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The working conditions may, for example, include the effects on strength of temperature (also in case of fire), environmental humidity, duration of a given action, etc and also the influence of any technological peculiarities of construction.

The uncertainties of a calculation model can be included in the model itself e.g. by use of additional parameters (see 3.1 and 5.1). The nature and magnitude of these uncertainties should be estimated by a comparison between calculated results and results observed during relevant tests. These uncertainties can be treated in a similar way to the uncertainties associated with the other basic variables.

5. THE METHOD OF PARTIAL COEFFICIENTS

5.1 Principles

The recommended method of partial coefficients requires the introduction of design values for each basic variable.

In this method:

- actions are expressed by design values F_d according to 5.2.
- strength of materials are expressed by design values f_d according to 5.3. Other relevant properties are treated in a similar way.
- geometrical parameters are expressed by design values a_d according to 5.4.

If the general conditions for the actual limit state not being exceeded is written as

$$\theta\,(F,\ f,\ a,\ \mu,\ C) \geq 0 \qquad (1)$$

the design criterion will be

$$\theta\,(F_d,\ f_d,\ a_d,\ \mu_d,\ C) \geq 0 \qquad (2)$$

where F represents actions

f represents material properties

a represents geometrical parameters

μ are quantities covering the uncertainties of the calculation model

C are constants including preselected design constrainst

and θ (·) = 0 represents the limit state function.

In many cases the condition for the actual limit state not beeing exceeded can also be represented by

$$\mu_R \; R \; (f, a, C) - \mu_S \; S \; (F, a, C) \geq 0 \tag{3}$$

and

$$\frac{1}{\gamma_R} \mu_{Rd} \; R \; (f_d, a_d, C) - \gamma_S \; \mu_{Sd} \; S \; (F_d, a_d, C) \geq 0 \tag{4}$$

where R represents a resistance function

S represents an action effect function

μ_R and μ_S are quantities covering the uncertainties of the calculation models

γ_R and γ_S are safety elements.

In many cases μ_{Rd}, μ_{Sd}, γ_R and γ_S may not appear explicitly and are compensated for by appropriate modifications of other factors.

If the design criterion is written according to inequality (4) the form of the expressions for R and S must be completely specified.

> If the form of the expressions are, to some extent, allowed to be arbitrarily chosen, there is a risk that the resulting reliability of the structure may depend on the individual choice.

5.2 Actions and their combinations

5.2.1 Representative values

Actions are introduced into the calculations by representative values. The main representative values are the characteristic values.

For a permanent action, when the action consists of the self weight of the structure (or in other similar cases), the characteristic value G_k should be obtained from the intended values of the geometrical parameters (in general taken from the drawings) and the mean unit weight of the material. I cases where the uncertainties in the permanent actions are important, the characteristic values may be determined so that the probability of their exceedance is sufficiently small. In such cases it may be necessary to define both upper and lower characteristic values.

For a variable action the characteristic value Q_k is defined as that value which has a prescribed probability of not being exceeded within the reference time and thus has a given return period (under certain conditions of stationarity). When characteristic values for variable actions cannot be determined from statistical data, as for example for actions from special equipment, the corresponding values may be estimated on the basis of available information.

For variable actions reduced representative values may also be used. The reduction can be made by factors ψ_i which may be different depending on the cause of the reduction.

Thus a factor ψ_0 may be used to take account of the reduced probability of simultaneously exceeding the design values of several actions as compared with the probability of the design value of a single action being exceeded;

Other factors ψ_1, ψ_2 etc may be used to determine reduced values of variable actions which are assumed to occur frequently or are used to evaluate long-time effects etc. This reduction is especially relevant for serviceability limit states.

For an accidental action the characteristic value F_{ak} corresponds to some event with a pre-selected occurrence rate and magnitude. In general this value is chosen so that it can be used directly as a design value.

5.2.2 Design values

The design values should be obtained from the representative values by multiplication with a partial coefficient γ_f.

$G_d = \gamma_f\, G_k$

$Q_d = \gamma_f\, Q_k$ or $Q_d = \gamma_f\, \psi_i\, Q_k$ (5)

γ_f takes account of:

- the possibility of unfavourable deviations of the actions from their representative values. In most cases an increase in the magnitude of the action is unfavourable but in some cases a decrease in the magnitude is unfavourable.
- uncertainty in the loading model.
- possible inaccurate assessment of the action effect (if not included in μ_{Sd} or γ_S), insofar as it is independent of the structural material.

The total partial coefficient may be decomposed into several different factors, each of them taking account of one or more of the uncertainties mentioned above.

For particular actions additive elements may be used to transform characteristic values into design values, when appropriate, as in the case of geometrical parameters (see 5.4.2).

For accidental actions design values should be taken as equal to their characteristic values.

