Second Generation of Eurocode 8

General rules and seismic action

2 - Seismic action

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Some words of introduction

- Provisions on seismic action in EN1998-1-1 were established by PT1, and supplemented at the margins by PT6.
- Background documents issued by PT1 and PT6 are available. Some parts of PT1 background document, which was issued in 2018, need to be updated to account for last developments.
- Considerations on seismic action are mainly presented in Clause 5, for which Roberto Paolucci was the major contributor. They are also disseminated in Clauses 4 and 6 as well as in Annexes A to D.

➢ In the next slides, quotations of EN1998 are in black with some words in red ; comments are in blue.

PT1 members: A. Benavent-Climent, M. Dolsek, P. Labbé (lead), R. Paolucci, J. Schwarz, Th. Wenk.

PT6 members: D. Davi, P. Franchin (lead), P. Labbé, T. Panagiotakos, A. Sextos.

Permanent PT members: Ph. Bisch (SC8 Chairman), A. Correia (SC8 Secretary).

Some words of introduction - global picture

- Out of 13 NDPs in Part 1-1, seven are related to seismic action, all in Clause 5.

5 Site conditions and seismic action

- There are 3 shall statements about seismic action, all in clause 5:

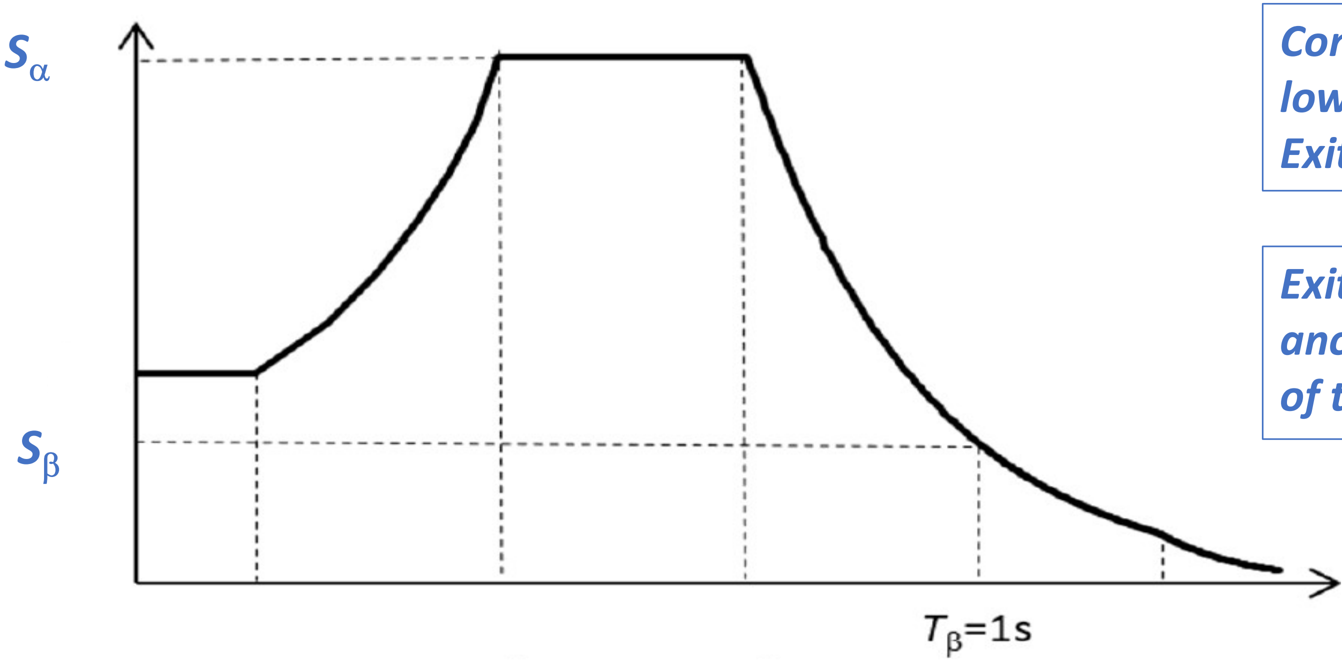
5.1.1 (1) Site conditions **shall be** identified to establish the seismic action.

5.2.1 (1) For use of EN 1998, territories **shall be** mapped depending on the local seismic hazard.

5.2.2.1 (1) Within the scope of EN 1998, the seismic action at a given location on the ground surface **shall be** represented by horizontal and vertical elastic pseudo-absolute acceleration response spectra … .

