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General principles on reliability for structures
ADDENDUM 1

Principes généraux de la fiabilité des constructions
ADDITIF 1

Addendum 1 to ISO 2394 : 1986 was prepared by ISO/TC 98, *Bases for design of structures.*

ISO 2394 includes two annexes, "Examples of permanent, variable and accidental actions" and "Example of a first order probabilistic method". The annexes presented here should therefore be regarded as three additional annexes to the International Standard. Thus the basic general concepts, definitions and explanations are not given here but are to be found in the main text of ISO 2394.

These annexes are intended for use by international or national structural committees and load committees who are cognizant of the necessary data and make use of it in the most rational way. In special cases engineers who have to choose characteristic values for certain actions could use them. In any case, those who use the annexes should have sufficient knowledge to judge to what extent their content is applicable to the specific type of action which is treated. They are thus not written for those who want to learn about action observations and their evaluation.

It should be regarded as a description of agreed principles within this subject.

This addendum constitutes annexes C, D and E of ISO 2394.

Page iii :

Add, below existing text :

C Characteristic values of permanent actions

D Principles for the determination of the characteristic values of variable actions

E Principles for the determination of quasi-permanent and frequent values of variable actions

Page 18 :

Add the following annexes C, D and E.

UDC 624.042 Ref. No. ISO 2394 : 1986/Add.1 : 1988 (E)

Descriptors : civil engineering, buildings, structures, reliability.

Price based on 9 pages

Annex C

Characteristic values of permanent actions

The characteristic values for the most common types of permanent actions should be determined as follows.[1]

a) The selfweight of structures is represented by a unique value calculated from the nominal dimensions, taken from the drawings of the project, and the mean unit weight of the materials.

In some cases it is necessary to pay regard to deviations from the nominal dimensions and introduce two values. This may, for example, be the case for structures which are very sensitive to the spatial distribution of the actions.

b) The weight of non-structural elements generally is represented by two values. One value is calculated according to the same principle as the weight of structures. The other value, equal to zero, should be used if this gives a more severe action effect.

c) The actions of earth pressure are in most cases represented by a maximum value of the active earth pressure or a minimum value of the passive earth pressure. In those cases where the earth can be removed (intentionally or unintentionally) the absence of earth pressure can be regarded as a special design situation.

d) The action of prestress may be represented by two characteristic values, an upper and a lower. Both values should be determined with regard to the time elapsed since prestressing.

e) The deformations imposed by the mode of construction of the structure and by shrinkage are normally represented by unique values or zero values. Deformation due to shrinkage or swelling is time-dependent.

f) The actions due to settlements and mining subsidence may normally be represented by upper and lower values; the latter is often zero. Support settlement is generally a composite action representing the global effect of the settlements of various supports. Mining subsidence is generally a succession of several forces or imposed deformations. Consideration should be given to possible differential settlements.

g) The selfweight can sometimes be calculated from the measured dimensions or the measured weight of identical or similar types of structures.

1) More detailed rules should be given in specialized texts.

Annex D

Principles for the determination of the characteristic values of variable actions

D.0 Field of application

The proposed method concerns the choice of the characteristic value of variable static or quasistatic actions to be used in checking for ultimate limit-states. In special cases it may be used also in checking for serviceability limit-states.

It can be used only for those kinds of actions for which the characteristic values are determined by observations. Actions for which the values are determined by decision or in other similar ways have to be treated with other methods.

It should be pointed out that the method described in this annex concerns the probability of the occurrence of values very rarely attained by actions. Therefore, in most cases the available data may not be sufficient to give accurate and reliable results.

D.1 Principles

D.1.1 General conditions concerning actions and action observations

The following method is intended for the simple case when the action (or the events causing the action) can be described by a one-dimensional stochastic process.

The action observations are assumed to cover a total observation period T_0 which should be chosen[1] as long as possible. It is further assumed that the total observation period can be divided into a number r of equal time intervals t_0 called unit observation periods and that the maximum value Q of the action for each interval can be determined.

A condition for the method described here is that the unit observation period t_0 is chosen long enough so that the maximum values in two successive unit observation periods can be regarded as statistically independent approximations. However t_0 should not be chosen too long because then the number of values Q may be insufficient. Also, if the period t_0 is too long, the action process model will not capture the time variation of the action very accurately. In many cases the length of the unit observation period can be linked in a natural way with the physical character of the action considered (for example, a year for some of the climatic actions).

D.1.2 Choice of input parameters

The definition of the characteristic value of a variable action (see 6.2) contains the following parameters :

— reference period, here denoted T;

— the accepted probability, here denoted p, that the characteristic value Q_K will not be exceeded during the reference period.

