TITLE 1. DESIGN BASIS

CHAPTER 2

SAFETY CRITERIA AND DESIGN BASIS

Article 6. Safety criteria

6.1 Principles

The demands of the safety and stability requirement, as well as those relating to the aptitude for service requirement may be expressed in terms of the overall probability of failure, connected with the reliability index, as indicated in 5.1.

The required reliability is ensured in this Code by means of the adoption of the Limit States method as laid down in Article 8. This method permits the random nature of the stress, strength and dimensional variables having an impact on the design to be taken into account in a simple fashion. The design value of a variable is obtained from its main representative value, assessed by means of its corresponding partial safety factor.

The partial safety factors do not take into account the influence of possible gross human errors. These faults must be avoided by means of appropriate quality inspection mechanisms which must cover all activities relating to the design, construction, use and maintenance of a structure.

6.2 Structural checking through design

Structural checking through design represents one of the possible measures to guarantee the safety of a structure and is the system proposed in this Code.

6.3 Structural checking through testing

In cases in which the rules of this Code are not sufficient or where the results of tests may give rise to a significant economy in relation to a structure, the possibility of addressing the structural dimensioning through testing shall also exist.

This procedure is not explicitly implemented in this Code and specialised literature should therefore be consulted. In any case, the planning, the execution and the assessment of the tests must take place at the reliability level laid down in this Code.

Article 7. Design situations

The design situations to be considered are those indicated below:

- Persistent situations, which correspond to the normal conditions of use of he structure.
- Temporary situations, such as those arising during the construction or repair of the structure.

- Accidental situations which correspond to exceptional conditions applicable to the structure.

Article 8 Basis of design

8.1 The Limit States design method

8.1.1 Limit States

Limit States are defined as those situations in which, when exceeded, it may be considered that the structure does not fulfil one of the functions for which it has been designed.

For the purposes of this Code, the Limit States shall be classified as:

- Ultimate Limit States
- Serviceability Limit States
- Durability Limit State

It must be checked that a structure does not exceed any of the Limit States previously laid down in any of the design situations indicated in Article 7, taking the design values of the actions, the characteristics of materials and geometric data into account.

The checking procedure for a certain Limit State consists in determining, on the one hand, the effect of the actions applied to the structure or part thereof and, on the other, the response of the structure for the limit situation being studied. The Limit State shall be guaranteed if it is verified, with a sufficient reliability index, that the structural response is no lower than the effect of the applied actions.

To determine the effect of the actions, the combined design actions according to the criteria laid down in Chapter 3 and the geometric data as defined in Article 16 must be considered, and a structural analysis carried out in accordance with the criteria laid down in Chapter 5.

For the determination of the structural response, the various criteria laid down in Title 5 should be considered, taking the design values of the materials and the geometric data into account pursuant to the provisions of Chapter 4.

In the case of the Durability Limit State, the environmental aggressivity pursuant to Article 8 of this Code must be classified and an efficient strategy implemented pursuant to Title 4 of this Code.

8.1.2 Ultimate Limit States

The designation Ultimate Limit State covers all Limit States giving rise to the failure of the structure, due to a loss in equilibrium, collapse or breakage thereof or part thereof. Ultimate Limit States must be considered as being those due to:

- failure due to excessive plastic strains, breakage or loss in stability of the structure or part thereof;
- loss in equilibrium of the structure or part thereof, considered to be a rigid solid;
- failure due to the accumulation of strains or progressive cracking under repeated loads.

In the checking of the Ultimate Limit States which include the breakage of a section or component, the condition must be satisfied

$$R_d \geq S_d$$

where:

R_d Design value of the structural response.

S_d Design value of the effect of actions.

For the assessment of the Equilibrium Limit State (Article 41) the following condition must be satisfied

$$E_{d,estab} \geq E_{d,desestab}$$

where:

$E_{d,\,estab}$ Design value of the effects of stabilizing actions.

$E_{d,\,desestab}$ Design value of the effects of destabilizing actions.

The Fatigue Limit State (Article 48) is related to the damage which may be suffered by a structure as a result of repeated variable stresses.

When checking the Fatigue Limit State, the following condition must be met:

$$R_F \geq S_F$$

where:

R_F Design value of the fatigue strength.

S_F Design value of the effect of fatigue actions.

8.1.3 Serviceability Limit States

The designation Serviceability Limit States covers all Limit States for which the required functionality, comfort or aspect requirements are not fulfilled.

When checking the Serviceability Limit States, the following condition must be met:

$$\boldsymbol{C_d \geq E_d}$$

where:

C_d Permitted limit value for the Limit State to be checked (strains, vibrations, crack opening, etc.).

