance on verification of vibration of footbridges due to pedestrian traffic.

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

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

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

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

According to the CEN-CENELEC Internal Regulations, the national standards 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 1990

This document gives the principles and requirements for safety, serviceability, robustness, and durability of structures that are common to all Eurocodes parts and are to be applied when using them.

### 0.3 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.

## 0.4 National Annex for EN 1990

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 1990 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 document is to be used.

When no national choice is made and no default is given in this document, 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 1990 through notes to the following:

|                          |                          |                            |                          |
|--------------------------|--------------------------|----------------------------|--------------------------|
| 4.2(3)                   | 4.3(1)                   | 4.4(2)                     | 4.7(1)                   |
| 6.1.3.2(4) – 3 choices   | 6.1.3.2(6)               | 7.1.5(7)                   | 8.3.2.1(4)               |
| 8.3.3.1(5)               | 8.3.3.6(1)               | 8.3.4.2(2) – 2 choices     | A.1.3(1)                 |
| A.1.4(1)                 | A.1.6.1(1) – 3 choices   | A.1.6.1(2) – 2 choices     | A.1.6.2(1)               |
| A.1.6.3(1)               | A.1.6.3(2)               | A.1.7(1) – 2 choices       | A.1.8.1(1)               |
| A.1.8.2.2(2)             | A.1.8.2.3(2)             | A.1.8.3(1)                 | A.1.8.3(3)               |
| A.1.8.3(4)               | A.1.8.4(2)               | A.1.8.4(4) – 3 choices     | A.2.3(1)                 |
| A.2.4(1)                 | A.2.7.1(1) – 3 choices   | A.2.7.3.6(1)               | A.2.7.4.1(1) – 2 choices |
| A.2.7.4.3(1)             | A.2.7.4.5(1)             | A.2.7.4.6(1) – 2 choices   | A.2.7.5.1(1)             |
| A.2.7.5.3(1)             | A.2.7.5.4(1) – 2 choices | A.2.7.6.1(1)               | A.2.7.6.4(1)             |
| A.2.7.10(5) – 2 choices  | A.2.7.10(9)              | A.2.8(1) – 3 choices       | A.2.9.1(1)               |
| A.2.9.3.1(5)             | A.2.9.3.3(1)             | A.2.9.3.3(3)               | A.2.9.3.3(4)             |
| A.2.9.4.1(1) – 2 choices | A.2.9.4.2.1(3)           | A.2.9.4.2.2(4)             | A.2.9.4.2.2(5)           |
| A.2.9.4.2.3(1)           | A.2.9.4.2.3(2)           | A.2.9.4.2.4(2) – 2 choices | A.2.9.4.2.4(4)           |
| A.2.9.5(1)               | A.2.10(1)                | A.2.11.1(9)                | A.2.11.4.5(3)            |
| A.2.11.4.7(1)            | B.2(1)                   | B.4(2)                     | B.5(1)                   |
| B.6(1)                   | B.6(2)                   | B.7(1)                     | B.8(1)                   |
| C.3.1(5)                 | C.3.4.2(3)               | D.4.1(1)                   | E.4(4)                   |
| G.2(1)                   | G.3.1(6)                 | G.3.3.2(1)                 | G.3.3.2(2)               |
| G.3.4(2)                 | G.3.4(3)                 | G.6(2)                     | G.7.1.2(2)               |
| G.7.1.3(2)               | G.7.3.2(2)               | G.7.4.2(1)                 | G.7.5.1(1)               |
| G.7.5.2(1) – 2 choices   |                          |                            |                          |

National choice is allowed in EN 1990 on the application of the following informative annexes:

|         |         |         |         |
|---------|---------|---------|---------|
| Annex B | Annex C | Annex D | Annex E |
| Annex F | 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 1990

(1) This document establishes principles and requirements for the safety, serviceability, robustness and durability of structures, including geotechnical structures, appropriate to the consequences of failure.

(2) This document is intended to be used in conjunction with the other Eurocodes for the design of buildings and civil engineering works, including temporary structures.

(3) This document describes the basis for structural and geotechnical design and verification according to the limit state principle.

(4) The verification methods in this document are based primarily on the partial factor method.

NOTE 1 Alternative methods are given in the other Eurocodes for specific applications.

NOTE 2 The Annexes to this document also provide general guidance concerning the use of alternative methods.

(5) This document is also applicable for:

- structural assessment of existing structures;
- developing the design of repairs, improvements and alterations;
- assessing changes of use.

NOTE Additional or amended provisions can be necessary.

(6) This document is applicable for the design of structures where materials or actions outside the scope of EN 1991 (all parts) to EN 1999 (all parts) are involved.

NOTE In this case, additional or amended provisions can be necessary.

### 1.2 Assumptions

(1) It is assumed that reasonable skill and care appropriate to the circumstances is exercised in the design, based on the knowledge and good practice generally available at the time the structure is designed.

(2) It is assumed that the design of the structure is made by appropriately qualified and experienced personnel.

(3) The design rules provided in the Eurocodes assume that:

- execution will be carried out by personnel having appropriate skill and experience;
- adequate control and supervision will be provided during design and execution of the works, whether in factories, plants, or on site;
- construction materials and products will be used in accordance with the Eurocodes, in the relevant product and execution standards, and project specifications;
- the structure will be adequately maintained;
- the structure will be used in accordance with the design assumptions.

NOTE Guidance on management measures to satisfy the assumptions for design and execution is given in Annex B.

## 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 1337-3, *Structural bearings - Part 3: Elastomeric bearings*

EN 1991 (all parts), *Eurocode 1: Actions on structures*

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

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

EN 1993 (all parts), *Eurocode 3: Design of steel structures*

EN 1994 (all parts), *Eurocode 4: Design of composite steel and concrete structure*

EN 1995 (all parts), *Eurocode 5: Design of timber structures*

EN 1996 (all parts), *Eurocode 6: Design of masonry structures*

EN 1997 (all parts), *Eurocode 7: Geotechnical design*

EN 1998 (all parts), *Eurocode 8: Design of structures for earthquake resistance*

EN 1999 (all parts), *Eurocode 9: Design of aluminium structures*

## 3 Terms, definitions and symbols

### 3.1 Terms and definitions

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

#### 3.1.1 Common terms used in the Eurocodes

##### 3.1.1.1

##### **construction works**

everything that is constructed or results from construction operations

**Note 1 to entry:** The term covers both buildings and civil engineering works. It refers to the complete construction works comprising structural members, geotechnical elements and elements other than structural.

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<sup>1</sup> Under preparation. Stage at the time of publication: prEN 1991-2:2021.

**3.1.1.2  
structure**

part of the construction works that provides stability, resistance, and rigidity, to meet the safety, serviceability and durability requirements

Note 1 to entry: This definition includes structures that comprise one member or a combination of connected members.

**3.1.1.3  
structural member**

physically distinguishable part of a structure, e.g. column, beam, plate, foundation

**3.1.1.4  
structural or geotechnical model**

physical, mathematical, or numerical idealization of the structural or geotechnical system used for the purposes of analysis, design, and verification

**3.1.1.5  
ground**

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

[SOURCE: ISO 6707-1:2020, 3.4.2.1]

**3.1.1.6  
geotechnical structure**

structure that includes ground or a structural member that relies on the ground for resistance

**3.1.1.7  
elements other than structural**

completion and finishing elements connected with the structure that are not classified as structural members and that have the lowest consequence of failure

Note 1 to entry: See 4.3 for the classification of consequences of failure.

EXAMPLE Roofing; surfacing and coverings; partitions and linings; kerbs; wall cladding; suspended ceilings; thermal insulation; bridge furniture, road surfacing; services fixed permanently to, or within, the structure such as equipment for lifts and moving stairways; heating, ventilating and air conditioning equipment; electrical equipment; pipes; cable trunking and conduits.

**3.1.1.8  
execution**

all activities carried out for the physical completion of the work including procurement, the inspection and documentation thereof

Note 1 to entry: The term covers work on site; it can also signify the fabrication of parts off site and their subsequent erection on site.

**3.1.1.9  
quality**

degree to which a set of inherent characteristics of an object fulfils requirements

Note 1 to entry: The term “quality” can be used with adjectives such as poor, good or excellent.

Note 2 to entry: “Inherent”, as opposed to “assigned”, means existing in the object.

[SOURCE: EN ISO 9000:2015, 3.6.2]

### 3.1.2 Terms relating to design

#### 3.1.2.1

##### **design criteria**

quantitative formulations describing the conditions to be fulfilled for each limit state

#### 3.1.2.2

##### **design situation**

physical conditions expected to occur during a certain time period for which it is to be demonstrated, with sufficient reliability, that relevant limit states are not exceeded

#### 3.1.2.3

##### **persistent design situation**

normal condition of use or exposure of the structure

Note 1 to entry: The duration of a persistent design situation is of the same order as the design service life of the structure.

#### 3.1.2.4

##### **transient design situation**

temporary conditions of use or exposure of the structure that are relevant during a period much shorter than the design service life of the structure

Note 1 to entry: A transient design situation refers to temporary conditions of the structure, of use, or exposure, e.g. during construction or repair.

#### 3.1.2.5

##### **fundamental design situation**

design situation that is either a persistent or a transient design situation

#### 3.1.2.6

##### **accidental design situation**

design situation in which the structure is subjected to exceptional events or exposure

Note 1 to entry: Caused by events such as fire, explosion, impact or local failure.

#### 3.1.2.7

##### **seismic design situation**

design situation in which the structure is subjected to a seismic event

#### 3.1.2.8

##### **fatigue design situation**

design situation where fatigue actions may cause fatigue failure

Note 1 to entry: For some materials, a distinction applies between low and high cycle fatigue. The other Eurocodes give guidance, where relevant.

