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New French seismic code orientations

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ABSTRACT : In 1990 was published in France, recommendations for the design ot structures built in regions prone to Earthquakes. Seismic code is presently being written and a preliminary draft has been achieved in January 91. The paper outlines the basic orientations regarding some sensitive problems mainly when they are different from the Eurocode 8. Among those are the following items :
a) The behaviour factor values for simple structures and hybrid structures such as those braced by walls and portals. How to choose it in relation to steel reinforcement ?
b) Minimum reinforcement : how to choose them ? Differences with EC8 in section and mainly in location ; are they constant all above the above the height ?
c) The lateral forces calculation by a new quasi static method and its validation.
d) Regularitie criteria and their validation - simplifications.
e) Torsion effect - simplifications.
f) Seismic movement for long structures and absence of synchronisation.

1 PREAMBLE

After EL ASNAM Earthquake in 1980 (Algeria) lessons learned from field reconnaissance studies led the French Seismic Commitee to write and publish in 1982 an Appendice to the French Seismic Code published in 1969 and called "PS 69".
In 1990, French Association for Earthquake Engineering (AFPS) published the French Recommendations for Earthquake Engineering : "AFPS 90" which is not a code but a useful guide-line book. In February 1991 a pre-draft of the seismic code for Housing was published. This paper tryes to outline the most advanced items of this futur code.
In 1990, the Seismic Committee published a handbook for low rise non-engineered buildings for housing, and devoted for use by those who are not experienced in Earthquake design.

2 SAFETY AND PROTECTION AGAINST SEISMIC HAZARD - GENERAL PHILOSOPHY.

France is a country which is considered as having a low occurence of seismic hazards. Hence seismic action is analysed for accidental limit state. The aim of the seismic code is to protect mainly human lifes as much as possible. The requirements for structures are that they should be planned, designed and constructed such that they can withstand the actions of the earthquake :
. with a low probability of appearance of damage of structures which lead to reparation
. with a very low probability that a damaged structure becomes unreparable
. with a much lower probability of collapsed constructions.
Hence the requirements for additional seismic measures are :
- drift limitations : H/250, H, being the height of the building
- minimum joint spacing : 40 to 60 mm.

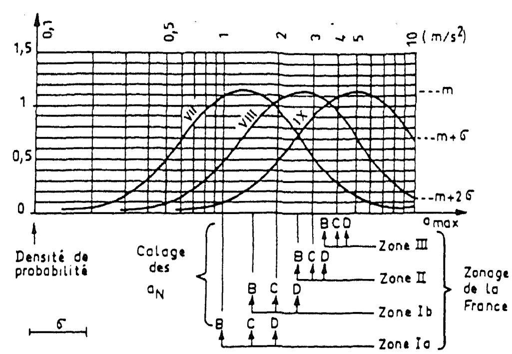


Fig. 1 Correlation between macro seismic intensity and maximum acceleration

SEISMIC ZONES

The method of zoning is based on the development of expectancy maps which contour the "nominal" ground horizontal acceleration a_N (different from effective peak ground acceleration) with return period from 100 to 500 years associated to intensity MERCALLI scale between VII to IX.
A medium zone, such as NICE area on the french riviera, correspond to a_N = 0,25 g for an habitation class of buildings (see Fig. 1).
The values of a_N are specified by the national authority.
The choice made in France for accidental limit state with its economical level leeds to methods of sizing structures and criteria for minimum reinforcement which are necesseraly different from those choosed by E.C.8 or SEOAC and ACI-318. In peculiar the partial

safety factors on materials are :
γ_b = 1,15 in place of 1,50 for concrete
γ_s = 1 in place of 1,15 for steel
γ_F = 1 in place of 1,4 for the Earthquake action.

3 SEISMIC MOTION OF THE GROUND

3.1 Accelerograms

When direct dynamic analysis is needed, excitation may be introduced by means of accelerograms under certain conditions given for their selection.
They can be either natural or artificial. For the last they shall last 10 to 20 seconds for low seismicitry area and 20 to 40 seconds for high seismicitry area [1, § 5.7]

3.2 Reference motion

The seismic motion is defined in a free field at the surface of the site which is the horizontal bedrock. Its intensity is defined conventionally by the parameter aN [1, § 5.3]
The design motion to consider in a given site results from the adaptation of the motion of reference to the particular conditions of the site. Its frequency content is defined by the spectra R (T).

