(e) tests during execution in order to take account of actual conditions experienced e.g. post-tensioning, soil conditions;
(f) control tests to check the behaviour of the actual structure or structural elements after completion, e.g. proof loading for the ultimate or serviceability limit states.

(2) For test types (a), (b) and (c), the test results may be available at the time of design; in those cases the design values can be derived from the tests. For test types (d),(e) and (f) the test results may not be available at the time of design; in these cases the design values correspond to that part of the production that is expected to meet the acceptance criteria at a later stage.

1.8.3 Derivation of Design Values

(1) The derivation of the design values for a material property, a model parameter or a resistance value from tests can be performed in either of the following two ways:

(a) by assessing a characteristic value, which is divided by a partial safety factor and possibly multiplied by an explicit conversion factor;
(b) by direct determination of the design value, implicitly or explicitly accounting for the conversion aspects and the total reliability required..

(2) In general method (a) above should be used. The derivation of a characteristic value from tests should be performed taking account of:

(a) the scatter of test data;
(b) statistical uncertainty resulting from a limited number of tests;
(c) implicit or explicit conversion factors resulting from influences not sufficiently covered by the tests such as:

(i) time and duration effects, not taken care of in the tests;
(ii) scale, volumes and length effects;
(iii) deviating environmental, loading and boundary conditions;
(iv) the way that safety factors as partial factors or additive elements are applied to get design values.

The partial safety factor used in method (a) above should be chosen in such a way that there is sufficient similarity between the tests under consideration and the usual application field of the partial safety factor used in numerical verifications. (see also Section 1.3.4).

(3) When for special cases method (b) above is used, the determination of the design values should be carried out by considering:

(a) the relevant limit states;
(b) the required level of reliability;
(c) the statistical and model uncertainties;
(d) the compatibility with the assumptions for the action side;
(e) the classification of design working life of the relevant structure according to Section 2;
(f) prior knowledge from similar cases or calculations.

(4) Further information may be found in EBCS 2 to 8.

1.9 VERIFICATION BY THE PARTIAL SAFETY FACTOR METHOD

1.9.1 General

(1) In EBCS 2 to 8 the reliability according to the limit state concept is achieved by application of the partial factor safety method. In the partial safety factor method, it is verified that, in all relevant design situations, the limit states are not exceeded when design values for actions, material properties and geometrical data are used in the design models.

(2) In particular, it shall be verified that:

(a) the effects of design actions do not exceed the design resistance of the structure at the ultimate limit state; and
(b) the effects of design actions do not exceed the performance criteria for the serviceability limit state.

Other verifications may also need to be considered for particular structures e.g. fatigue. Details are presented in EBCS 2 to 8.

(3) The selected design situations shall be considered and critical load cases identified. For each critical load case, the design values of the effects of actions in combination shall be determined.

(4) A load case identifies compatible load arrangements, sets of deformations and imperfections which should be considered simultaneously for a particular verification.

(5) Rules for the combination of independent actions in design situations are given in this section. Actions which cannot occur simultaneously, for example, due to physical reasons, should not be considered together in combination.

(6) A load arrangement identifies the position, magnitude and direction of a free action. Rules for different arrangements within a single action are given in Chapters 2 and 3.

(7) Possible deviations from the assumed directions or positions of actions should be considered.

(8) The design values used for different limit states may be different and are specified in this section.

1.9.2 Limitations and Simplifications

(1) Application rules in Chapter 1 are limited to ultimate and serviceability limit states for structures subject to static loading. This includes cases where the dynamic effects are assessed using equivalent quasi-static loads and dynamic amplification factors, e.g. wind.

(2) Simplified verification based on the limit state concept may be used:

(a) by considering only limit states and load combinations which from experience or special criteria are known to be potentially critical for the design;
(b) by using the simplified verification for ultimate limit states and/or serviceability limit states as specified for buildings in Sections 1.9.4.5 and 1.9.5.5;
(c) by specifying particular detailing rules and/or provisions to meet the safety and serviceability requirements without calculation.

1.9.3 Design Values

1.9.3.1 *Design Values of Actions*

(1) The design value F_d of an action is expressed in general terms as:

$$F_d = \gamma_F F_{rep} \tag{1.1}$$

where γ_F is the partial safety factor for the action considered taking account of:

(a) the possibility of unfavourable deviations of the actions;
(b) the possibility of inaccurate modelling of the actions;
(c) uncertainties in the assessment of effects of actions.
F_{rep} is the representative value of the action.