#### 3.1.2.9

##### **verification case**

classification of load cases for fundamental design situations in ultimate limit states, for which a set of partial factors is defined

#### 3.1.2.10

##### **fire design**

design of a structure to fulfil the required performance in case of fire

**3.1.2.11**

**design service life**

assumed period for which a structure or part of it is to be used for its intended purpose with anticipated maintenance but without major repair being necessary

**3.1.2.12**

**load arrangement**

identification of the position, magnitude, and direction of a free action

**3.1.2.13**

**load case**

compatible load arrangements, deformations and geometrical imperfections considered, where relevant, for verification of a specific limit state

**3.1.2.14**

**limit state**

state beyond which the structure no longer satisfies the relevant design criteria

**3.1.2.15**

**ultimate limit state**

**ULS**

state associated with collapse or other forms of structural failure

**3.1.2.16**

**serviceability limit state**

**SLS**

state that corresponds to conditions beyond which specified service requirements for a structure or structural member are no longer met

**3.1.2.17**

**irreversible serviceability limit state**

serviceability limit state in which effects of actions remain when the actions are removed

**3.1.2.18**

**reversible serviceability limit state**

serviceability limit state in which the effects of actions do not remain when the actions are removed

**3.1.2.19**

**serviceability criterion**

performance criterion for a serviceability limit state

**3.1.2.20**

**resistance**

capacity of a structure, or a part of it, to withstand actions without failure

**3.1.2.21**

**strength**

mechanical property of a material indicating its ability to resist actions, usually given in units of stress

**3.1.2.22**

**fatigue**

damaging process caused by cyclic actions or actions inducing cyclic effects that may culminate in failure

**3.1.2.23****excessive deformation**

deformation that exceeds limits to such an extent that the structure can be considered to have reached an ultimate limit state

**3.1.2.24****structural reliability**

ability of a structure or a structural member to fulfil the specified requirements during the service life for which it has been designed

Note 1 to entry: Reliability covers safety, serviceability and durability of a structure.

**3.1.2.25****reliability differentiation**

measures intended for the socio-economic optimization of the resources to be used to execute construction works, taking into account all the expected consequences of failure and the cost of the construction works

**3.1.2.26****basic variable**

variable representing a physical quantity that characterizes actions and environmental influences, geometrical quantities, and material properties, including ground properties

**3.1.2.27****maintenance**

set of activities performed during the service life of the structure so that it fulfils the requirements for reliability

Note 1 to entry: Activities to restore the structure after an accidental or seismic event are normally outside the scope of maintenance.

**3.1.2.28****repair**

activities, beyond the definition of maintenance, performed to preserve or to restore the function of a structure

**3.1.2.29****nominal value**

value fixed on a non-statistical basis; for instance, on acquired experience or on physical conditions

**3.1.2.30****robustness**

ability of a structure to withstand unforeseen adverse events without being damaged to an extent disproportionate to the original cause

**3.1.2.31****durability**

ability of a structure or structural member to satisfy, with planned maintenance, its design performance requirements over the design service life

**3.1.2.32****sustainability**

ability to minimize the adverse impact of the construction works on non-renewable resources in the environment, on society, and on economy during their entire life cycle

### 3.1.2.33

#### **consequence class**

categorization of the consequences of structural failure in terms of loss of human lives or personal injury and of economic, social, or environmental losses

### 3.1.2.34

#### **gross human error**

error resulting from ignorance or oversight that causes a change in the behaviour or a reduction in reliability of the structure that are unacceptable

## 3.1.3 Terms relating to actions

### 3.1.3.1

#### **action**

$F$

mechanical influence on a structure, or a structural member, exerted directly or indirectly from its environment

### 3.1.3.2

#### **direct action**

set of forces, or loads, applied to the structure

### 3.1.3.3

#### **indirect action**

set of imposed deformations or accelerations

EXAMPLE Imposed deformations or accelerations caused by temperature changes, moisture variation, uneven settlement or earthquakes.

### 3.1.3.4

#### **effect of actions**

$E$

action-effect

resulting effect, on a structural member or on the whole structure, from the application of actions

EXAMPLE Internal forces, moments, stresses, strains, deflections, and rotations.

### 3.1.3.5

#### **permanent action**

$G$

action that is likely to act throughout the design service life and for which any variation in magnitude is either small, compared with the mean value, or monotonic; i.e. it either only increases or decreases, until it reaches a limit value

### 3.1.3.6

#### **variable action**

$Q$

action that is likely to occur during the design service life for which the variation in magnitude with time is neither negligible nor monotonic

### 3.1.3.7

#### **fatigue action**

$F_{\text{fat}}$

cyclic action or action inducing cyclic effects that can cause fatigue

**3.1.3.8****accidental action** $A$ 

action, usually of short duration but of significant magnitude, that is unlikely to occur during the design service life

Note 1 to entry: An accidental action can be expected in many cases to cause severe consequences, unless appropriate measures are taken.

**3.1.3.9****seismic action** $A_E$ 

action that arises due to earthquake

**3.1.3.10****climatic action**

action arising from the climatic system

EXAMPLE Snow, wind, temperature variation, atmospheric icing, and humidity.

Note 1 to entry: Waves and currents are considered as an effect of climatic actions and other influences on water.

**3.1.3.11****fixed action**

action that has a fixed distribution and position over a structure or structural member such as its magnitude and direction are determined unambiguously for the whole structure or structural member

**3.1.3.12****free action**

action that can have various spatial distributions over the structure

**3.1.3.13****bounded action**

action that has a limiting value that cannot be exceeded and which is known to a sufficient accuracy

**3.1.3.14****single action**

action that can be assumed to be statistically independent in time and space of any other action acting on the structure

**3.1.3.15****static action**

action that does not cause significant acceleration of the structure or structural members

**3.1.3.16****dynamic action**

action that causes significant acceleration of the structure or structural members

**3.1.3.17****quasi-static action**

dynamic action represented by an equivalent static action in a static model

### 3.1.3.18

#### **representative value of an action**

$F_{\text{rep}}$

value of an action used for the verification of a limit state

Note 1 to entry: The representative value can be the characteristic, combination, frequent, or quasi-permanent value.

### 3.1.3.19

#### **characteristic value of an action**

$F_k$

value of an action chosen, as far as it can be fixed on a statistical basis, to correspond to a prescribed probability of not being exceeded unfavourably during a specified reference period

Note 1 to entry: If a characteristic value cannot be fixed on a statistical basis, it can be replaced by a nominal value.

### 3.1.3.20

#### **design value of an action**

$F_d$

value obtained by multiplying the representative value of an action by a partial factor  $\gamma_F$  or determined directly

### 3.1.3.21

#### **reference period**

period of time that is used as a basis for statistically assessing extreme realizations of variable actions and possibly for accidental actions

### 3.1.3.22

#### **return period**

average number of years in which a stated action statistically is exceeded once

### 3.1.3.23

#### **combination of actions**

set of design values of actions used for the verification of the structural reliability for a limit state considering the simultaneous influence of different actions

### 3.1.3.24

#### **leading action**

principal action in a combination

### 3.1.3.25

#### **accompanying action**

action that accompanies the leading action in a combination

### 3.1.3.26

#### **combination value of a variable action**

$Q_{\text{comb}}$

value of an accompanying action to be used in the verification of ultimate limit states in persistent or transient design situations and irreversible serviceability limit states, chosen - in so far as it can be fixed on statistical bases - so that the probability that the effects caused by the combination will be exceeded is approximately the same as by the characteristic value of an individual action

Note 1 to entry:  $Q_{\text{comb}}$  can be expressed as a proportion  $\psi_0$  of the characteristic value (i.e.  $Q_{\text{comb}} = \psi_0 Q_k$ ) where  $\psi_0 \leq 1$ .

**3.1.3.27****frequent value of a variable action** $Q_{\text{freq}}$ 

value used in the verification of ultimate limit states involving accidental actions and in the verification of some reversible serviceability limit states

Note 1 to entry:  $Q_{\text{freq}}$  can be expressed as a proportion  $\psi_1$  of the characteristic value (i.e.  $Q_{\text{freq}} = \psi_1 Q_k$ ), where  $\psi_1 \leq 1$ .

**3.1.3.28****quasi-permanent value of a variable action** $Q_{\text{qper}}$ 

value used in the verification of ultimate limit states involving accidental or seismic actions; in the verification of some reversible serviceability limit states and in the calculation of long-term effects

Note 1 to entry:  $Q_{\text{qper}}$  can be expressed as a proportion  $\psi_2$  of the characteristic value (i.e.  $Q_{\text{qper}} = \psi_2 Q_k$ ), where  $\psi_2 \leq 1$ .

**3.1.3.29****natural frequency**

frequency of free oscillation of a structure

**3.1.3.30****dynamic amplification factor**

ratio between the characteristic value of the effect of the dynamic action and the characteristic value of the effect of the static action

Note 1 to entry: The definition applies also for other representative values.

**3.1.4 Terms relating to material and product properties****3.1.4.1****characteristic value of a material or product property** $X_k$ 

value of a material or product property having a prescribed probability of not being attained in a hypothetical unlimited test series

Note 1 to entry: This value generally corresponds to a specified fractile of the assumed statistical distribution of the particular property of the material or product. A nominal value is used as the characteristic value in some circumstances.

**3.1.4.2****representative value of a material or product property** $X_{\text{rep}}$ 

value obtained by multiplying the characteristic value of a material or product property by a conversion factor accounting for scale effects, effects of moisture and temperature, effects of ageing of materials, and any other relevant parameters

#### 3.1.4.3

##### **design value of a material or product property**

$X_d$

value obtained by either dividing the inferior representative value of a material or product property by a partial material factor or, when it is more critical, by multiplying the superior representative value by a partial material factor

Note 1 to entry: In special circumstances, the value may be obtained by direct determination.

