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Actions

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Summary

Some basic concepts concerning actions and action models are outlined and a probabilistic modelling of actions is discussed. With this as a background some of the basic principles given in Eurocode 1 "Basis of Design" are commented.

1. Action models

Actions are generally caused by some kind of event e.g. construction of a building, snow fall, trucks passing a bridge, collision, fire, etc. Thus a causal sequence from the event to the response of a structure can be written.

Causal event → Action → Action effect → Response of the structure

The transition from the causal event to the action implies in the design procedure consideration both to the data which describe the causal event and some of the data which characterize the object of the action (e.g. building, bridge). Thus in many cases one can distinguish between two kinds of action variables, F_o and W, and describe an action F in a very schematic way by the equation

$$F = \varphi \, (F^{o}, W) \qquad (1)$$

where

$\varphi\,(\cdot)$ is a suitable function, often a simple product.

F^{o} is a basic action variable which is directly associated with the causal event and which should be defined so that it is as far as possible independent of the structure. F^{o} is often time dependent. For example, for snow load F^{o} is the snow load on ground, on a flat horizontal surface.

W is a kind of conversion factor appearing in the transformation from the basic action to that action F which affects the particular structure. W can normally be considered as time independent. For the snow load example W is the conversion factor which transforms the snow load on ground to the snow load on roof.

The basic data which give the numerical values of the action variables (F^o and W) can be obtained in different ways which may shortly be described as
- observation (e.g. snow load, wave data on the sea)
- calculation according to physical laws (e.g. self weight, dynamic forces from machines)
- choice (e.g. maximum lifted load in a crane, maximum wheel load on a bridge deck)
- judgement (e.g. accidental actions).

Often different ways are combined.

As far as possible the values of the action parameters should be described in statistical terms and be based on statistical data. Thus the background for the description of the basic action variable F^o could be a stochastic process or, if only the maximum value is of interest, a random variable. The factor W could in most cases be described by a random variable.

If the action parameters are determined by observation and/or calculation the procedures will normally include analysis of statistical data and the results can then be presented in statistical terms. If the action parameters are determined mainly by choice or judgement the procedures will generally not give results expressed in statistical terms. However action values determined in different ways are all treated in the same way in a design process according to Eurocode 1. Therefore in some cases, action data such as mean values, characteristic values, frequent values etc, which in principle have a statistical meaning, have to be determined in a fairly subjective way. Such values are denoted as nominal values. It is assumed that this does not prevent actions of different kinds to be treated according to unified principles in the design.

2. Uncertainties

The numerical values of the action variables are generally more or less uncertain. The sources of the uncertainties can normally be referred to one or more of the following categories:

- Inherent uncertainties i.e. uncertainties associated with the variability of the action characteristics themselves. Examples may be uncertainties concerning snow depths, wind speeds etc. In most cases there is nothing that can be done to decrease uncertainties of this kind, they have to be accepted and introduced in some way into the action models.
- Uncertainties which depend on lack of knowledge about the action variables or are associated with approximations made, for example, to simplify the design calculations. These uncertainties may be denoted "model uncertainties". They may be decreased through research activities or refined action models. Statistical uncertainties depending, for example, on a small number of observations are also referred to this category and in this case they may be decreased by increasing the number of observations.

- Uncertainties about the future development, for example, concerning traffic loads on bridges. This kind of uncertainties can be affected through research activities only to a limited extent.

The uncertainties should be considered in the design format. In a description of actions according to the principles given by eq. (1) the uncertainties in the action variables (F° and W) may be considered by defining these variables in a probabilistic way, for example, as random variables. The model uncertainties, i.e. the uncertainties in the function φ, may be considered by introducing an additional random variable θ which exclusively accounts for the model unceraintties. It could, for example, be given the mean value 1 and a coefficient of variation V_{θ}.

In Eurocode 1, "Basis of Design" the uncertainties in the action variables are considered by using representative values (e.g. characteristic values) and partial factors. The model uncertainties may be considered by using a special partial factor γ_{Sd}.