(2) Depending on the type of verification and combination procedures, design values for particular actions are expressed as follows:

$$\begin{aligned} G_d &= \gamma_G G_k \text{ or } G_k \\ Q_d &= \gamma Q_k,\ \gamma Q \Psi_o Q_k,\ \Psi_1 Q_k \text{ or } Q_k \\ A_d &= \gamma_A A_k \text{ or } A_d \\ P_d &= \gamma_p P_k \text{ or } P_k \\ A_{Ed} &= A_{Ed} \end{aligned} \tag{1.2}$$

(3) Where distinction has to be made between favourable and unfavourable effects of permanent actions, two different partial saftey factors shall be used.

(4) For seismic actions the design value may depend on the structural behaviour characteristics (see EBCS 8).

1.9.3.2 *Design Values of the Effects of Actions*

(1) The effects of actions (E) are responses (for example internal forces and moments, stresses, strains and displacements) of the structure to the actions. For a specific load case the design value of the effect of actions (E_d) is determined from the design values of the actions, geometrical data and material properties when relevant:

$$E_d = E(F_{d1}, F_{d2}, \ldots a_{d1}, a_{d2}, \ldots X_{d1}, X_{d2}, \ldots) \tag{1.3}$$

where $F_{d1}, \ldots, a_{d1}, \ldots$ and $X_{d1}, \ldots$ are chosen according to Sections 1.9.3.1, 1.9.3.3 and 1.9.3.4, respectively.

(2) In some cases, in particular for non-linear analysis, the effect of the uncertainties in the models used in the calculations should be considered explicitly. This may lead to the application of a coefficient of model uncertainty γ_{sd} applied either to the actions or to the action effects, whichever is the more conservative. The factor γ_{sd} may refer to uncertainties in the action model and/or the action effect model.

(3) For non-linear analysis, i.e. when the effect is not proportional to the action, the following simplified rules may be considered in the case of a single predominant action.

(a) When the effect increases more than the action, the partial safety factor is applied to the representative value of the action.
(b) When the effect increases less than the action, the partial safety factor is applied to the action effect of the representative value of the action.

In other cases more refined methods are necessary which are defined in the relevant Codes (e.g. for prestressed structures).

1.9.3.3 *Design Values of Material Properties*

(1) The design value X_d of a material or product property is generally defined as:

$$X_d = \eta X_k/\gamma_M \text{ or } X_d = X_k/\gamma_M \quad (1.4)$$

where γ_M is the partial saftey factor for the material or product property, given in EBCS 2 to 8 which covers
(a) unfavourable deviations from the characteristic values;
(b) inaccuracies in the conversion factors; and
(c) uncertainties in the geometric properties and the resistance model.

η is the conversion factor taking into account the effect of the duration of the load, volume and scale effects, effects of moisture and temperature and so on.

In some cases the conversion is implicitly taken into account by the characteristic value itself, as indicated by the definition of η, or by η_M.

1.9.3.4 *Design Values of Geometrical Data*

(1) Design values of geometrical data are generally represented by the nominal values:

$$a_d = a_{nom} \quad (1.5)$$

Where necessary EBCS 2 to 8 may give further specifications.

(2) In some cases when deviations in the geometrical data have a significant effect on the reliability of a structure, the geometrical design values are defined by:

$$a_d = a_{nom} + \Delta_a \quad (1.6)$$

where Δ_a takes account of the possibility of unfavourable deviations from the characteristic values
Δ_a is only introduced where the influence of deviations is critical, e.g. imperfections in buckling analysis. Values of Δ_a are given in EBCS 2 to 8.

1.9.3.5 *Design Resistance*

(1) Design values for the material properties, geometrical data and effects of actions, when relevant, shall be used to determine the design resistance R_d from:

$$R_d = R(a_{d1}, a_{d2}, \ldots X_{d1}, X_{d2}, \ldots) \quad (1.7)$$

where a_{d1}, ... is defined in Section 1.9.3.4 and X_{d1}, ... in Section 1.9.3.3.

(2) Operational verification formulae, based on the principle of expression (1.7), may have one of the following forms:

$$R_d = R\{X_k / \gamma_M, a_{nom}\} \tag{1.7a}$$
$$R_d = R\{X_k, a_{nom}\} / \gamma_R \tag{1.7b}$$
$$R_d = R\{X_k / \gamma_m, a_{nom}\} / \gamma_{rd} \tag{1.7c}$$

where γ_R is a partial safety factor for the resistance;
γ_m is a material safety factor;
γ_{rd} covers uncertainties in the resistance model and in the geometrical properties.

(3) The design resistance may also be obtained directly from the characteristic value of a product resistance, without explicit determination of design values for individual basic variables, from:

$$R_d = R_k / \gamma_R \tag{1.7d}$$

This is applicable for steel members, piles, etc. and is often used in connection with design by testing.

