Q_{ki}	characteristic value of the non-dominant variable action i
Q_k	characteristic value of a single variable action
Q_k	concentrated load
Q_{k1}	characteristic value of the dominant variable action
R	resistance
R_d	design value of the resistance
Re	reynolds number
R_k	characteristic resistance
X	material property
X_d	design value of a material property
X_k	characteristic value of a material property
a_d	design value of geometrical data
a_{nom}	nominal value of geometrical data
a_k	characteristic dimension
b	width of the structure
c_{ALT}	altitude factor
c_d	dynamic coefficient
c_{DIR}	direction factor
c_e	exposure coefficient
c_f	force coefficient
c_{fo}	force coefficient of structures or structural elements with infinite slenderness ratio
c_p	pressure coefficient
c_r	roughness coefficient
c_t	topography coefficient
c_{TEM}	temporary factor
d	depth of the structure, diameter
e	eccentricity of a force or edge distance
g	peak factor
g_k	weight per unit area, or weight per unit length
h	height of the structure
k	equivalent roughness
k_T	terrain factor
l	length of a horizontal structure
n	exponent
p	annual probability of exceedence
q_k	uniformly distributed load, or line load
q_{ref}	reference mean velocity pressure
r	radius
s	factor
t	plate thickness
v_m	mean wind velocity
v_{ref}	reference wind velocity
w	wind pressure
x	horizontal distance of the site from the top of a crest
z	height above ground
z_e, z_i	reference height for local and internal pressure
z_o	roughness length
z_{min}	minimum height

Indices

e	external, exposure
fr	friction
i	internal, mode number
j	current number of incremental area or point of a structure
m	mean
ref	reference
z	vertical direction

Upper case Greek letters

θ	torsional angle
Φ	upwind slope
Φ_B	obstruction factor

Lower case Greek letters

α_{an}	reduction coefficients
γ	bulk weight desity
γ	partial safety factor (safety or serviceability)
γ_A	partial safety factor for accidental actions
γ_F	partial safety factor for actions, also accounting for model uncertainties and dimensional variations
γ_{GA}	as γ_G but for accidental design situations
γ_G	partial safety factor for permanent action
γ_{GAj}	as γ_{Gj} but for accidental design situations
$\gamma_{G,inf}$	partial safety factor for permanent actions in calculating lower design values
γ_{Gj}	partial safety factor for permanent action j
$\gamma_{G,sup}$	partial safety factor for permanent actions in calculating upper design values
γ_M	partial safety factor for a material property, also accounting for model uncertainties and dimensional variations
γ_m	partial safety factor for a material property
γ_P	partial safety factor for prestressing actions
γ_{PA}	as γ_p but for accidental design situations
γ_Q	partial safety factor for variable actions
γ_{Qi}	partial safety factor for variable action i
γ_{rd}	partial safety factor associated with the uncertainty of the resistance model and the dimensional variations
γ_R	partial safety factor for the resistance, including uncertainties in material properties, model uncertainties and dimensional variations
γ_{Rd}	partial safety factor associated with the uncertainty of the resistance model
γ_{sd}	partial safety factor associated with the uncertainty of the action and/or action effect model
δ_a	change made to nominal geometrical data for particular design purpose, e.g. assessment of effective imperfection
η	conversion factor
λ	slenderness ratio
ν	expected frequency, Poisson ratio, kinematic viscosity
ξ	reduction factor
ρ	air density
ϕ	angle of repose

Ψ_λ reduction factor of force coefficient for structural
ψ_o coefficient for combination value of a variable action
ψ_2 coefficient for quasi-permanent value of a variable action
ψ_r reduction factor of force coefficient for square sections with rounded corners
ψ_1 coefficient for frequent value of a variable action
φ solidity ratio

1.2 REQUIREMENTS

1.2.1 Fundamental Requirements

(1) A structure shall be designed and executed in such a way that it will, during its intended life with appropriate degrees of reliability and in an economic way:

(a) remain fit for the use for which it is required; and
(b) sustain all actions and influences likely to occur during execution and use.

(2) Design according to (1) above implies that due regard is given to structural safety and serviceability, including durability, in both cases.

(3) A structure shall also be designed and executed in such a way that it will not be damaged by events like fire, explosion, impact or consequences of human errors, to an extent disproportionate to the original cause.

(4) The potential damage shall be avoided or limited by appropriate choice of one or more of the following:

(a) avoiding, eliminating or reducing the hazards which the structure may sustain;
(b) selecting a structural form which has low sensitivity to the hazards considered;
(c) selecting a structural form and design that can survive adequately the accidental removal of an individual element or a limited part of the structure, or the occurrence of acceptable localized damage;
(d) avoiding as far as possible structural systems which may collapse without warning;
(e) tying the structure together.

