Technical University of Civil Engineering Bucharest
Fundamental field: Engineering Sciences
PhD Field: Civil Engineering and Installations
Specialisation: Seismic Engineering & Constructions Safety
Doctoral School – 1st Year 2nd Semester: 2014-2015

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Scientific Research Programme
Research Report I – European codes / standards and norms for the anti-seismic design of constructions

A. European codes / standards and norms

1) Introduction

Within the wider effort of the 1980s to harmonize codes / standards and norms across the European Union and beyond, Eurocodes occupy a leading place. These standards contain common structural design rules for the complete calculation of traditional and innovative components and structures.

As specified in the European Commission Recommendation on the Implementation and Use of Eurocodes in the European Space for Construction Works and Structural Building Products Relevant to the European Economic Area, in Romania also Eurocodes and National Annexes, approved as national standards, are used as normative reference documents within the technical regulations in construction. EU Member States recognize Eurocodes as benchmarks for the following uses:

- as a means of proving compliance of buildings and engineering works with the essential requirements of Council Directive 89/106/EEC, in particular Essential Requirement No.1 Mechanical stability and strength and Essential Requirement no. 2 Safety in case of fire;
- as the basis of specifications in construction works contracts and afferent technical services;
- Framework for harmonised technical specifications for construction products.

The National Annexes may only contain information and data on Eurocode parameters defined as parameters to be determined on the national level; The items of information and data subject to the option of the national authorities are used for the design of construction and engineering works in that country and refer to:

-values and / or classes for which the Eurocode allow national alternatives;

-values that may be used if the Eurocode does not provide the value of the parameter and indicates only its symbol;

- country-specific data (geography, climate, etc.), such as earthquake zoning maps, snow load maps, wind maps, etc .;

-the procedure to be used when the Eurocode presents alternative procedures.

The Eurocodes program for Structures comprises the following standards, each generally composed of several parts:

EN 1990 Eurocode: The Basics of Structures Design

EN 1991 Eurocode 1: Actions on Structures

EN 1992 Eurocode 2: Design of concrete structures

EN 1993 Eurocode 3: Design of steel structures

EN 1994 Eurocode 4: Design of composite steel and concrete structures
EN 1995 Eurocode 5: Design of timber structures
EN 1996 Eurocode 6: Design of masonry structures
EN 1997 Eurocode 7: Geotechnical design
EN 1998 Eurocode 8: Design of structures for earthquake resistance
EN 1999 Eurocode 9: Design of aluminium structures.

2) Presentation of EN-1998 and SR EN-1998 norms

2.1 General presentation of norms

Within the Eurocodes, the reference standard for the antiseismic design of structures is EN 1998 Eurocode 8. This standard is structured in turn in 6 main parts covering various areas: buildings, bridges, silos, tanks, pipes, towers, pillars, chimneys, foundations, supporting structures, geotechnical aspects, etc.

EN 1998 Eurocode 8 was transposed into Romanian national legislation becoming SR EN 1998, adding to it the National Annexes. The National Annexes define the conditions for application of the aforementioned norm on our territory, including seismic zoning and the concrete definition of some parameters and coefficients.

Among these parts of Eurocode 8, one of the most important and frequently used is "SR EN 1998-1: 2004 Design of structures for earthquake resistance. Part 1: General rules, seismic actions and building rules". It presents and regulates performance requirements and design compliance criteria, field conditions and seismic action, principles and specific rules for the design of concrete, steel, composite, wood or masonry buildings, as well as description of the building isolation method.

It is worth mentioning that the Seismic Design Code P100-1 / 2013, part 1 Building design provisions, came into force on the 1st of January 2014 in Romania. The provisions of this code are harmonized with the provisions of SR EN 1998-1: 2004.

Table 1 shows the contents of SR EN 1998 in full.

SR EN 1998-1:2004	Eurocode 8: Design of structures for earthquake resistance. Part 1: General rules, seismic actions and building rules
SR EN 1998-1:2004/A1:2014	Eurocode 8: Design of structures for earthquake resistance. Part 1: General rules, seismic actions and building rules
SR EN 1998-1:2004/AC:2010	Eurocode 8: Design of structures for earthquake resistance. Part 1: General rules, seismic actions and building rules
SR EN 1998-2:2006	Eurocode 8: Design of structures for earthquake resistance. Part 2: Bridges
SR EN 1998-2:2006/A1:2009	Eurocode 8: Design of structures for earthquake resistance. Part 2: Bridges
SR EN 1998-2:2006/A2:2012	Eurocode 8: Design of structures for earthquake resistance. Part 2: Bridges
SR EN 1998-2:2006/AC:2010	Eurocode 8: Design of structures for earthquake resistance. Part 2: Bridges
SR EN 1998-3:2005	Eurocode 8: Design of structures for earthquake resistance. Part 3: Building evaluation and consolidation
SR EN 1998-3:2005/AC:2013	Eurocode 8: Design of structures for earthquake resistance. Part 3: Building evaluation and consolidation
SR EN 1998-4:2007	Eurocode 8: Design of structures for earthquake resistance. Part 4: Silos, tanks and pipelines
SR EN 1998-5:2004	Eurocode 8: Design of structures for earthquake resistance. Part 5: Foundations, supporting structures and geotechnical aspects
SR EN 1998-6:2005	Eurocode 8: Design of structures for earthquake resistance. Part 6: Towers, pillars and chimneys
SR EN 1998-1:2004/NA:2008	Eurocode 8: Design of structures for earthquake resistance. Part 1: General rules, seismic actions and building rules. National annex

SR EN 1998-2:2006/NA:2010	Eurocode 8: Design of structures for earthquake resistance. Part 2: Bridges. National annex
SR EN 1998-3:2005/NA:2010	Eurocode 8: Design of structures for earthquake resistance. Part 3: Building evaluation and consolidation. National annex
SR EN 1998-4:2007/NB:2008	Eurocode 8: Design of structures for earthquake resistance. Part 4: Silos, tanks and pipelines. National Annex
SR EN 1998-5:2004/NA:2007	Eurocode 8: Design of structures for earthquake resistance. Part 5: Foundations, supporting structures and geotechnical aspects. National annex
SR EN 1998-6:2005/NB:2008	Eurocode 8: Design of structures for earthquake resistance. Part 6: Towers, pillars and pans. National Annex

Tab.1 The complete component of the European standard transposed into the Romanian legislation, including the national annexes, SR EN 1998 Design of structures for earthquake resistance. Source: M.D.R.A.P.

2.2 SR EN 1998-1: 2004 Design of structures for earthquake resistance. Part 1: General Rules, Seismic Actions and Building Rules" corresponding to EN 1998-1: 2004; correspondence with Code P100-1 / 2013 - presentation of seismic action

2.2.1 Performance requirements and compliance criteria

Fundamental performance requirements are Non-Collapsing Requirement and the Damage Limitation Requirement.

In the context of the non-collapsing requirement, the seismic calculation is expressed in accordance with the reference seismic action associated with a probability of exceeding of the P_{NCR} reference in 50 years or with a T_{NCR} return period, as well as in correlation with the relevant factor of importance and afferent to structures (EN1990: 2002), in order to differentiate the safety level.

Values recommended in the standard are P_{NCR} = 10% in 50 years and T_{NCR} = 475 years. As for Romania, although in the National Annex of 2008 one provides the old values P_{NCR}=39% in 50 years and T_{NCR}=100 years, at present, within Code P100-1 / 2013 in force, we have P_{NCR} = 20% in 50 years and T_{NCR} = 225 years as a transition from the old rules to the Eurocode provisions and recommendations.

The classification of buildings in classes of importance-exposure is regulated by the code "CR 0-2012 Design Code. Basics of Construction Design", Annex A1. Buildings are divided into 4 classes of importance-exposure to which an importance-exposure factor is associated to each. Particularly, with regard to the level of earthquake assurance of buildings, it is differentiated according to the class of importance-earthquake exposure (in accordance with CR 0-2012) to which they belong, as detailed in the code P100 -1/2013, ch.4, pt.4.4.5. Table 4.2. The importance of construction depends on the consequences of collapse on people's lives, their importance for public safety and civil protection in the immediate aftermath of the earthquake, and the social and economic consequences of the collapse or serious damage.

The class of importance and exposure to earthquake is characterized by the value of the importance-exposure factor, with 0.8 for buildings in class IV (least important constructions), 1.0 for class III, 1.2 for class II and 1.4 for class I More important); In Table 4.3 of EN 1998-1 the classes have the inverted name, I the least important and IV the most important.

Regarding the requirement for limiting the degradation, the seismic action will be taken into account having a probability of exceeding P_{DLR} in ten years and a T_{DLR} return period. Similarly, the values recommended in the standard are P_{DLR} = 10% in 10 years and T_{DLR} = 95 years. As regards Romania, although in the 2008 National Annex the P_{DLR} values are set = 28% in 10 years and T_{DLR} = 30 years, currently within the Code P100-1 / 2013 in force, we have P_{DLR} = 20% in 10 years and T_{DLR} = 40 years as a transition from the old rules to the provisions and recommendations of the Euro code.

In order to meet the aforementioned requirements, as criteria of compliance, checks must be made at the latest limit states and service conditions (limitation of degradation).

2.2.2 Seismic action and site conditions

Site conditions

In the process of assessing the seismic action, in order to quantify the influence of local field conditions, in the European norm, one defined 5 distinct types of soil A, B, C, D, E, S1 and S2, described by parameters and specific stratigraphic profiles, presented in table no. 2.

The geotechnical investigations that can be carried out to determine the seismic action more precisely in a given location, depending on the site conditions, correlate the importance classes of the constructions and the specifics of the projects. For sites falling under S1 and S2, special studies are required, taking into account the possibility of soil being disposed of under seismic action (especially class S2).

Ground type	Description of stratigraphic profile	Parameters		
		$v_{s,30}$ (m/s)	N_{SPT} (blows/30cm)	c_u (kPa)
A	Rock or other rock-like geological formation, including at most 5 m of weaker material at the surface.	> 800	_	_
B	Deposits of very dense sand, gravel, or very stiff clay, at least several tens of metres in thickness, characterised by a gradual increase of mechanical properties with depth.	360 – 800	> 50	> 250
C	Deep deposits of dense or medium-dense sand, gravel or stiff clay with thickness from several tens to many hundreds of metres.	180 – 360	15 - 50	70 - 250
D	Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil.	< 180	< 15	< 70
E	A soil profile consisting of a surface alluvium layer with v_s values of type C or D and thickness varying between about 5 m and 20 m, underlain by stiffer material with v_s > 800 m/s.			
S_1	Deposits consisting, or containing a layer at least 10 m thick, of soft clays/silts with a high plasticity index (PI > 40) and high water content	< 100 (indicative)	_	10 - 20
S_2	Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in types A – E or S_1			

Tab.2 Classification of soil types, according to SR EN 1998-1:2004.

N_{SPT} - The number of strokes for the standard penetration test;
C_u - Shear resistance of undressed soil;

$V_{s,30}$ - The average velocity of the shear propagation velocity S at 30 m in the upper part of the soil profile for a deformation less than or equal to 10^{-5}.

$$v_{s,30} = \frac{30}{\sum_{i=1,N} \frac{h_i}{v_i}}$$

where h and v are the thickness in m and the shear velocity of the formation or layer i of the total N in the 30 m from the surface.
Thus, the location is classified according to the average shear propagation velocity or alternatively to the N_{SPT} value.
At present, when it comes to the design of seismic constructions in Romania, the level of seismic hazard is indicated by Code P100-1 / 2013. Within this Code, the soil classification model does not apply directly, as specified in the National Annex to SR EN 1998-1: 2004. According to the 2008 National Annex, the site conditions are classified into three distinct areas covering the national territory, Z1, Z2, Z3. This zoning was mainly based on the seismic records of the 1977, 1986 and 1990 Vrancea subcrustal earthquakes, and corresponds to the national zoning in terms of TC response time, as described in P100-1 / 2013 Code: Z1 (T_C = 0.7 sec), Z2 (T_C = 1.0 sec) and Z3 (T_C = 1.6 sec).

