ACTIONS

CHAPTER III

Article 9 Action classification

The actions considered in the design of a structure or structural element can be classified in accordance with the following criteria:

- Classification according to nature.
- Classification according to variation with time.
- Classification according to variation in space.

9.1 Classification according to nature

Actions may be classified according to their nature into the following groups:

- *Direct actions*. These are actions that are applied directly to the structure. This group includes the structure's own weight, other permanent loads, ~~and~~ imposed service loads, etc.
- *Indirect actions*. These are those imposed deformations or accelerations that are capable of indirectly giving rise to forces. This group includes temperature effects, foundation settlement, rheological action, seismic actions, etc.

9.2 Classification of actions according to variation with time

Actions can be classified according to their variation with time into the following groups:

- *Permanent Actions (G*). These are continuously-acting actions that are constant in both magnitude and position. The structure's own weight , contained elements, fittings and fixed equipment fall within this group.
- *Non-constant Value Permanent Actions (G*)* These are continuously-acting actions that are not constant in magnitude. This group includes those actions that vary as a function of elapsed time, acting in a given direction, and tending to a limiting value, such as rheological actions. Prestressing force (P) may be considered as being of this type.
- *Variable Actions (Q).* These are actions that may or may not act on the structure. Within this group are found the imposed service loads, weather actions, ~~and~~ actions due to the construction process, etc.
- *Accidental Actions (A).* This group consist of actions that are unlikely to occur, but are highly significant. It includes actions due to impacts, ~~and~~ explosions, etc. Seismic effects may be considered to be of this type.

9.3 Classification of actions according to variation in space.

Actions can be classified according to their variation in space into the following groups:

- *Fixed actions*. Those actions that always apply in the same position. This group basically contains actions due to the structural and functional elements' own weight.
- *Free Actions.* These are those actions, the position of which may vary within the structure. This group basically consists of the imposed service loads.

Article 10 The characteristic values of actions

10.1 General

The characteristic value of an action is its main representative value. It may be determined by a mean value, a nominal value or, in cases where it is set through statistical criteria, a value corresponding to a determined probability that it will not be exceeded during a reference period that depends on the service life-span of the structure and the action's duration.

10.2 The characteristic values of permanent actions

For those permanent actions in which significant dispersion is expected or which may be subject to certain variation during the structure's service life, upper and lower characteristic values shall be taken. In other cases it is sufficient to adopt a single value.

In general, for the structure's own weight, a single value deduced from the nominal dimensions and mean specific gravity values will be adopted for the characteristic value. The following density values shall be adopted for concrete elements:

Mass concrete:	2300 kg/m^3
Reinforced and prestressed concrete:	2500 kg/m^3

10.3 Characteristic values of permanent actions with non-constant values

The characteristic values to be used for the determination of rheological actions shall be those corresponding to shrinkage and creep deformations established in Article 39.

10.4 Prestressing action characteristic values

10.4.1 General considerations

In general, the actions due to the prestressing of a structural element are determined from the prestressing forces of the tendons. These actions vary along their length and with time.

The prestressing force is applied to each tendon by means of a jack or tensioning device. This force, where the tendon leaves the anchorage on the concrete side, takes on the value P_0, which is be limited by the values indicated in 20.2.1.

The instantaneous losses of force ΔP_i and the time-dependent losses of force ΔP_{dif} are calculated for each cross-section in accordance with 20.2.2 and 20.2.3. The characteristic value for the prestressing force P_k is calculated from the values P_0, ΔP_i and P_{dif} for each cross-section and moment in time in accordance with 10.4.2

COMMENTS

The force provided by the jack or tensioning device employed in tensioning the tendon is the only one that is known with precision on site or at the factory if suitable control is maintained during the prestressing operations.

The losses of force that are located in both the prestressing elements and in the anchorage, make up a characteristic of the employed prestressing system.

The prestressing force P_0 is, therefore, the load provided by the jack, deducing the system force losses, among which is not included those of wedge penetration if they exist.

10.4.2 Prestressing force characteristic value

The characteristic value of the prestressing force at any cross-section and phase is given by:

$$P_k = P_0 - \Delta P_i - \Delta P_{dif}$$

COMMENTS

There are as many characteristic values for the prestressing force as phases considered in the study of the structure. In particular, it is always necessary to consider the initial value, which corresponds to the initial prestressing phase or application, and the final value, which corresponds to $t = \infty$.. It may be necessary to consider time-dependent losses during intermediate construction phases.