Note 2 to entry: For specific rules, see the other Eurocodes.

#### 3.1.5 Terms relating to geometrical property

##### 3.1.5.1

##### **nominal value of a geometrical property**

$a_{\text{nom}}$

value of a geometrical property corresponding to the dimensions specified in the design

Note 1 to entry: Where appropriate, nominal values of geometrical properties can be replaced by a prescribed fractile of their statistical distribution.

##### 3.1.5.2

##### **design value of a geometrical property**

$a_d$

value of a geometrical property that includes any deviation

Note 1 to entry: Where relevant, it can include possible deviations from nominal value.

#### 3.1.6 Terms relating to structural and geotechnical analysis

##### 3.1.6.1

##### **structural analysis**

procedure or algorithm for determination of effects of actions within a structure

Note 1 to entry: Structural analyses are sometimes performed at more than one level using different models (e.g. global, member and local analyses).

##### 3.1.6.2

##### **linear behaviour**

behaviour of a structure or a structural member in which the relationship between actions and their effects is directly proportional

##### 3.1.6.3

##### **non-linear behaviour**

behaviour of a structure or a structural member in which the relationship between actions and their effects is not proportional

##### 3.1.6.4

##### **geometric non-linearity**

non-linearity caused by changes in geometry from the initial undeformed state

EXAMPLE Examples of structures where geometric non-linearity can occur are membranes, cables, flat arches, catenaries, slender columns and slender beams.

**3.1.6.5****first order theory**

relationship between actions and effects when the deformations of a structural member or the entire structure do not have significant influence on the equilibrium equation

**3.1.6.6****second order theory**

relationship between actions and effects when the deformations have influence on the equilibrium equation

**3.1.6.7****material non-linearity**

non-linearity caused by a non-linear stress-strain relationship of the material

EXAMPLE      Plasticity, cracking in concrete, strain hardening, hysteresis.

**3.1.6.8****contact non-linearity**

non-linearity caused by changes at the contact boundary between structural parts during introduction of actions

EXAMPLE      Friction interface, interface between concrete floor slab and masonry wall, soil and footing.

**3.1.6.9****non-linearity of the limit state function**

non-linearity between the resistance and the variables influencing the resistance

Note 1 to entry:    This is important for the application of partial factors.

**3.1.6.10****stress history**

stress variation during time

**3.1.7 Terms relating to bridges**

NOTE 1    Definitions, symbols, notations, load models and groups of loads for traffic loads are those used or defined in the relevant section of EN 1991-2.

NOTE 2    Symbols, notations and models of actions during execution are those defined in EN 1991-1-6.

**3.1.7.1****integral abutment bridge**

bridge without joints in the deck that accommodates thermal expansion and contraction by movement of the abutments in and out of the backfill

**3.1.7.2****support system**

arrangement of supports that transfer the loads from the superstructures (e.g. bridge, overpass) to the substructures (e.g. piers, abutments) and allow movements for specified degrees of freedom

**3.1.7.3****notional fixed point**

point where thermal expansion, or other free or partially free strains of the superstructure do not generate global movements

**3.1.7.4****expansion length**

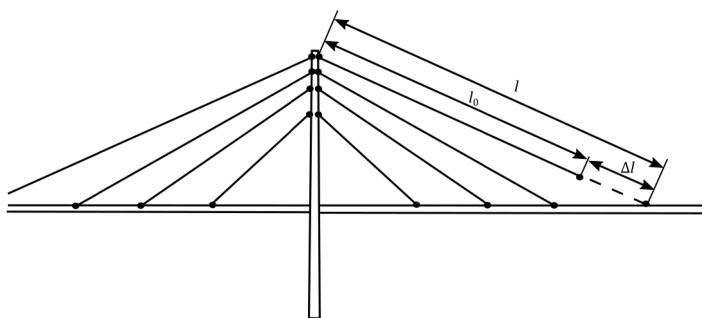
distance from notional fixed point to location in question

**3.1.7.5****prestrain**

prestressing force caused by controlled deformations imposed to a tension component

Note 1 to entry: Contrary to the axial force, the prestrain is independent of the loads on the structure. It changes only when the adjustment of the stay is modified. The prestrain can be applied step by step, depending on the construction process. Due to the deflection during construction, the distance between terminations in the completed structure can be different from the distance between terminations at the time of installation.

Note 2 to entry: The prestrain of a stay cable is characterized by its pre-deformation (see Figure 3.1) or the reference tension  $F_{\text{ref}}$  that is to be applied to the stay to force its ends to coincide with the position of the terminations in the reference geometry. If the stay is modelled with a linear behaviour, the reference tension is proportional to the predeformation:  $F_{\text{ref}} = EA_m \varepsilon$  where  $A_m$  is the nominal metallic cross-section of the tension element. If the stay is modelled as a catenary, it is more convenient to use the reference tension. As the prestrain, the reference force does not depend on the loads applied on the structure. It can differ from the stay force at the time of stay installation.

**Key**

$l$  distance between terminations in the reference geometry

$l_0$  length of the cable without tension and gravity

$\varepsilon$  predeformation,  $\varepsilon = \Delta l / l_0$

**Figure 3.1 — Prestrain for stay cables in cable supported bridges**

## 3.2 Symbols and abbreviations

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

NOTE The notation used is based on ISO 3898:2013.

### 3.2.1 Latin upper-case letters

|              |                                                                         |
|--------------|-------------------------------------------------------------------------|
| $A$          | Accidental action                                                       |
| $A_d$        | Design value of an accidental action                                    |
| $A_E$        | Seismic action                                                          |
| $A_{Ed}$     | Design value of seismic action                                          |
| $A_{Ed,ULS}$ | Design value of seismic action in an ultimate limit state               |
| $A_{Ed,SLS}$ | Design value of seismic action in a serviceability limit state          |
| $A_{eff,i}$  | Effective plan area for layer $i$ of elastomeric bearing                |
| $A_m$        | Nominal metallic cross-section of the tension element                   |
| $A_{w,rep}$  | Representative value of accidental water action                         |
| $C_{d,SLS}$  | Limiting design value of the relevant serviceability criterion          |
| $C_{d,ULS}$  | Limiting design value for ultimate limit state of excessive deformation |
| CC           | Consequence class                                                       |
| CL           | Comfort level                                                           |
| $D_{int}$    | Limiting value for characteristic movement at integral abutment         |
| DL           | Damage limitation                                                       |
| $E$          | Effect of actions                                                       |
| $E(X)$       | Mean value of $X$                                                       |
| $E_d$        | Design value of effect of actions                                       |
| $F$          | Action                                                                  |
| $F_{bd}$     | Design value of bearing force                                           |
| $F_d$        | Design value of an action                                               |
| $F_{Ed}$     | Design value of actions used in assessment of $E_d$                     |
| $F_{fat}$    | Fatigue action                                                          |
| $F_{fat,d}$  | Design value of a fatigue action                                        |
| $F_k$        | Characteristic value of an action                                       |
| $F_{ref}$    | Reference tension                                                       |
| $F_{rep}$    | Representative value of an action                                       |

|              |                                                                                                       |
|--------------|-------------------------------------------------------------------------------------------------------|
| $F_w^*$      | Limiting value for accompanying wind force for road bridges                                           |
| $F_w^{**}$   | Limiting value for accompanying wind force for railway bridges                                        |
| $F_{wk}$     | Wind force                                                                                            |
| $G$          | Permanent action                                                                                      |
| $G_d$        | Design value of a permanent action                                                                    |
| $G_{de}$     | Design shear modulus of elastomer                                                                     |
| $G_{de,i}$   | Design value of shear modulus of elastomer for layer $i$                                              |
| $G_{d,fav}$  | Design value of a permanent action that produces a favourable effect                                  |
| $G_{exp}$    | Tolerance for shear modulus                                                                           |
| $G_k$        | Characteristic value of a permanent action                                                            |
| $G_{k,i}$    | Characteristic value of a permanent action $i$                                                        |
| $G_{k,inf}$  | Lower characteristic value of a permanent action                                                      |
| $G_{nom}$    | Nominal shear modulus                                                                                 |
| $G_{k,sup}$  | Upper characteristic value of a permanent action                                                      |
| $G_{rep}$    | Representative value of a permanent action                                                            |
| $G_w$        | Water action                                                                                          |
| $G_{wk}$     | Characteristic value of water action                                                                  |
| $G_{wk,inf}$ | Lower characteristic value of water action                                                            |
| $G_{w,rep}$  | Representative value of water action                                                                  |
| $G_{wk,sup}$ | Upper characteristic value of water action                                                            |
| HSLM         | High speed load model                                                                                 |
| LM           | Load model                                                                                            |
| $N_d$        | Design value of the normal forces at the bearing in the applicable combination                        |
| $N_{d,i}$    | Design value of normal force at sliding bearing of support $i$                                        |
| $N_{d,j}$    | Design value of normal forces of permanent actions and prestressing at sliding bearing of support $j$ |
| NC           | Near collapse                                                                                         |
| NDP          | Nationally Determined Parameter                                                                       |
| $P$          | Prestressing force                                                                                    |
| $P_d$        | Design value of a prestressing force                                                                  |
| $P_f$        | Failure probability level                                                                             |