Values of these parameters are discussed in D.1.5.

D.1.3 Evaluation of characteristic values

During the total observation period T_0 there are r observations Q, one for each of the unit observation periods t_0 (thus $r = T_0/t_0$). With these values, the cumulative probability function $F(Q)$ can be obtained. One method is the following (order statistics).

Arrange the r observed values Q in an increasing order. Then denote the ith observation value Q_i. $F(Q)$ may be determined as a function of Q from the expressions

$$Q_i < Q < Q_{i+1}$$

$$F(Q) = \frac{i}{r+1} \qquad \ldots (32)$$

In many cases it is useful to fit some of the available probability distributions to the observed values of $F(Q)$. If this is done, it is important to recognize that the distribution function should be regarded as an approximation which, strictly speaking, is valid only within the limits of the observed values.

The characeristic value can be obtained from the equation

$$F(Q_K) = p^{t_0/T} \qquad \ldots (33)$$

1) In many cases data from observations already made has to be used and it is not possible to chose T_0; it has to be accepted as it is.

The procedure is illustrated in figure 3.

Alternative methods of determining the characteristic values, e.g. directly from the stochastic process, are available and can in some cases be used, if the above-mentioned values Q are not sufficiently reliable (e.g. for wind).

D.1.4 Return period

In some cases a convenient way to characterize Q_K is to use its return period T_r, defined as the mean duration between consecutive occurrences of Q_K being exceeded. T_r can be calculated from the expression

$$T_r = \frac{t_o}{1 - F(Q_K)} = \frac{t_o}{1 - p^{t_o/T}} \quad \ldots (34)$$

If $p^{t_o/T}$ is close to unity, this expression can be approximated by

$$T_r = \frac{1}{\ln(1/p)} T \quad \ldots (35)$$

D.1.5 Numerical relations

In many cases the most illustrative parameter used to define the characteristic value of an action is its return period. For characteristic values of actions used in the design for ordinary permanent buildings with regard to safety, return periods of 50 to 100 years are reasonable. In certain cases justified by experience and permitted by national codes or for temporary buildings the return period can be chosen considerably shorter. For special cases a longer return period might be justified.

The relation between the accepted probability p, that the characteristic value will not be exceeded during the reference period T, and the return period T_r is shown in figure 4. The values are calculated from equation (34). For the values used for T (1 to 50 years) and for T_r (5 to 100 years), the differences in the results obtained for t_o = 1 year and t_o = 1 week are insignificant. The values obtained by equation (35) are also close to the values obtained by equation (34).

D.2 Validity and accuracy in the application of the principles

For actions of natural origin (such as wind, snow, temperature, etc.), the information available on their variations in a single observation place is very limited. In most cases the data do not cover more than about 50 years. Thus in such cases when the unit observation period is chosen equal to one year, the number of values obtained is fairly small. This means that action values with return periods of more than about 20 to 30 years cannot be determined confidently. In the same way, the probability distribution of the maximum for the reference period cannot be determined accurately if the reference period is more than about 50 years. The available data may not permit anything more than the estimation of the mean value. The type of distribution and the coefficient of variation have to be determined by judgement. Of course if the reference period is chosen considerably shorter (for example one year) the results will formally be more accurate. However for a building with a life time of about 50 years, this does not make the predictions more well determined.

Sometimes it is possible to get more data from observations, for example, if

— the observations can be made simultaneously in several places and the results can be regarded as belonging to a common population;

— the unit observation period can be chosen shorter than one year.

In such cases the use of a greater quantity of data often permits an extension of the conclusions which can be drawn from the statistics.

D.3 Numerical corrections

In many cases, the characteristic value of an action, determined from observations as described above, cannot be used directly but has to be corrected for some reason. In the following, some of the most common cases are given in D.3.1 to D.3.3.

D.3.1 Influence of additional factors

Many actions cannot be defined sufficiently by means of a single variable referred to the cause of the action. For example, the wind actions cannot be sufficiently defined from standardized measurements since they depend also on local topography and the shape of the buildings. Similar circumstances apply, for example, to snow load and earthquake forces.

In some cases, the influence of such factors can be explicitly described by special coefficients. In other cases, their effect is included in the characteristic value of the action. One way to do this is to correct those values of the mean and the coefficient of variation which are obtained directly from the measurements. Other ways are also possible.

