PRINCIPLES OF EARTHQUAKE RESISTANT DESIGN

by

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SYNOPSIS

A set of principles is presented to be used as a check-list in code writing and structural design. As earthquake resistant design should be viewed within the general framework of planning and design, most of the principles are of general character and aim to express modern tendencies in structural design.

INTRODUCTION

Several international bodies are active in improving and unifying structural design and construction codes ((1) to (6)). Some of these bodies are particularly concerned with earthquake resistant design ((4) to (6)). It is recognised that international codes shall play a very important rôle in worldwide construction in the near future. The main object of this paper is to contribute to the discussion of the principles on which these codes should be based.

The paper is presented as a series of simple and precise statements. Some of them may be controversial. Others may seem obvious. However, instances of cases in which they were not followed are numerous. The references associated to the principles may serve further to justify the statements and to exemplify cases in which the principles were not followed.

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PRINCIPLES

P1 - Design codes should not hinder progress in design and construction methods.

P2 - Design codes should reflect present knowledge. Codes should include a variety of design procedures making it possible to adjust the accuracy and difficulty of the procedures to the importance of the problems and the technical development of the societies concerned (7).

P3 - Structural design should be viewed as a part of the broader activity of planning. Interdependence of general planning, structural design, construction methods and use should be taken into account (8).

P4 - Structural reliability should be discussed as a socio-economic problem. Points of view of authorities, owner, designer, builder, and user should be considered and harmonized.

P5 - Owing to the difficulty and shortage of the information required to base design on optimal decision rules minimizing generalized costs (or maximizing utilities), it is accepted that safety be checked with respect to a set of limit states. These should be defined and classified according to the types of the structural behaviour of and resulting damage in the structure ((1) and (2)). Classification based on the intensity of the actions is unsuitable (5).

P6 - Design should be based on limiting the probability of different limit states (ultimate and serviceability) being surpassed. This probability should refer: for a ultimate limit state, to a single occurrence of this; for serviceability limit states,to the limit state being surpassed during given intervals of time (or fractions of the reference period). In particular cases serviceability limit states may refer to very short durations, which can be assimilated to single occurrences (1).

P7 - Defining the safety of a structure in a given site should be viewed as a single problem, not to be separately dealt with for each type of action and each type of member ((1), (4) and (5)).

P8 - The range of applicability of safety parameters indicated in codes (partial factors, γ; reliability indices, β; probabilities of failures, P_f) should be clearly stated and should cover usual situations. Refinements of these parameters to take into account: cost of failure, attenuation cost, material and workmanship control, loads control, design accuracy, etc., should make possible an undistorted consideration of these different aspects without disregarding the most important ones (3).

P9 - Climatic actions, in particular snow, wind and earthquakes, vary from region to region, but structural design can be based on common reliability levels in most regions.

Special cases in which actions may be extremely severe (for instance zones of extremely high seismicity) should be separately dealt with according to special rules (5).

P10 - Actions to be used in design should be defined by idealized models, which characterize the actions independently of the structure. It should clearly be stated separately how to deal with interaction problems (9).

P11 - The need to have different levels of sophistication in design justifies that actions are also defined by various models. These should have a common basis, it being clearly indicated how the simpler can be derived from the more refined ones ((9) and (10)).

P12 - Variable actions cannot be quantified without specifying the period of time to which extreme values refer. This period of time has not to equal the expected life of the structure. It should be chosen as a reference. This choice should take into account aspects such as: usual values of actualization (interest) rate to be applied to damage cost; uniformity of the probability of failure of structures where permanent and variable actions are not equally important; mean duration of human life; duration anticipated for the structure. The reference period of 50 years is at present accepted as standard (7).

P13 - Models of variable actions should be such as to allow easily to transform extreme values in the standard reference period into extreme values within other reference periods ((9) to (11)).

P14 - Models of actions should be developed bearing in mind that owing to the variety of limit states consideration should be given not only to extreme values during the reference period but also to times above given intensity levels and numbers of cycles between given limits (11).

P15 - Models of actions should distinguish between controlable (in general man-produced) actions and uncontrolable (in general climatic) actions (12).

P16 - Safety should be checked for combinations of actions defined according to probabilistic criteria (12).

P17 - For checking ultimate limit states, the basic concept of the combination of actions consists in taking one at the time the extreme value (in the reference period) of any of them, all the other variable actions being reduced. The rules for reducing the combined actions should be clearly stated in the codes ((7) and (12)).

P18 - For checking serviceability limit states it is recommended to define standard durations, e.g. 50% and 5% of the reference period,and to derive combination rules in order that combined actions are mean values only exceeded during the standard durations (1).

P19 - When dealing with earthquake actions serviceability should also be checked to single occurrences, thus disregarding duration ((5) and (13)).

P20 - Event-type models of actions should include three types of modelling: occurrence of the event, modelling at the source, and modelling at the site (14).

P21 - The application of the preceding principle to earthquake actions leads to distinguish: i) the occurrence of earthquakes, to be modelled according to, for instance, a Poisson process; ii) the vibration at the focus, to be modelled by a white noise; and iii) the vibration at the site, to be modelled by a filtered Gaussian process ((9) and (10)).

P22 - Occurrence models cannot be split from models at the source and at the site without introducing intensity measures. These should consist in parameters which together with other assumptions define the processes.

Magnitude and peak acceleration and velocity are usually adopted as intensity measures at the focus and at the site (14).

P23 - Bed-rock vibrations estimated at each site by general studies on seismicity have to be transformed into vibrations at the surface by the consideration of local soil conditions. Non-linear behaviour of soils may be important and should not be disregarded ((9) and (10)).

P24 - Response spectra should be viewed as an alternative way of expressing soil vibration.They should be related to the more fundamental descriptions by random vibrations (such as power spectral density of acceleration) (13).

P25 - The earthquake intensities to be used in design should derive from a Bayesian amalgamation of all information including past observed seismicity, sismo-tectonics and analogies with other regions. Unbiased estimates of seismicity should be used without any consideration of types of structural behaviour and, particularly, of structural ductility (13).

P26 - Coefficients of simplified design methods based on equivalent static forces should be derived from more accurate descriptions of seismic actions. The simplifying assumptions adopted should be indicated (13).

P27 - For combinations of actions including earthquakes, checking safety for ultimate limit states can be carried out in terms of ultimate displacements or ultimate action-effects. However, the non-linear relationship between action effects and displacements must be taken into account (14).

P28 - The reduction of seismic action effects by means of ductility factors is a simple way to take non-linear behaviour into account. It should not be forgotten however that ductility factors also apply to other than seismic action effects. Their numerical values are very sensitive to many factors such as construction types and materials, detailing, other simultaneous action effects, amplitude and number of action effect cycles ((13) and (14)).

P29 - Earthquake actions to be combined with other types of actions should include vibrations in horizontal and vertical directions, as well as torsional vibrations. Simplifying assumptions based on probabilistic criteria may be adopted to decouple the components. Pending on distance to focus and type of structure vertical components may be disregarded.

P30 - Proper detailing is as important as sound structural concept and design.

P31 - Earthquake acts on the construction. Construction errors due to improper control and poor materials and workmanship well show up. This is the experience of past earthquakes. Avoid it.

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