Seismic action

According to EN 1998, the surfaces of the European countries have to be divided into seismic regions in relation to the local hazard, which is definitely considered constant within each zone of this kind. According to the same norm, the seismic movement at a given point on the terrain surface is represented by an elastic response range or spectrum for the ground acceleration, called the elastic response spectrum, for both horizontal and vertical components.

- the horizontal elastic response spectrum Se (T) according to SR EN 1998-1: 2004 (EN 1998-1) is defined by the formulas:

$$0 \le T \le T_B : S_e(T) = a_g \cdot S \cdot \left[1 + \frac{T}{T_B} \cdot (\eta \cdot 2{,}5 - 1)\right]$$

$$T_B \le T \le T_C : S_e(T) = a_g \cdot S \cdot \eta \cdot 2{,}5$$

$$T_C \le T \le T_D : S_e(T) = a_g \cdot S \cdot \eta \cdot 2{,}5\left[\frac{T_C}{T}\right]$$

$$T_D \le T \le 4s : S_e(T) = a_g \cdot S \cdot \eta \cdot 2{,}5\left[\frac{T_C T_D}{T^2}\right]$$

where,
T - the vibration period of a linear system with one degree of freedom;
a_g – design calculation acceleration for class A (ag = γI * agR);
T_B - the lower limit of periods corresponding to the constant spectral acceleration plane;
T_C - the upper limit of periods corresponding to the constant spectral acceleration plane;
T_D - the value that defines the beginning of the constant range of the response spectrum;
S - soil factor;

η – The damping correction factor with a reference value n = 1 for a viscous damping of 5%; $\eta = \sqrt{10/(5+\xi)} \geq 0,55$, where ξ - the viscous damping coefficient.

We must point out that the values of the TB, TC, TD and S-periods that can be used in the territory of a country are to be found in the national annexes. Generally, according to SR EN 1998-1: 2004 (EN 1998-1) it is recommended to use two types of spectra, 1 and 2, depending on the Ms type magnitude of the surface waves of the earthquakes. If MS≤5.5, it is recommended to adopt the spectrum type 2.

Tab.3a

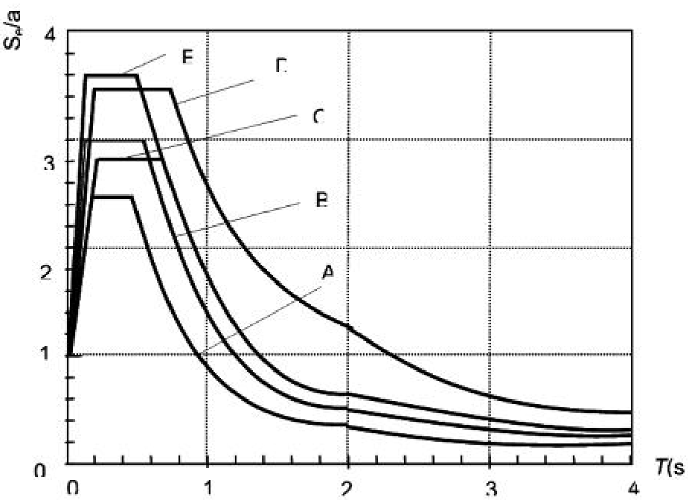
Clasă de teren	S	T_B(s)	T_C(s)	T_D(s)
A	1,0	0,15	0,4	2,0
B	1,2	0,15	0,5	2,0
C	1,15	0,20	0,6	2,0
D	1,35	0,20	0,8	2,0
E	1,4	0,15	0,5	2,0

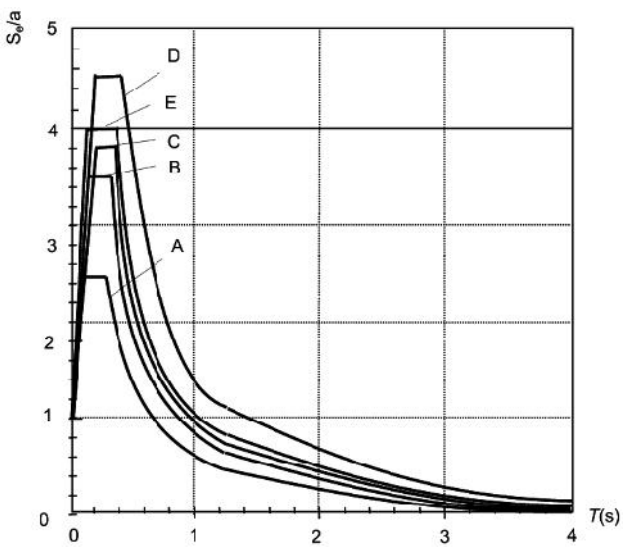
Tab.3 a and 3b. Values of parameters T_B, T_C, T_D and S, describing the elastic response spectra. recommended type 1 (tab.3a) and type 2 (tab.3b), acc. to SR EN 1998-1:2004 (EN 1998-1).

Clasă de teren	S	T_B(s)	T_C(s)	T_D(s)
A	1,0	0,05	0,25	1,2
B	1,35	0,05	0,25	1,2
C	1,5	0,10	0,25	1,2
D	1,8	0,10	0,30	1,2
E	1,6	0,05	0,25	1,2

Tab.3b

Figure 1 Type 1 (left) and Type 2 (right) elastic response spectra for Class A to E soil, according to SR EN 1998-1: 2004 (EN 1998-1).





- Horizontal elastic response spectrum Se (T), customized according to the National Annex SR EN 1998-1:2004/NA:2008

According to all the above, taking into account the specificity of seismic hazard on the territory of Romania, the National Annex SR EN 1998-1: 2004 / NA: 2008 provides for the general application on the national territory of the elastic response spectrum type 1, Banat area where the elastic type 2 response spectrum is applied, both in conjunction with the three Z1-Z3 site / soil areas, as follows:

$$0 \le T \le T_B : S_e(T) = a_g S\left[1 + \frac{T}{T_B}(2{,}75\eta - 1)\right]$$
$$T_B \le T \le T_C : S_e(T) = 2{,}75 a_g S\eta$$
$$T_C \le T \le T_D : S_e(T) = 2{,}75 a_g S\eta\left[\frac{T_C}{T}\right]$$
$$T_D \le T \le 4\text{s} : S_e(T) = 2{,}75 a_g S\eta\left[\frac{T_C T_D}{T^2}\right]$$

η este factorul de corecție a amortizării (η = 1 pentru ξ = 5 %).

Definition of Type 1 Spectrum in Romania, in accordance with Annex Nat. SR EN 1998-1: 2004 / NA: 2008.

$$0 \le T \le T_B : S_e(T) = a_g S\left[1 + \frac{T}{T_B}(3{,}00\eta - 1)\right]$$
$$T_B \le T \le T_C : S_e(T) = 3{,}00\ a_g\ S\eta$$
$$T_C \le T \le T_D : S_e(T) = 3{,}00\ a_g S\eta\left[\frac{T_C}{T}\right]$$
$$T_D \le T \le 4\text{s} : S_e(T) = 3{,}00\ a_g S\eta\left[\frac{T_C T_D}{T^2}\right]$$

Definition of the Type 2 Spectrum in Romania, in accordance with Annex Nat. SR EN 1998-1: 2004 / NA: 2008.

Zone de teren/ amplasament	*S*	T_B(s)	T_C(s)	T_D(s)
Z_1	1	0,07	0,7	3,0
Z_2	1	0,10	1,0	3,0
Z_3	1	0,16	1,6	2,0

Zone de teren/ amplasament	*S*	T_B(s)	T_C(s)	T_D(s)
Z_1	1	0,07	0,70	3,00

Table 4a and 4b. The values of the TB, TC, TD and S parameters describing the elastic response spectra generally recommended in Romania Type 1 (Table 4a) and Type 2 - Banat Area (Table 4b) according to the National Annex SR EN 1998-1: 2004 / NA: 2008.

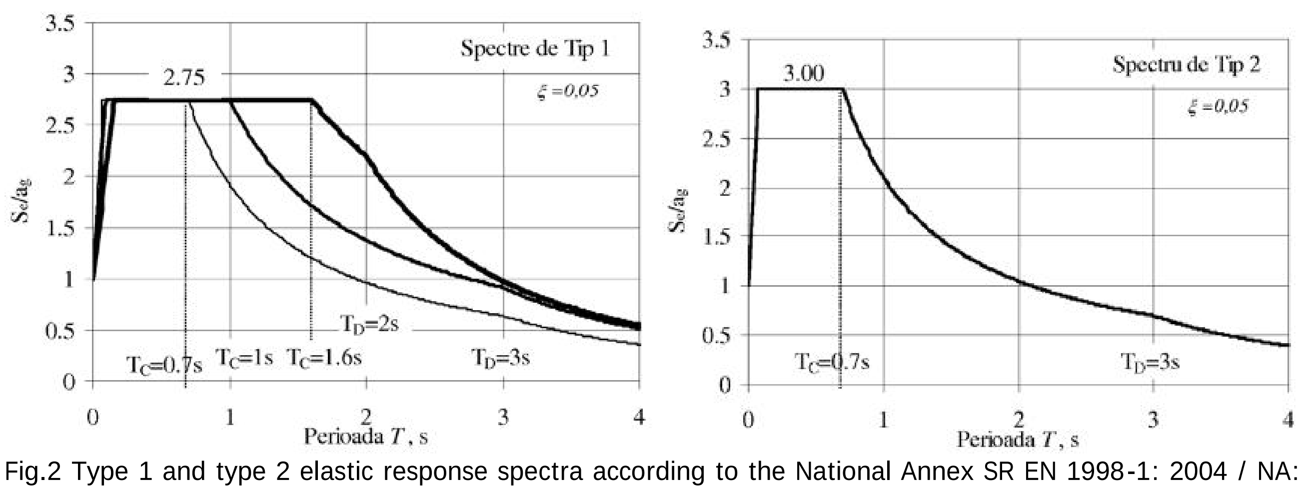


Fig.2 Type 1 and type 2 elastic response spectra according to the National Annex SR EN 1998-1: 2004 / NA: 2008.

- the vertical elastic response spectrum Sve (T) according to SR EN 1998-1: 2004 (EN 1998-1) is similarly defined by the formulas:

Spectru	a_{vg}/a_g	T_B(s)	T_C(s)	T_D(s)
Tip 1	0,9	0,05	0,15	1,0
Tip 2	0,45	0,05	0,15	1,0

Table 5. Parameter values describing the vertical elastic response spectrum, according to SR EN 1998-1: 2004 (EN 1998-1).

$$0 \le T \le T_B : S_{ve}(T) = a_{vg} \cdot \left[1 + \frac{T}{T_B} \cdot (\eta \cdot 3{,}0 - 1)\right]$$

$$T_B \le T \le T_C : S_{ve}(T) = a_{vg} \cdot \eta \cdot 3{,}0$$

$$T_C \le T \le T_D : S_{ve}(T) = a_{vg} \cdot \eta \cdot 3{,}0 \left[\frac{T_C}{T}\right]$$

$$T_D \le T \le 4s : S_{ve}(T) = a_{vg} \cdot \eta \cdot 3{,}0 \left[\frac{T_C \cdot T_D}{T^2}\right]$$

where,
Sve(T) – Vertical elastic response spectrum;
ag - Vertical design acceleration.