(5) The above requirements shall be met by the choice of suitable materials, by appropriate design and detailing, and by specifying control procedures for design, production, execution and use relevant to the particular project.

1.2.2 Reliability Differentiation

(1) The reliability required for the majority of structures shall be obtained by design and execution according to EBCS 1 to 8, and appropriate quality assurance measures.

(2) A different level of reliability may be generally adopted:

(a) for structural safety;
(b) for serviceability;

(3) A different level of reliability may depend on:

(a) the cause and mode of failure;
(b) the possible consequences of failure in terms or risk to life, injury, potential economic losses and the level of social inconvenience;
(c) the expense and procedures necessary to reduce the risk of failure;
(d) different degrees of reliability required at national, regional or local level.

(4) Differentiation of the required levels of reliability in relation to structural safety and serviceability may be obtained by the classification of whole structures or by the classification of structural components.

(5) The required reliability relating to structural safety or serviceability may be achieved by suitable combinations of the following measures:

(a) Measures relating to design:

- Serviceability requirements;
- representative values of actions;
- the choice of partial factors or appropriate quantities in design calculations;
- consideration of durability;
- consideration of the degree of robustness (structural integrity);
- the amount and quality of preliminary investigations of soils and possible environmental influences;
- the accuracy of the mechanical models used;
- the stringency of the detailing rules.

(b) Measures relating to quality assurance to reduce the risk of hazards in:

- gross human errors;
- design;
- execution.

(6) Within individual reliability levels, the procedures to reduce risks associated with various potential causes of failure may, in certain circumstances, be interchanged to a limited extent. An increase of effort within one type of measure may be considered to compensate for a reduction of effort within another type.

1.2.3 Design Situations

(1) The circumstances in which the structure may be required to fulfil its function shall be considered and the relevant design situations selected. The selected design situations shall be sufficiently severe and so varied as to encompass all conditions which can reasonably be foreseen to occur during the execution and use of the structure.

(2) Design situations are classified as follows:

(a) persistent situations, which refer to the conditions of normal use;
(b) transient situations, which refer to temporary conditions applicable to the structure, e.g. during execution or repair;
(c) accidental situations, which refer to exceptional conditions applicable to the structure or to its exposure, e.g. to fire, explosion, impact;
(d) seismic situations, which refer to exceptional conditions applicable to the structure when subjected to seismic events.

(3) Information for specific situations for each class is given in other Parts of EBCS 1 to 8.

1.2.4 Design Working Life

(1) The design working life is the assumed period for which a structure is to be used for its intended purpose with anticipated maintenance but without major repair being necessary.

(2) An indication of the required design working life is given in Table 1.1.

Table 1.1 Design Working Life Classification

Class	Required Design Working life (years)	Examples
1	1-5	Temporary structure
2	25	Replaceable structural parts, e.g gantry girders, bearings
3	50	Building structures and other common structures
4	100	Monumental building structures, bridges, and other civil engineering structures

1.2.5 Durability

(1) It is an assumption in design that the durability of a structure or part of it in its environment is such that it remains fit for use during the design working life given appropriate maintenance.

(2) The structure should be designed in such a way that deterioration should not impair the durability and performance of the structure having due regard to the anticipated level of maintenance.

(3) The following interrelated factors shall be considered to ensure an adequately durable structure:

(a) the intended and possible future use of the structure;
(b) the required performance criteria;
(c) the expected environmental influences;
(d) the composition, properties and performance of the materials;
(e) the choice of the structural system;
(f) the shape of members and the structural detailing;
(g) the quality of workmanship, and level of control;
(h) the particular protective measures;
(i) the maintenance during the intended life.

(4) The relevant EBCS 2 to 8 specify the appropriate measures.

(5) The environmental conditions shall be appraised at the design stage to assess their significance in relation to durability and to enable adequate provisions to be made for protection of the materials and products.

(6) The degree of deterioration may be estimated on the basis of calculations, experimental investigation, experience from earlier constructions, or a combination of these considerations.

1.2.6 Quality Assurance

(1) It is assumed that appropriate quality assurance measures are taken in order to provide a structure which corresponds to the requirements and to the assumptions made in the design. These measures comprise definition of the reliability requirements, organizational measures and controls at the stages of design, execution, use and maintenance.

