



Actions on structures

Actions sur les structures

Technical Report 6116 was drawn up by Technical Committee ISO/TC 98, *Bases for design of structures*, and approved by the majority of its members. The reason which led to the decision to publish this document in the form of a Technical Report rather than an International Standard is the impact of the revision of ISO 2394, *General principles for the verification of structures*, undertaken by TC 98. The future International Standard will be based partly on this Technical Report which will probably form an integral part of the revised text of ISO 2394.

0 Introduction

This document which has been prepared as a contribution towards the revision of ISO 2394-1973, *General principles for the verification of the safety of structures*, is based on principles worked out by the Joint Committee on Structural Safety (JCSS), taking into account other relevant documents such as the CEB Model Code, CMEA Standards, etc. This document is published as a Technical Report because it covers only some of the problems which enter into the content of ISO 2394, and because the rules for establishing design values and combination values of actions given in this document are closely related to the principles of verification of structural safety currently under review. The document points out the existence of divergences in approach between regional organizations on standardization.

It is hoped to review and possibly transform this document into a standard after the agreement on the new version of ISO 2394 has been reached.

During the preparation of this document care was taken to weigh off the physical and theoretical soundness versus clarity and simplicity. The flexibility of the document which ensures its acceptability to all member bodies, is achieved by the introduction of a large number of decision parameters. These are :

- the reference period T and the probability of non-exceedance p for the characteristic values;
- the partial safety coefficient γ_{fu} for the ultimate limit states;
- the coefficients ψ_0 and γ_{fu} for combination values;
- the number r_1 of variable actions for fundamental combinations;
- the fraction c_1 and the coefficient γ_{fs} for frequent values;
- the fraction c_2 and the coefficients γ_{fu} and γ_{fs} for quasi-permanent values;
- the number r_2 of variable actions for long-term combinations.

The adoption of these parameters and their numerical values are left to the discretion of national code committees. A proper calibration of decision parameters should be carried out for those rare situations which — for the sake of simplicity — do not appear explicitly in this document (service value and some rare combinations of actions for the serviceability limit states).

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1 Scope and field of application

The aim of this document is to create a common basis for the determination of actions for the verification of safety and serviceability of structures.

The document concerns building and civil engineering structures whatever the nature of the material used.

2 Terminology

An action F is :

- a) an assembly of concentrated or distributed forces acting on the structure (direct actions), or
- b) the cause of imposed or constrained deformations in the structure (indirect actions).

An action is considered to be *one* single action if it can be assumed as being stochastically independent, in time and space of any other action acting on the structure.

NOTE — Actions, however, often occur simultaneously and they may be stochastically dependent to some extent. For the sake of calculation, it is more convenient to treat them as single actions. The problem of stochastic dependence may be treated as a special case. To facilitate the calculation of the action effects, it may be convenient to regroup several analogous elementary actions into one composite action or to resolve certain actions into a sum or difference of several components.

Actions and their random variations should normally be established on the basis of reliable observations, tests, or from data supplied by manufacturers of material, equipment, etc.

Other sources of information, for example, judgement on the type of use, legal or physical constraints, may also be taken into account.¹⁾

3 Qualitative classification of actions

3.1 General considerations

Actions may be classified according to the variation of their magnitude with time and/or space, or according to the effects of the actions on the structure (static or dynamic).

NOTE — Actions may be further classified according to other criteria.

3.2 Classification of actions according to the variation of their magnitude with time

Actions are divided — according to their variation in time — into :

3.2.1 Permanent actions, G , which are likely to act throughout a given design situation²⁾ and for which variation in magnitude with time are negligible in relation to the mean value; or those for which the variation is in one sense and the actions attain some limiting values.

The permanent actions include :

- a) the weight of structures themselves (except possibly certain parts of this weight during certain phases of construction);
- b) the weight of superstructures when appropriate;
- c) the forces applied by earth pressure, resulting from the weight of soil;
- d) the deformations imposed by the mode of construction of the structure;

1) In existing documents, values obtained within this group of information are described as “nominal values”.

2) For any structure it is generally necessary to consider several distinct design situations, for example consecutive stages of construction, normal use, changes in use, accidents etc. Separate safety checking is required for each design situation.

- e) the actions resulting from shrinkage of concrete, and distortions due to welding;
- f) the forces resulting from water pressure when appropriate;
- g) the actions resulting from support settlements and mining subsidence;
- h) prestressing forces.

3.2.2 Variable actions, Q , which are unlikely to act throughout a given design situation or for which variations in magnitude with time are not negligible in relation to the mean value.

The variable actions include :

- a) loads due to use and occupancy;
- b) certain parts of the weight of structures themselves during certain phases of construction;
- c) erection loads;
- d) all moving loads and their effects;
- e) wind loads;
- f) snow loads;
- g) ice formation;
- h) earthquakes¹⁾;
- j) the effects of variable level of water surface, when appropriate;
- k) temperature changes;
- m) wave loads.

For some materials it is useful to distinguish between variable actions of long and short duration, depending upon the behaviour of the structure on which they are acting.

3.2.3 Accidental actions, F_a , the occurrence of which, in any given structure and with a significant value, is unlikely for a period of time under consideration.

In the total population of structures only a limited number of structures will be exposed to an accidental action.

The accidental actions include :

- a) collisions;
- b) explosions;
- c) subsidence of subsoil;
- d) tornados in regions not normally exposed to them;
- e) earthquakes¹⁾;
- f) fire;
- g) extreme erosion.

1) Earthquakes may be considered either as a variable action or as an accidental action.