3.3 Site response factor [1, § 5.33] or Topography factor τ

Except if the effect of the topography on the seismic motion is directly taken into account using calculation based on a proper idealization of the relief, a multiplying coefficient τ called site response factor or topography factor will be used.

If one considers a ridge C delimiting a downhill slope of gradient I (tangent of the slope angle) and an uphill slope of gradient i, and if :
- $H \geqslant 10$ m (H being the height of the ridge above the base of the relief)
- $i \leqslant I/3$
Coefficient τ:
a) - takes the value :
$\tau = 1$ for $I-1 \leqslant 0.40$
$\tau = 1 + 0,8\,(I-i-0,4)$ for $0.40 \leqslant I-1 \leqslant 0.90$
$\tau = 1.40$ for $I-1 \geqslant 0.90$

On segment CB of the uphill slope defined by length b of its horizontal projection (expressed in meters) :

$$b = \text{minimum of} \begin{cases} 20\,I \\ \dfrac{H + 10}{4} \end{cases}$$

b) - is given by a linear relation connecting the values 1 and along segments AC and BD, of length :

a = AC = H/3
c = bd = H/4

c) - takes value 1 downhill from point A and uphill from point D.

3,3. Normalized Elastic Spectra

The definition of normalized elastic spectra is founded on the following classifications :

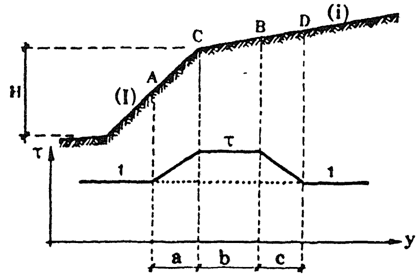
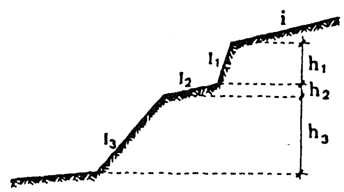


Figure 3 A

The determination of H leaves a large latitude to self-judgment. As an example, one may consider as base of the relief the point above which the general slope of the site becomes inferior to 0.4

The determination of I may also set a few problems if the segment of slope I is of small length. In a situation like the one of figure 3 A, I1 may be replaced by the weighted average :



$$I_m = \frac{\sum h_i I_i}{\sum h_i}$$

Figure 3 B

Figure 3. Topography factor

3,31. Classification of soils

In order to define types of sites, soils are classified in four groups, depending on their mechanical properties, as detailed below :
. Sound rock ;
. Group a : Good to very good mechanical resistance (for instance sands and compacted gravels, marls or stiff, highly consolidated clays) ;
. Group b : Average mechanical resistance (for instance, weathered rocks, medium dense sands and gravels, medium stiff clays or marls ;
. Group c : Low mechanical resistance (for instance, sands or loose gravels, soft clays, weathered chalks, muds).

Knowing one or several of the parameters presented in the following table makes it possible to establish the classification on an objective basis :

TYPE OF SOIL		Static penetration: Resistance (MPa)	SPT: Blow count	Pressuremeter: Modulus (MPa)	Pressuremeter: Limit pressure (MPa)	Resistance: Unconfined compressive strength (MPa)	Relative density [%]	Compression index Cc	Shear wave velocity [m/s]	Compression wave velocity: Below water-table [m/s]	Compression wave velocity: Above water-table [m/s]
ROCKS	Sound rocks and hard chalks			> 100	> 5	> 10			> 800		> 2500
Soils with good to very good mechanical resistance	Dense granular soils	> 15	> 30	> 20	> 2		> 60		> 400	> 1800	> 800
	Cohesive soils (hard clays or marls)	> 5		> 25	> 2	> 0.4		< 0.02			> 1800
Soils with medium mechanical resistance	Weathered or faulted rock			50 to 100	2.5 to 5	1 to 10			300 to 800		400 to 2500
	Medium density granular soils	5 to 15	10 to 30	6 to 20	1 to 2		40 to 60		150 to 400	1500 to 1800	500 to 800
	Medium consistency cohesive soils and tender chalks	1.5 to 5		5 to 25	0.5 to 2	0.1 to 0.4		0.02 to 0.10			1000 to 1800
Soils with low mechanical resistance	Loose granular soils	< 5	< 10	< 6	< 1		< 40		< 150	< 1500	< 500
	Soft cohesive soils (soft clays or silts) and weathered chalks	< 1.5	< 2	< 5	< 0.5	< 0.1		> 0.10			