- - Sve (T) vertical elastic response spectrum, customized according to the National Annex SR EN 1998-1:2004/NA:2008

According to the National Annex SR EN 1998-1: 2004 / NA: 2008, a single type of spectrum for the vertical component of the seismic action, the elastic type response spectrum 1, is applied on the territory of Romania, applying the above-mentioned formulas related to SR EN 1998-1: 2004 (EN 1998-1) and using in particular the parameters in table no.6.

Spectru	Zone de teren/ amplasament	a_{vg}/a_g	T_B(s)	T_C(s)	T_D(s)
Tip 1	Z_1	0,7	0,03	0,32	3,0
	Z_2	0,7	0,04	0,45	3,0
	Z_3	0,7	0,07	0.72	2,0

Tab.6 Values of the parameters describing the vertical elastic response spectrum, according to the National Annex SR EN 1998-1: 2004 / NA: 2008.

- - the design calculation spectrum for the horizontal components of the seismic action Sd (T), according to SR EN 1998-1:2004 (EN 1998-1)

According to the European norm, for the horizontal components of the seismic action the design calculation spectrum Sd (T) is defined as follows:

$$0 \le T \le T_{\mathrm{B}} : S_{\mathrm{d}}(T) = a_{\mathrm{g}} \cdot S \cdot \left[\frac{2}{3} + \frac{T}{T_{\mathrm{B}}} \cdot \left(\frac{2{,}5}{q} - \frac{2}{3}\right)\right]$$

$$T_B \le T \le T_C: \; S_d(T) = a_g \cdot S \cdot \frac{2,5}{q}$$

$$T_C \le T \le T_D: \; S_d(T) \begin{cases} = a_g \cdot S \cdot \frac{2,5}{q} \cdot \left[\frac{T_C}{T}\right] \\ \ge \beta \cdot a_g \end{cases}$$

$$T_D \le T: \quad S_d(T) \begin{cases} = a_g \cdot S \cdot \frac{2,5}{q} \cdot \left[\frac{T_C T_D}{T^2}\right] \\ \ge \beta \cdot a_g \end{cases}$$

where a_g, S, T_C and T_D were previously defined,
$S_d(T)$ – design calculation spectrum;
q – behaviour factor;
β - The coefficient corresponding to the lower limit of the horizontal design calculation spectrum; The value can be found in the national annexes;

Particularly, in Romania, according to the National Annex SR EN 1998-1: 2004 / NA: 2008, the value of β is 0.2.

With respect to the vertical component, in the adjacent formulas we replace the a_g with the a_{vg} and S = 1.

Regarding the design of seismic constructions in Romania, the level of seismic hazard is indicated by Code P100-1/2013, the main technical antiseismic design rule in force at the moment. The peak value of the horizontal acceleration of the ground movement, ag, called design ground acceleration, corresponds to an average RP recurrence interval of 225, which corresponds to a seismic event whose magnitude has a probability of exceeding 20% in 50 years. ag values are between 0.10g in Ardeal and 0.40g in Buzau, Vrancea. In this Code, seismic motion at a point on the ground surface is represented by elastic response spectra for absolute accelerations.

$S_e(t) = a_g * \beta(t)$, Where ag is the value of the ground acceleration for design, and β (t) the normalized response spectrum of the absolute acceleration.

The normalized elastic response of the absolute accelerations for the horizontal components of the ground movement, β (T), for the conventional fraction of the critical damping = 0.05 and depending on the control periods T_B, T_C and T_D are given by the following relations:

$0 \le T \le T_B$ $\qquad \beta(T) = 1 + \frac{(\beta_0 - 1)}{T_B} T$

$T_B < T \le T_C$ $\qquad \beta(T) = \beta_0$

$T_C < T \le T_D$ $\qquad \beta(T) = \beta_0 \frac{T_C}{T}$

$T_D < T \le 5s$ $\qquad \beta(T) = \beta_0 \frac{T_C T_D}{T^2}$

where:

β_0 The maximal dynamic amplification factor of the horizontal acceleration of the ground by the structure, whose value is β_0 =2.5;

T The vibration period of a structure with a degree of dynamic freedom and elastic response.

Similarly, the normalized elastic response spectrum of absolute accelerations for the vertical component of the ground movement, βv (T) is given by the following relations:

$0 \le T \le T_{Bv}$ $\qquad \beta_v(T) = 1 + \frac{(\beta_{0v} - 1)}{T_{Bv}} T$

$T_{Bv} < T \leq T_{Cv}$ $\qquad\qquad$ $\beta_v(T) = \beta_{0v}$

$T_{Cv} < T \leq T_{Dv}$ $\qquad\qquad$ $\beta_v(T) = \beta_{0v} \dfrac{T_{Cv}}{T}$

$T_{Dv} < T \leq 5\text{s}$ $\qquad\qquad$ $\beta_v(T) = \beta_{0v} \dfrac{T_{Cv} T_{Dv}}{T^2}$

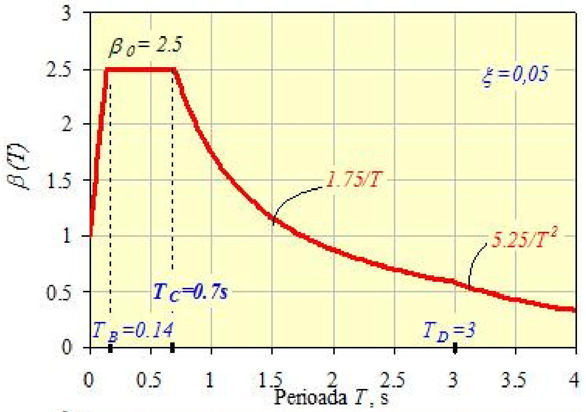
where, β_{0v} the maximal dynamics of the vertical acceleration of the ground movement, whose value is 2.75;
T_{Bv}, T_{Cv} and T_{Dv} are the control periods of the response spectrum of the vertical component: $T_{Bv}=0.1*T_{Cv}$; $T_{Cv}=0.45*T_C$; $T_{Dv}=T_D$.

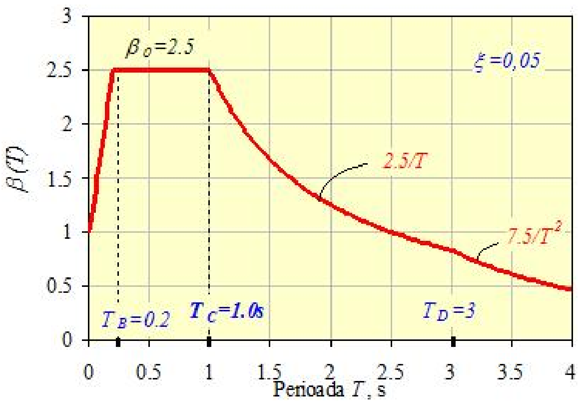
The local site conditions are described in a simplified way by the values of the corner period T_C of the response spectrum for the site area considered. These values synthetically characterize the frequency composition of seismic movements.

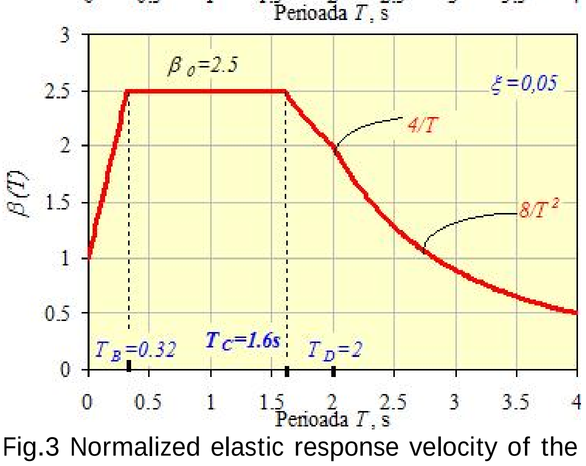
In the seismic and terrain conditions in Romania, based on existing instrumental data, the zoning for the design of the territory in terms of control period, T_C (0.7, 1.0, 1.6 sec) , of the response spectrum is presented in the table below:

T_C (s)	0,7	1,0	1,6
T_B (s)	0,14	0,2	0,32
T_D (s)	3,0	3,0	2,0

Tab.7 Response Spectrum Control Periods for the horizontal components of the seismic movement







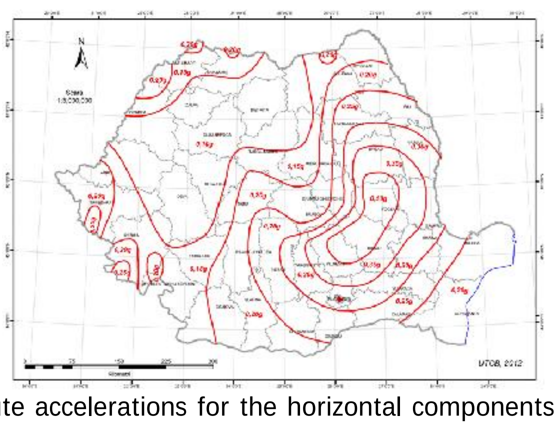


Fig.3 Normalized elastic response velocity of the absolute accelerations for the horizontal components of the ground movement in areas characterized by the control period TC = 0.7s, 1.0s and 1.6s.
Fig.4 Romania. Zoning of peak ground acceleration values for design, RP 225 years and 20% probability of exceeding in 50 years; 0.10g≤ag≤0.40 g.

The design spectrum for the horizontal components of the soil movement Sd (T) (expressed in m / s2) is the inelastic response spectrum of the absolute accelerations defined with the relations:

$$S_d(T) = a_g \left[1 + \frac{\frac{\beta_0}{q} - 1}{T_B} T \right] \qquad 0 < T \leq T_B$$

$$S_d(T) = a_g \frac{\beta(T)}{q} \geq 0{,}2 \cdot a_g \qquad T > T_B$$

where q is the behaviour factor of the structure called modulation factor from elastic response in inelastic response.

The design spectrum for the vertical component of the seismic movement is obtained in a similar way to the horizontal component, using the behaviour factor q with the general value of 1.5.

It should be noted that both SR EN 1998-1: 2004 (EN 1998-1) and P100-1 / 2013 code provide for the possibility of alternative description of seismic motion by accelerograms recorded in different artificial simulated locations and / or accelerograms , Compatible with the absolute acceleration response spectrum, accelerograms used in dynamic calculation methods.

3) Presentation of other European standards (Greece, Portugal, Italy)

Evaluation of seismic action in technical prescriptions on antiseismic design in Greece

Greece, as a EU member, participated in the elaboration of Eurocodes and also adopted EN 1998-1: 2004 in the form of ELOT EN 1998-1: 2005. After the transposition of the European norm as a national standard, a National Annex was drafted, initially presented as SEP ELOT 1498-1: 2009 and later as Annex ELOT EN 1998-1:2005/NA:2010.

Like in Romania, in Greece equally a separate anti-seismic code called EAK2000 coexisted, but it took over the concepts promoted by Eurocodes. It was modified in 2003, introducing a new seismic hazard map.