1.3 LIMIT STATES

1.3.1 General

(1) Limit states are states beyond which the structure no longer satisfies the design performance requirements.

(2) In general, a distinction is made between ultimate limit states and serviceability limit states. Verification of one of the two limit states may be omitted if sufficient information is available to prove that the requirements of one limit state are met by the other.

(3) Limit states may relate to persistent, transient or accidental design situations.

1.3.2 Ultimate Limit States

(1) Ultimate limit states are those associated with collapse or with other similar forms of structural failure.

(2) States prior to structural collapse, which, for simplicity, are considered in place of the collapse itself are also treated as ultimate limit states.

(3) Ultimate limit states concern:

(a) the safety of the structure and it contents;
(b) the safety of people.

(4) Ultimate limit states which may require consideration include:

(a) loss of equilibrium of the structure or any part of it, considered as a rigid body;
(b) failure by excessive deformation, transformation of the structure or any part of it into a mechanism, rupture, loss of stability of the structure or any part of it, including supports and foundations;
(c) failure caused by fatigue or other time-dependent effects.

1.3.3 Serviceability Limit States

(1) Serviceability limit states correspond to conditions beyond which specified service requirements for a structure or structural element are no longer met.

(2) The serviceability requirements concern:

(a) the functioning of the construction works or parts of them;
(b) the comfort of people;
(c) the appearance.

(3) A distinction shall be made, if relevant, between reversible and irreversible serviceability limit states.

(4) Unless specified otherwise, the serviceability requirements should be determined in contracts and/or in the design.

(5) Serviceability limit states which may require consideration include:

(a) deformations and displacements which affect the appearance or effective use of the structure (including the functioning of machines or services) or cause damage to finishes or non-structural elements;
(b) vibrations which cause discomfort to people, damage to the structure or to the materials it supports, or which limit its functional effectiveness;.
(c) damage (including cracking) which is likely to affect appearance, durability or the function of the structure adversely;
(d) Observable damage caused by fatigue and other time-dependent effects.

1.3.4 Limit State Design

(1) Limit state design shall be carried out by:

(a) setting up structural and load models for relevant ultimate and serviceability limit states to be considered in the various design situations and load cases;
(b) verifying that the limit states are not exceeded when design values for actions, material properties and geometrical data are used in the models.

(2) Design values are generally obtained by using the characteristic or representative values in combination with partial and other factors as defined in EBCS 1 to 8.

(3) In exceptional cases, it may be appropriate to determine design values directly. The values should be chosen cautiously and should correspond to at least the same degree of reliability for the various limit states as implied in the partial factors in this Code.

1.4 ACTIONS AND ENVIRONMENTAL INFLUENCES

1.4.1 Principal Classifications

(1) An action (F) is:

(a) a direct action, i.e. force (load) applied to the structure; or
(b) an indirect action, i.e. an imposed or constrained deformation or an imposed acceleration caused, for example by temperature changes, moisture variation, uneven settlement or earthquakes.

(2) Actions are classified:

(a) by their variation in time:

- (i) permanent actions (G), e.g. self-weight of structures, fixed equipment and road surfacings;
- (ii) variable actions (Q), e.g. imposed loads, wind loads or snow loads;
- (iii) accidental actions (A), e.g. explosions, or impact from vehicles.

(b) by their spatial variation:

- (i) fixed actions, e.g. self-weight;
- (ii) free actions, e.g. movable imposed loads, wind loads, snow loads.

(c) by their nature and/or the structural response:

- (i) static actions, which do not cause significant acceleration of the structure or structural member;
- (ii) dynamic actions, which cause significant acceleration of the structure or structural member.

(3) In many cases, dynamic effects of actions may be calculated from quasi-static actions by increasing the magnitude of the static actions or by the introduction of an equivalent static action.

(4) Some actions, for example seismic actions and snow loads, can be considered as either accidental and/or variable actions, depending on the site location (see other Parts of ENV 1991).

(5) Prestressing (P) is a permanent action. Detailed information is given in EBCS 2,3 and 4.

(6) Indirect actions are either permanent $G_{ind.}$ (e.g. settlement of support), or variable $Q_{ind.}$ (e.g. temperature effect). and should be treated accordingly.

(7) An action is described by a model, its magnitude being represented in the most common cases by one scalar which may take on several representative values. For some actions (multi-component actions) and some verifications (e.g. for static equilibrium) the magnitude is represented by several values. For fatigue verifications and dynamic analysis a more complex representation of the magnitudes of some actions may be necessary.

1.4.2 Characteristic Values of Actions

(1) The characteristic value of an action is its main representative value.