Figure 4. Soil identification parameters

3,32. Classification of sites

Four types of sites are considered, corresponding to the following descriptions :

. Sites S0 - bedrock sites (site of reference)
- group a, soils in less than 15 m thick layer

. Sites S1 - group a, soils in more than 15 m thick layer
- group b, soils in less than 15 m thick layer

. Sites S2 - group b, soils in 15 to 50 m thick layer
- group c, soils in less than 10 m to 100 m thick layer

. Sites S3 - group b, soils in more than 50 m thick layer
- group c, soils in 10 to 100 m thick layer

In the case of sites that include soils of group c in a more than 100 m thick layer, a particular study will be carried out so as to determine a specific spectrum.

Sections are schematically represented hereafter :

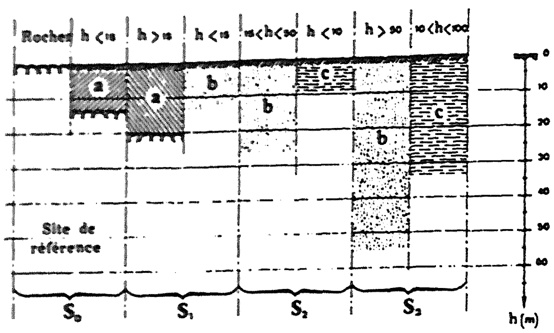


Figure 5. Classification of sites

3,33 Normalized elastic spectra

Normalized elastic spectra are given for a 5 % value of relative damping. They correspond to a unit value of the nominal acceleration.

Their general shape is represented on figure No. 6

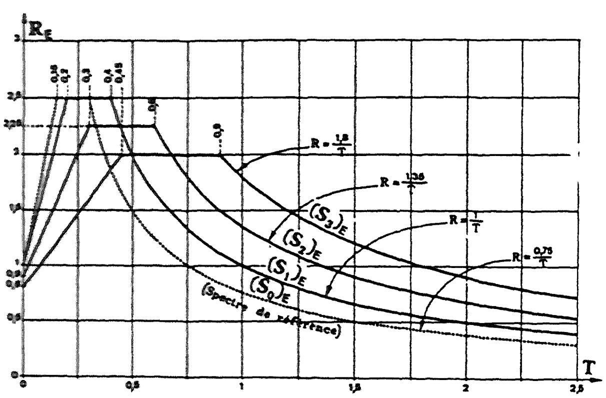


Figure 6. Normalized elastic spectra

3,34 Damping correction

When an elastic spectrum is used to calculate a structure (linear calculation) and the relative damping is different from 5 %, ordinates will be multiplied by the ratio :

$$\rho = \left(\frac{5}{\zeta}\right)^{0.4}$$

$0.5\% \leq \zeta \leq 30\%$

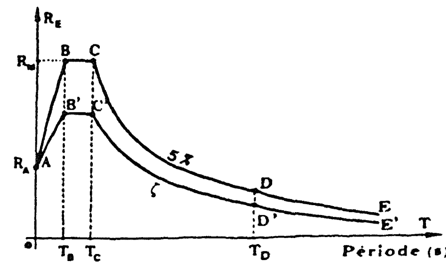


Figure 7

4 OVER ALL SEISMIC ACTIONS

The horizontal components of the design motion will be oriented following the principal axes of the structure.

4.1 Idealization of the seismic motion

4,11 Standard model

Seismic action applied to a structure may be considered as constituted of :
- deformations or forces of dynamic origines
- deformations or displacement imposed on the structure (torsion) or the foundations by differential motion.