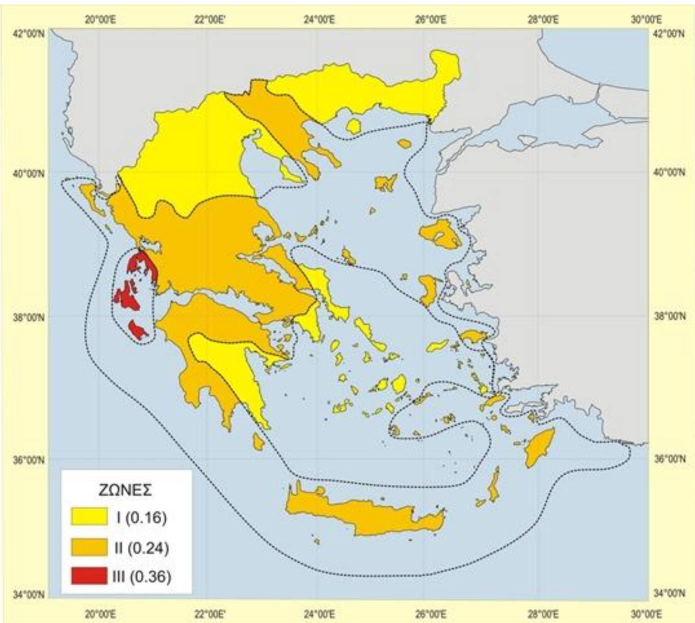


Fig.5 Greece. EAK-2000 seismic design code revised in 2003. Zoning top soil acceleration values for RP 475 years and 10% probability of overtaking in 50 years in accordance with EN1998-1: 2004;
ag = 0.16g, 0.24g and 0.36g.

Seismic zone	a_g
I	0.16g
II	0.24g
III	0.36g

Zone III, ag = 0.36g - Lefkada-Kefalonia-Zakynthos area, Ionian Sea.

The fundamental performance requirements are represented by Non-Collapsing Requirement and

Degradations Limitation Requirement. Within the Non-Collapsing Requirement, the recommended values in the Greek standards are P_{NCR} = 10% in 50 years and T_{NCR} = 475 years. Similarly, within the Degradations Limitation Requirement, the values recommended by standards in Greece are P_{DLR} = 10% in 10 years and T_{DLR} = 95 years. (recommendations EN1998-1).

As regards the classes of importance, there is a slight change between the initial provisions of the EAK2000 code and the National Annex ELOT EN 1998-1: 2005 / NA: 2010, the latter taking the factors from EN 1998-1: 2004, as shown in Table no.8.

Importance Category		γ_I
Σ1	Buildings of small importance for public safety e.g. agricultural buildings, sheds, stables etc.	0.85
Σ2	Ordinary residential and office buildings, industrial buildings, hotels, etc.	1.00
Σ3	School buildings, public assembly buildings, airport terminals and generally buildings where a large number of people gather during the greater part of the day. Buildings that house installation of great economic value (e.g. buildings that house computer centres, special industries, etc).	1.15
Σ4	Buildings whose operation both during an earthquake and after the event is of vital importance, such as telecommunication buildings, power stations, hospitals, fire stations, public services buildings. Buildings that house works of unique artistic value (e.g. museums)	1.30

Tab.8a

Importance Class	I	II	III	IV
Importance Factor γ_I	0,80	1,00	1,20	1,40

Tab.8b

Tab.8 Values of factors γ_I according to the classes of importance according to EAK2000 - tab 8a and according to the National Annex to EN 1998-1 - tab 8b.

Greek Aseismic Code (EAK 2000)		Eurocode 8 (EC8)	
A	• Rock or rock-like formations extending in wide area and large depth provided that they are not strongly weathered • Layers of dense granular material with little percentage of silty-clayey mixtures, having thickness less than 70 m • Layers of stiff overconsolidated clay with thickness less than 70 m	A	Rock or other rock-like geological formation, including at most 5 m of weaker material at the surface ($v_{s,30}$ > 800 m/s)
B	• Strongly weathered rocks or soils which can be considered as granular materials in terms of their mechanical properties • Layers of granular material of medium density with thickness larger than 5 m or of high density with thickness over 70 m • Layers of stiff overconsolidated clay with thickness over than 70 m	B C	Deposits of very dense sand, gravel, or very stiff clay, at least several tens of meters in thickness, characterized by a gradual increase of mechanical properties with depth (360 < $v_{s,30}$ < 800 m/s). Deep deposits of dense or medium-dense sand, gravel or stiff clay with thickness from several tens to many hundreds of meters (180 < $v_{s,30}$ < 360 m/s)
C	• Layers of granular material of low relative density with thickness over 5 m or of medium density with thickness over 70 m • Silty-clayey soils of low strength with thickness over 5 m	D E	Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil ($v_{s,30}$ < 180 m/s) A soft profile consisting of a surface alluvium layer with v_s values of type C or D and thickness varying between about 5 and 20 m, underlain by stiffer material with $v_{s,30}$ > 800 m/s
D	Soft clays of high plasticity index (I_p > 60) with total thickness over 12 m	S_1	Deposits consisting, or containing a layer at least 10 m thick, of soft clays/silts with a high plasticity index (PI > 40) and high water content ($v_{s,30}$ < 100 m/s)
X	• Loose fine-grained silty-sandy soils under the water table which may liquefy (unless a specific study proves that such a hazard can be excluded or their mechanical characteristics will be improved) • Soils which are close to apparent tectonic faults • Steep slopes covered with loose debris • Loose granular soils or soft silty-clayey soils, which have been proved hazardous in terms of dynamic compaction or loss of strength • Recent loose backfills. Organic soils • Soils of class C with excessively steep inclination	S_2	Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in types A–E or S_1

Tab.9 Correlation of ground classification between EAK2000 and EN1998-1.

As regards the site conditions, code EAK2000 provides, like EN1998-1 5, distinct types of soil A, B, Γ, Δ and X, described by specific parameters and stratigraphic profiles. O comparison between the ground conditions in EAK2000 and EN1998-1 is shown in table no.9.

According to EAK2000, the elastic spectrum for the horizontal components R_e (T) is determined with the relations (for the vertical component, the ordinates multiply by 0.7):

$$0 < T < T_1 \qquad R_e(T) = A.\gamma_I.\,[1 + (n.\beta_o - 1).\,(T/T_1)]$$

$$T_1 < T < T_2 \qquad R_e(T) = A.\gamma_I.\,n.\beta_o$$

$$T < T_2 \qquad R_e(T) = A.\gamma_I.\,n.\beta_o.\,(T_2/T)$$

The design spectrum for the horizontal components of the soil movement Φ_D (T) / A * γ_I, is defined by the relations:

$$0 \le T < T_1 \qquad \Phi_d(T) = \gamma_I\,.\,A\,[1 + \frac{T}{T_1}\,(\frac{n.\theta}{q}\,\beta_o - 1)]$$

$$T_1 \le T \le T_2 \qquad \Phi_d(T) = \gamma_I\,.\,A\,\frac{n.\theta.\beta_o}{q}$$

$$T_2 < T \qquad \Phi_d(T) = \gamma_I\,.\,A\,\frac{n.\theta.\,\beta_o}{q}\,(T_2/T)^{2/3}$$

where,

T - the vibration period of a linear system with a single degree of freedom;

A - the peak value of horizontal soil acceleration (corresponding to the 3 zones, 0.16g, 0.24g or 0.36g);

g - gravitational acceleration;

T_1, T_2 - characteristic spectrum periods, similar to T_B and T_C;

γ_I - the structure factor of importance;

q - the structure behaviour factor;

Θ - the influence factor of the foundation;

β_0 - dynamic amplification factor = 2.50;

A,B,Γ,Δ - soil categories;

η - damping correction factor for a 5% viscous damping; N = √7 / (2 + ξ) ≥0.7, where ξ - the viscosity damping coefficient.

It should be noted that $\Phi_D(T)/A*\gamma_I$ has the inferior limit of 0.25.

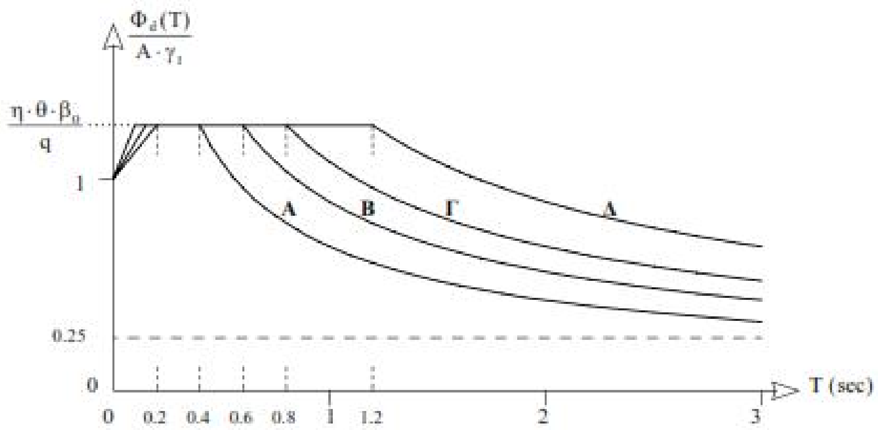


Fig.6 Design Spectrum for Horizontal Ground Moving Components ΦD(T)/A*γI, according to the Greek code EAK2000.

The characteristic periods of the T1, T2 spectra according to EAK2000, respectively T_B, T_C, T_D proposed by the National Annex ELOT EN 1998-1: 2005 / NA: 2010 are shown in table no.10.

Soil Class	A	B	Γ	Δ
T_1	0.10	0.15	0.20	0.20
T_2	0.40	0.60	0.80	1.20

Tab.10a

Ground Type	S	T_B (s)	T_C (s)	T_D (s)
A	1,0	0,15	0,4	**2,5**
B	1,2	0,15	0,5	**2,5**
C	1,15	0,20	0,6	**2,5**
D	1,35	0,20	0,8	**2,5**
E	1,4	0,15	0,5	**2,5**

Tab.10b

Table 10 Values of the T1, T2 periods according to EAK2000, respectively TB, TC, TD proposed by the National Annex ELOT EN 1998-1: 2005 / NA: 2010 depending on the soil categories.

Evaluation of seismic action in technical prescriptions concerning antiseismic design in Portugal

Like Greece, Portugal as a member of the EU and has adopted the Eurocodes, including EN 1998-1: 2004 as NP EN 1998-1: 2010. Prior to the transposition of the European Standard as a national standard including the National Annex, the basic code in the design activity was the RSA 1983 Code for the Safety and Evaluation of Actions for Buildings and Bridges. Like in other European countries, the use of the old seismic norms has been followed since the adoption of the Eurocodes. In a presentation at the European Conference on Seismic Engineering and Seismology in Istanbul on August 25-29, 2014, it was reported that 55% of Portuguese designers still used the RSA standard since 1983 along with other national or Eurocode parts.

The provisions of the RSA 1983 standard for seismic assessment include a seismic coefficient α having values related to the four distinct seismic zones.

Seismic zone	α
A	1.0
B	0.7
C	0.5
D	0.3

Table 11 Values of the seismic coefficient a, according to the norm RSA 1983.