|              |                                                                            |
|--------------|----------------------------------------------------------------------------|
| $P_k$        | Characteristic value of a prestressing force                               |
| $P_{k,inf}$  | Lower characteristic value of a prestressing force                         |
| $P_{k,sup}$  | Upper characteristic value of a prestressing force                         |
| $Q$          | Variable action                                                            |
| $Q_c$        | Construction action                                                        |
| $Q_{comb}$   | Combination value of a variable action                                     |
| $Q_d$        | Design value of a variable action                                          |
| $Q_{freq}$   | Frequent value of a variable action                                        |
| $Q_{fwk}$    | Characteristic value of the concentrated load (wheel load) on a footbridge |
| $Q_k$        | Characteristic value of a variable action                                  |
| $Q_{k,j}$    | Characteristic value of the accompanying variable action $j$               |
| $Q_{k,1}$    | Characteristic value of the leading variable action 1                      |
| $Q_{Lk}$     | Horizontal force resulting from acceleration and braking                   |
| $Q_{qper}$   | Quasi-permanent value of a variable action                                 |
| $Q_{rep}$    | Representative value of a variable action                                  |
| $Q_{Sn,k}$   | Characteristic value of snow load                                          |
| $Q_{w,comb}$ | Combination value of variation in water action                             |
| $Q_{w,freq}$ | Frequent value of variation in water action                                |
| $Q_{w,qper}$ | Quasi-permanent value of variation in water action                         |
| $Q_{w,rep}$  | Representative value of variation in water action                          |
| $Q_{wk}$     | Characteristic value of variation in water action                          |
| $R$          | Resistance                                                                 |
| $R_d$        | Design value of the resistance                                             |
| $R_{fat}$    | Representative value of the fatigue resistance                             |
| $R_{fat,d}$  | Design value of the fatigue resistance                                     |
| SD           | Significant damage                                                         |
| SLS          | Serviceability limit state                                                 |
| $T_{fi}$     | Duration of fire exposure                                                  |
| $T_k$        | Thermal action                                                             |
| $T_{lf}$     | Design service life                                                        |
| $T_0$        | Initial temperature                                                        |

|            |                                                                                                                                                                       |
|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| TS         | Tandem system                                                                                                                                                         |
| UDL        | Uniformly distributed load                                                                                                                                            |
| ULS        | Ultimate limit state                                                                                                                                                  |
| $V$        | Coefficient of variation, $V = (\text{standard deviation})/(\text{mean value})$                                                                                       |
| $V_T$      | Train speed                                                                                                                                                           |
| $V_X$      | Coefficient of variation of $X$                                                                                                                                       |
| $V_\delta$ | Estimator for the coefficient of variation of the error term $\delta$                                                                                                 |
| $X$        | Array of $j$ basic variables $X_1 \dots X_j$                                                                                                                          |
| $X_d$      | Design value of a material or product property                                                                                                                        |
| $X_k$      | Characteristic value of a material or product property                                                                                                                |
| $X_k(n)$   | Characteristic value, including statistical uncertainty for a sample of size $n$ , with any conversion factor excluded prior to application of any correction factor. |
| $X_m$      | Array of mean values of the basic variables                                                                                                                           |
| $X_{Rd}$   | Value of a material or product property used in the assessment of $R_d$                                                                                               |
| $X_{rep}$  | Representative value of a material or product property                                                                                                                |

### 3.2.2 Latin lower-case letters

|                 |                                                                                |
|-----------------|--------------------------------------------------------------------------------|
| $a_{bt}$        | Limiting value for bridge deck acceleration for ballasted track                |
| $a_d$           | Design value of a geometrical property                                         |
| $a_{df}$        | Limiting value for bridge deck acceleration for ballastless track              |
| $a_{lim,v}$     | Limiting value for acceleration in vertical direction                          |
| $a_{lim,h}$     | Limiting value for acceleration in horizontal direction                        |
| $a_{nom}$       | Nominal value of a geometrical property                                        |
| $b$             | Correction factor                                                              |
| $b_i$           | Correction factor for test specimen $i$                                        |
| $b_v$           | Limiting value of vertical acceleration                                        |
| $b'_v$          | Maximum permissible vertical acceleration                                      |
| $d_{d,con}$     | Design contraction movement of a bearing                                       |
| $d_{d,exp}$     | Design expansion movement of a bearing                                         |
| $d_{execution}$ | Movements of bearings during execution before the structure becomes restrained |
| $d_{Gd}$        | Design movement due to permanent effects                                       |
| $d_{Pd}$        | Design movement due to prestressing                                            |

|                         |                                                                                                                                        |
|-------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| $d_{Qd,con}$            | Design contraction movement due to variable actions                                                                                    |
| $d_{Qd,exp}$            | Design expansion movement due to variable actions                                                                                      |
| $d_{Set,i}$             | Difference in settlement of an individual foundation or part of a foundation                                                           |
| $f_{h0}$                | Limitation value for fundamental natural frequency of lateral vibration of a span                                                      |
| $g_{rt}(\underline{X})$ | Theoretical resistance function, of the basic variables $\underline{X}$ , used as the design model                                     |
| $h$                     | Height of building                                                                                                                     |
| $h_i$                   | Storey height                                                                                                                          |
| $i_d$                   | Design value of a geometrical imperfection                                                                                             |
| $k_{d,n}$               | Design fractile factor for a sample size $n$                                                                                           |
| $k_{dyn}$               | Dynamic factor                                                                                                                         |
| $k_F$                   | Consequence factor                                                                                                                     |
| $k_n$                   | Characteristic fractile factor for a sample size $n$                                                                                   |
| $k_{temp}$              | Temperature factor                                                                                                                     |
| $k_\varphi$             | Factor for reducing geometric imperfections                                                                                            |
| $l$                     | Span                                                                                                                                   |
| $m_X$                   | Mean value of the variable $X$ from $n$ sample results                                                                                 |
| $n$                     | Number of a quantity                                                                                                                   |
| $q_{1k}$                | Action due to aerodynamic effects                                                                                                      |
| $r$                     | Resistance value                                                                                                                       |
| $r_d$                   | Design value of the resistance                                                                                                         |
| $r_e$                   | Experimental resistance value                                                                                                          |
| $r_{ee}$                | Extreme (maximum or minimum) value of the experimental resistance, i.e. value of $r_e$ that deviates most from the mean value $r_{em}$ |
| $r_{e,i}$               | Experimental resistance for specimen $i$                                                                                               |
| $r_{em}$                | Mean value of the experimental resistance                                                                                              |
| $r_k$                   | Characteristic value of the resistance                                                                                                 |
| $r_m$                   | Mean value of the resistance calculated using the mean values $X_m$ of the basic variables                                             |
| $r_t$                   | Theoretical resistance determined from the resistance function $g_{rt}(\underline{X})$                                                 |
| $r_{t,i}$               | Theoretical resistance determined using the measured parameters $\underline{X}$ for specimen $i$                                       |
| $r_{tr}$                | Change of radius of a track across a deck                                                                                              |
| $s$                     | Estimated value of the standard deviation $\sigma$                                                                                     |

|                |                                                                                     |
|----------------|-------------------------------------------------------------------------------------|
| $s_{Cd}$       | Differential settlement                                                             |
| $s_g$          | Track gauge                                                                         |
| $s_{\Delta}$   | Estimated value of $\sigma_{\Delta}$                                                |
| $s_{\delta}$   | Estimated value of $\sigma_{\delta}$                                                |
| $t$            | Maximum twist                                                                       |
| $t_{el;eff,i}$ | Effective thickness of elastomer layer $i$                                          |
| $t_T$          | Limiting value for total track twist                                                |
| $u$            | Horizontal displacement of a structure or structural member                         |
| $u_{d,i}$      | Design value of relative displacement of elastomer layer $i$                        |
| $u_i$          | Relative horizontal displacement over a storey height excluding rigid body rotation |
| $x_i$          | the $i$ -th measurement of the variable $X$                                         |
| $w$            | Vertical deflection of a structural member                                          |
| $w_c$          | Precamber                                                                           |
| $w_{max}$      | Remaining total deflection taking into account precamber                            |
| $w_{tot}$      | Total deflection                                                                    |
| $w_1$          | Initial part of deflection under permanent loads                                    |
| $w_2$          | Long-term part of deflection under permanent loads including quasi-permanent loads  |
| $w_3$          | Instantaneous deflection due to variable actions excluding quasi-permanent loads    |

### 3.2.3 Greek upper-case letters

|                     |                                                                                                  |
|---------------------|--------------------------------------------------------------------------------------------------|
| $\Phi$              | Cumulative distribution function of the standardized Normal distribution                         |
| $\Phi_{dyn}$        | Dynamic factor                                                                                   |
| $\Delta$            | Logarithm of the error term $\delta$ , $\Delta_i = \ln(\delta_i)$                                |
| $\bar{\Delta}$      | Estimated value for $E(\Delta)$                                                                  |
| $\Delta a$          | Deviation in a geometrical property                                                              |
| $\Delta d$          | Geometric uncertainty                                                                            |
| $\Delta d_{Set,i}$  | Uncertainty attached to the assessment of the settlement of a foundation or part of a foundation |
| $\Delta s_{Cd,SLS}$ | Maximum differential settlement                                                                  |
| $\Delta T_{d,con}$  | Characteristic value of maximum fall of a uniform temperature component resulting in contraction |
| $\Delta T_{d,exp}$  | Characteristic value of maximum rise of a uniform temperature component resulting in expansion   |

|                    |                                                                                                  |
|--------------------|--------------------------------------------------------------------------------------------------|
| $\Delta T_{N,con}$ | Characteristic value of maximum fall of a uniform temperature component resulting in contraction |
| $\Delta T_{N,exp}$ | Characteristic value of maximum rise of a uniform temperature component resulting in expansion   |
| $\Delta T_0$       | Range of initial bridge temperature                                                              |
| $\Delta \delta_h$  | Maximum differential transverse deflection                                                       |