D.3.2 Influence of different directions

Certain actions (for example, wind, earthquake and waves) can produce effects in any direction. The majority of limit states can result only from the components of these actions in one direction. If the statistical data obtained from observations are valid without regard to directions, i.e. they are valid for all possible directions together, they have to be corrected to represent the single component action worth considering. Such correction should depend on the type of action and the local conditions.

D.3.3 Influence of simplifying action models

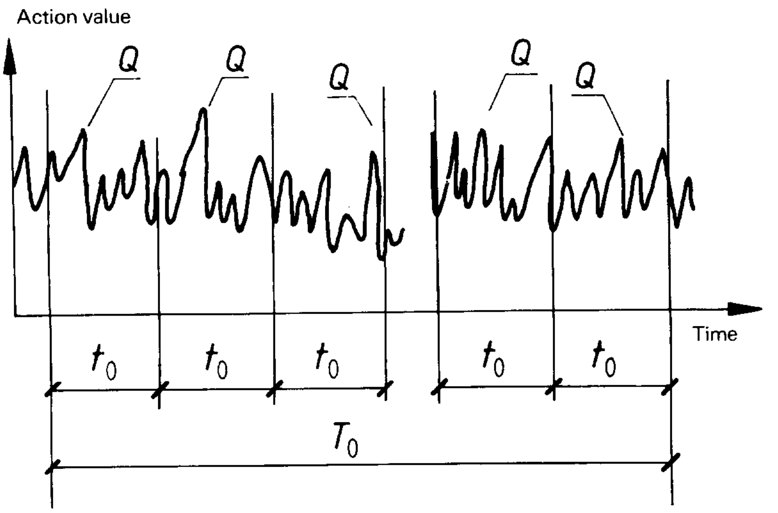
Sometimes action models are adopted which implies idealizations of the real nature of the actions. For example, snow load on a roof is normally assumed to be uniform in the direction parallel to the eaves.

In general, the distortion of the model with respect to reality must be assessed for a set of representative cases :

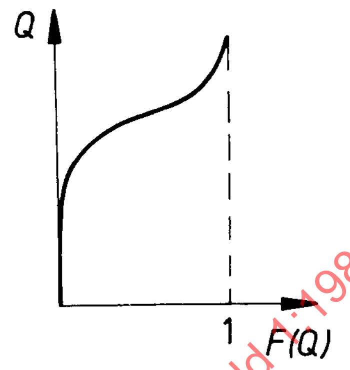
- in terms of a standard deviation;
- if possible, in terms of maximum deviation ΔQ.

The standard deviation should be taken into account to assess an increased value of Q_K. However the increase in Q_K should not be taken greater than ΔQ.

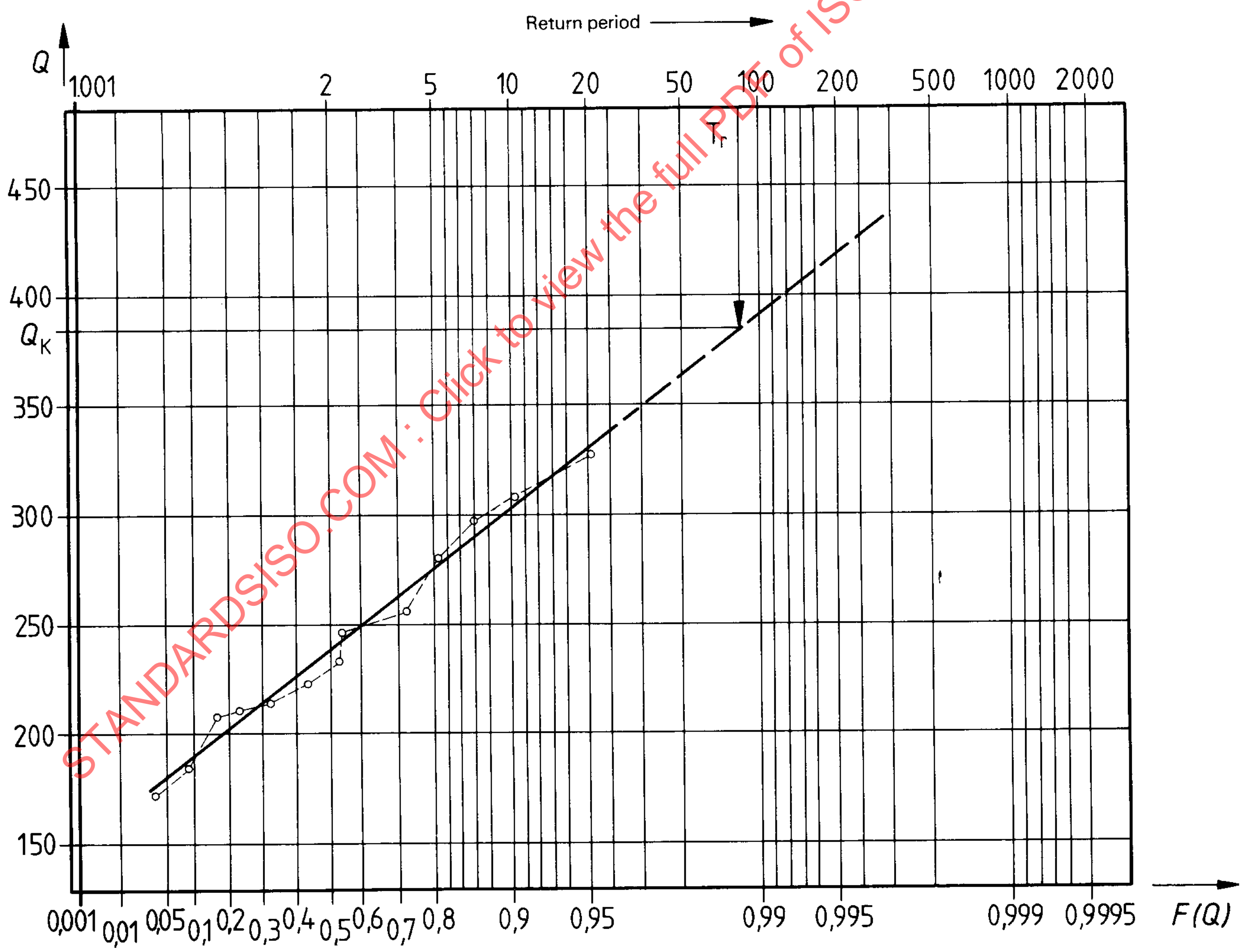
Similar methods are applicable when uniform values of Q_K are assumed to apply throughout a geographical region.