With regard to field conditions, this rule considers three types of soil as follows:

-Type 1 Rock and rigid cohesive soils;

-Type 2 Very strong, medium and medium cohesive soils, hard non-cohesive soils;

-Type 3 Soft and very soft cohesive soils, poor soils

The value of the global seismic coefficient β is determined by the expression:

$$\beta = \beta_0 * \alpha / \eta$$

Where β_0 is the seismic reference coefficient, depending on the ground conditions and the fundamental frequency of the structure in the considered direction of action;

α is the seismic coefficient, depending on the location; In table no.11 are given the values corresponding to the four seismic zones;

η is the behaviour factor, depending on the type and ductility characteristics of the structure.

At the same time, the RSA 1983 norm limits the β coefficient as follows:

$0.04\ \alpha \le \beta \le 0.16\ \alpha$.

Soil Type	Fundamental natural frequency of the structure, f(HZ)	β_o
I	$0.5 \leq f < 5.6$	$0.17 \sqrt{f}$
	$f \geq 5.6$	0.40
II	$0.5 \leq f < 4.0$	$0.20 \sqrt{f}$
	$f \geq 4.0$	0.40
III	$0.5 \leq f < 2.0$	$0.23 \sqrt{f}$
	$f \geq 2.0$	0.32

Table 12 Values of the seismic reference coefficient β_0, according to the RSA 1983 norm.

For estimating the fundamental frequency f (Hz) of the structures, the norm provides the following values:

- structures in frames, f = 12 / n;
- mixed structures, f = 16 / n;
- rigid wall structures, f = 6b / h.

where n is the number of floors, h the height of the building, and b the horizontal dimension of the building in the direction of action considered.

This assessment of seismic action based on a global seismic coefficient is only possible for certain structures that satisfy certain requirements specified by the norm RSA 1983.

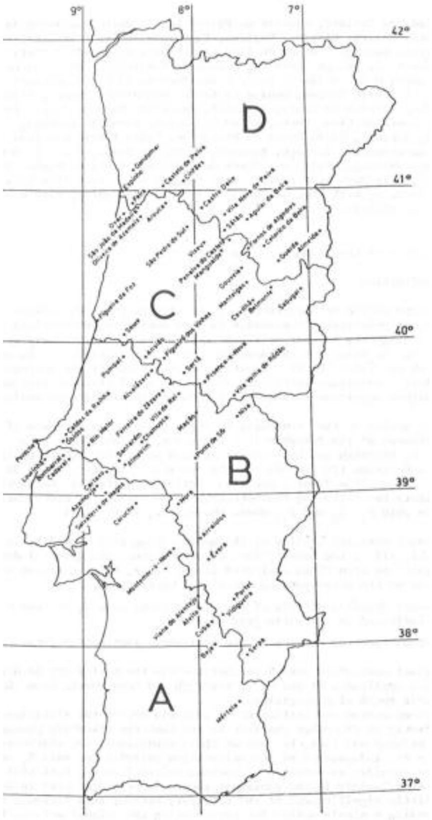


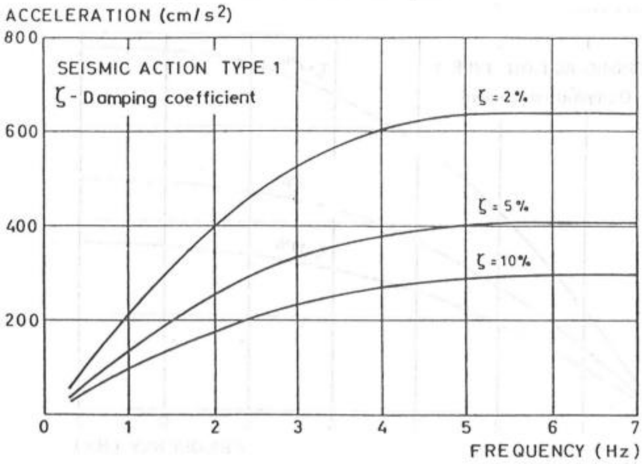
Fig.7 Portugal. Seismic zoning according to the norm RSA 1983.

Because the territory of Portugal is affected by two types of earthquakes, some with epicentre proximity, moderate magnitude and low focal length, and others with epicentre, large magnitude and high focal length. Consequently, RSA 1983 provides for two types of seismic actions that should generally be considered for type 1 and type 2 design, the first, near epicentre seismic, moderate magnitude and reduced focal length and 10 sec and the second for long epicentre, high magnitude and high focal length, lasting 30 seconds.

The RSA 1983 standard shows response spectra for the seismic area A and the three types of terrain. For the other areas B, C and D the spectra are multiplied by the seismic coefficients of location a.

For the vertical component evaluation, the norm recommends multiplying the horizontal spectrum by 0.67.

Of note is that the rule provides for a RP = 975 years.



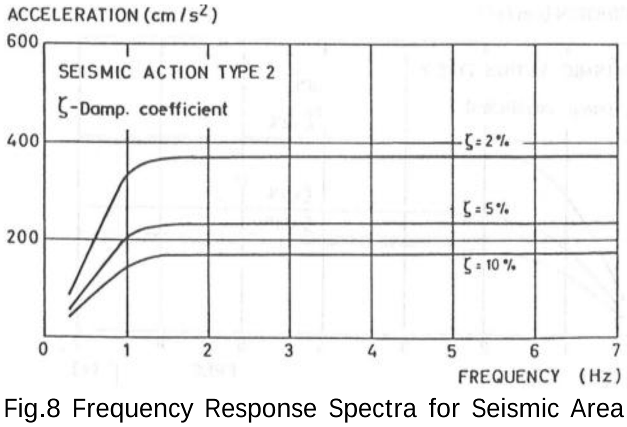


Fig.8 Frequency Response Spectra for Seismic Area A and Ground Type 2 with damping coefficients ξ = 2%, 5%, 10% according to RSA 1983.

The provisions regarding the assessment of seismic action contained in the National Standard and in the Portuguese National Annex to Eurocode 8 Part 1, NP EN 1998-1: 2010 are mainly the following:

The fundamental performance requirements are represented by Non-Collapsing Requirement and Degradations Limitation Requirement. Within the Non-Collapsing Requirement, the recommended values in Portugal are P_{NCR} = 10% in 50 years and T_{NCR} = 475. Similarly, within the Degradations Limitation Requirement, the recommended values in Portuguese standards are P_{DLR} = 10% in 10 years and T_{DLR} = 95 years. (recommendations EN1998-1).

The seismic zoning of continental Portugal is shown in figure 9.

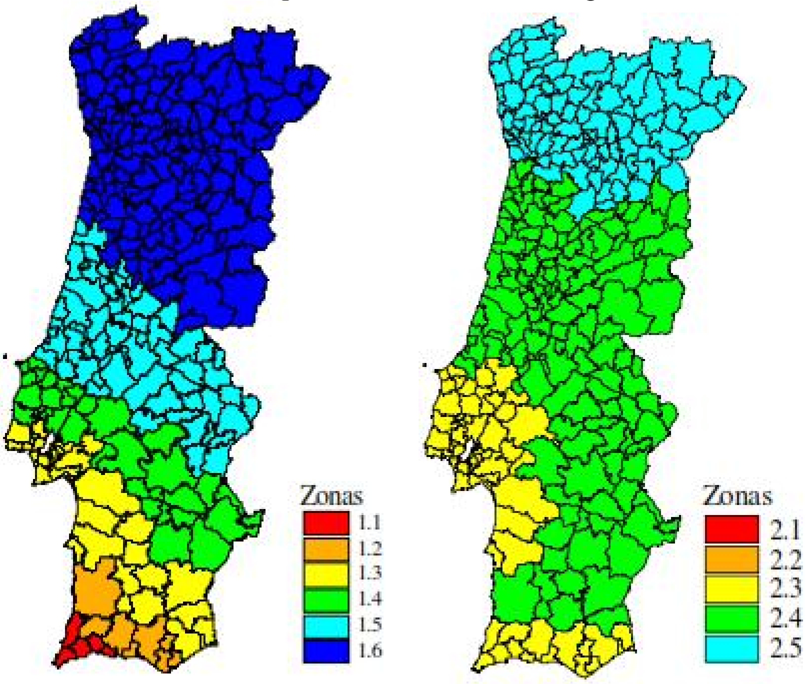


Fig.9 Portugal. Code NP EN 1998-1:2010. Zoning of top ground acceleration values for RP 475 years and 10% probability of exceeding in 50 years.

Acção sísmica Tipo 1		Acção sísmica Tipo 2	
Zona Sísmica	a_{gR} (m/s^2)	Zona Sísmica	a_{gR} (m/s^2)
1.1	2,5	2.1	2,5
1.2	2,0	2.2	2,0
1.3	1,5	2.3	1,7
1.4	1,0	2.4	1,1
1.5	0,6	2.5	0,8
1.6	0,35	–	–

Tab.13 Reference peak values of soil acceleration a_{GR} values for type 1 and type 2 seismic actions according to NP EN 1998-1: 2010.

$a_g = \gamma_I * a_{gR}$.

We must remark the application of the two types of seismic actions type 1 and type 2, mandatory on the continental zone, actions present and in the old norm RSA 1983. In Madeira only the type 1 action is applied, and in Azore only the type 2 action.

Regarding the classes of importance, in the Portuguese standard NP EN 1998-1: 2010, factors γ_I are presented in table no. 14, being modified in accordance with the recommendations of EN 1998-1: 2004, (0.8, 1.0, 1.2, 1.4; the classes of importance are EN-compliant and reversed compared to in P100-1 / 2013.

Classe de Importância	Acção sísmica Tipo 1	Acção sísmica Tipo 2	
		Continente	Açores
I	0,65	0,75	0,85
II	1,00	1,00	1,00
III	1,45	1,25	1,15
IV	1,95	1,50	1,35

Tab.14 Values of γ_I factors according to the classes of importance and type of seismic action (1 or 2) according to NP EN 1998-1: 2010.

The elastic response spectrum for ground acceleration for horizontal components S according to NP EN 1998-1: 2010 is determined by the relations:

$$\text{para } a_g \leq 1 \text{ m/s}^2 \qquad S = S_{max}$$

$$\text{para } 1 \text{ m/s}^2 < a_g < 4 \text{ m/s}^2 \qquad S = S_{max} - \frac{S_{max} - 1}{3}(a_g - 1)$$

$$\text{para } a_g \geq 4 \text{ m/s}^2 \qquad S = 1{,}0$$

where,
ag - calculation acceleration for class A (ag = γI * agR);
TB - the lower limit of periods corresponding to the constant spectral acceleration plane;
TC - the upper limit of periods corresponding to the constant spectral acceleration plane;
TD - the value that defines the beginning of the constant range of the response spectrum;
Smax - field factor;
A, B, C, D, E - soil categories.

tab.15a (stg) and tab.15b (dr)

Tipo de Terreno	S_{max}	T_B (s)	T_C (s)	T_D (s)
A	1,0	0,1	0,6	2,0
B	1,35	0,1	0,6	2,0
C	1,6	0,1	0,6	2,0
D	2,0	0,1	0,8	2,0
E	1,8	0,1	0,6	2,0

Tipo de Terreno	S_{max}	T_B (s)	T_C (s)	T_D (s)
A	1,0	0,1	0,25	2,0
B	1,35	0,1	0,25	2,0
C	1,6	0,1	0,25	2,0
D	2,0	0,1	0,3	2,0
E	1,8	0,1	0,25	2,0

Acção sísmica	a_{vg}/a_g	T_B (s)	T_C (s)	T_D (s)
Tipo 1	0,75	0,05	0,25	1,0
Tipo 2	0,95	0,05	0,15	1,0

tab.15c

Tab.15a, 15b and 15c. The values of the T_B, T_C, T_D, S_{max}, a_{vg}/a_g parameters describing the elastic response spectra, generally recommended in Portugal for seismic action type 1 (tab.15a), seismic action type 2 (tab.15b) and the vertical component (tab.15c), according to NP EN 1998-1:2010.