### 3.2.4 Greek lower-case letters

|                         |                                                                                                                                |
|-------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| $\alpha$                | Adjustment factor                                                                                                              |
| $\alpha_{Qi}$           | Adjustment factors of some load models on lanes $i$ ( $i = 1, 2, \dots$ )                                                      |
| $\alpha_n$              | Factor depending on the type of bearing and number of bearings                                                                 |
| $\alpha_{qi}$           | Adjustment factors of some load models on lanes $i$ ( $i = 1, 2, \dots$ )                                                      |
| $\alpha_{qr}$           | Adjustment factor of load models on the remaining area                                                                         |
| $\alpha_{Q_{i,max},T}$  | FORM (First Order Reliability Method) sensitivity factor of $Q_i$ dominating ( $i = 1, 2$ )                                    |
| $\alpha_{Q_{i,\tau 1}}$ | FORM (First Order Reliability Method) sensitivity factor of $Q_i$ not dominating ( $i = 1, 2$ )                                |
| $\alpha_Y$              | Sensitivity factor indicating the importance of $Y$ in the reliability estimation                                              |
| $\beta$                 | Reliability index                                                                                                              |
| $\beta_{Cd}$            | Angular distortion                                                                                                             |
| $\beta_{Cd,SLS}$        | Maximum angular distortion                                                                                                     |
| $\beta_Q$               | Adjustment factor of load model 2                                                                                              |
| $\gamma$                | Partial factor                                                                                                                 |
| $\gamma_E$              | Partial factor applied to the effects of actions accounting for the uncertainties covered by $\gamma_f$ and $\gamma_{Sd}$      |
| $\gamma_{E,fav}$        | Partial factor applied to the favourable effects of actions                                                                    |
| $\gamma_f$              | Partial factor for actions, which takes account of unfavourable deviations of the action values from the representative values |
| $\gamma_F$              | Partial factor for actions, accounting for the uncertainties covered by $\gamma_f$ and $\gamma_{Sd}$                           |
| $\gamma_{FF}$           | Partial factor for fatigue actions                                                                                             |
| $\gamma_G$              | Partial factor for a permanent action that produces unfavourable effects                                                       |
| $\gamma_{G,fav}$        | Partial factor for a permanent action that produces favourable effects                                                         |
| $\gamma_{G,i}$          | Partial factor for permanent action $i$                                                                                        |
| $\gamma_{G,set}$        | Partial factor for the effects of settlement                                                                                   |
| $\gamma_{G,set,fav}$    | Partial factor for the effects of settlement that produces favourable effects                                                  |

|                           |                                                                                                                                                                                                                                                                                                       |
|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $\gamma_{G, \text{stb}}$  | Partial factor for the favourable (stabilizing) part of a permanent action treated as a single-source                                                                                                                                                                                                 |
| $\gamma_{Gw}$             | Partial factor for water actions                                                                                                                                                                                                                                                                      |
| $\gamma_{Gw, \text{stb}}$ | Partial factor for the favourable (stabilizing) part of water actions                                                                                                                                                                                                                                 |
| $\gamma_m$                | Partial factor for a material property accounting for unfavourable deviation of the material or product properties from their characteristic values, the random part of the conversion factor $\eta$ and geometric deviations, if these are not modelled explicitly                                   |
| $\gamma_M$                | Partial factor for a material property, accounting for the uncertainties covered by $\gamma_m$ and $\gamma_{Rd}$                                                                                                                                                                                      |
| $\gamma_{Mf}$             | Partial factor for fatigue resistance                                                                                                                                                                                                                                                                 |
| $\gamma_P$                | Partial factor for prestressing forces                                                                                                                                                                                                                                                                |
| $\gamma_Q$                | Partial factor for variable actions, accounting for the uncertainties covered by $\gamma_F$                                                                                                                                                                                                           |
| $\gamma_{Q, \text{fav}}$  | Partial factor applied to variable actions that produce favourable effects                                                                                                                                                                                                                            |
| $\gamma_{Q, j}$           | Partial factor for variable action $j$                                                                                                                                                                                                                                                                |
| $\gamma_{Q, \text{red}}$  | Reduced partial factor applied to unfavourable variable actions in geotechnical design                                                                                                                                                                                                                |
| $\gamma_{Q, T}$           | Partial factor for thermal actions                                                                                                                                                                                                                                                                    |
| $\gamma_{Qw}$             | Partial factor for variation in water actions                                                                                                                                                                                                                                                         |
| $\gamma_R$                | Partial factor for the resistance accounting for unfavourable deviation of the material or product properties from their characteristic values, the random part of the conversion factor $\eta$ , geometric deviations (if these are not modelled explicitly) and uncertainty in the resistance model |
| $\gamma_{Rd}$             | Partial factor for the resistance associated with the uncertainty of the resistance model and geometric deviations, if these are not modelled explicitly                                                                                                                                              |
| $\gamma_{Sd}$             | Partial factor associated with the uncertainty of the action and/or action effect model                                                                                                                                                                                                               |
| $\delta$                  | Error term                                                                                                                                                                                                                                                                                            |
| $\delta_i$                | Observed error term for test specimen $i$ obtained from a comparison of the experimental resistance $r_{e, i}$ and its theoretical resistance $br_{t, i}$ corrected using correction factor for corresponding mean values ( $b_m$ )                                                                   |
| $\delta_v$                | Vertical deflection                                                                                                                                                                                                                                                                                   |
| $\delta_h$                | Transverse deflection                                                                                                                                                                                                                                                                                 |
| $\eta$                    | Conversion factor accounting for scale effects, effects of moisture and temperature, effects of ageing of materials, and any other relevant parameters                                                                                                                                                |
| $\eta_d$                  | Design value of the possible conversion factor, so far as it is not included in partial factor for resistance $\gamma_M$                                                                                                                                                                              |
| $\eta_k$                  | Reduction factor applicable in the case of prior knowledge                                                                                                                                                                                                                                            |
| $\theta$                  | End rotation of structure                                                                                                                                                                                                                                                                             |

|                     |                                                                                                                                                                          |
|---------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $\mu_d$             | Design value of the bearing friction coefficient                                                                                                                         |
| $\mu_{d,fav}$       | Favourable coefficient of friction                                                                                                                                       |
| $\mu_{max}$         | Maximum coefficient of friction                                                                                                                                          |
| $\xi$               | Reduction factor applied to unfavourable permanent actions                                                                                                               |
| $\rho$              | Reduction factor applied to $\gamma_G$ when deriving $\gamma_{G,stb}$                                                                                                    |
| $\sigma$            | Standard deviation, $\sigma = \sqrt{\text{variance}}$                                                                                                                    |
| $\sigma_{\Delta}^2$ | Variance of the term $\Delta$                                                                                                                                            |
| $\psi$              | Combination factor applied to a characteristic variable action                                                                                                           |
| $\psi_j$            | Reduction coefficient taking into account the probability that the footfall frequency (jogging) approaches the critical range of natural frequencies under consideration |
| $\psi_W$            | Reduction coefficient taking into account the probability that the footfall frequency (walking) approaches the critical range of natural frequencies under consideration |
| $\psi_0$            | Combination factor applied to a variable action to determine its combination value                                                                                       |
| $\psi_1$            | Combination factor applied to a variable action to determine its frequent value                                                                                          |
| $\psi_2$            | Combination factor applied to a variable action to determine its quasi-permanent value                                                                                   |
| $\psi_{0,j}$        | Combination factor applied to variable action $j$ to determine its combination value                                                                                     |
| $\psi_{1,j}$        | Combination factor applied to variable action $j$ to determine its frequent value                                                                                        |
| $\psi_{2,j}$        | Combination factor applied to variable action $j$ to determine its quasi-permanent value                                                                                 |
| $\omega_{Cd}$       | Tilt                                                                                                                                                                     |

## 4 General rules

### 4.1 Basic requirements

(1) The assumptions given in 1.2 and in the other Eurocodes shall be met.

(2) A structure shall be designed and executed in such a way that it will, during its design service life, with appropriate degrees of reliability and in an economical way:

- sustain all reasonably foreseeable actions and influences that can occur during its execution and use, as specified for the structure;
- meet the specified serviceability requirements for the structure or a structural member;
- meet the specified durability requirements for the structure or a structural member.

NOTE Design carried out in accordance with the Eurocodes is assumed to satisfy these requirements.

(3) In the case of fire, the structural resistance shall be adequate for the required period of time.

NOTE For general provisions related to fire design, see also EN 1991-1-2.

## 4.2 Structural reliability

(1) The reliability required for structures within the scope of this document shall be achieved by design in accordance with the Eurocodes (all parts): EN 1991, EN 1992, EN 1993, EN 1994, EN 1995, EN 1996, EN 1997, EN 1998 and EN 1999.

(2) Appropriate measures should be taken to avoid gross human errors and omissions and to limit their effects on the structural reliability.

NOTE 1 This document does not make allowance for gross human errors.

NOTE 2 Guidance on appropriate measures to limit the probability of occurring of gross human errors and omissions is given in Annex B.

(3) The choice of an appropriate level of reliability for the structure should take account of the following:

- possible consequences of failure in terms of risk to life, injury, and potential economic losses, see 4.3;
- the possible cause and mode of attaining a limit state;

NOTE 1 Examples of modes of attaining a limit state are failure modes with or without warnings, e.g. ductile or brittle failure.

- public aversion to failure;
- the expense and procedures necessary to reduce the risk of failure.

NOTE 2 Reliability levels can be set by the National Annex. Further guidance is given in Annex C.

NOTE 3 Different levels of reliability are commonly adopted for limit states relating to structural failure, serviceability, and durability.

NOTE 4 Levels of reliability for structural failure, serviceability and durability are achieved by:

- appropriate representation of the basic variables, see Clause 6;
- accuracy of the mechanical models used and interpretation of their results;
- prevention of errors in design and execution of the structure, including gross human errors, see also Annex B for further guidance;
- adequate inspection and maintenance according to procedures specified in the project documentation.