3.3 Classification of actions according to their variation in space

Actions are divided — according to their variation in space — into two groups :

- a) fixed actions, which have a fixed, spatial distribution over the structure, so that the magnitude of the action is unambiguously determined for the whole structure if it is given for one point;
- b) free actions, which may have arbitrary spatial distribution over the structure within given limits.

Actions which cannot be defined as belonging to either of these two groups may be considered as consisting of a fixed part and a free part.

The treatment of free actions needs consideration of different load cases. A load case is determined by fixing the configuration of each of the free actions.

NOTE — In some cases it is necessary to distinguish fixed actions and actions which are movable or act in a probabilistic way at certain points or on certain parts of structures. In such cases and in the absence of a more detailed study, it is generally agreed that such actions are separated into different elementary actions; those applied to points or parts recognized, *a priori*, as the most unfavourable, and those applied to other parts.

3.4 Classification of actions according to the structural response

According to the way in which the structure responds to an action it is distinguished between :

- a) static actions, which are applied to the structure without causing significant acceleration of the structure or structural member;
- b) dynamic actions, which cause significant acceleration of the structure.

Whether or not the action is regarded as a dynamic one is thus dependent on the structure.

NOTE — For simplification, dynamic actions may be often treated as static actions, dynamic effects which depend on the behaviour of the structure, being taken into account by an appropriate increase in the magnitude of actions.

4 Quantitative representation of actions

4.1 Representative values

An action is specified by its representative value. Each action may have several representative values. The main representative value is the characteristic value of an action. Representative values may also be used to study the effects resulting from frequent or long-term application of an action (frequent and quasi-permanent values). Other representative values may be values for a combination of actions (combination values). It is also possible, in the alternative approach, instead of using these combination values, to modify the safety factors (see 4.3.4).

The characteristic value F_k of an action is a value with an accepted probability p of not being exceeded towards unfavourable values during some reference period, having regard to the intended life of the structure and to the duration of the design situation.

In some cases an action may have two characteristic values : upper and lower. In cases where the effect of a reduction in the action is more dangerous for the structure, the lower values should be taken as the more unfavourable.

4.2 Representative values of permanent action, G

All representative values of permanent actions, G , are in general assumed to be equal to the characteristic values.

- a) The weight, G_o , of structures themselves is represented, in general, by a unique value calculated from the drawings of the project and the mean unit weight of the materials;
- b) The weight of non-structural elements may be represented, where appropriate, by two values, upper and lower, assessed by taking into account all variations which are reasonably foreseeable.

NOTE — For many structures, only the maximum values of weight of non-structural elements are relevant for design. The minimum value of the weight of certain non-structural elements is often taken as zero.

- c) The actions of earth pressure are in the present state of knowledge represented in the same manner, as in b) above.

NOTE — For many structures, only the maximum value of the active earth pressure, and the minimum value of the passive earth pressure, are relevant for design.

- d) The actions of pre-stress may be represented by two characteristic values, an upper and a lower; both values depend on the time elapsed since pre-stressing.

- e) The deformations imposed by the mode of construction of the structure and by shrinkage, are normally represented by unique values.

NOTE — However, the shrinkage varies with time, and the action of shrinkage during a certain interval of time may be represented by taking into account the values calculated at the beginning and the end of this interval of time.

- f) The actions due to settlement and mining subsidence are represented by two values, an upper and a lower which is often zero.

NOTE — Support settlement is generally a composite action representing the global effect of the settlements of various supports. Mining subsidence is generally a succession, sometimes complex, of several forces or imposed deformations. Consideration should be given to possible differential settlement which may be positive or negative.

4.3 Representative values of the variable actions

Representative values of the variable actions may be, in general, all those given in 4.1.

4.3.1 Characteristic values, Q_k , of variable actions are determined by the general definition given in 4.1.

NOTE — If an action satisfies certain conditions of stability, the probability p of non-exceedance during the reference period (see 4.1) may be alternatively expressed by the corresponding return period (mean return period).

Various statistical procedures for determination of characteristic values may be used. One example of such a procedure is given in annex A.

For certain actions dependent on use, the characteristic values may be taken as those values which the users are expected not to exceed.

4.3.2 The representative frequency value

The frequency value $\psi_1 F_k$ of a variable action may be determined so that the total duration T_1 of its exceedance constitutes a small portion $c_1^{(1)}$ of the reference period T ;

$$T_1 = c_1 T$$

A value of an action, which has a significant number of occurrences but a value of c_1 below the specified one, should nevertheless be taken as the frequency value. The same applies for a value which is exceeded frequently, regardless of numerical value of the coefficient c_1 .

4.3.3 The representative quasi-permanent value

The quasi-permanent value $\psi_2 F_k$ of a variable action may be determined so that the total duration T_2 of its exceedance constitutes a large portion $c_2^{(2)}$ of the reference period T :

$$T_2 = c_2 T$$

1) For many types of actions where the relevant data are available (for example, stationary normal processes), this is equivalent to the condition :

$$\psi_1 F_k = q_m + k_1 s_q$$

where q_m and s_q are the mean and standard deviation of the instantaneous values of the action, k_1 is a coefficient depending on the chosen value of c_1 (see annex B). The value of c_1 may be taken, for example, as 0,05.

2) For many types of actions this is equivalent to the condition :

$$\psi_2 F_k = q_m + k_2 s_q$$

Usually, the value of c_2 will be taken as equal to or greater than 0,5. For $c_2 > 0,5$ the coefficient k_2 is in most cases negative.