Evaluation of seismic action in technical prescriptions concerning antiseismic design in Italy

Italy, as a EU member state, has adopted the Eurocodes, including EN 1998-1: 2004 as UNI EN 1998-1: 2007. The European norm was translated into Italian and the National Annex was drafted. The basic code in force for the design activity is NTC 2008 "Technical Rules for Constructions" approved by Ministerial Decree on January 14, 2008, the European norms having a consultative and complementary role. This code also contains a distinct chapter on seismic action. In addition to the NTC 2008 code, the Government Ordinances OPCM3274 / 2003 "Basic Elements on General Criteria for Seismic Classification of the National Territory and Technical Regulations for Construction in Seismic Areas" and OPCM3431 / 2005 contain amendments and completions to the first previously mentioned regulation.

The NTC 2008 national code takes over in a centralised and synthesized manner the provisions of the Eurocodes, being practically a first step towards the exclusive regulation of European standards (expected by the end of 2018), while OPCM3274 and 3431 presents more national specific parameters and data.

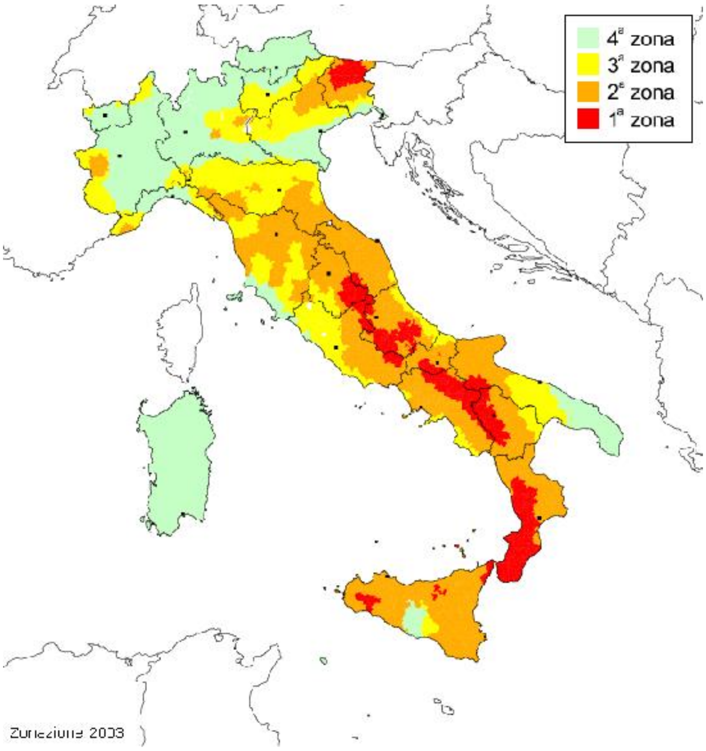


Fig.10 Italy. Standard OPCM3274 / 2003. Zoning of top ground acceleration values for RP 475 years and 10% probability of exceeding in 50 years.

According to NTC 2008, the ground classification is practically identical to that of EN1998-1: 2004, with soil A, B, C, D, E, S1, S2 and Vs,30, NSPT, Cu. At the same time, topographical amplification (assumption in EN1998 for structures with significant coefficients> 1, as detailed in the informative annex of EN1998-5: 2004) is also taken into account when defining response spectra. For the four topographic categories T1-T4, the ST factor has values of 1.0, 1.2, 1.2, and 1.4.

Zona	Valore di a_g
1	0,35g
2	0,25g
3	0.15g
4	0,05g

Tab.16 Peak values of the soil acceleration a_g for A-category soil for RP 475 years and 10% probability of exceeding in 50 years according to OPCM3431 / 2005.

In NTC 2008, the basic safety and performance requirements are:

- verification of design situations of the constructions at the ultimate limit state;
- verification of design situations of the constructions at the service limit state;
- ensuring the robustness of the constructions to exceptional actions.

Thus, similarly to the provisions of the Eurocode, in order to satisfy the requirements of non-collapsing and degradations limitation, as criteria of conformity, one must perform checks at the Ultimate Limit State (ULS) and Degradation Limiting States (SLS).

Checking limit states that refer to time-dependent effects should be related to the designed lifespan of the structure (similar to EN1990 and CR0-2012). Depending on the VN designed lifespan, the constructions are divided into three classes, with VN ≤10 year, ≥50 years and ≥100 years. Similarly to the European norms, the constructions are divided into four classes of importance, from class IV - constructions of strategic importance to class I - construction of low importance, agricultural annexes.

The VR reference period is defined by the formula: VR = VN * CU, where CU is a coefficient according to the class of importance of construction, class I-0.7, class II-1.0, class II-1.5, class IV-2.0.

The reference probabilities of exceeding, PVR in VR years according to the required ULS and SLS status checks are shown in table no.17.

SLO - the state of the operability assurance limit (normal operation);
SLD - limit state of degradation limitation;
SLV - limit state of life safety;
SLC - limit state of collapse prevention.

One can notice a difference compared to the Eurocodes recommendations.

Stati Limite		P_{V_R} : Probabilità di superamento nel periodo di riferimento V_R
Stati limite di esercizio	SLO	81%
	SLD	63%
Stati limite ultimi	SLV	10%
	SLC	5%

Tab.17 PVR exceeding probability values at Ultimate and Service limit states, according to the Italian norm NTC 2008.

According to the NTC 2008 norm (newer than OPCM3431 / 2005), the elastic response spectrum of the accelerations for the horizontal components of the soil movement Se (T) is determined by the relations:

$$0 \le T < T_B \qquad S_e(T) = a_g \cdot S \cdot \eta \cdot F_o \cdot \left[\frac{T}{T_B} + \frac{1}{\eta \cdot F_o}\left(1 - \frac{T}{T_B}\right)\right]$$

$$T_B \le T < T_C \qquad S_e(T) = a_g \cdot S \cdot \eta \cdot F_o$$

$$T_C \le T < T_D \qquad S_e(T) = a_g \cdot S \cdot \eta \cdot F_o \cdot \left(\frac{T_C}{T}\right)$$

$$T_D \le T \qquad S_e(T) = a_g \cdot S \cdot \eta \cdot F_o \cdot \left(\frac{T_C T_D}{T^2}\right)$$

Where T is the period of vibration of a linear system with one degree of freedom;
ag – design calculation acceleration for Class A soil;
F0 - quantification factor for maximum spectral amplification at the reference location, horizontal and rigid, having a minimum value of 2.2;
TB - the value that defines the beginning of the constant response range of acceleration; TB = TC / 3;
TC - the value that defines the beginning of the constant response range of the response spectrum: TC = C_C * T_C'; C_C - coefficient according to the soil category;
TD - the value that defines the beginning of the constant range of the response spectrum; TD = 4.0 * ag / g +1.6;
S - factor that takes into account the soil category (SS factor) and the topographic conditions (by the topo ST factor): S = S_S * S_T;
η - the damping correction factor with a reference value of η = 1 for a viscous damping of 5%; $\eta = \sqrt{10/(5+\xi)} \ge 0{,}55$, where ξ - the viscous damping coefficient.

Categoria sottosuolo	S_S	C_C
A	1,00	1,00
B	$1{,}00 \le 1{,}40 - 0{,}40 \cdot F_o \cdot \frac{a_g}{g} \le 1{,}20$	$1{,}10 \cdot (T_C^*)^{-0{,}20}$
C	$1{,}00 \le 1{,}70 - 0{,}60 \cdot F_o \cdot \frac{a_g}{g} \le 1{,}50$	$1{,}05 \cdot (T_C^*)^{-0{,}33}$
D	$0{,}90 \le 2{,}40 - 1{,}50 \cdot F_o \cdot \frac{a_g}{g} \le 1{,}80 \cdot$	$1{,}25 \cdot (T_C^*)^{-0{,}50}$
E	$1{,}00 \le 2{,}00 - 1{,}10 \cdot F_o \cdot \frac{a_g}{g} \le 1{,}60$	$1{,}15 \cdot (T_C^*)^{-0{,}40}$

Tab.18. The values of Cc and Ss parameters, describing the influence of the soil categories on the seismic action assessment in Italy, according to the norm NTC 2008.

Similarly, the elastic response spectrum of accelerations for the vertical component of the soil movement, S_{ve} (T) is determined by the relation:

$0 \le T < T_B$ $$S_{ve}(T) = a_g \cdot S \cdot \eta \cdot F_v \cdot \left[\frac{T}{T_B} + \frac{1}{\eta \cdot F_v}\left(1 - \frac{T}{T_B}\right) \right]$$

$T_B \le T < T_C$ $$S_{ve}(T) = a_g \cdot S \cdot \eta \cdot F_v$$

$T_C \le T < T_D$ $$S_{ve}(T) = a_g \cdot S \cdot \eta \cdot F_v \cdot \left(\frac{T_C}{T}\right) \qquad F_v = 1{,}35 \cdot F_o \cdot \left(\frac{a_g}{g}\right)^{0,5}$$

$T_D \le T$ $$S_{ve}(T) = a_g \cdot S \cdot \eta \cdot F_v \cdot \left(\frac{T_C \cdot T_D}{T^2}\right)$$

Tab.19. Parameters describing the influence of the soil type categories on the assessment of the vertical component of the seismic action in Italy, according to the norm NTC 2008.

Categoria di sottosuolo	S_S	T_B	T_C	T_D
A, B, C, D, E	1,0	0,05 s	0,15 s	1,0 s

With respect to the S_d (T) design spectrum for ULS, it is determined by using the elastic spectra for the horizontal and vertical components in which the factor η with 1 / q is replaced, where q is the behaviour factor of the structure called the change factor of Elastic response in inelastic response. $S_d(T) \ge 0.2a_g$.

For a more accurate assessment of seismic activity, NTC 2008 provides in Annex B a detailed seismic zoning by specifying the values of the coefficients ag, F_0 and T_C 'defined in 10751 distinct points on the territory of Italy, values specified for 9 periods of return T_R of 30, 50, 72, 101, 140, 201, 475, 975 and 2475 years of seismic action.

The formula for obtaining T_R (provided also by EN1998-1; P_{VR} and V_R defined above) is:

$$T_R = -\frac{V_R}{\ln\left(1 - P_{V_R}\right)}$$

The Italian National Annex to UNI EN 1998-1: 2007 (Eurocode 8) takes on the NTC 2008 approach, adapting it to the EN 1998-1 form and essence.

Regarding the non-collapsing and degradations limitation requirements, the NTC 2008 approaches on limit states:

(ULS) SLV – the state limit of life safety of

For structures with reference period V_R=50 year, reference probability of exceeding P_{NCR} will be 10%, the return period T_{NCR} being 475 years.

For structures with V_R=75 years, T_{NCR} will be 712.5 years, and for structures with V_R=100 years, T_{NCR} will be 950 years.

(SLS) SLD – limit state of degradations limitation

For structures with the reference period V_R=50 years, the reference probability of exceeding P_{DLR} will be 63%, return period T_{DLR} being 50 years.

For structures with V_R=75 years, T_{DLR} will be 75 years, and for structures with V_R=100 years, T_{DLR} will be 100 years.