E_d Design value of the effect of actions (stresses, vibration level, crack opening, etc.).

8.1.4 Durability Limit State

Durability Limit State shall be understood to mean the Limit State produced by chemical and physical actions other than the loads and actions of the structural analysis which may deteriorate the characteristics of the concrete or reinforcements to unacceptable limits.

The checking of the Durability Limit State consists in verifying that the following condition is met:

$$t_L \geq t_d$$

where:

t_L Time needed for the aggressive agent to produce an attack or significant degradation.

t_d Design value of the service working life

8.2 Additional design basis aimed to durability

Before embarking on the design, the type of environment defining the aggressivity to which each structural element is to be subject must be identified.

To achieve an adequate durability, and in accordance with the type of environment, a strategy consistent with the criteria laid down in Chapter VII must be set out in the design.

8.2.1 Definition of type of environment

The type of environment to which a structural element is subject is defined by the set of physical and chemical conditions to which it is exposed, and which may give rise to its deterioration as a result of effects which differ from those relating to the loads and stresses considered in the structural analysis.

The type of environment is defined by the combination of:

- one of the general exposure classes in the presence of the corrosion of the reinforcements pursuant to 8.2.2.
- the specific exposure classes relating to the other deterioration processes appropriate to each case, from amongst those laid down in 8.2.3.

Should a structural element be subject to any specific exposure class, all of the classes must be included in the designation of the type of environment, joined together using the addition sign "+".

When a structure contains elements with different types of environment, the Designer must define groups with structural elements presenting similar environmental exposure characteristics. In order to do this, wherever possible, elements of the same type shall be grouped together (for example, piers, cover beams, foundations, etc.), with care also taken that the criteria followed are consistent with the aspects appertaining to the construction phase.

For each group, the class, or, where appropriate, the combination of classes, shall be identified which define the *aggressivity* of the environment to which its elements are subject.

8.2.2 General classes of environmental exposure in relation to the corrosion of reinforcements

Generally speaking, every structural element is subject to a single general exposure class or subclass.

For the purposes of this Code, general exposure classes are defined as those which refer exclusively to processes related to the corrosion of reinforcements and are laid down in Table 8.2.2.

In the case of non-submerged marine structures, the Designer may, under his own responsibility, adopt a general exposure class different to III provided that the distance to the coast is greater than 1.5 km and he has experimental data relating to nearby structures already in existence and located in conditions similar to those of the designed structure, as advised.

8.2.3 Specific classes of environmental exposure in relation to deterioration processes other than corrosion.

In addition to the classes laid down in 8.2.2, another series of specific exposure classes related to concrete deterioration processes other than the corrosion of the reinforcements is established (Table 8.2.3.a).

A component may be subject to no, to one or to various specific exposure classes relating to other concrete deterioration processes.

Conversely, a component may not be simultaneously subject to more than one of the subclasses defined for each specific exposure class.

In the case of structures subject to attack by chemicals (class Q), the aggression shall be classified pursuant to the criteria laid down in Table 8.2.3.b.

Table 8.2.2 General exposure classes relating to the corrosion of the reinforcements

GENERAL EXPOSURE CLASS				DESCRIPTION	EXAMPLES
Class	Subclass	Designation	Type of process		
non-aggressive		I	None	- insides of buildings, not subject to condensation, - -plain concrete elements	- structural elements of buildings, including floor slabs, protected against bad weather
Normal	High humidity	IIa	corrosion of origin different from chlorides	- interiors subject to high average relative humidities (> 65%) or to condensation - exteriors in the absence of chlorides, and exposed to rain in areas with an average annual rainfall over 600 mm - buried or submerged elements	- structural elements in non-ventilated basements -foundations, -bridge stirrups, -piers and decks in non-waterproofed areas with an average annual rainfall over 600 mm - Waterproofed bridge decks in areas with de-icing salts and average annual rainfall over 600 mm concrete elements, exposed to bad weather or in the covers of buildings in areas with an average annual rainfall over 600 mm - Floor slabs in toilets, or inside kitchens and bathrooms, or under non-protected cover
	Average humidity	I Ib	corrosion of origin different from chlorides	- exteriors in the absence of chlorides, subject to the action of rain water, in areas with an average annual rainfall under 600 mm	- structural elements in external constructions protected from rain - bridge piers and decks, in areas with an average annual rainfall under 600 mm
Marine	Aerial	IIIa	corrosion by chlorides	- elements of marine structures, above the high tide level - element exteriors of structures located close to the coastline (at least 5 km)	- structural elements of buildings in the proximity of the coast - bridges in the proximity of the coast - aerial parts of breakwaters - docks and other coastal defence works port installations
	Submerged	IIIb	corrosion by chlorides	- elements of permanently submerged marine structures, below the minimum low tide level	- submerged areas of breakwaters, docks and other coastal defence works - foundations and submerged areas of bridge piers in the sea
	Tidal and splash zones	Iile	corrosion by chlorides	- elements of marine structures located in the tidal path area	- areas located in the tidal path of breakwaters, docks and other coastal defence works - areas of bridge piers above the sea, located in the tidal path
with chlorides other than from the marine environment		IV	corrosion by chlorides	- non-insulated installations in contact with water which present a high chloride content, not related to the marine - environment non-insulated surfaces exposed to de-icing salts.	- swimming pools and the insides of buildings housing these, - piles of overpasses or passageways in snowy areas - water treatment stations.