a) **Action process**



b) **Probability function** $F(Q)$



c) **Plotted observations for external distribution type 1**

Figure 3 — Procedure in determining characteristic values

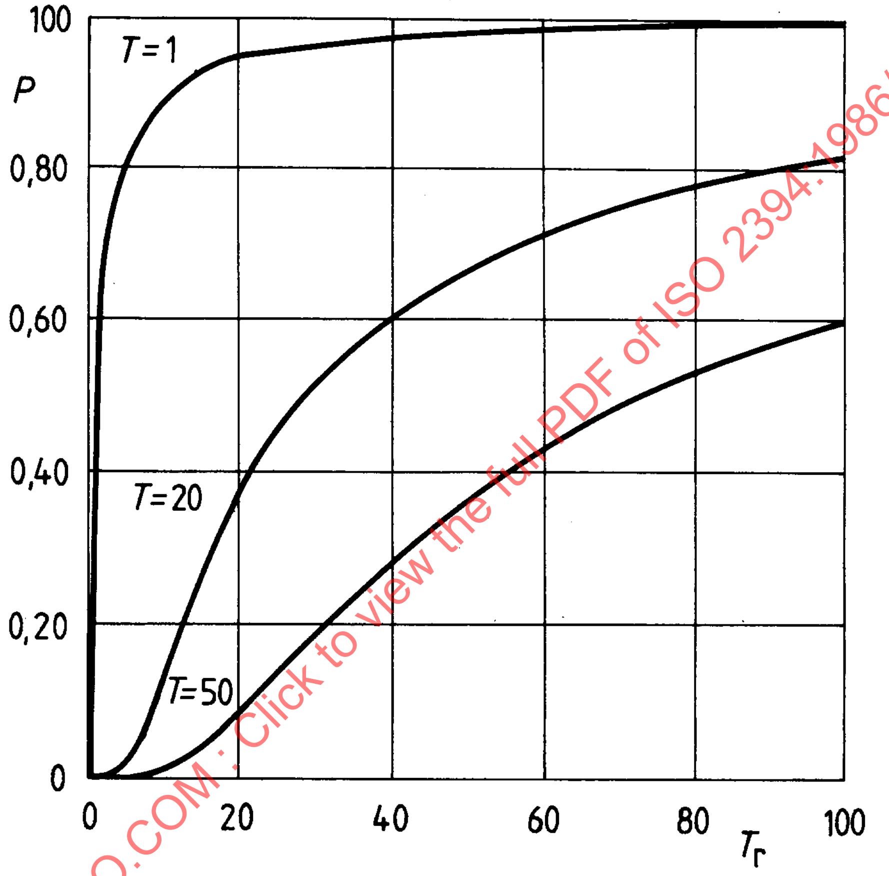


Figure 4 — Relations between return period T_r and the probability, p, that the characteristic value will not be exceeded during the reference period T

Annex E

Principles for the determination of quasi-permanent and frequent values of variable actions

E.0 Field of application

This annex concerns the choice of quasi-permanent and frequent values of variable actions to be used in checking for serviceability limit-states and sometimes also in checking for ultimate limit-states.