1.9.4 Ultimate Limit States

1.9.4.1 *Verifications of Static Equilibrium and Strength*

(1) When considering a limit state of static equilibrium or of gross displacement of the structure as a rigid body, it shall be verified that:

$$E_{d,dst} \leq E_{d,stb} \tag{1.8}$$

where $E_{d,dst}$ is the design value of the effect of destabilizing actions;
$E_{d,stb}$ is the design value of the effect of stabilizing actions.

In some cases if may be necessary to replace eq. (1.8) by an interaction formula.

(2) When considering a limit state of rupture or excessive deformation of a section, member or connection it shall be verified that:

$$E_d \leq R_d \tag{1.9}$$

where E_d is the design value of the effect of actions such as internal force, moment or a vector representing several internal forces or moments;
R_d is the corresponding design resistance, associating all structural properties with the respective design values.

In some cases it may be necessary to replace eq. (1.9) by an interaction formula. The required load cases are identified as described in Section 1.9.1.

1.9.4.2 *Combination of Actions*

(1) For each critical load case, the design values of the effects of actions (E_d) should be determined by combining the values of actions which occur simultaneously, as follows:

(a) **Persistent and transient situations:** Design values of the dominant variable actions and the combination design values of other actions.

(b) **Accidental situations:** Design values of permanent actions together with the frequent value of the dominant variable action and the quasi-permanent values of other variable actions and the design value of one accidental action.

(c) **Seismic situations:** Characteristic values of the permanent actions together with the quasi-permanent values of the other variable actions and the design value of the seismic actions.

(2) When the dominant action is not obvious, each variable action should be considered in turn as the dominant action.

(3) The above combination process is represented in Table 1.1.

Table 1.1: Design Values of Actions for use in the Combination of Actions

Design situation	Permanent actions G_d	Single variable actions Q_d		Accidental actions or seismic actions A_d
		Dominant	Others	
Persistent and transient	$\gamma_G G_k$ $(\gamma_p P_k)$	$\eta_{Q1} Q_{k1}$	$\eta_{Q1} \Psi_{Qi} Q_{ki}$	
Accidental	$\gamma_{GA} G_k$ $(\gamma_{PA} P_k)$	$\Psi_{11} Q_{k1}$	$\Psi_{2i} Q_{ki}$	$\gamma_A A_k$ *or* A_d
Seismic	G_k		$\Psi_{2i} Q_{ki}$	A_{Ed}

Symbolically the combinations may be represented as follows

(a) persistent and transient design situations for ultimate limit states verification other than those relating to fatigue

$$\sum_{j \geq 1} \gamma G_{kj} + \gamma_{p_k} + \gamma_{qi} + \sum_{i > l} \gamma_{Qi} \psi_{oi} Q_{ki} \qquad (1.10)$$

Note: This combination rule is an amalgamation of two separate load combinations:

$$\sum_{j \geq 1} \gamma G_{kj} + \gamma_{p_k} + \gamma_{qi} + \sum \psi_{01} Q_{kl} + \sum_{i > l} \gamma_{Qi} \psi_{01} Q_{ki} \qquad (1.10a)$$

$$\sum_{j \geq 1} \xi \gamma G_{kj} + \gamma_{p_k} + \gamma_{qi} + \sum \psi_{01} Q_{kl} + \sum_{i > l} \gamma_{Qi} \psi_{01} Q_{ki} \qquad (1.10b)$$

ξ is a reduction factor for γ_{Gj} within the range 0.85 and 1.

(b) Combinations for accidental design situations

$$\sum \gamma_{GAj} G_{kj} + \gamma_{PA} P_k + A_d + \psi_{11} Q_{kl} + \sum \psi_{2i} Q_{ki} \qquad (1.11)$$

(c) Combination for the seismic design situation

$$\sum G_{kj} + P_k + A_{Ed} + \sum \psi_{2i} Q_{ki} \qquad (1.12)$$

"+" "implies" to be combined with"
Σ implies "the combined effect of";
G_{kj} is the characteristic value of permanent actions;
P_k is the characteristic value of a prestressing action;
Q_{kl} is the characteristic value of the variable action;
Q_{kj} is the characteristic value of the variable actions;
A_d is the design value of the accidental action;
A_{Ed} is the design value of seismic action;
γ_{Gj} is the partial factor for permanent action j;
γ_{GAj} is the same as γ_{Gj}, but for accidental design situations;
γ_{PA} is the same as γ_p, but for accidental actions;
γ_p is the partial factor for prestressing actions;
γ_{Qi} is the partial factor for variable action i;
Ψ are combination coefficients (see 1.4.3).