For structures where the priority is the checking at service limit state (degradations limitation), depending on the structure category, we encounter:

For structures of type 2, T_{DLR} will be 92 years, with P_{DLR}=42% in 50 years, and for structures of type 3, T_{DLR} will be 132 years, with P_{DLR}=31.5% in 50 years.

Seismic zoning is based on ground acceleration values ag for soils in A category for RP 475 and 10% probability of exceeding in 50 years (as in the old Italian standard). From the European norms, the representation of the seismic action by the elastic response spectra for the acceleration of the ground, the horizontal and the vertical ones, is assumed, but it is proposed to maintain some factors such as C_U, F_0, F_v and T_C', with the meaning of the Italian norm NTC 2008.

B. General presentation of certain important codes / standards and norms in zones with high seismic hazard outside Europe

In the USA the main rules that provide information about seismic action, zoning and seismic assessment, technical regulations, etc., are UBC1997 codes - ex. Chap.16 (Uniform Building Code), IBC-2006 (International Building Code) and ASCE 7-2010 - ex. head. 11-23 (American Society of Civil Engineers).

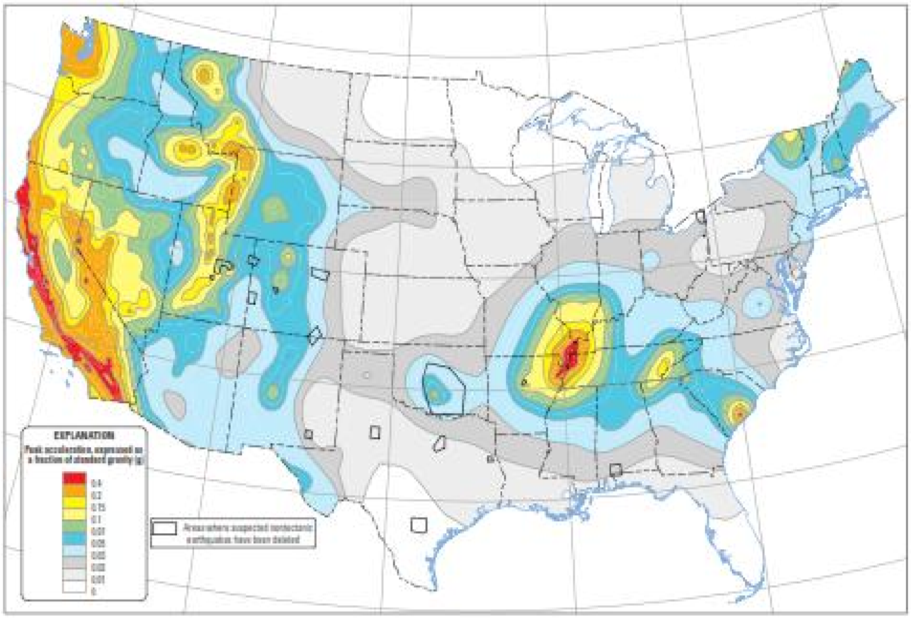


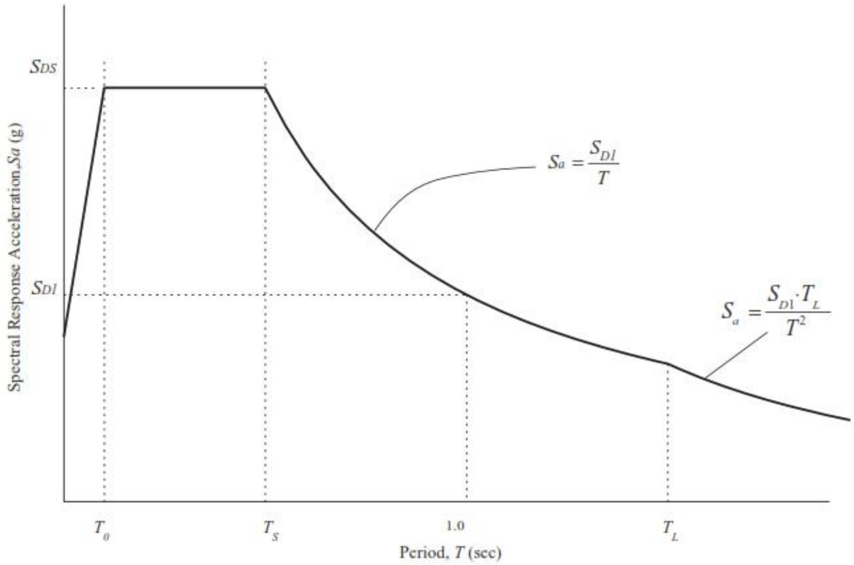
Fig.11 DOOR. Zoning of peak ground acceleration values for RP 475 years and 10% probability of exceeding in 50 years, 2014. Source: USGS.

ASCE 7 introduces two concepts: MCER (maximum considered earthquake) and DBE (design basis earthquake), with the design spectrum, Sa (DBE) = 2/3 from the Sa (MCER) spectrum.

The maps of Seismic Zoning and Parameters are provided by USGS in accordance with ASCE 7 requirements, for MCER a 2% exceeding probability in 50 years (RP 2475 years) and a 10% exceeding probability in 50 years (RP 475y) for DBE common seismic assessment. In both variants, the maps provide spectral values for accelerations for 0.2 sec and 1.0 sec respectively (two types of different seismic actions).

The code also provides coefficients according to the nature of the soils Fa (parameters for short periods, 0.2 sec) and Fv (parameters for long periods, 1.0 sec). The types of soil are divided into 6 categories from A to F.

Fig.12 Design Response Spectrum, according to the American Code ASCE 7-2010.



For the fundamental period $T < T_0$:

$$S_a = S_{DS}\left(0.4+0.6\frac{T}{T_0}\right)$$

For the fundamental period $T_0 < T \leq T_S$:
$S_a = S_{DS}$
For the fundamental period $T_S < T \leq T_L$:

$$S_a = \frac{S_{D1}}{T}$$

For the fundamental period $T > T_L$:

$$S_a = \frac{S_{D1}T_L}{T^2}$$

where $S_{DS}=0.67S_{MS}$, $S_{DI}=0.67S_{MI}$; $S_{MS}=Fa*S_S$, $S_{MI}=F_V*S_I$; S_S and S_I are the accelerations defined in zoning maps for MCER for short periods 0.2 sec, respectively long periods 1.0 sec.
$T_0=0.2\ S_{DI}/\ S_{DS}$, $T_S=S_{DI}/\ S_{DS}$, T_L provided by seismic zoning maps.

In China the seismic design code of buildings is in force GB 50011-2010.
According to this code, three distinct groups of antiseismic design of buildings are considered. The soils are divided into five categories I_0, I_1, II, III and IV, as it results from table no. 22, their influence being taken into account in the assessment of seismic action.
The code introduces seismic intensity into the design process. When assessing the seismic action for design, three types of earthquake, of minor, moderate and major intensity are considered, the minor ones being considered frequent and the major ones as rare. The code defines the conditions in which the necessary checks are carried out and what seismic actions it is necessary to consider.

Seismic Effect I	VI	VII	VIII	IX
Frequently Occurred Earthquakes	0.04	0.08(0.12)	0.16(0.24)	0.32
Expected Rare Earthquakes	-	0.50(0.72)	0.90(1.20)	1.40

Tab.20.a Seismic coefficient αmax, characteristic of seismic movement according to seismic type and seismic intensity, in China, according to the code GB 50011-2010.

Seismic Effect I	VI	VII	VIII	IX
Design basic acceleration of ground motion	0.05g	0.10(0.15)g	0.20(0.30)g	0.40g

Tab.20.b Correspondence of soil acceleration with degrees of seismic intensity in China, according to the code GB 50011-2010.

Condition	P_f	a_{max} (cm/s²)	α_{max}
Minor earthquake	63.2%	35	0.08
Moderate earthquake	10%	100	0.23
Major earthquake	2-3%	220	0.50

Tab.21. Example. The main parameters Pf, amax, αmax, for intensity grade of VII, in China, according to GB 50011-2010. a_{max} - PGA; α_{max} - the maximum seismic horizontal coefficient (see response spectrum fig.13); Pf – the reference exceeding probability of over 50 years. RP 50, 475, 2000 years respectively.

Design Earthquake Groups	Site Category				
	I_0	I_1	II	III	IV
First Group	0.20	0.25	0.35	0.45	0.65
Second Group	0.25	0.30	0.40	0.55	0.75
Third Group	0.30	0.35	0.45	0.65	0.90

Tab.22. The characteristic period of the Tg seismic motion according to the soil categories in China, according to GB 50011-2010.

We can notice the dependence of the seismic coefficient used in the design of αmax on the seismic intensity I and the characteristic period T_g.

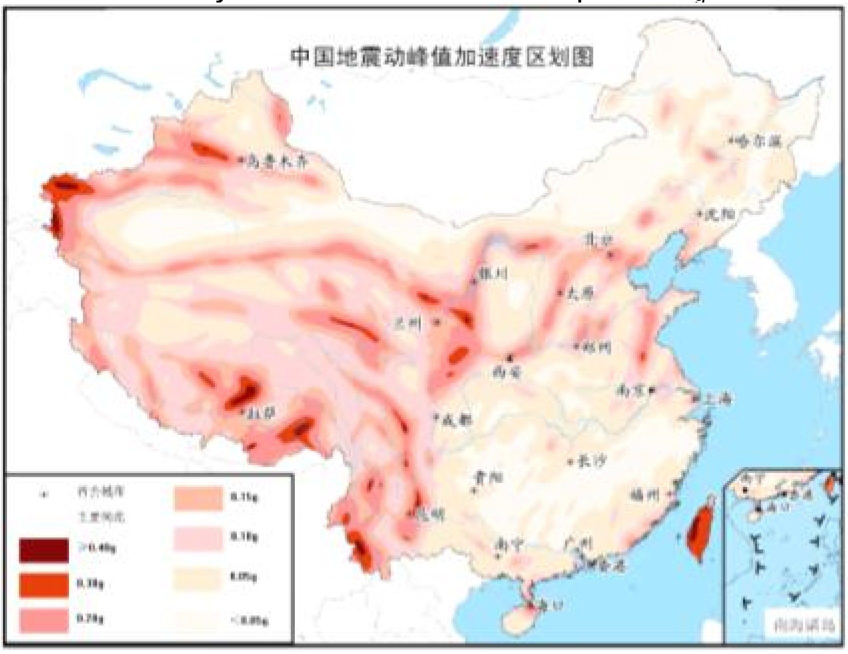


Fig.13 China's seismic zoning having as parameter the peak value of the soil acceleration 2001 with ag ranging from 0.05g to 0.40g.

Figure 14 shows the response spectrum for design according to the Chinese code GB 50011, where:

T- structure fundamental period;

$$\gamma = 0.9 + \frac{0.05 - \zeta}{0.3 + 6\zeta}$$

γ – mitigation index for $T_g < T \leq 5T_g$;

$$\eta_1 = 0.02 + \frac{0.05 - \zeta}{4 + 32\zeta}$$

η_1 – slope correction coef., for $5T_g < T \leq 6.0$; $\eta_1 \geq 0$;

$$\eta_2 = 1 + \frac{0.05 - \zeta}{0.08 + 1.6\zeta}$$

η_2 – damping correction coef.; $\eta_2 \geq 0.55$, cu ξ – viscous damping coefficient.