In many cases the effect of the model uncertainties are included in the partial factor γ_F for the actions. Ideally values of γ_{Sd} should be presented in connection with the action models.

3. Probabilistic description of actions

A probabilistic description of actions is in many cases useful as a basis for the evaluation of representative values of actions and of partial factors.

The basic action variable (F° in eq. (1)) is often time dependent and in those cases a description as a stochastic process according to fig. 1 may be convenient.

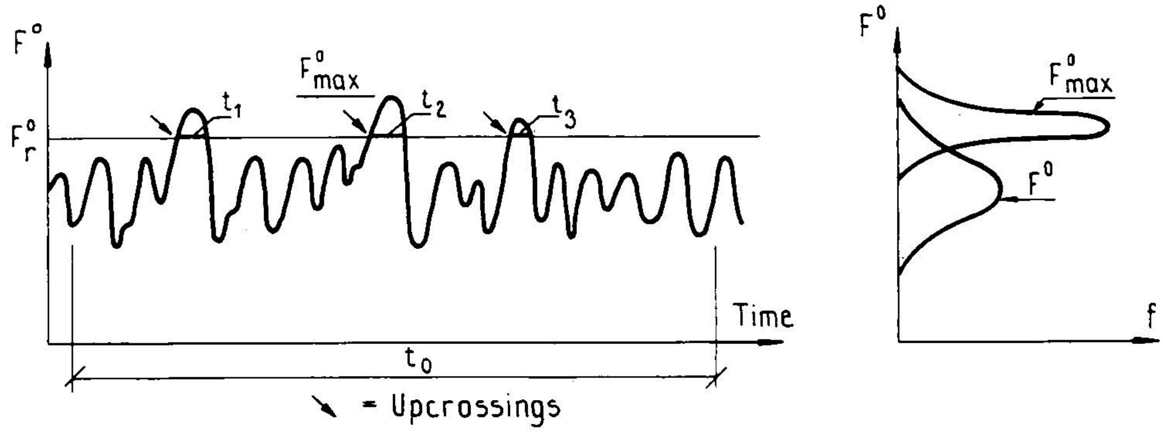

Fig. 1 A stochastic process as a model for the basic action variable

The following properties of such a process are of interest in connection with design problems.

1) Mean, standard deviation and fractiles for point-in-time values, i.e. F° in fig. 1.
2) Mean, standard deviation and fractiles for maximum values referred to a specified period of time t_o, i.e. F°_{max} in fig. 1.
3) Mean number of upcrossings (see fig. 1) per unit time for a specified level, F°_r, of the action variable, upcrossing rate.

4) The time for which the magnitude is above a specified level, F^o_r, of the action, the excursion time, i.e. t_1, t_2, t_3 in fig. 1.

In many cases a probabilistic description of an action can be simplified to a sequence of random variables according to fig. 2. This is especially the case if only the maximum value, F^o_{max}, within a specified period of time, t_o, is of interest. For the simple case, shown in figure 2, with n statistically independent action values occurring during the reference time, t_o, the relation between the probability distribution functions, F_Q for the point-in-time values and F_{Qmax} for the maximum values can be written

$$F_{Qmax}(Q) = [F_Q(Q)]^n \quad (2)$$

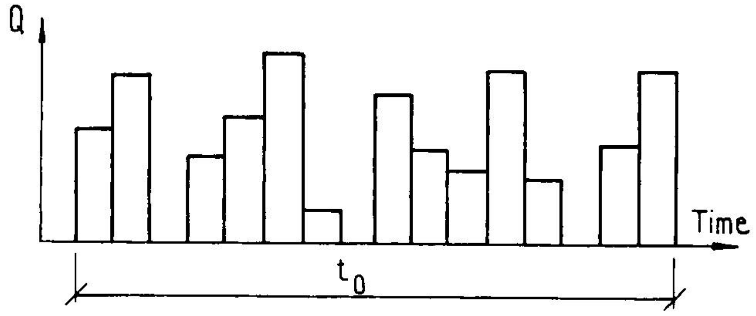

Fig. 2 A simple action-time diagram

Sometimes a description of the action variable F^o as deterministic is sufficient. This is especially the case if the magnitude of the action variable is of minor importance for a design problem.