Article 11 The representative values of actions

The representative value of an action is the value of that action as used for limit state verification.

The same action may have one or various representative actions, depending on its type.

The representative value of an action is obtained by multiplying its characteristic value, F_k, by the factor Ψ_i.

$$\Psi_i F_k$$

As representative values of actions, those indicated in the current instructions or standards for actions shall be taken.

COMMENTS

In general, for permanent actions, the representative value is the characteristic value.

For variable actions, the following representative actions may exist, depending on the type of structure and the considered loads.

- Combination value $\Psi_0 Q_k$. This is the value of the action when it acts alone or in combination with another variable action.
- Frequent value $\Psi_1 Q_k$. This is the value of the action that is only exceeded in short duration periods with respect to the structure's service life-span.
- Quasi-permanent value $\Psi_2 Q_k$. This is the value of the action that is exceeded during a large part of the structure's service life-span.

In general, for accidental actions, the representative value is the characteristic value.

Article 12 Design values of actions

The design value of an action is defined as the product of the representative value (Article 11) and a partial safety factor.

$$F_d = \gamma_f \Psi_i F_k$$

where:

F_d The design value of action F.
γ_f The partial safety factor for the action under consideration.

12.1 Ultimate Limit States

The values to be adopted as partial safety factors for actions in Ultimate Limit State verifications are those given in Table 12.1.a, provided that the corresponding action instructions do not indicate otherwise.

Table 12.1.a. Partial safety factors for actions applicable in Ultimate Limit State verifications

TYPE OF ACTION	Persistent or transient situation		Accidental situation	
	Favourable effect	Unfavourable effect	Favourable effect	Unfavourable effect
Permanent	γ_G = 1.00	γ_G = 1.35	γ_G = 1.00	γ_G = 1.00
Prestressing	γ_P = 1.00	γ_P = 1.00	γ_P = 1.00	γ_P = 1.00
Permanent non-constant value	γ_{G^*} = 1.00	γ_{G^*} = 1.50	γ_{G^*} = 1.00	γ_{G^*} = 1.00
Variable	γ_Q = 0.00	γ_Q = 1.50	γ_Q = 0.00	γ_Q = 1.00
Accidental	-	-	γ_A = 1.00	γ_A = 1.00

The factors defined in Table 12.1.a shall be corrected in accordance with Article 95, depending on the level of control over the adopted execution.

In general, for permanent actions, the favourable or unfavourable effect is obtained by weighting all actions of the same origin by the same factor, as shown in Table 12.1.a.

When the results of a verification are highly sensitive to variations in the magnitude of a permanent action from one part of the structure to another, the favourable and unfavourable parts of this action shall be considered as individual actions. This particularly applies to the verification of the Equilibrium Limit State, in which a factor γ_G = 0.9 shall be adopted for the favourable part and γ_G = 1.1 for the unfavourable part in service situations, or γ_G = 0.95 for the favourable part and γ_G = 1.05 for the unfavourable part in construction situations.

For the evaluation of local prestressing effects (anchorage zones, etc.), an action equivalent to the ultimate characteristic prestressing force shall be applied to the tendons.

COMMENTS

For the project of highway bridges, the criteria established by the Instruction on the actions to be considered in the highway bridge project shall be taken into account (IAP).

Strictly speaking, the coefficient γ_P should take on different values of the unit. However, the value γ_P has been fixed at 1.0 for simplicity's sake, taking the following considerations into account:

- For bending, if the prestressing is taken into account as a pre-deformation, the uncertainty in relation to the prestressing force implies a small variation in the evaluation of this pre-deformation with practically no consequences as far as the evaluation of the section's strength capacity is concerned.
- For shear, the prestressing effect is always taken into account with much lower values than those that represent the deformation state of the prestressing steel for ultimate states.