(4) Combinations for accidental design situations either involve and explicit accidental action (A (e.g. fire or impact)or refer to a situation after an accidental event (A=0). For fire situations, apart from the temperature effect on the material properties, A_d refers to the design value of the indirect thermal action.

(5) Equations (1.10) and (1.11) may refer to either actions or action effects; for non-linear analysis, see Section 1.9.3.2 (3).

(6) Where components of a vectorial force are partially correlated, the factors to any favourable component may be reduced by 20%.

(7) Imposed deformations should be considered where relevant.

(8) In some cases eqs. (9.10) to (9.12) need modification; detailed rules are given in the relevant parts of EBCS 1 to 8.

1.9.4.3 *Partial Safety Factors*

(1) In the relevant load cases, those permanent actions that increase the effect of the variable actions (i.e. produce unfavourable effects) shall be represented by their upper design values, those that decrease the effect of the variable actions (i.e. produce favourable effects) by their lower design values.

(2) Where the result of a verification may be very sensitive to variations of the magnitude of a permanent action from place to place in the structure, the unfavourable and the favourable parts of this action shall be considered as individual actions. This applies in particular to the verification of static equilibrium.

(3) For building structures, the partial safety factors for ultimate limit states in the persistent, transient and accidental design situations are given in Table 1.2. The values have been based on theoretical considerations, experience and back calculations on existing designs.

Table 1.2 Partial Safety Factors: Ultimate Limit States for Buildings

Case[1])	Action	Symbol	Situations	
			P/T	*A*
Case A Loss of static equilibrium;strength of structural material or ground insignificant (see Section 1.9.4.1	Permanent actions:self weight of structural and non-structural components, permanent actions caused by ground, ground-water and free water - unfavourable - favourable	 γ_{Gsup} [4)] γ_{Ginf} [4)]	 1.10[2)] 0.90[2)]	 1.00 1.00
	Variable actions - unfavourable	 γ_Q	 1.60	 1.00
	Accidental actions	γ_A		1.00
Case B[5)] Failure of structure or structural elements, including those of the footing, piles, basement walls etc., governed by strength of structural material (see Section 1.9.4.1)	Permanent actions [6)] (see above) - unfavourable - favourable	 γ_{Gsup} [4)] γ_{Ginf} [4)]	 1.30[3)] 1.00[3)]	 1.00 1.00
	Variable actions - unfavourable	 γ_Q	 1.60	 1.00
	Accidental actions	γ_A		1.00
Case C[5)] Failure in the ground	Permanent actions (see above) - unfavourable - favourable	 γ_{Gsup} [4)] γ_{Ginf} [4)]	 1.00 1.00	 1.00 1.00
	Variable actions - unfavourable	 γ_Q	 1.30	 1.00
	Accidental actions	γ_A		1.00

P: Persistent situation *T*: Transient situation *A*: Accidental situation

(1) The design should be verified for each A, B and C separately as relevant.
(2) In this verification the characteristic value of the unfavourable part of the permanent action is multiplied by the factor 1.1 and the favourable part by the factor 0.9. More refined rules are given in EBCS 3 and EBCS 4.
(3) In this verification the characteristic values of all permanent actions from one source are multiplied by 1.3 if the total resulting action effect is unfavourable and by 1.0 if the total resulting action effect is favourable.
(4) In cases when the limit state is very sensitive to variation of permanent actions, the upper and lower characteristic values of these actions should be taken according to Section 1.4.2 (3).
(5) For cases B and C the design ground properties may be different, see EBCS 7.
(6) Instead of using γ_G (1.30 and γ_Q = (1.60) for lateral earth pressure actions the design ground properties may be introduced in accordance with EBCS 7 and a model factor γ_{sd} is applied.

1.9.4.4 Ψ *Factors*

(1) Ψ factors for buildings are given in Table 1.3. For other applications see relevant Chapter of this code.

Table 1.3 ΨFactors for Buildings

Action	Ψ_0	Ψ_1	Ψ_2
Imposed loads in buildings [1)			
category A: domestic, residential	0.7	0.5	0.3
category B: offices	0.7	0.5	0.3
category C: congregation areas	0.7	0.7	0.6
category D: shopping	0.7	0.7	0.6
category E: storage	1.0	0.9	0.8
Traffic loads in buildings			
category F: vehicle weight ≤30kN	0.7	0.7	0.6
category G: 30kN < vehicle weight ≤160kN	0.7	0.5	0.3
category H: roofs	0	0	0
Wind loads on buildings	0.6	0.5	0
Temperature (non-fire) in buildings	0.6	0.5	0
(1) For combination of imposed loads in multistorey buildings, see Chapter 2.			