(2) Characteristic value of actions F_K shall be specified:

(a) in the relevant parts of ENV 1991, as a mean value, an upper or lower value, or a nominal value (which does not refer to a known statistical distribution);
(b) in the design, provided that the provisions, specified in EBCS 1 are observed.

Note: The provisions may be specified by the relevant competent authority.

(3) The characteristic value of a permanent action shall be determined as follows:

(a) if the variability of G is small, one single value G_K may be used;

(b) if the variability of G is not small, two values have to be used; an upper value $G_{K,sup}$ and a lower value $G_{K,inf}$.

(4) In most cases the variability of G can be assumed to be small if G does not vary significantly during the design working life of the structure and its coefficient of variation is not greater than 0.1. However in such cases when the structure is very sensitive to variations in G (e.g. some types of prestressed concrete structures), two values have to be used even if the coefficient of variation is small.

(5) The following may be assumed in most cases:

(a) G_k is the mean value
(b) G_{kinf} is the 0.5 fractile, and G_{ksup} is the 0.95 fractile of the statistical; distribution for G which may be assumed to be Gaussian.

(6) The self-weight of the structure can, in most cases, be represented by a single characteristic value and be calculated on the basis of the nominal dimensions and mean unit masses. The values are given in Chapter 2.

(7) For variable actions the characteristic value (Q_k) corresponds to either.

(a) an upper value with an intended probability of not being exceeded or a lower value with an intended probability of not falling below, during some reference period;
(b) a nominal value which may be specified in cases where a statistical distribution is not known.

Values are given in Chapter 2 and 3

(8) The following may be assumed for the time-varying part for most cases of characteristic values of variable actions:

(a) the intended probability is 0.98;
(b) the reference period is one year.

However in some cases the character of the action makes another reference period more appropriate. In addition, design values for other variables within the action model may have to be chosen, which may influence the probability of being exceeded for the resulting total action.

(9) Actions caused by water should normally be based on water levels and include a geometrical parameter to allow for fluctuation of water level. Tides, currents and waves should be taken into account where relevant.

(10) For accidental actions the representative value is generally a characteristic value A_k corresponding to a specified value.

(11) Values of A_{Ed} for seismic actions are given in EBCS 8.

(12) For multi-component actions (see Section 1.4.1 (7) the characteristic action is represented by groups of values, to be considered alternatively in design calculations.

1.4.3 Other Representative Values of Variable and Accidental Actions

(1) In the most common cases the other representative values of a variable action are:

(a) the combination value generally represented as a product: $\Psi_o\ Q_k$;
(b) the frequent value generally represented as a product: $\Psi_1\ Q_k$;
(c) the quasi-permanent value generally represented as a product: $\Psi_2\ Q_k$.

(2) Combination values are associated with the use of combinations of actions, to take account of a reduced probability of simultaneous occurrence of the most unfavourable values of several independent actions.

(3) The frequent value is determined such that:

(a) the total time, within a chosen period of time, during which it is exceeded for a specified part, or
(b) the frequency with which it is exceeded,

is limited to a given value.

(4) The part of the chosen period of time or the frequency, mentioned in (3) above should be chosen with due regard to the type of construction works considered and the purpose of the calculations. Unless other values are specified the part may be chosen to be 0.05 or the frequency to be 300 per year for ordinary buildings.

(5) The quasi-permanent value is so determined that the total time, within a chosen period of time, during which it is exceeded is a considerable part of the chosen period of time.

(6) The part of the chosen period of time, mentioned in (5) above, may be chosen to be 0.5. The quasi-permanent value may also be determined as the value averaged over the chosen period of time.

(7) These representative values and the characteristic value are used to define the design values of the actions and the combinations of actions as explained in section 9. The combination values are used for the verification of ultimate limit states and irreversible serviceability limit states. The frequent values and quasi-permanent values are used for the verification of ultimate limit states involving accidental actions and for the verification of reversible serviceability limit states. The quasi-permanent values are also used for the calculation of long term effects of serviceability limit states. More detailed rules concerning the use of representative values are given, for example, in EBCS 2 to 8

(8) For some structures or some actions other representative values or other types of description of actions may be required, e.g. the fatigue load and the number of cycles when fatigue is considered.

1.4.4 Environmental Influences

The environmental influences which may affect the durability of the structure shall be considered in the choice of structural materials, their specification, the structural concept and detailed design. The EBCS 2 to 8 specify the relevant measures.