The structural effect produced by imposed deformations depends both directly and significantly on the stiffness conditions of the structure and these, in turn, on the load conditions. In general, for structures with sufficient ductility, for advanced load states, such as those corresponding to ultimate limit states, the stiffness is much less than that of the un-cracked concrete sections usually used for calculating the internal forces~~,~~ and, consequently, these internal forces are generally considerably dampened. In these cases, if the stiffness degradation due to acting exterior actions is not taken into consideration, the effects may be increased by a partial reduced safety factor γ_{G^*}

In accordance with that established in Article 95, the safety factors defined in Table 12.1.a. should be corrected in function of the adopted execution level, so that, when dealing with a persistent or transient situation with unfavourable effects, the values to be adopted for the partial safety factors for the actions should be those established in Table 95.5, which are as follows:

Table 12.1.b

TYPE OF ACTION	Execution control level		
	Intense	Normal	Reduced
Permanent	$\gamma_G = 1.35$	$\gamma_G = 1.50$	$\gamma_G = 1.60$
Prestressed	$\gamma_P = 1.00$	$\gamma_P = 1.00$	—
Permanent non-constant value	$\gamma_{G^*} = 1.50$	$\gamma_{G^*} = 1.60$	$\gamma_{G^*} = 1.80$
Variable	$\gamma_Q = 1.50$	$\gamma_Q = 1.60$	$\gamma_Q = 1.80$

12.2 Serviceability Limit States

The values to be adopted as partial safety factors for actions in Serviceability Limit State verifications are those provided in Table 12.2.

Table 12.2. Partial safety factors for actions, applicable to the evaluation of the Serviceability Limit States

TYPE OF ACTION		Favourable effect	Unfavourable effect
Permanent		$\gamma_G = 1.00$	$\gamma_G = 1.00$
Prestressed	Prestressed reinforcement	$\gamma_P = 0.95$	$\gamma_P = 1.05$
	Post-stressed reinforcement	$\gamma_P = 0.90$	$\gamma_P = 1.10$
Permanent non-constant value		$\gamma_{G^*} = 1.00$	$\gamma_{G^*} = 1.00$
Variable		$\gamma_Q = 0.00$	$\gamma_Q = 1.00$

COMMENTS

Certain serviceability limit states in prestressed structures are very sensitive to the value of prestress force and this depends on the evaluation of the instantaneous and time-dependent losses. The uncertainty in the evaluation of the losses is less when pre-tensioned reinforcement is used and for this reason, the values of γ_P for the serviceability limit states depend~~s~~ on the type of prestressing employed.

Article 13 Combination of actions

13.1 General principles

The possible combinations of actions shall be established for each of the studied situations. A combination of actions consists of a set of compatible actions which shall be considered as acting simultaneously for a given verification.

In general, each combination is formed by the permanent actions, one determinant variable action and one or more additional concomitant variable actions. Any of the variable actions may be determinant.

13.2 Ultimate Limit States

The combinations of actions shall be defined for the various project design situations in accordance with the following criteria.

- Permanent or transient situations:

$$\sum_{j\geq 1}\gamma_{G,j}\,G_{k,j}+\sum_{j\geq 1}\gamma_{G^*,j}\,G^*_{k,j}+\gamma_P\,P_k+\gamma_{Q,1}\,Q_{k,1}+\sum_{i>1}\gamma_{Q,i}\,\psi_{0,i}\,Q_{k,i}$$

- Accidental situations:

$$\sum_{j\geq 1}\gamma_{G,j}\,G_{k,j}+\sum_{j\geq 1}\gamma_{G^*,j}\,G^*_{k,j}+\gamma_P\,P_k+\gamma_A\,A_k+\gamma_{Q,1}\,\psi_{1,1}\,Q_{k,1}+\sum_{i>1}\gamma_{Q,i}\,\psi_{2,i}\,Q_{k,i}$$

- Seismic situations:

$$\sum_{j\geq 1}\gamma_{G,j}\,G_{k,j}+\sum_{j\geq 1}\gamma_{G^*,j}\,G^*_{k,j}+\gamma_P\,P_k+\gamma_A\,A_{E,k}+\sum_{i\geq 1}\gamma_{Q,i}\,\psi_{2,i}\,Q_{k,i}$$

where:

$G_{k,j}$	The characteristic values of the permanent actions.
$G^*_{k,j}$	Characteristic value of the permanent actions with non-constant values.
P_k	Prestressing action characteristic value.
$Q_{k,1}$	Characteristic value for the determinant variable action.
$\psi_{o,i}\,Q_{k,l}$	The representative value for the combination of concomitant variable actions.
$\psi_{1,1}\,Q_{k,1}$	Frequent representative value for the determinant variable action.
$\psi_{2,i}\,Q_{k,l}$	Quasi-permanent representative values of the variable actions with the determinant action or with the accidental action.
A_k	The characteristic values of the accidental action.
$A_{E,k}$	The characteristic value~~s~~ of the seismic action.

