Principles of limit state design

The assignment of a structure to a particular reliability classification requires the selection of the relevant safety requirements and the selection of appropriate standards of control and maintenance.

In order to control the effects of human error and negligence, higher control levels should generally be required for higher safety classes (corresponding to a greater risk to life).

2. PRINCIPLES OF LIMIT STATE DESIGN

2.1 Limit states

The structural performance of a whole structure or part of it should be described with reference to a limited set of limit states beyond which the structure no longer satisfies the design requirements.

Limit states can be regarded as a discretisation of a more general and often continuous loss function.

The limit states are classified into the following two categories, which in turn may be subclassified:

a) the ultimate limit states, which are those corresponding to the maximum load carrying capacity or where exceedande results in complete unserviceability.
b) the serviceability limit states, which are those related to the criteria governing normal use.

Ultimate limit states may for example correspond to:

- loss of static equilibrium of the structure, or of a part of the structure, considered as a rigid body (overturning).
- rupture of critical sections of the structure due to exceedance of the material strength (in some cases reduced by repeated loading) or by deformations.
- transformation of the structure into a mechanism (collapse).
- loss of stability (buckling etc).
- qualitative change in the configuration of the system.
- states which prevent the full use of the structure until a damaged part has been repaired. Such states may occur by plastic deformation of the material, creep or excessive cracking.

Serviceability limit states may for example correspond to:

- deformations which affect the efficient use of a structure or the appearance of structural or non-structural elements.
- excessive vibrations producing discomfort or affecting non structural elements or equipment (especially if resonance occurs).
- local damage (including cracking) which reduces the durability of a structure or affects the efficiency or appearance of structural or non-structural elements.

2.2 Design

2.2.1 General

All relevant limit states should be considered in design. A calculation model should be established for each specific limit state; this model should incorporate appropriate variables allowing for the uncertainties with respect to actions, the response of the structure as a whole and the behaviour of individual elements and materials of the structure.

The method of partial coefficients is described in chapter 5 and can generally be used for the verification of reliability.

It may also be possible to verify reliability according to a probabilistic method[1]. Its level of sophistication should be governed by the amount of knowledge concerning the nature and magnitude of the uncertainties. Furthermore, a probabilistic method is theoretically indispensable in determining partial coefficients.

2.2.2 Design situations

For any structure it is generally necessary to consider several distinct design situations. Corresponding to each of these design situations there may be different structural systems, different reliability requirements, different design values, different environmental conditions, etc. Separate reliability checking

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[1] See for example: CEB-FIP Model Code for Concrete Structures, COMITE EURO-INTERNATIONAL DU BETON (CEB), Volume I, Appendix 1, Paris, May 1978.

is required for each design situation.

The design situations may be classified as

- persistent situations having a duration of the same order as the life of the structure
- transient situations, having a shorter duration and a high probability of occurrence
- accidental situations (during or after an accident), generally having a short duration and a low probability of occurrence.

For example accidental situations may be associated with:

- fire
- impact
- important local damage.

Temporary situations may be used as a concept that includes transient situations and accidental situations.

2.2.3 Design requirements

For persistent and transient situations, all parts of a structure and the structure as a whole should be designed for relevant ultimate limit states and relevant serviceability limit states.

In general for accidental situations, the main structure alone should be designed only for relevant ultimate limit states.

2.2.4 Robustness requirements

The main structure should normally be designed in such a way that it should not subsequently be damaged to an extent disproportionate to the extent of the original incident. This requirement may be achieved by:

a) designing the structure in such a way that if any single load bearing member becomes incapable of carrying load this will not cause collapse of the whole structure or any significant part of it

or

b) where necessary, ensuring (by design or by protective measures) that no essential load bearing member can be made ineffective as a result of an accident.