Some words of introduction – a major update

The seismic action is represented by pseudo-absolute acceleration response spectra, anchored at S_α and S_β values.



Convenient to high and low seismicity areas. Exit Type 1 and Type 2.

Exit the PGA as anchoring parameter of the seismic action.

Seismic action in Clause 4
Basis of design

Performance requirements ; § 4.1

4.1(2) In order to meet the performance requirements in (1), it shall be verified that structures are designed in such a way that specified limit states are not exceeded under prescribed seismic actions.

NOTE Seismic actions are introduced in this standard to meet the performance requirements despite the unpredictable variability of the seismic input motion. Such actions are to be regarded as conventional and cannot be related to any specific earthquake event.

Although every effort is made such that spectral shapes, and other parameters as well, be controlled by physics, they should be regarded as load cases, not as representative of possible actual input motions.

Seismic action class ; seismic action index ; § 4.1

$S_\delta = \delta\, F_\alpha\, F_T\, S_{\alpha,475}$ Consequence class / site / topography / hazard

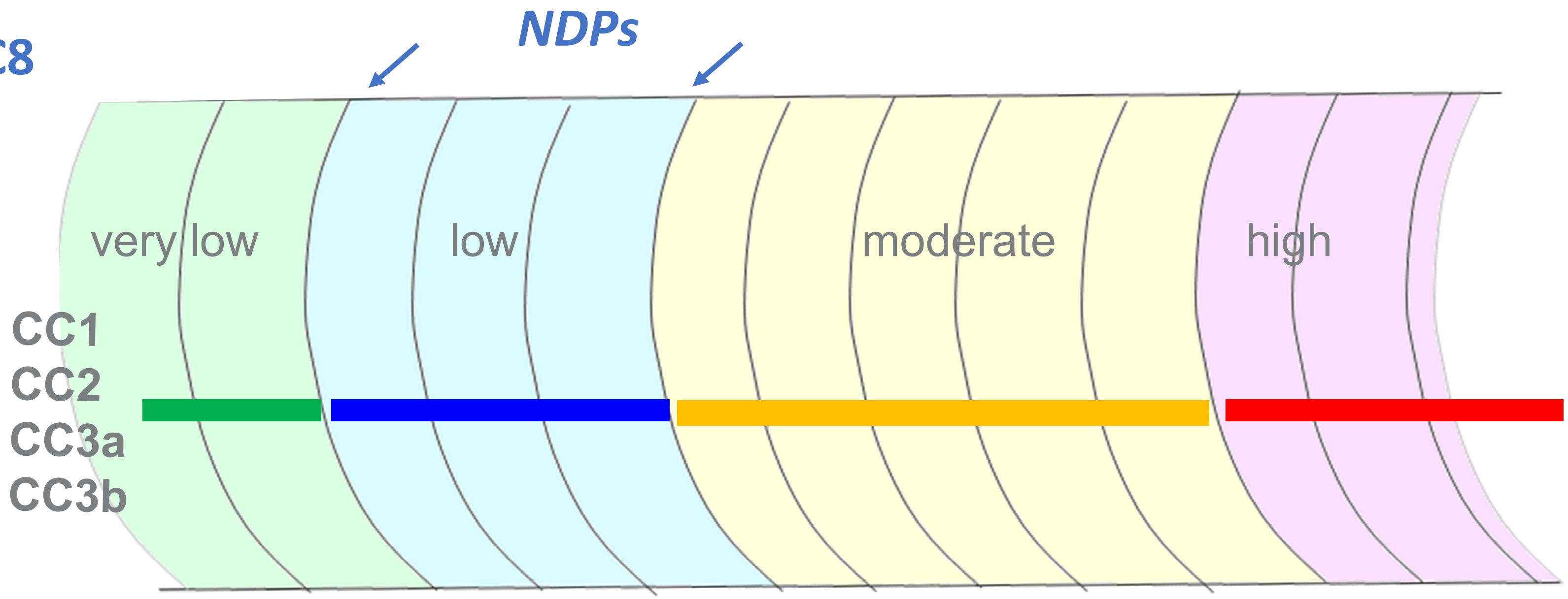
Seismic action class	Range of seismic action index
Very low	$S_\delta < 1{,}30\ \mathrm{m/s^2}$
Low	$1{,}30\ \mathrm{m/s^2} \leq S_\delta < 3{,}25\ \mathrm{m/s^2}$
Moderate	$3{,}25\ \mathrm{m/s^2} \leq S_\delta < 6{,}50\ \mathrm{m/s^2}$
High	$S_\delta \geq 6{,}50\ \mathrm{m/s^2}$

δ is an NDP, default values of which are given in relevant Parts of EC8.