In permanent or transient situations where the determinant action $Q_{k,l}$ is not obvious, various possibilities shall be evaluated using different variable actions as determinants.

For building structures, the following simplified criteria may be used for the various design situations.

- Persistent or transient situations.

  a) Situations with a single variable action $Q_{k,1}$

$$\sum_{j\geq 1}\gamma_{G,j}\,G_{k,j}+\gamma_{Q,1}\,Q_{k,1}$$

  b) Situations with two or more variable actions.

$$\sum_{j\geq 1}\gamma_{G,j}\,G_{k,j}+\sum_{i\geq 1}0{,}9\,\gamma_{Q,i}\,Q_{k,i}$$

- Seismic situations:

$$\sum_{j\geq 1}\gamma_{G,j}\,G_{k,j}+\gamma_{A}\,A_{E,k}+\sum_{i\geq 1}0{,}8\,\gamma_{Q,i}\,Q_{k,i}$$

The Fatigue Ultimate Limit State, with the present state of knowledge, requires special verifications which depend on the type of material involved, whether metal or concrete elements, which gives rise to the following particular criteria:

- For fatigue verification of reinforcement and anchoring devices, the exclusive situation produced by the variable fatigue load shall be taken into account, using a γ factor of unity.

- For the verification of fatigue in concrete, the stresses produced by the permanent loads and the variable fatigue load shall be taken into account, using a γ factor of unity for both actions.

COMMENTS

The Standard for Actions in Building currently in force do not define any combination criteria that is directly compatible with the Limit States Method. The defined simplifications constitute a reference for this type of structures.

The variable fatigue actions are defined in the above mentioned Standard as a simplified model of the variable action.

13.3 Serviceability Limit States

For these Limit States, only persistent and transient design situations shall be taken into account. In these situations, combinations of actions shall be defined in accordance with the following criteria:

- Rare combination:

$$\sum_{j\geq 1}\gamma_{G,j}G_{k,j}+\sum_{j\geq 1}\gamma_{G^*,j}G^*_{k,j}+\gamma_P P_k+\gamma_{Q,1}Q_{k,1}+\sum_{i>1}\gamma_{Q,i}\Psi_{0,1}Q_{k,i}$$

- Frequent combination:

$$\sum_{j\geq 1}\gamma_{G,j}G_{k,j}+\sum_{j\geq 1}\gamma_{G^*,j}G^*_{k,j}+\gamma_P P_k+\gamma_{Q,1}\psi_{1,1}Q_{k,1}+\sum_{i>1}\gamma_{Q,i}\psi_{2,i}Q_{k,i}$$

- Quasi-permanent combination:

$$\sum_{j\geq 1}\gamma_{G,j}G_{k,j}+\sum_{j\geq 1}\gamma_{G^*,j}G^*_{k,j}+\gamma_P P_k+\sum_{i\geq 1}\gamma_{Q,i}\Psi_{2,i}Q_{k,i}$$

For building structures, the following simplified criteria may be used for the various design situations.

- Improbable or frequent situation

  a) Situations with a single variable action Qk,1

$$\sum_{j\geq 1}\gamma_{G,j}G_{k,j}+\gamma_{Q,1}Q_{k,1}$$

  b) Situations with two or more variable actions Qk,i.

$$\sum_{j\geq 1}\gamma_{G,j}G_{k,j}+0,9\sum_{i\geq 1}\gamma_{Q,i}Q_{k,i}$$

- Quasi-permanent situation

$$\sum_{j\geq 1}\gamma_{G,j}G_{k,j}+0,6\sum_{i\geq 1}\gamma_{Q,i}Q_{k,i}$$

COMMENTS

In the case of the prestressing action, the favourable or unfavourable effect of this action should be taken into account, in accordance with the limit state being studied.

The Standard for Actions in Building currently in force do not define any combination criteria that is directly compatible with the Limit States Method. The defined simplifications constitute a reference for this type of structures.

Nevertheless for the quasi-permanent situation and in store building, the factor 0,6 proposed in the article could be insufficient and specific studies could be necessary.