## 4.3 Consequences of failure

(1) The consequences of failure of the structure or a structural member shall be classified into one of the five following consequence classes:

- CC4 – highest consequence;
- CC3 – high consequence;
- CC2 – normal consequence;
- CC1 – low consequence;
- CC0 – lowest consequence.

NOTE 1 Table 4.1 (NDP) gives the classification of consequence classes with reference to indicative qualification of consequences, unless the National Annex gives different qualifications.

**Table 4.1 (NDP) — Qualification of consequence classes**

| Consequence class                                                                           | Indicative qualification of consequences           |                                                             |
|---------------------------------------------------------------------------------------------|----------------------------------------------------|-------------------------------------------------------------|
|                                                                                             | Loss of human life or personal injury <sup>a</sup> | Economic, social or environmental consequences <sup>a</sup> |
| CC4 – Highest                                                                               | Extreme                                            | Huge                                                        |
| CC3 – High                                                                                  | High                                               | Very great                                                  |
| CC2 – Normal                                                                                | Medium                                             | Considerable                                                |
| CC1 – Low                                                                                   | Low                                                | Small                                                       |
| CC0 – Lowest                                                                                | Very low                                           | Insignificant                                               |
| <sup>a</sup> The consequence class is chosen based on the more severe of these two columns. |                                                    |                                                             |

NOTE 2 The provisions in Eurocodes cover design rules for structures classified as CC1 to CC3.

NOTE 3 The provisions in the Eurocodes do not entirely cover design rules needed for structures classified as CC4. For these structures, additional provisions to those given in the Eurocodes can be needed.

NOTE 4 Annex A gives examples of the classification of structures into consequence classes.

NOTE 5 The consequence class is used to determine the value of consequence factor  $k_F$ , see Annex A.

NOTE 6 The consequence class can be used to determine the management measures to achieve the intended structural reliability, see Annex B for further guidance.

NOTE 7 The consequence class can be used to modify the failure probability levels  $P_f$  or reliability indices  $\beta$ , see Annex C for further guidance.

NOTE 8 The consequence class can be used in the direct assessment of the design values for ULS verifications, see Annex D for further guidance.

NOTE 9 The consequence class can be used to choose design methods for enhancing robustness, see Annex E for further guidance.

(2) Consequence classes CC1 to CC3 may be divided into upper and lower sub-classes, provided that consistency when specifying the consequence classes is ensured for the design of the structures as a whole.

(3) For consequence class CC0, either the Eurocodes or alternative provisions may be used.

#### 4.4 Robustness

(1) A structure should be designed to have an adequate level of robustness so that during its design service life it will not be damaged by unforeseen adverse events to an extent disproportionate to the original cause.

NOTE 1 Progressive collapse is an example of a damage that is disproportionate to the original cause.

NOTE 2 For most structures, design in accordance with the Eurocodes is assumed to provide an adequate level of robustness without the need for any additional design measures to enhance structural robustness.

(2) Design measures to enhance structural robustness should be applied when specified by the relevant authority or, where not specified, as agreed for a specific project by the relevant parties.

NOTE 1 Guidance on additional design measures to enhance structural robustness for buildings and bridges is given in Annex E.

NOTE 2 Further guidance can be given in the National Annex.

## 4.5 Design service life

(1) The design service life  $T_{lf}$  of the structure should be specified.

NOTE Values of  $T_{lf}$  are given in Annex A for different categories of structures.

(2) The design service life should be used to determine the time-dependent performance of the structure.

NOTE Examples of time-dependent performance include durability, fatigue, and deformation due to consolidation of the ground.

(3) Structures or parts of structures that can be dismantled in order to be re-used should not be classified as temporary structures.

(4) A reduced design service life may be used for the verification of fatigue and durability of replaceable structures and parts, provided that the replacement is explicitly taken into account in the design.

NOTE For the verification of durability, see 4.6. For the verification of fatigue, see 8.3.5.4.

## 4.6 Durability

(1) The structure shall be designed such that any deterioration over its design service life does not impair its intended performance, having due regard to its exposure to the environment and its anticipated level of maintenance.

(2) To achieve adequate durability, the structural design should take into account:

- the structure's intended or foreseeable use;
- any required design criteria;
- expected environmental conditions;
- composition, properties and performance of structural materials and products, both on their own and in combination with other materials;
- properties of the ground;
- the choice of structure, the shape of structural members, and structural detailing;
- the quality of workmanship and level of control on site;
- any protective measures that are implemented;
- any intended inspection and maintenance during the structure's design service life.

NOTE The other Eurocodes specify appropriate measures to increase the durability of the structure.

(3) The environmental conditions shall be identified during design so as to enable assessment of their impact on durability and to allow adequate provisions for protection of the materials used in the structure to be made.

(4) The degree of any deterioration affecting the resistance of a structure or a structural member may be estimated using calculation, experimental investigation, experience from earlier constructions, or a combination of these methods.

## 4.7 Sustainability

(1) The structure should be designed to limit its adverse impact on non-renewable environmental resources, on society, and on economy during its entire life cycle, as specified by the relevant authority or, where not specified, as agreed for a specific project by the relevant parties.

NOTE 1 The adverse impact of a structure on its environment, on society, and on economy can be minimized by for example appropriate choice of construction process and environmentally compatible building materials, including their manufacture, design solutions, durability, recyclability, and reusability.

NOTE 2 Supplementary requirements to account for sustainability in the design can be given in the National Annex.

## 4.8 Quality management

(1) Appropriate quality management measures should be implemented to provide a structure that corresponds to the design requirements and assumptions.

(2) The following quality management measures should be implemented:

- organizational procedures for design, execution, use, and maintenance;
- controls at the stages of design, detailing, execution, use, and maintenance.

NOTE For guidance on appropriate quality management measures, see Annex B and the other Eurocodes.

# 5 Principles of limit state design

## 5.1 General

(1) A distinction shall be made between ultimate and serviceability limit states.

(2) Verification of a particular limit state may be omitted if the verification of another limit state demonstrates that the particular limit state will not be exceeded.

(3) Limit states shall be verified for all relevant design situations.

(4) Limit states that involve the time-dependent performance of the structure should be verified taking into account its design service life.

NOTE See 4.5(1).

## 5.2 Design situations

(1) Design situations shall be selected appropriately for the conditions under which the structure has to meet all requirements.

(2) Design situations shall be sufficiently severe and varied so that they encompass all conditions that can reasonably be foreseen to occur during execution and use of the structure.

(3) Design situations should be classified according to Table 5.1.

NOTE Information on specific design situations within each of these classes is given in the other Eurocodes.

**Table 5.1 — Classification of design situations**

| Design situation | Conditions                                                                                            | Examples                                                                                               |
|------------------|-------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| Persistent       | Normal use and exposure                                                                               | During everyday use                                                                                    |
| Transient        | Temporary use and exposure during a period much shorter than the design service life of the structure | During execution, repair or temporary environmental influence                                          |
| Accidental       | Exceptional conditions or exposure                                                                    | During flooding, extreme sea water level, fire, explosion, or impact; or local failure                 |
| Seismic          | Exceptional conditions during a seismic event                                                         | During an earthquake                                                                                   |
| Fatigue          | Conditions caused by fatigue actions                                                                  | Owing to traffic loads on a bridge, wind induced vibration of chimneys, or machinery-induced vibration |

### 5.3 Ultimate limit states (ULS)

(1) Limit states that concern the safety of the structure to prevent:

- human losses or injury to people,
- unacceptable economic or environmental losses,

shall be classified as ultimate limit states (ULS).

(2) States prior to structural collapse may be treated as ultimate limit states.

EXAMPLE When the structural response is ductile and collapse is difficult to define, it can be convenient to treat a state prior to collapse as the ultimate limit state.

(3) The following ultimate limit states shall be verified, as relevant:

- failure of the structure or the ground, or any part of them including supports and foundations, by rupture, excessive deformation, transformation into a mechanism, or buckling;
- loss of static equilibrium of the structure or any part of it;
- failure of the ground by hydraulic heave, internal erosion, or piping caused by excessive hydraulic gradients;
- failure caused by fatigue;
- failure caused by vibration;
- failure caused by other time-dependent effects.

NOTE 1 Details of ultimate limit states caused by fatigue are given in the other Eurocodes.

NOTE 2 Details of ultimate limit states caused by hydraulic gradients are given in the relevant part of EN 1997.

NOTE 3 Loss of static equilibrium includes uplift by water pressure (buoyancy) or other vertical actions.

NOTE 4 Details of ultimate limit states for seismic design situations are given in EN 1998 (all parts).

(4) When verifying loss of static equilibrium, variations in the magnitude or spatial distribution of permanent actions from a single-source should be considered.

NOTE The term 'single-source' is explained in 6.1.1(3) and 8.3.3.1.

## 5.4 Serviceability limit states (SLS)

(1) Limit states that concern:

- the functioning of the structure or structural members under normal use;
- the comfort of people,
- the appearance of the construction works

shall be classified as serviceability limit states (SLS).

NOTE The term 'appearance' here is concerned with criteria such as large deflections or extensive cracking, rather than aesthetics.

(2) A distinction shall be made between reversible and irreversible serviceability limit states.

(3) The verification of serviceability limit states should be based on criteria concerning the following:

- deformations that adversely affect the appearance, the comfort of users, or the functioning of the structure;

NOTE 1 The functioning of the structure includes the functioning of machines and services.

- deformations that cause damage to finishes or elements other than structural;
- vibrations that cause discomfort to people or limit the functional effectiveness of the structure;
- damage that is likely to adversely affect the appearance, durability, or functioning of the structure.

NOTE 2 Additional provisions related to serviceability criteria are given in the other Eurocodes.

(4) Serviceability requirements should be specified individually for each project.