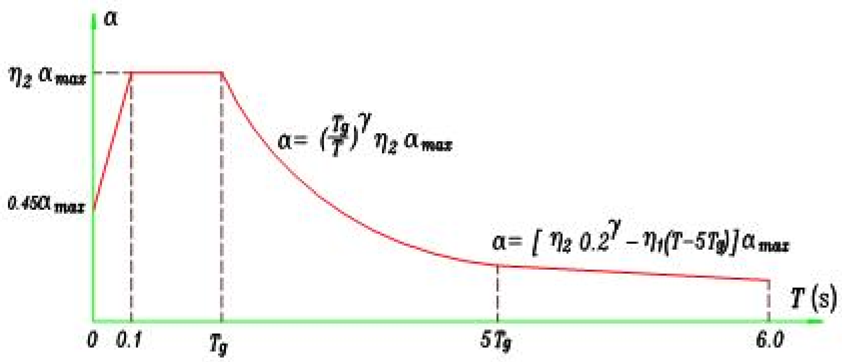


Fig.14 Design Spectrum Response, according to GB 50011.

In Chile The Seismic Construction Design Code NCh433 / 1996, amended in 2012, is in force. According to this code, Chile is divided into three distinct seismic zones.

Similar to European standards, constructions are divided into four major classes I (coef. 0.6) least important, II (coef.1.0), III (coef.1.2) and IV (coef.1.2) most important.

The types of soil are divided into six categories A-F, as shown in table no.23.

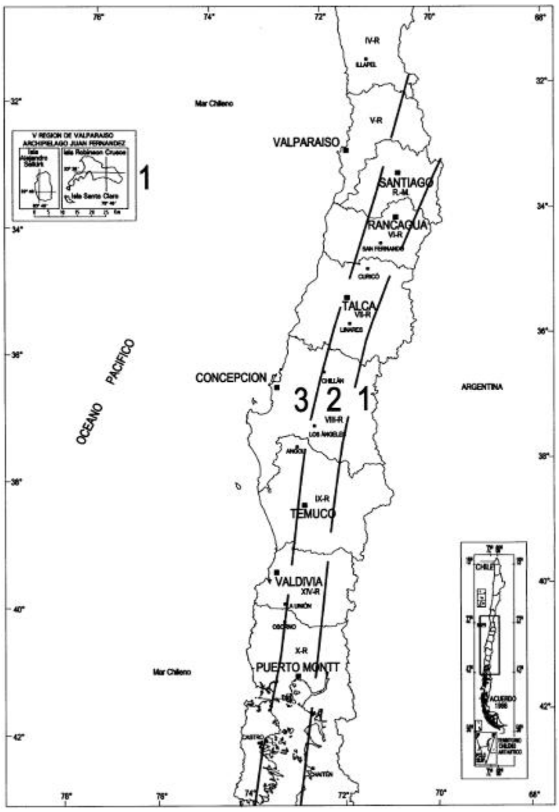


Fig.15 Seismic zoning of Rep. of Chile, according to NCh433 / 96 (2012). Zone 1 A_0 = 0.20g, Zone 2 A_0 = 0.30g, Zone 3 A_0 = 0.40g.

	Suelo Tipo	V_{s30} (m/s)	RQD	q_u (MPa)	(N_1) (golpes/pie)	S_u (MPa)
A	Roca, suelo cementado	≥ 900	≥ 50%	≥10 (ε_{qu}≤2%)		
B	Roca blanda o fracturada, suelo muy denso o muy firme	≥ 500		≥ 0,40 (ε_{qu}≤2%)	≥ 50	
C	Suelo denso o firme	≥ 350		≥ 0,30 (ε_{qu}≤2%)	≥ 40	
D	Suelo medianamente denso, o firme	≥ 180			≥ 30	≥0,05
E	Suelo de compacidad, o consistencia mediana	< 180			≥ 20	<0,05
F	Suelos Especiales	*	*	*	*	*

Tab.23 Classification of soil types according to Chilean rule NCh433-96 (2012).

The design spectrum of pseudo accelerations is determined by the formula:

$$S_a = \frac{S A_o \alpha}{(R^* / I)}$$

where, A_0 is the maximum effective acceleration, I is the coefficient of function of the class of importance of the construction, α is the amplification factor determined by the formula:

$$\alpha = \frac{1 + 4{,}5\left(\frac{T_n}{T_o}\right)^p}{1 + \left(\frac{T_n}{T_o}\right)^3}$$

T_n is the vibration period afferent to mode n;
S,T_0, p, are ground-type parameters, according to table no.24;
R* represents reduction factor determined with the formula:
T* is the vibration period of the mode with the largest equivalent translational mass on the analyzed direction;
R_0 is the global reduction factor, depending on the type of structure.

$$R^* = 1 + \frac{T^*}{0{,}10\, T_o + \frac{T^*}{R_o}}$$

For structures with structural walls, the norm provides for a simplified formula in which the number of N floors is entered and the T *.

Tab.24 The values of the basic parameters used in the assessment of the seismic action, according to the classification of the types of soil, according to the Chilean NCh433-96 (2012).

Tipo de Suelo	S	T_o (s)	T' (s)	n	p
A	0.90	0.15	0.20	1.00	2.0
B	1.00	0.30	0.35	1.33	1.5
C	1.05	0.40	0.45	1.40	1.6
D	1.20	0.75	0.85	1.80	1.0
E	1.30	1.20	1.35	1.80	1.0
F	*	*	*	*	*

Apart from the presented norms from USA, China and Chile, the design codes from Japan and New Zealand should also be mentioned.

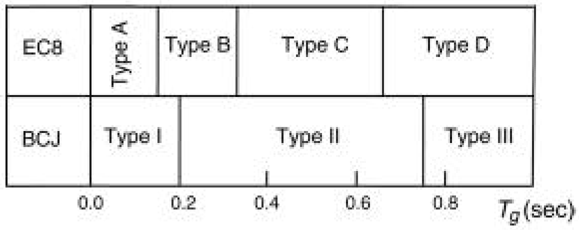
In Japan, a modified design code was in force in 2000. According to the Japanese code, the elastic response spectrum for PGA 0.40g (significant value in Japan) is determined by the formulas:

$$0 \le T \le T_J \qquad R_t = 1$$

$$T_J < T \le 2T_J \qquad R_t = 1 - 0.2\left(\frac{T}{T_J} - 1\right)^2$$

$$2T_J < T \qquad R_t = \frac{1.6T_J}{T}$$

Tab.25 Correspondence between the main categories of soil between Eurocode 8 and the Japanese Code.



where Tj is the period that depends on the type of soil, having the values of 0.4 sec soil class I, 0.6 class II and 0.8 class III.

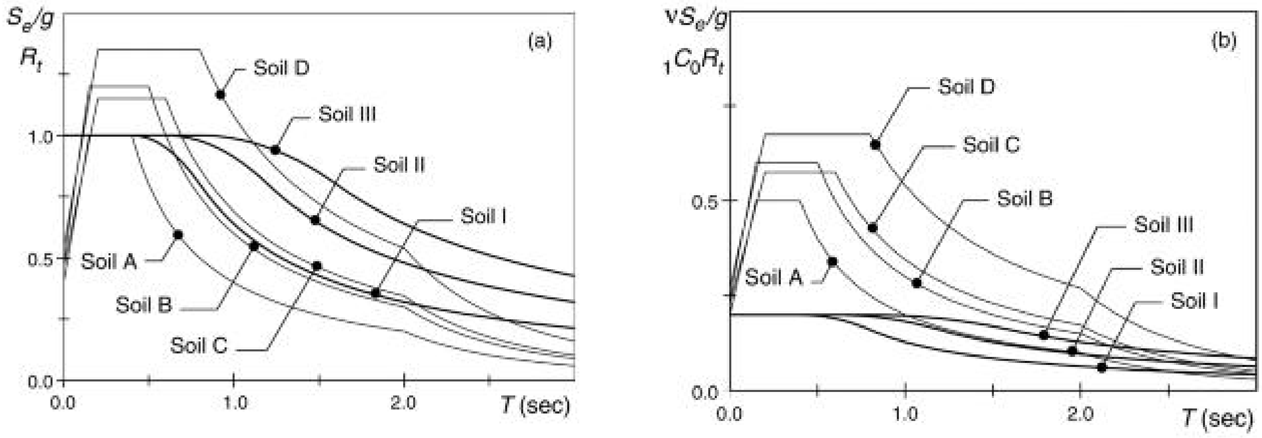


Fig.15.a and 15.b, Comparison of the elastic response spectra according to EN1998 and the Japanese Code for different terrain categories, for strong seismic movements (15a) and moderate movements (15b).

It should be noted that both the European and Japanese norms provide two levels of seismic action, and both norms provide for a 10% reference exceeding probability in 50 years, RP 475 for strong seismic movements.

Regarding the evaluation of seismic action, New Zealand seismic design rule is in force, i.e. NZS 1170 Part 5: 2004 Actions for structural design; Earthquake actions for New Zealand. The design spectrum according to NZS 1170 is obtained by the formula:

$$C(T) = C_h(T)\, Z\, R\, N(T, D)$$

Where $C_h(T)$ spectrum shape factor (fig.16), Z seismic hazard factor, R factor in relation with the RP, =1 for ULS, N (T, D) factor that modifies the shape of the elastic response spectrum for locations in epicentral areas, =1 for buildings located at more than 20 km from epicentral area.

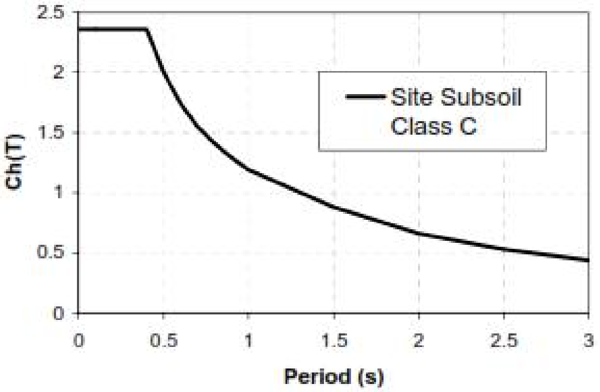


Fig.16. Coefficient $C_h(T)$ for the C type soil category.

C. Conclusions

Although the process of uniformisation of standards / norms across the European Union began in the 1980s, it is not yet fully completed. The status of the Eurocodes and the National Annexes in the 28 EU Member States is still different, some countries adopting these codes as unique rules, others publishing them and still maintaining for them a recommendation / advisory nature, coexisting with national rules that are generally adapted to the Eurocodes. Thus, it can be said that the adoption of the Eurocodes together with the National Annexes has progressed significantly and is approaching its end. However, due to the existence of the Eurocodes, the general design rules have undergone a strong convergence, the engineering body, the users of these norms, have exhibited a degree of inertia in the acceptance of the new technical rules, and there is a great deal of habituation to the provisions and the symbolism of the national norms. The widest adaptation of the last remaining national rules, which coexist with the Eurocodes, to their provisions, is an important factor in completing the process of general adoption of the Eurocodes, facilitating the mission of the engineering body, the main users of these rules. As regards the provisions of the National Annexes of EN1998-1 part of the Eurocode 8, it may be considered natural that there are differences, which are generated both by the national specificity of the hazard and the seismic vulnerability, but also by the economic context and the national engineering traditions and practices.

Throughout the world, in countries with high seismic risk such as the USA, China, Japan, Chile, New Zealand they have developed advanced seismic design codes for buildings. Like in Europe, these codes are tailored to specific seismic risk (hazard and vulnerability), economic context, and national engineering practices. Between these codes and Eurocodes there are constant comparisons conducted by specialists for in view of their optimisation.

D. Selective bibliography

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