E.1 Principles

E.1.1 General conditions concerning actions and action observations

The principles described are intended for the simple case when the action (or the event causing the action) can be described by a one-dimensional stochastic process.

The action observations are assumed to cover a total observation period which should be chosen as long as possible. It is further assumed that the observations of the process are made continuously during certain observation periods, so that the results can be expected to be representative. Continuous observation means that all values above a certain level are observed. The level should be chosen so that only values of no interest are deleted.

In many cases, it is not possible or reasonable (from an economic point of view) to make observations of actions in this way. Then it is necessary to simplify the procedure and to complete the data obtained by judgement. However, for the descriptions in E.1.2 and E.1.3, it is assumed that the procedure is in accordance with this description.

E.1.2 Evaluation of quasi-permanent values

For each observation period, the quasi-permanent value $\psi_2 Q_K$ is determined so that the corresponding total duration above $\psi_2 Q_K$ is a certain acceptable portion μ of the length t_o of the observation period. With notations according to figure 5, this means

$$\sum_{i=1}^{n} t_i = \mu t_o$$

The values of $\psi_2 Q_K$ obtained during the different observation periods should be mutually compared and compared also with the value of $\psi_2 Q_K$ obtained for the sum of all observation periods regarded as a single period. The aim of the comparisons is an approximate evaluation of systematic variations.

The value of μ may be different for different types of actions and different design situations. Normally $\mu \leqslant 0,5$.

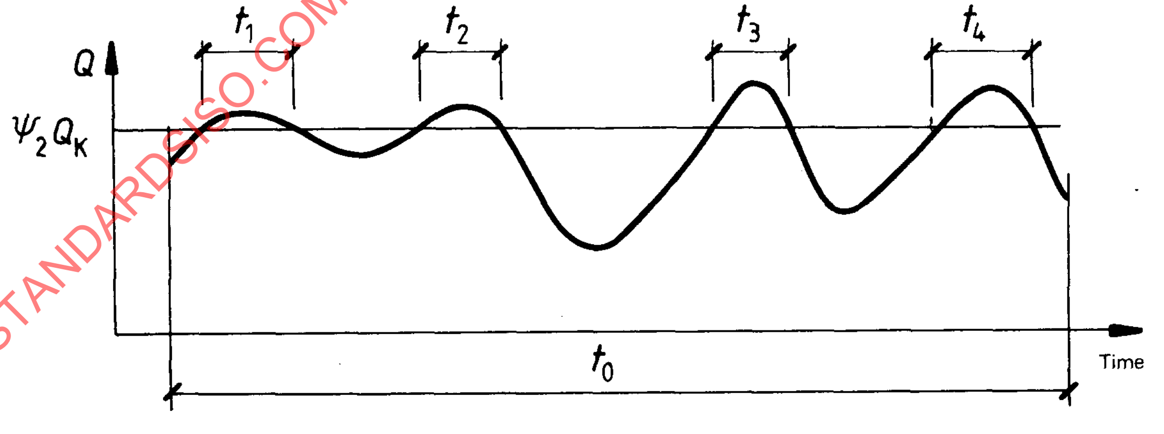


Figure 5 — Quasi-permanent values

E.1.3 Evaluation of frequent values

Depending on the type of action and on the way the requirement in a serviceability limit-state is given, the frequent value of a variable action may be determined in one (or both) of the followings ways.

a) A frequent value is determined on the basis of the duration according to the same principles which are given in E.1.2. However the value of μ is chosen considerably smaller.

b) A frequent value is determined on the basis of the average (average during t_0) upcrossing rate. Dependent on the requirements, the upcrossing rate corresponding to frequent values can range within very wide limits. Their values will often be determined by economic considerations.

Two types of cases can be distinguished, when the serviceability requirements are not fulfilled :

— damage on building parts (for example cracking);

— bad function (for example unpleasant vibrations).

The values of the actions may be quite different in these two cases. In the case of damage the occurrence of actions with high values is important and the frequent value should be determined acccording to b). In the case of bad function the time during which the value of the action is above a certain limit is important and the frequent value should be determined according to a).