NOTE Serviceability criteria for some serviceability limit states are given in Annex A.

## 5.5 Structural models, geotechnical models and loading models

(1) Limit states shall be verified using appropriate structural models, geotechnical models and loading models.

(2) The models that are used to verify limit states shall be based on design values for:

- actions;

- material and product properties;
- geometrical properties.

(3) The structure shall be verified for all critical load cases in each relevant design situation.

(4) Design values for the basic variables given in (2) should be obtained using the partial factor method, given in Clause 8.

(5) As an alternative to (4), design based on probabilistic methods may be used when specified by the relevant authority or, where not specified, as agreed for a specific project by the relevant parties.

NOTE Further guidance on probabilistic methods is given in Annex C.

## 6 Basic variables

### 6.1 Actions and environmental influences

#### 6.1.1 Classification of actions

(1) Actions  $F$  shall be classified by their variation in time as follows:

- permanent ( $G$ ); or
- variable ( $Q$ ); or
- accidental ( $A$ ); or
- seismic ( $A_E$ ).

NOTE 1 Climatic actions, such as wind and snow actions, can be classified as either variable or accidental, depending on site location. See EN 1991 (all parts).

NOTE 2 Actions arising from elements other than structural can be classified as either permanent or variable. See EN 1991-1-1.

NOTE 3 For fatigue actions, see 6.1.3.3.

(2) Actions may also be classified by their:

- origin, as direct or indirect; or
- spatial variation, as fixed or free; or
- nature and/or the structural response, as static or dynamic.

(3) Actions that, owing to physical reasons, induce effects that are strongly correlated with one another, even when they originate in, or act on, different parts of the structure, or originate from different materials, may be treated as an action arising from a single source.

NOTE 1 This rule is commonly known as the 'single-source principle'.

NOTE 2 The single-source principle typically applies to the self-weight of the structure or the ground, including self-weight from different materials, as well as for water pressures acting on opposite sides of a structure with flow passing around or underneath.

(4) Climatic actions that act on different parts of a structure may be considered to come from a single-source.

## 6.1.2 Representative values of actions

### 6.1.2.1 General

(1) The principal representative value of an action  $F_{\text{rep}}$  should be its characteristic value  $F_k$ .

NOTE 1 Representative values are not defined for accidental and seismic actions, nor for bearing forces.

NOTE 2 For the definition of design values, see Clause 8.

(2) For variable actions (see 6.1.2.3) and actions inducing fatigue (see 6.1.3.3), other representative values may be chosen, depending on the limit state being verified.

(3) The characteristic value of an action shall be chosen according to the methods given in EN 1991 (all parts), the relevant part of EN 1997 and EN 1998 (all parts).

NOTE The characteristic value of an action  $F_k$  can be:

- a mean value; or
- an upper or lower value; or
- a nominal value.

### 6.1.2.2 Permanent actions

(1) The representative value  $G_{\text{rep}}$  of a permanent action  $G$  shall be taken as its characteristic value  $G_k$ .

(2) Provided its coefficient of variation is small, a permanent action  $G$  should be represented by a single characteristic value  $G_k$ .

(3) For most structural members, the coefficient of variation of  $G$  may be considered small if:

- it is not greater than 5 %, when verifying limit states involving loss of static equilibrium or uplift; or
- it is not greater than 10 %, otherwise.

NOTE For the assessment of the coefficient of variation of permanent actions from the ground, see the relevant part of EN 1997.

(4) If a single characteristic value of  $G_k$  is used, then its value may be taken as the mean value of  $G$ .

(5) If the uncertainty in  $G$  is not small, or if the structure is sensitive to variations in its value or spatial distribution, then the permanent action  $G$  should be represented by upper and lower characteristic values  $G_{k,\text{sup}}$  and  $G_{k,\text{inf}}$  respectively.

NOTE Permanent actions are usually assumed to be normally distributed.

(6) For materials other than the ground, the upper (or "superior") characteristic value  $G_{k,\text{sup}}$  should be selected as the 95 % fractile and the lower (or "inferior") characteristic value  $G_{k,\text{inf}}$  as the 5 % fractile of the statistical distribution of  $G$ .

NOTE 1 For the ground, see the relevant part of EN 1997 for the specification of  $G_{k,\text{sup}}$  and  $G_{k,\text{inf}}$ .

NOTE 2 For the specification of permanent water actions, see 6.1.3.2.

### 6.1.2.3 Variable actions

(1) The representative value  $Q_{\text{rep}}$  of a variable action  $Q$  shall be taken as one of the following, depending on the limit state being verified:

- its characteristic value  $Q_k$ ; or
- its combination value  $Q_{\text{comb}}$ ; or
- its frequent value  $Q_{\text{freq}}$ ; or
- its quasi-permanent value  $Q_{\text{qper}}$ .

(2) The characteristic value of a variable action  $Q_k$  shall correspond to one of the following:

- an upper value with an intended probability of not being exceeded during a specific reference period; or
- a lower value with an intended probability of being exceeded during a specific reference period; or
- when the statistical distribution of  $Q$  is not known, a nominal value.

NOTE 1 Upper and lower values and nominal values are given in the various parts of EN 1991.

NOTE 2 The characteristic value of a variable climatic action is based upon a 2 % probability that its time-varying part is exceeded during a one-year reference period. This is equivalent to a mean return period of 50 years. For other actions than climatic actions another fractile and/or return period can be more appropriate.

NOTE 3 For actions from waves and currents on coastal structures, see Clause A.6.

NOTE 4 All coefficients or models, to derive characteristic values of variable actions are chosen so that the annual probability of exceedance of the calculated characteristic value does not exceed the annual probability of exceedance of the time-varying part of the variable action.

(3) The combination, frequent and quasi-permanent values should be determined by multiplying the characteristic values  $Q_k$  by combination factors  $\psi_0$ ,  $\psi_1$  and  $\psi_2$  as given in Formulae (6.1) to (6.3):

$$Q_{\text{comb}} = \psi_0 Q_k \quad (6.1)$$

$$Q_{\text{freq}} = \psi_1 Q_k \quad (6.2)$$

$$Q_{\text{qper}} = \psi_2 Q_k \quad (6.3)$$

NOTE 1 The values of  $\psi_0$ ,  $\psi_1$ , and  $\psi_2$  are given in Annex A.

NOTE 2 The characteristic value and combination value are used in the verification of ultimate limit states and irreversible serviceability limit states.

NOTE 3 The frequent value is used in the verification of ultimate limit states involving accidental actions and in the verification of reversible serviceability limit states. For buildings, the frequent value is chosen so that the fraction of time it is exceeded is 1 %. For road traffic loads on bridges, the frequent values are assessed on the basis of a return period of one week.

NOTE 4 The quasi-permanent value is used in the verification of ultimate limit states involving accidental or seismic actions; in the verification of reversible serviceability limit states; and in the calculation of long-term effects. The quasi-permanent value is chosen so that the fraction of time it is exceeded is 50 %. It can alternatively be determined as the value averaged over a chosen period of time.

(4) For some specific types of actions, particularly water actions, representative values may be defined directly, without the use of combination factors.

NOTE For the specification of variable water actions, see 6.1.3.2.

### 6.1.3 Specific types of action

#### 6.1.3.1 Prestressing

(1) Prestressing forces  $P$  that are caused by the controlled application of forces (prestressing) or deformations (prestrain) to a structure or to a tension component should be classified as permanent actions.

NOTE Prestressing forces acting on a structure or on a tension component can arise from prestressing tendons, imposed deformations at supports, prestrain applied to tension components, etc.

(2) A prestressing force  $P$  should be represented by its upper or lower characteristic value,  $P_{k,\text{sup}}$  or  $P_{k,\text{inf}}$  respectively.

(3) For ultimate limit states, if allowed by the other Eurocodes, a prestressing force  $P$  may be represented by a single characteristic value  $P_k$ .

#### 6.1.3.2 Water actions

(1) Actions that arise from water should be classified as permanent, variable, or accidental.

NOTE 6.1.3.2 is not applicable to water actions induced by currents and waves and to actions for hydraulic structures with fast-flowing water, e.g. in rivers. For actions for coastal structures induced by currents and waves, see Annex A and EN 1991-1-8.

(2) When a water action is classified as permanent, as defined in 6.1.2.2, its representative value  $G_{w,\text{rep}}$  should be selected as either:

- a single characteristic value  $G_{wk}$  taken as the mean value of  $G_w$ ; or
- the more onerous of its characteristic upper and lower values  $G_{wk,\text{sup}}$  or  $G_{wk,\text{inf}}$ ; or
- a nominal value.

NOTE Further information can be found in Annex A, EN 1991 (all parts) and the relevant part of EN 1997.

(3) When a water action is classified as variable, it should be represented by two components:

- a permanent component  $G_{w,\text{rep}}$  taken as the mean of  $G_w$ ;
- a variable component  $Q_{w,\text{rep}}$  equal to the representative value of the variation in water action.

(4) The representative value  $Q_{w,\text{rep}}$  should be selected in line with the definitions of characteristic, frequent and quasi-permanent values in 6.1.2.3(1).

NOTE 1 The value of  $Q_{wk}$  is based on a 2 % probability that it is exceeded during a one-year reference period, unless the National Annex gives a different value.

NOTE 2 The value of  $Q_{w,\text{freq}}$  is chosen so that the fraction of time it is exceeded is 1 %, unless the National Annex gives a different value.

NOTE 3 The value of  $Q_{w,qper}$  is chosen so that the fraction of time it is exceeded is 50 %, unless the National Annex gives a different value.

NOTE 4 For seismic verifications involving water actions, see EN 1998-5.

(5) The values of  $Q_{wk}$  and  $Q_{w,comb}$  may alternatively be determined taking account of any physical limitations that affect the actions.