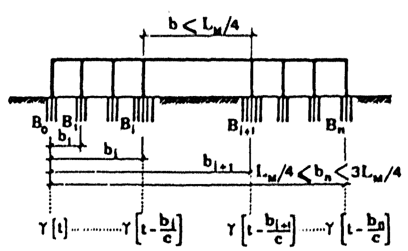
4,12 Great length structures

Will be considered as great length structures, continuous structures in which the distance between extreme points of support is superior to a quarter (1/4) of the length Lm defined in relation to the site classification :

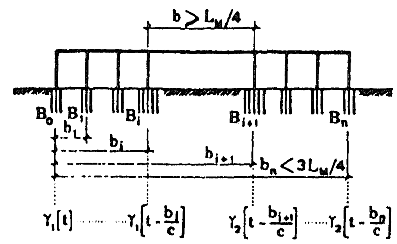
for : S0 LM = 600 meters
S1 LM = 500 "
S2 LM = 400 "
S3 LM = 300 "

This definition does not concern structures built on a monolithic raft. Distances will be understood as between the centers of gravity of the footings horizontal sections (footings, caissons, clusters of piles,...).
For these structures, and subject to the condition that their total length be inferior to 3LM/4, the same seismic motion (3 components) may be applied to each point of support, as long as an interval in time is made for between these points, equal to the propagation time of the motion (multiple excitation), the latter supposed propagating along the longitudinal axis of the structure.

In the case when two adjacent points of support are separated by a distance superior to LM/4, distinct accelerograms will be used in these two points, presenting a mean value for the intercorrelation function inferior to 0.2 approximately.



C = propagation velocity of the motion along the structure axis
γ(t) = accelerogram



C = propagation velocity of the motion along the structure axis
$\gamma_1(t)$, $\gamma_2(t)$ distinct accelerograms (uncorrelated)

Figure 8_Great length structures

4,13 Soil - Structure interaction

When the designer has enough information regarding foundation soils, the designer may calculate the overall response of the system : soil + foundation + structure.
In the case of structures noticeably imbedded in the soil, the seismic motion shall be defined at the same level as the base of the foundation.
However a simplified method defines a "seizing height" in relation to the heights of the upper structure and the embedded part and as a function of the soil quality (see Fig 9). [2]

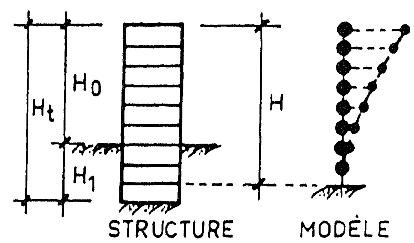


Figure 9_Soil structure interaction

4,2 Non linear behaviour

AFPS Recommendations make a distinction between non linear systems as follows :
- systems that exhibit only inelastic behaviour non-linearities and little marked geometrical non-linearities
- systems that exhibit marked geometrical non-linearities or mechanical non linearties.

4,3 Equivalent linear calculation : Design spectrum and behaviour factor

Systems that exhibit only inelastic behavior non-linearties and little marked geometrical non-linearties may be calculated using a linear approach in the following conditions :
. model : the structure will be fictitiously considered as remaining indefinitely elastic, however intense the actions or loads acting upon it;
. seismic motion : normalized elastic spectra will be replaced by the design spectra;
. displacements and deformations : displacements and deformations of the structure will be considered equal to those calculated for the fictitious elastic model using the design spectrum;
. forces and loads : design forces and loads will be found by dividing forces and loads calculated in the same conditions as above by a coefficient q called "behaviour coefficient".
Coefficient q, identical for the whole structure, will be chosen with regards to the nature of constitutive materials, to the construction type, the possible stress repartition in the structure (hyperstaticity), the overall ductility of the latter and ductility of critical areas, as well as to the simplifying assumptions introduced when modeling the actions.
Values of q different of 1 may be used only in conjunction with a design spectrum (or with a motion having the properties defined by the spectrum).

4,4 Combination of effects of seismic motion components

When a linear calculation method is used, the maximum effects of each component may be determined separately then combined using the following symbolic formulas :

$$\begin{cases} S = \pm S_x \pm \lambda S_y \pm \mu S_z \\ S = \pm \lambda S_x \pm S_y \pm \mu S_z \\ S = \pm \lambda S_x \pm \mu S_y \pm S_z \end{cases}$$

λ and μ are generally taken equal to 0.3

4,5 Design spectra

Normalized design spectra are given for a 5 % value of relative damping and are derived from the unit value of nominal acceleration.