In many respects, the concept of seismic action class replaces the concept of seismicity level.

Seismic action class ; seismic action index ; § 4.1

Current EC8

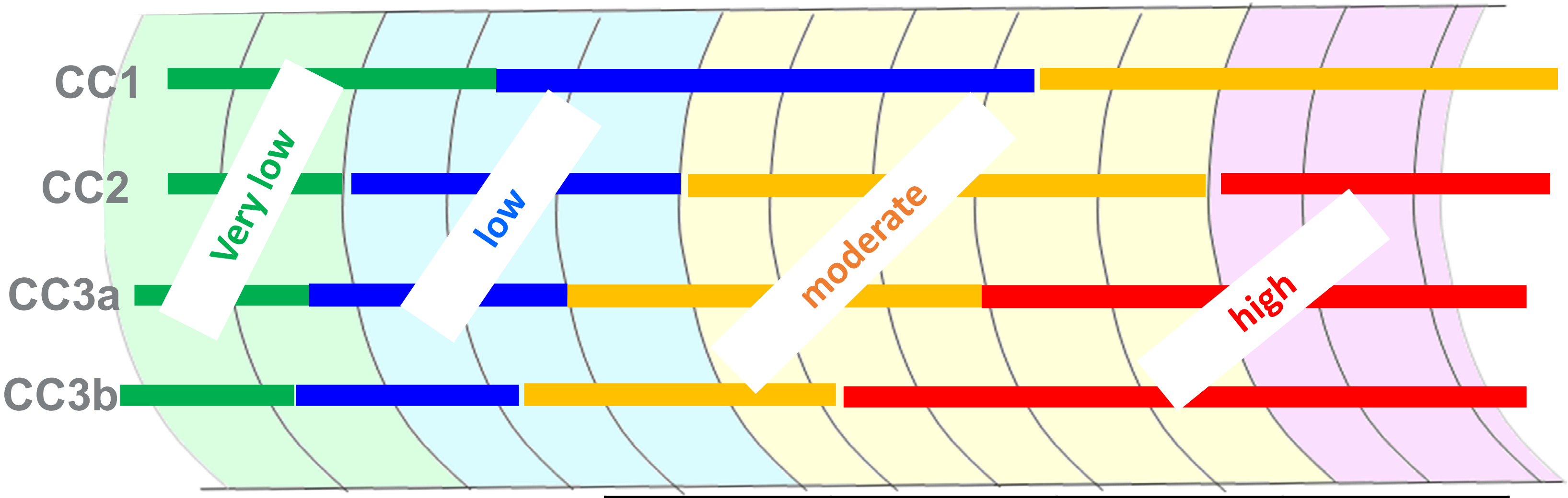


Current EC8 Part 1 , 10.1.3 (1)

Seismic design for ductility class DC1, … is recommended only for very low or low seismicity levels.