1.9.4.5 ***Simplified Verification for Building Structures***

(1) The process for the persistent and transient situations described in Section 1.9.4.2 may be simplified by considering the most unfavourable for the following combinations:

(a) Design situations with only one variable action Q_{kl}

$$\sum_{j\geq 1} \gamma_{Gi}\, G_{kj} + 1.6\, Q_{kl} \qquad (1.13)$$

(b) Design situations with two or more variable actions $Q_{k,i}$

$$\sum_{j\geq l} \gamma_{Gj} + 1.35 \sum Q_{ki} \qquad (1.14)$$

In this case the effect of actions should also be verified for the dominant variable actions using Eq. (1.13).

(2) The γ_G values are given in Table 1.2.

1.9.4.6 ***Partial Safety Factors for Materials***

Partial safety factors for properties of materials and products are given in EBCS 2 to 8.

1.9.5 Serviceability Limit States

1.9.5.1 *Verification of Serviceability*

(1) It shall be verified that:

$$E_d \leq C_d \tag{1.15}$$

where C_d is a nominal value or a function of certain design properties of materials related to the design effects of actions considered; and

E_d is the design value of the action effect (e.g. displacement, acceleration), determined on the basis of one of the combinations defined in Section 1.9.5.2.

1.9.5.2 Combination of Actions

(1) The combination of actions to be considered for serviceability limit states depends on the nature of the effect of actions being checked, e.g. irreversible, reversible or long term. Three combinations designated by the representative value of the dominant action are given in Table 1.4.

Table 1.4 Design Values of Actions for use in the Combination of Actions

Combination	Permanent actions G_d	Variable actions Q_d	
		Dominant	Others
Characteristic (rare)	G_k (P_k)	Q_{kl}	$\psi_{0i}Q_{ki}$
Frequent	G_k (P_k)	$\Psi_{1l}Q_{kl}$	$\Psi\Psi_{2i}Q_{ki}$
Quasi-permanent	G_k (P_k)	$\Psi_{2l}Q_{kl}$	$\Psi_{2i}Q_{ki}$
Note: For serviceability limit states, the partial factors (serviceability) γ_G γ_Q are taken as 1.0 except where specified otherwise.			

(2) Three combinations of actions for serviceability limit states are defined symbolically by the following expressions:

(a) Characteristic (rare) combination

$$\Sigma\, G_{ki} \text{ "+" } P_k \text{ "+" } Q_{k1} \text{ "+" } \Sigma\Psi_{o1}Q_{ki} \tag{1.16}$$

(b) Frequent combination

$$\Sigma\, G_{kj} \text{ "+" } P_k \text{ "+" } \Psi_{11}Q_{k1} \text{ "+" } \Sigma\Psi_{2i}Q_{ki} \tag{1.17}$$

(c) Quasi-permanent combination

$$\Sigma\, G_{kj} \text{ "+" } P_k \text{ "+" } \Sigma\, \Psi_{2i}Q_{ki} \tag{1.18}$$

Where the notation is as given in Sections 1.1.6 and 1.9.4.2

(3) Loads due to imposed deformations should be considered where relevant.

(4) In some cases Eqs. (1.16) to (1.18) may require a modification; detailed rules are given in EBCS 1 to 8.

1.9.5.3 *Partial Safety Factors*

The partial safety factors for serviceability limit states are equal to 1.0 except where specified otherwise, e.g. in EBCS 2 to 8.

1.9.5.4 Ψ *Factors*

Values of Ψ factors are given in Table 1.3

1.9.5.5 *Simplified Verification for Building Structures*

(1) For building structures the characteristic (rare) combination may be simplified to the following expressions, which may also be used as a substitute for the frequent combination.

(a) Design situations with only one variable action Q_{k1}

$$\sum_{j \geq 1} G_{kj} + Q_{k1} \tag{1.19}$$

(b) Design situations with two or more variable actions, Q_{k1}

$$\sum_{j \geq 1} G_{kj} + 0.9 \sum_{i \geq 1} Q_{ki} \tag{1.20}$$

In this case the effect of actions should also be verified for the dominant variable action using Eq. (1.19).

(2) Where simplified prescriptive rules are given for serviceability limit states, detailed calculations using combinations of actions are not required.

1.9.5.6 *Partial Safety Factors for Materials*

Partial safety factors for the properties of materials and products are given in EBCS 2 to 8.

[THIS PAGE INTENTIONALLY LEFT BLANK]