Table 8.2.3.a Specific exposure classes relating to other deterioration processes other than corrosion

SPECIFIC EXPOSURE CLASS				DESCRIPTION	**EXAMPLES**
Class	Subclass	Designation	Type of process		
Aggressive Chemical	Weak	Qa	chemical attack	- elements located in environments with contents of chemical substances capable of causing an alteration in the concrete with slow speed (see Table 8.2.3.b)	- industrial installations, with weakly aggressive substances according to Table 8.2.3.b - constructions close to industrial areas, with weak aggressivity according to Table 8.2.3.b
	Average	Qb	chemical attack	- elements in contact with sea water - elements located in environments with contents of chemical substances capable of causing an alteration in the concrete with average speed (see Table 8.2.3.b)	- spars, blocks and other elements for breakwaters - marine structures, in general - industrial installations in general with substances of average aggressivity according to Table 8.2.3.b - constructions close to industrial areas with average aggressivity according to Table 8.2.3b - installations for the carriage and treatment of waste waters with substances of average aggressivity according to Table 8.2.3.b
	Strong	Qc	chemical attack	- elements located in environments with contents of chemical substances capable of causing an alteration in the concrete with fast speed (see Table 8.2.3.b)	- industrial installations, with substances of high aggressivity in accordance with Table 8.2.3.b - installations for the carriage and treatment of waste waters with substances of high aggressivity according to Table 8.2.3.b. - constructions in the proximity of industrial areas, with high aggressivity according to Table 8.2.3b
with frost	without deicing salts	H	attack from freezing-melting	- elements located in frequent contact with water, or areas with an average relative environmental humidity over 75%, and which have an annual probability of over 50% of reaching temperatures below -5°C at least once	- constructions in mountainous areas - Winter resorts
	with deicing salts	F	attack by deicing salts	- elements intended for the passage of vehicles or pedestrians in areas with more than 5 annual snowfalls or with an average minimum temperature in the winter months under 0°C	- bridge decks or passageways in mountainous regions, in which deicing salts are used.
Erosion		E	abrasion cavitation	- elements subject to surface wear - elements of hydraulic structures in which the piezometric quota may fall below the vapour pressure of the water	- bridge piers in very rainy waterways - elements of breakwaters, docks and other coastal defence works subject to strong waves - concrete pavements - high pressure pipelines

Table 8.2.3.b Classification of chemical aggressivity

TYPE OF AGGRESSIVE ENVIRONMENT	PARAMETERS	TYPE OF EXPOSURE		
		Qa	Qb	Qc
		WEAK ATTACK	AVERAGE ATTACK	STRONG ATTACK
WATER	pH VALUE, according to UNE 83.952	6.5 - 5.5	5.5 - 4.5	< 4.5
	AGGRESSIVE CO_2 (mg CO_2/ l), according to UNE-EN 13.577	15 - 40	40 - 100	> 100
	AMMONIUM ION (mg NH_4^+ / l), according to UNE 83.954	15 - 30	30 - 60	> 60
	MAGNESIUM ION (mg Mg^{2+} / l), according to UNE 83.955	300 - 1000	1000 - 3000	> 3000
	SULPHATE ION (mg SO_4^{2-} / l), according to UNE 83.956	200 - 600	600 - 3000	> 3000
	DRY RESIDUE (mg / l), according to UNE 83.957	75 - 150	50 - 75	< 50
GROUND	BAUMANN-GULLY ACIDITY INDEX (ml/kg), according to UNE 83.962	> 200	(*)	(*)
	SULPHATE ION (mg SO_4^{2-} / kg of dry ground), according to UNE 83.963	2000 - 3000	3000 - 12000	> 12000

(*) These conditions do not arise in practice