The action variable W in eq. (1) should in principle be regarded as a random variable. In many cases the character of this variable is such that it has natural lower and/or upper limits. This may, for example, be the case for the conversion factor: snow load on ground to snow load on roof. Sometimes the variability of the action variable W is fairly unimportant and then W may be taken as deterministic.

4. Action values according to the partial factors format

4.1 Classification of actions

Important characteristics of actions could be
- their probability of occurrence
- their variability in time and space characterized, for example, by mean values and standard deviations
- other uncertainties of stochastic or non-stochastic character.

In "Basis of Design" these characteristics are considered through classifications. Thus with regard to the variation of their magnitude with time actions are classified as permanent actions, variabale actions and accidental actions. With regard to their spatial variation actions are classified as fixed actions and free actions.

The concept of *permanent actions* implies that their probability of occurrence at any arbitrary point-in-time is close to one and that their variability with time is small. One can distinguish between different kinds of permanent actions
- self weight of a structure
- weight of non structural components
- other kinds of permanent actions.

The self weight is normally fairly well defined and its uncertainties are small, the coefficient of variation is seldom more than 0.05. The weight of structural components, e.g. partition walls, have greater uncertainties often due to foreseen future alterations. Other permanent actions, e.g. settlements of foundations, may have very great uncertainties.

The probability of occurrence of *variable actions* at any arbitrary point-in-time is very different but the occurrences sometimes during the working life of a particular structure is generally close to one. The concept of variable actions implies that their variability with time is not small, in many cases it can be intense. The uncertainties of the magnitude may vary very much from one action to another.

The probability of occurrence of *accidental actions* sometimes during the working life of a particular structure is small. If it occurs the variability in time and space of an accidental action is generally great. The uncertainty of its magnitude is in most cases very great.

4.2 Representative action values

For the application in different design situations the actions have in "Basis of Design" been given one or more representative values of different kinds. Thus in ordinary cases the following kinds of values are used.

For permanent actions, one kind of values:
    Characteristic value
For variable actions, four kinds of values:
    Characteristic value
    Combination value
    Frequent value
    Quasi-permanent value.
For accidental actions, one kind of values:
    Design value.

As characteristic value for *permanent actions* one value may be chosen if the variability is small e.g. for most cases of self weight. In other cases, e.g. for the weight of non structural components, where the variability often is greater the use of upper and lower characteristic values may be justified.

For *variable actions* the characteristic value is associated with the probability distribution function for the maximum value, Q_{max}, occuring within the specified reference time. The other representative values are associated with the probability distribution function for the point-in-time values, Q, even if they are specified as the characteristic value multiplied with a factor ψ. This is illustrated in fig. 3.