5.2.3 Combinations of actions

In the ultimate limit states the following two types of combinations may be applied:

- ordinary combinations - combinations of permanent actions and variable actions. In most cases a combination should not involve more than one variable action having short duration and unreduced characteristic value.
- accidental combinations - combinations of one accidental action with permanent actions and variable actions with reduced values.

In general the combinations of actions can be expressed by

$C\ (\gamma_{f1}\, G_{k1},\ \ldots.\ \gamma_{fm}\, G_{km},\ \gamma_{f\ m+1}\, \psi_{i1}\, Q_{k1},\ \ldots.\ \gamma_{f\ m+n}\, \psi_{in}\ Q_{kn},\ F_{ak})$ (6)

where C is a symbol of combination
m is the number of permanent actions
n is the number of variable actions
i is a variable intex (0, 1, 2, ...)
and the other notation is in accordance with 5.2.1 and 5.2.2.

In the serviceability limit states the combinations of actions should be chosen with regard to the purpose of the actual calculation.

5.3 Properties of materials and soils

5.3.1 Characteristic values

In general the characteristic value of material properties can be presented as that value which has a prescribed probability of not being attained in a hypothetical unlimited test series (corresponding to a fractile in the distribution of the resistance parameter).

The method of quality control including the acceptance rules should be chosen so that the actual characteristic value is assured.

In cases where environmental conditions may cause deviations in the material properties, the characteristic values used for the design should be modified to take into account such deviations.

5.3.2 Design values

The design value f_d of the strength of materials (or other material properties) are obtained from the characteristic value f_k by division with a partial coefficient γ_m.

$$f_d = \frac{f_k}{\gamma_m} \tag{7}$$

γ_m takes account of:

- the possibility of unfavourable deviations of the strength of material, interpreted as a random variable, from the characteristic value,
- possible inaccurate assessment of the resistance of sections or load carrying

capacity of parts of the structure (if not included in μ_{Rd} or γ_R).
- uncertainties in geometrical parameters, if they are not taken into account according to 5.4.2.
- uncertainties in the relation between the material properties in the structure and those measured by tests on control specimens, i.e. uncertainties in the conversion factor or function according to 3.3.

The total partial coefficient γ_m may be decomposed into several different factors each one of them taking account of one or more or the uncertainties mentioned above.

For particular material properties additive elements may be used to transform characteristic values into design values, when appropriate, as in the case of geometrical parameters (see 5.4.2).

Further factors (or additive elements) may be introduced to take occount of working conditions. They may be used in the same way as the partial coefficients although they are not safety elements.

5.4 Geometrical parameters

5.4.1 Characteristic values

For geometrical parameters the characteristic values a_k usually correspond to the nominal values specified in the design.

5.4.2 Design values

The design values a_d of geometrical parameters should be obtained from the characteristic (nominal) values a_k and an additive element

$$a_d = a_k \pm \Delta_a \qquad (8)$$

Δ_a takes account of

- the importance of variations i a
- the given tolerance limits for a.

In the cases where deviations of the geometrical parameters have less significant effects and where the effects are accounted for by γ_m, Δ_a should be set equal to zero.

For geometrical parameters, additive elements (Δ_a) are generally more suitable than factors (γ).

5.5 Choice of values for the partial coefficients

The values of the partial coefficients should be chosen with regard to the actual limit state and may depend on the methods used for assessing of the action effects, resistance, etc.

The influence of the consequences of failure, including the significance of the type of failure, may be taken into account by a modifying, γ_n, introduced to adjust the values of the partial coefficients.

The values of the partial coefficients may be chosen on the basis of:

- decisions taking into account the available amount of knowledge and experience,
- a semi-probabilistic approach in which each design value considered separately has a prescribed probability of being exceeded in the unfavourable sense,
- an approach in which the target reliability index, or target operational failure probability is established from a study of the values implicit in existing acceptable designs. Deviations from target indices for a proposed design criterion should be examined over the domain of application of the criterion,
- other appropriate probabilistic analyses including optimization studies.

APPENDIX

GLOSSARY

Reliability: In the most general sense, the reliability of a structure is its ability to fulfil its design purpose for some specified time. In a narrow sense (implied by this document) it is the probability that the structure will not attain each specified limit state (ultimate or serviceability) during the reference period.

Failure has been used in this document with reference to both the ultimate limit states and the serviceability limit states to express that a structure does not fulfil the requirements.

Reference period is a time interval that must be specified if the definitions of variable actions and the degrees of reliability are to be unambiguous. The reference period relates to the particular design situation under consideration.

Characteristic values are those values which serve as a basis for determination of all values of actions, material properties and geometrical parameters used in the design calculation.

Nominal values for measurements and dimensions are for example values given on drawings, in tables of prefabricated products, etc.

Safety element is a general term including partial coefficients (partial safety factors) and additive elements. The magnitude of the safety element takes into account the probability of exceedance of the characteristic or nominal value.