Seismic action class ; seismic action index ; § 4.1

Revised EC8	1 m/s²	2,5 m/s²	5 m/s²	$S_{\alpha,475}$	*not NDP*

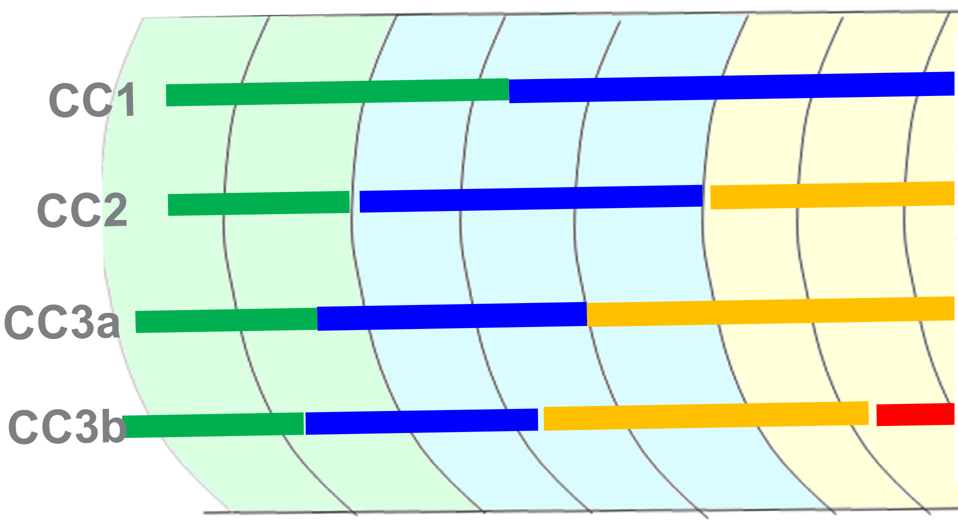


	$\delta=$	CC1	CC2	CC3a	CC3b
For buildings and bridges :	$\delta=$	0,60	1,00	1,25	1,60
In Part 4 :	$\delta=$	0,60	1,0	1,4	1,8
In Part 5 :	$\delta=$	0,6	1,0	1,5	

NDPs

Seismic action class ; seismic action index ; § 4.1

Revised EC8 Seismic action index calibration



Seismic action class	$S_\delta = \delta\ S_{\alpha,475}$
Very low	< 1,0
Low	1,0 – 2,5
Moderate	2,5 – 5,0
High	> 5,0

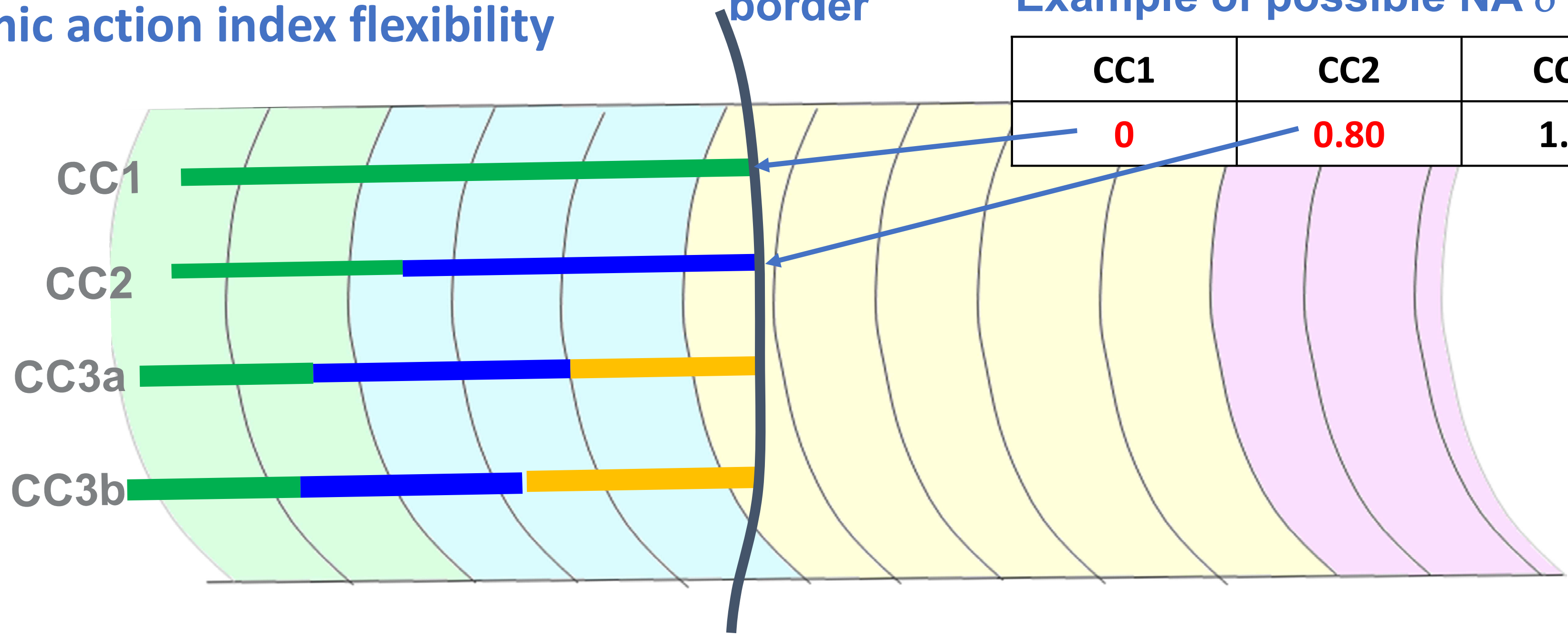
$S_\delta = \delta\ F_\alpha\ F_T\ S_{\alpha,475}$
< 1,30
1,30 - 3,25
3,25 - 6,50
> 6,50

Step 1 : coincide with seismicity level for CC2

Step 2 : an evaluated inclusive value of $F_\alpha\ F_T$ =1,3 is retained.