NOTE Physical limitation can include, for example, the top of a retaining wall or the presence of drains.

(6) When a water action is classified as accidental, it should be represented by a single value  $A_{w,rep}$  equal to the representative value of the water action.

NOTE The value of  $A_{w,rep}$  is based on a 0,1 % probability that it is exceeded during a one-year reference period, unless the National Annex gives a different value.

### 6.1.3.3 Fatigue actions

(1) Models for fatigue actions shall be defined considering the magnitude and the number of repetitions of the actions during the design service life.

NOTE The action repetitions relevant for fatigue depend on the type of structure and the type of material.

(2) When relevant, interaction between the action and the structure shall be taken into account, either in the action or in the effect of action.

(3) The models for fatigue actions in EN 1991 (all parts) may be used for the description of fatigue actions.

NOTE The models for fatigue actions in EN 1991 (all parts) include the dynamic action effect, either:

- implicitly for those models for which this is specified in EN 1991 (all parts); or
- explicitly by applying dynamic amplification factors to fatigue actions.

(4) For structures outside the field of application of the models given in EN 1991 (all parts), fatigue actions should be defined from the evaluation of measurements or ad hoc studies devoted to determine the effect of action and the number of cycles.

(5) Stress ranges due to fatigue should be derived by an appropriate cycle counting method.

(6) Stress ranges due to fatigue may be derived either by the rain-flow counting method or the reservoir counting method.

NOTE For further guidance, see Annex F.

(7) When fatigue damage depends on the mean stress of the cycle, the assessment procedure should be consistent with this dependency.

### 6.1.4 Environmental influences

(1) The environmental influences that could affect the durability of the structure should be considered in the choice of structural materials, their specification, the structural concept, and detailed design.

NOTE The other Eurocodes give relevant measures for considering environmental influences.

## 6.2 Material and product properties

(1) Properties of materials and products should be represented by characteristic values.

NOTE Materials in this sub-clause include the ground.

(2) Unless otherwise stated in the Eurocodes, when the verification of a limit state is sensitive to the variability of a material property, its characteristic value should be defined as:

- the 5 % fractile value where a low value of material or product property is unfavourable; or
- the 95 % fractile value where a high value of material or product property is unfavourable.

NOTE For the specification of characteristic values of ground properties, see the relevant part of EN 1997.

(3) When the verification of a limit state is insensitive to the variability of a material property, its characteristic value should be defined as the mean value, unless otherwise stated in the other Eurocodes.

(4) Material properties should be determined from standard tests performed under specified conditions.

(5) A conversion factor should be applied when it is necessary to convert test results into values that represent the behaviour of the material or product in the structure or ground, or when a material property is sensitive to the duration of the effects of actions.

NOTE 1 For values of the conversion factor, see the other Eurocodes.

NOTE 2 Further guidance is given in Annex D.

(6) When available statistical data is considered insufficient to establish the characteristic value of a material or product property, the characteristic value may be taken as a nominal value.

(7) When material or product properties are not specified in the Eurocodes, or when nominal values are selected, their values should be chosen to achieve a level of structural reliability no less than that specified in the Eurocodes.

NOTE For guidance on structural reliability, see Annex C.

## 6.3 Geometrical properties

(1) Unless the design of the structure is sensitive to deviations of a geometrical property, that property should be represented by its nominal value.

(2) If the design of the structure is sensitive to deviations of a geometrical property, corresponding geometrical imperfections defined in the other Eurocodes should be taken into account.

(3) When there is sufficient data, the characteristic value of a geometrical property may be determined from its statistical distribution and used instead of a nominal value.

(4) The effect of degradation on geometrical properties (e.g. due to corrosion) should be taken into account.

(5) For geotechnical design, geometrical properties that affect the mechanical behaviour of the ground should be considered when determining ground properties, in accordance with the relevant part of EN 1997.

EXAMPLE The spacing and orientation of discontinuities are taken into account when selecting the characteristic material properties of rock.

## 7 Structural analysis and design assisted by testing

### 7.1 Structural modelling

#### 7.1.1 General

(1) Calculations shall be carried out using appropriate structural and geotechnical models involving relevant variables and relevant boundary conditions.

NOTE 1 Such calculations can be used to model potential failure modes, predict ultimate capacity, or model deformations and vibrations (provided the results can be verified with satisfactory accuracy).

NOTE 2 For geotechnical analysis, see EN 1997-1.

(2) Structural and geotechnical models shall be based on well-founded engineering theory and practice.

(3) Structural models should be validated to establish whether the model reproduces the physical phenomena to be investigated with an acceptable level of accuracy.

NOTE Depending on the physical phenomena being investigated, validation tests can include basic material tests, physical reference tests and/or comparisons with other structural models that have been already validated.

#### 7.1.2 Static actions

(1) The modelling of static actions shall be based on an appropriate choice of the force-deformation relationships of the members and their connections and between members and the ground.

(2) Effects of displacements and deformations shall be taken into account in ultimate limit state verifications if they result in a significant increase of the effects of actions.

NOTE Particular methods for dealing with effects of deformations are given in the other Eurocodes.

(3) Indirect actions should be introduced into the analysis as follows:

- in linear elastic analysis, directly or as equivalent forces (using appropriate modular ratios where relevant); or
- in non-linear analysis, directly as imposed deformations.

#### 7.1.3 Dynamic actions

(1) When time-dependent actions cause significant acceleration of the structure, a dynamic structural analysis of the system should be performed.

NOTE 1 Guidance on the need for dynamic structural analysis is given in EN 1991 (all parts).

NOTE 2 For seismic actions, see EN 1998 (all parts).

(2) Dynamic actions or effects of actions may be expressed by time histories or content in the frequency domain.

(3) Where relevant, effects of actions may be determined by a modal analysis.

(4) For structures that have regular geometry, stiffness, and mass distribution, an explicit modal analysis may be replaced by an analysis with equivalent static actions provided.

NOTE Examples of relevant effects of actions are wind induced vibrations or seismic action effects.

(5) When it is appropriate to consider a dynamic action as quasi-static, its dynamic part may be considered either by including it in the quasi-static value of the action or by applying an equivalent dynamic amplification factor to the quasi-static action.

NOTE 1 Quasi-static actions are defined in EN 1991 (all parts).

NOTE 2 For limitations to verifications by the partial factor method, see 8.2.

#### 7.1.4 Actions inducing fatigue

(1) The structural models used with fatigue actions should allow for fatigue action effects to be determined taking into account relevant material specific aspects.

NOTE Relevant material specific aspects are defined by the other Eurocodes and can be for example:

- mean stress effects;
- load sequence effects;
- stress state.

#### 7.1.5 Fire design

(1) Structural fire design analysis shall be based on design fire scenarios and shall consider models for the temperature evolution within the structure as well as models for the mechanical behaviour of the structure exposed to fire.

NOTE For guidance on selecting design fire scenarios, see EN 1991-1-2.

(2) The behaviour of a structure exposed to fire shall be assessed by taking into account the accompanying actions and either:

- nominal fire exposure; or
- physically-based fire exposure.

(3) The required performance of a structure exposed to fire should be verified by either:

- global analysis; or
- analysis of parts of the structure; or
- member analysis by means of one or more of the following design methods:
  - tabulated design data;
  - simplified design methods;
  - advanced design methods.

(4) As an alternative to design by calculation, fire resistance assessment may be based on the results of fire tests or on fire tests in combination with calculations.

(5) In case of design by calculation, the behaviour of the structure exposed to fire shall be assessed according to relevant clauses in the other Eurocodes concerning thermal and mechanical models for analysis.

(6) The mechanical models of the structure exposed to fire should take account of both temperature-dependent mechanical properties and non-linear behaviour, where relevant.

(7) With physically-based fire exposure, the behaviour of the structure should be assessed for the duration of the fire exposure  $T_{fi}$ .

NOTE The value of  $T_{fi}$  is the full duration of the fire (including the cooling phase), unless the National Annex or national regulations give a different value.

## 7.2 Structural analysis

### 7.2.1 Linear analysis

(1) Linear analysis may be used when the relation between stresses and strains is linear and deformations do not influence the equilibrium of the structure.

NOTE The law of superposition is valid for linear analysis.

(2) Linear analysis may also be used as a simplification of real behaviour of the structure, in accordance with the other Eurocodes.

### 7.2.2 Non-linear analysis

(1) Non-linear analysis should be used when the behaviour of the structure or members has a significant influence on forces in and deformations of the structure.

NOTE The law of superposition is not valid for non-linear analysis.

(2) Non-linear analysis should take into account the relevant type of non-linearity.

NOTE Non-linearity can occur in loading (contact non-linearity), material behaviour (material non-linearity), and geometry (geometric non-linearity) or non-linearity of the limit state function.

(3) Numerical models that describe material properties and their interaction should capture all significant and relevant aspects of mechanical behaviour for the specific problem being considered.

(4) Non-linear numerical models should be validated, to establish whether the numerical model correctly reproduces the necessary physical phenomena.

NOTE Depending on the physical phenomena being investigated, validation can include basic material tests, physical reference tests, and mesh sensitivity tests.

(5) A sensitivity study should be carried out when a non-linear limit state function is used or, when no explicit limit state function is given, to determine the most sensitive input parameter and how to apply the partial factors given in the Eurocodes.

## 7.3 Design assisted by testing

(1) Physical testing may be used to determine parameters for use in design.

(2) Testing may be used to determine the performance of a structure or structural member as specified by the relevant authority or, where not specified, as agreed for a specific project by the relevant parties.

NOTE Physical testing is carried out, for example, in the following circumstances:

- if adequate calculation models are not available;
- to confirm by control checks assumptions made in the design;
- to determine the fatigue resistance;
- to determine shape factors for snow load;