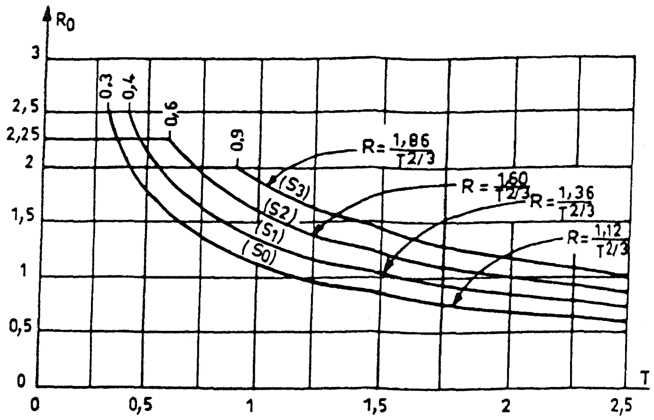


Figure 10_ Design spectra

4,6 Methods of analysis

According to their fields of validity various methods can be used :
- spectral modal analysis
- simplified methods
- time history calculations
- stochastic dynamics
- accounting for vertical axis torsions

4,61 Spectral modal analysis

Modal analysis may be applied to all systems except those that exhibit marked geomitrical non-linearities or mechanical non-linearities.
The system is modelled as a tridimensional elastic system.
The design seismic motion is taken into account as a design spectrum (accompanied by a proper behavior coefficient q) if incursions in the post-elastic phase are authorized ; as an elastic spectrum if the struture is to be kept within the elastic range.
Design spectrum ordinates (spectral accelerations) are given by :

$$R(T) = a_N \, \tau \, \rho \, R_E(T)$$

or

$$R(T) = a_N \, \tau \, \rho \, R_D(T)$$

depending on whether an elastic or equivalent linear calculation is carried out, with :
. aN : nominal acceleration
. τ : site response factor
. ρ : damping correction
. $R_D(T)$ ordinate of the normalized design spectrum
. $R_E(T)$ ordinate of the normalized elastic spectrum.

4,62 Simplified methods

Ordinary type of buildings may, subject to some conditions to be fullfilled and namely their regularity, be calculated using simplified methods.
So-called regular structures may be calculated using a deemed-to-satisfy deformed shape defined a simple analytical expression such as : $u = z^k$
u : elongation of the deformed shape
k : exponent depending on the type of structure, $1 < k < 2$.

4,63 Case of regular buildings

When regularities conditions are fullfilled, regular buildings can be calculated according to "PS91" [2] by the following relation

$$f_r = \rho' m_r Z_r^{1.5} \frac{\Sigma m_i Z_i^{1.5}}{\Sigma m_i Z_i^3} \cdot \frac{R(T)}{q}$$

f_r is the design force at each level where is a current mass m_r and is a factor which takes into account the neglected higher modes :

$$\rho' = 1 + 0{,}10 \left(\frac{T}{T_c}\right)^{1.5} \geq 1.10$$

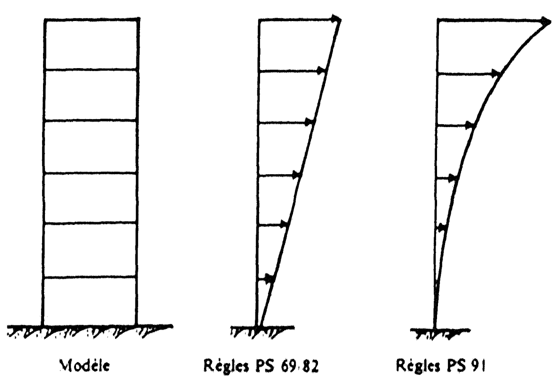


Figure 11. Simplified methods

4,64 Behavior factors

Base values of behavior factors q are given for various materials masonry, concrete, steel, wood) and various type of structures.
For instance for :
- shear walls in R.C : q = 2 to 3,5
- frames in R.C. : q = 5
- masonry walls : q = 1,5 to 3
 (with ties)

4,65 Shear walls

"PS 91" [2] makes a new development for concrete tied walls for which the behavior factor is choosen in relation to the amount of reinforcement and to the level of stresses in the wall. Sections with high level of stresses are reinforced while the upper part of the wall with low level of stresses is only tied with a minimum amount of steel.

5 CONCLUSIONS

New French Recommendations "AFPS 90" [1] and the futur standard "PS 91" [2] introduced the following new items :
- soil classification and site classification for the choice of the spectrum
- differential displacements for long structures (see LOMA PRIETA Earthquake Lessons)
- simplified method for embedded buildings
- behavior factor linked to the amount of reinforcement, to the level of stresses and to the aspect ratio, for concrete walls
- behavior factors are reduced if the structure is irregular (15 to 30 %).

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