1.5 MATERIAL PROPERTIES

(1) Properties of materials (including soil and rock) or products are represented by characteristic values which correspond to the value of the property having a prescribed probability of not being attained in a hypothetical unlimited test series. They generally correspond for a particular property to a specified fractile of the assumed statistical distribution of the property of the material in the structure.

(2) Unless otherwise stated in EBCS 2 to 8, the characteristic values should be defined as the 5% fractile for strength parameters and as the mean value for stiffness parameters.

(3) Material property values shall normally be determined from standardized tests performed under specified conditions. A conversion factor shall be applied where it is necessary to convert the test results into values which can be assumed to represent the behaviour of the material in the structure or the ground (see also EBCS 2 to 8).

(4) A material strength may have two characteristic values, an upper and a lower. In most cases only the lower value will need to be considered. In some cases, different values may be adopted depending on the type of problem considered. Where an upper estimate of strength is required (e.g. for the tensile strength of concrete for the calculation of the effects of indirect actions) a nominal upper value of the strength should normally be taken into account.

(5) Where there is a lack of information on the statistical distribution of the property a nominal value may be used; where the limit state equation is not significantly sensitive to its variability a mean value may be considered as the characteristic value.

(6) Values of material properties are given in EBCS 2 to 8.

1.6 GEOMETRICAL DATA

(1) Geometrical data are represented by their characteristic values, or in the case of imperfections directly by their design values.

(2) The characteristic values usually correspond to dimensions specified in the design.

(3) Where relevant, values of geometrical quantities may correspond to some prescribed fractile of the statistical distribution.

(4) Tolerances for connected parts which are made from different materials shall be mutually compatible. Imperfections which have to be taken into account in the design of structural members are given in EBCS 2 to 8

1.7 MODELLING FOR STRUCTURAL ANALYSIS AND RESISTANCE

1.7.1 General

(1) Calculations shall be performed using appropriate design models involving relevant variables. The models shall be appropriate for predicting the structural behaviour and the limit states considered.

(2) Design models should normally be based on established engineering theory and practice, verified experimentally if necessary.

1.7.2 Modelling in the Case of Static Actions

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

(2) Effects of displacements and deformations should be considered in the context of ultimate limit state verifications (including static equilibrium) if they result in an increase of the effects of actions by more than 10%.

(3) In general the structural analysis models for serviceability limit states and fatigue may be linear.

1.7.3 Modelling in the Case of Dynamic Actions

(1) When dynamic actions may be considered as quasi-static, the dynamic parts are considered either by including them in the static values or by applying equivalent dynamic amplification factors to the static actions. For some equivalent dynamic amplification factors, the natural frequencies have to be determined.

(2) In some cases (e.g. for cross wind vibrations or seismic actions) the actions may be defined by provisions for a modal analysis based on a linear material and geometric behaviour. For regular structures, where only the fundamental mode is relevant, an explicit modal analysis may be substituted by an analysis with equivalent static actions, depending on mode shape, natural frequency and damping.

(3) In some cases the dynamic actions may be expressed in terms of time histories or in the frequency domain, for which the structural response may be determined by appropriate methods. When dynamic actions may cause vibrations that may infringe serviceability limit states guidance for assessing these limit states is given in annex C, together with the models of some actions.

1.8 DESIGN ASSISTED BY TESTING

1.8.1 General

(1) Where calculation rules or material properties given in EBCS 2 TO 8 are not sufficient or where economy may result from tests on prototypes, part of the design procedure may be performed on the basis of tests. Some of the clauses in this section may also be helpful in cases where the performance of an existing structure is to be investigated.

(2) Tests shall be set up and evaluated in such a way that the structure has the same level of reliability with respect to all possible limit states and design situations as achieved by design based on calculation procedures specified in EBCS 2 to 8.

(3) Sampling of test specimens and conditions during testing should be representative.

(4) Where EBCS 2 to 8 include implicit safety provisions related to comparable situations, these provisions shall be taken into account in assessing the test results and may give rise to corrections. An example is the effect of tensile strength in the bending resistance of concrete beams, which is normally neglected during design.

1.8.2 Types of Tests

(1) The following test types are distinguished:

(a) tests to establish directly the ultimate resistance or serviceability properties of structural parts e.g. fire tests;
(b) tests to obtain specific material properties, e.g. ground testing in situ or in the laboratory, testing of new materials;
(c) tests to reduce uncertainties in parameters in load or resistance models, e.g. wind tunnel testing, testing of full size prototypes, testing of scale models;
(d) control tests to check the quality of the delivered products or the consistency of the production characteristics, e.g. concrete cube testing;