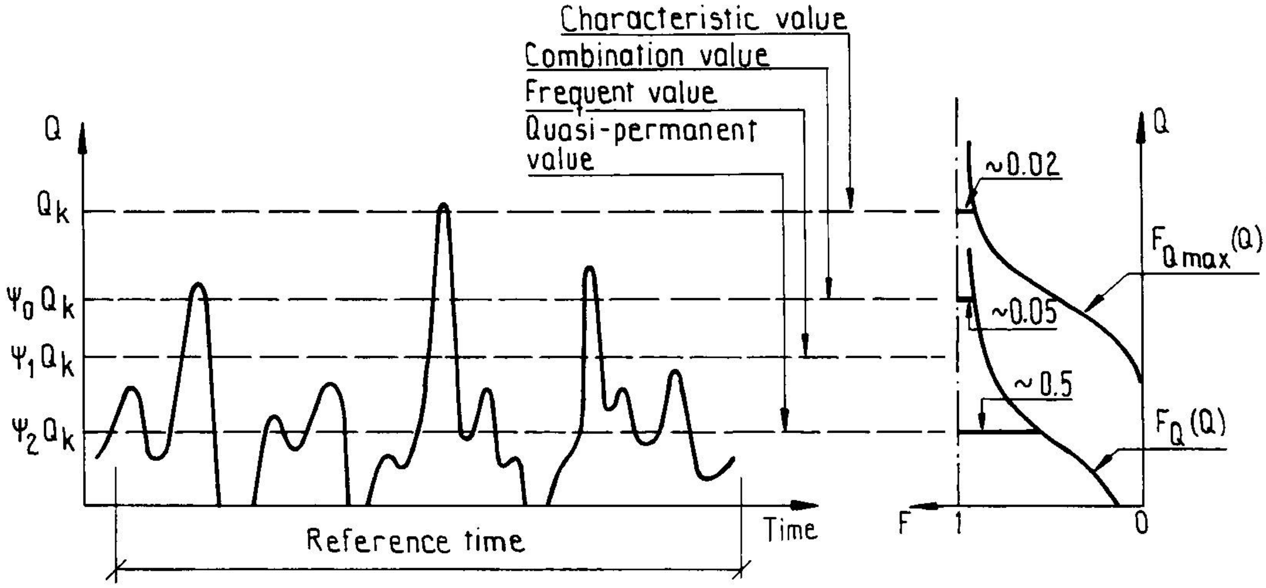

Fig. 3 Representative values of variable actions. (The numerical values are examples).

The characteristic value of a variable action is a comparatively high value which can be expected to be exceeded very seldom, in average once in a period of 50 years.

The combination value should be chosen so that the probability that the action effect values caused by the combination will be exceeded is approximately the same as when a single action is considered. Thus the combination value is defined according to a somewhat different principle in comparison with the other representative values. The portion of time when no load (or a very small load) occurs is often important.

The frequent value is defined with regard to the portion (η) of the time or to the number (ν) of times, when the load value is above the frequent value. With the numerical values proposed in "Basis of Design", i.e. $\eta = 0.05$ and $\nu = 300$ per year, it is obvious that the frequent value may be exceeded fairly often.

The quasi-permanent value is defined so that it can be expected to be exceeded about half the time. Thus the quasi-permanent value should be about the time average value.

Vind load could be taken as an example. There is a considerable part of the time during which the wind load is very small and absolutely unimportant. This does not affect the characteristic value which should be about the greatest value occuring during a 50 years period. It affects also the frequent value very little as this value should be chosen so that it is exceeded during about 400 hours every year in average. As one storm has a duration of 4 - 10 hours it can be concluded that the frequent value does not require a very strong wind. If winds of importance are assumed to occur only during 25 percent of the time this may have influence on the combination value at least for combinations with other short term loads. Further this is determining for the quasi-permanent value which should be zero for wind load.

4.3 Combinations of actions

The representative action values are introduced into the different types of combinations. The basic principle of combination of actions is to take **one** action (the dominating action) with a comparatively high value and combine it with the other actions (the non-dominating actions) which have lower values. Thus the kind of limit state and the type and purpose of the considered combination determine which kind of action value that should be chosen as dominating.

For *ultimate limit states* the "ordinary" combination", i.e. the combination applied in persistant or transient design situations, contains as value of the dominant action the characteristic value of either a permanent action or a variable action. This is shown in the expressions (9.10a) or (9.10b) respectively. The expression (9.10) is a simplified combination of (9.10a) and (9.10b).

The combination for accidental design situations (expression (9.11)) contains quite naturally the accidental action as dominating action.

For *serviceability limit states* the characteristic combination should be used for irreversible limit states when failure implies serious permanent damage. Consequently a high value, the characteristic value, should be chosen for the dominating variable action.

The frequent combination should be used for reversible limit states when, with certain limitations, passage of the limit state is considered as acceptable. Therefore the frequent value, which may be exceeded now and then, may be convenient to use as value of the dominating action. The frequent combination could also be used for irreversible limit states if the consequences of failure are not serious.

Finally the quasi-permanent combination is indented to be applied for long term problems. Thus the quasi-permanent action value should be chosen for the dominating as well as all other variable actions.

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