Seismic action class ; seismic action index ; § 4.1

Seismic action index flexibility



Example of possible NA δ values

CC1	CC2	CC3a	CC3b
0	0.80	1.25	1.60

Next EC8, Part 2, 4.3.6 (5)

Seismic design for DC1 should not be adopted in moderate and high seismic action class.

Limit states and associated seismic action § 4.3

(3) Except when (5) is used, seismic actions should be specified in terms of their **return periods**. The attainment of the performance requirements should be achieved by selecting appropriate return periods, $T_{LS,CC}$, depending on the **specified limit states**, LS, and **consequence class**, CC, of the structures.

NOTE For a given type of structure, $T_{LS,CC}$ values are given in the relevant parts of EN 1998.

(4) The value of the return period specified for limit state SD and consequence class CC2, $T_{SD,2}$ should be considered as the reference return period T_{ref} introduced in 5.2.1(2).

$$T_{ref} = T_{SD,2}$$

(5) **Performance factors**, $\gamma_{LS,CC}$, may be used alternatively to the return periods defined in (3). A value of 1,0 should be assigned to $\gamma_{SD,2}$.

NOTE For a given type of structure, $\gamma_{LS,CC}$ values are given in the relevant part of EN 1998.

$$\gamma_{SD,2} = 1$$

Limit states and associated seismic action § 4.3

RP default values

Part 1-2

	CC1	CC2	CC3-a	CC3-b
NC	800	1600	2500	5000
SD	250	475	800	1600
DL	50	60	60	100

Part 4

	CC1	CC2	CC3-a	CC3-b
NC	800	1600	2500	5000
SD	250	475	1300	2500
DL	50	60	150	250

Part 2

NC	800	1600	2500	5000
SD	250	475	800	1600
DL	50	60	100	200

Part 5

NC	800	1600	2500
SD	250	475	800
DL	50	60	60

Limit states and associated seismic action § 4.3

performance factors default values

Part 1-2

	CC1	CC2	CC3-a	CC3-b
NC	1,2	1,5	1,8	2,2
SD	0,8	1	1,2	1,5
DL	0,4	0,5	0,5	0,6

Part 4

	CC1	CC2	CC3-a	CC3-b
NC	1,2	1,5	1,8	2,2
SD	0,8	1,0	1,4	1,8
DL	0,4	0,5	0,7	0,8

Part 2

NC	1,2	1,5	1,8	2,2
SD	0,8	1,0	1,25	1,5
DL	0,5	0,5	0,6	0,7

Part 5

NC	1,2	1,5	1,8
SD	0,8	1,0	1,2
DL	0,4	0,5	0,5

Seismic action in Clause 5
Site conditions and seismic action

Site conditions ; § 5.1

5.1.1 (1) Site conditions shall be identified to establish the seismic action.

- Stable site definition. If not stable, apply Part 5 for stability assessment.
- In case of vicinity to active faults, site-specific hazard studies should be carried out as per **Annex C.**

5.2.1 (1) The site may be categorised in one of the categories A to F given in Table 5.1.

Other categories are possible
e.g. hard rocks, deep basins …

Several meetings were held in common between PT1 and WG4 (K. Pitilakis convenor) and a PT1-WG4 workshop was dedicated to site categorisation and site amplification factors. A specific SC8 Ad hoc Group was established in order to achieve a consensus on the subject (S. Foti convenor).

Site categorisation ; § 5.1.2

Table 5.1 — Standard site categorisation

	Ground class	stiff	medium stiffness	soft
Depth class	$v_{s,H}$ range / H_{800} range	400 - 800 m/s	250 -400 m/s	150 -250 m/s
very shallow	$H_{800} \leq 5$ m	A	A	E
shallow	5 m < $H_{800} \leq 30$ m	B	E	E
intermediate	30 < $H_{800} \leq 100$ m	B	C	D
deep	$H_{800} > 100$ m	B	F	F

$v_{s,H} = v_{s,H_{800}}$

$v_{s,H} = v_{s,30}$

down to 100 m/s for low seismic action class; 5.2.2.2 (6)

Unambiguous categorisation

- H_{800} is the depth of the seismic bedrock formation identified by v_s at least equal to 800 m/s.
- The standard rock site should be characterised by H_{800} = 0 m and categorised as type A.
- If the information on H_{800} and/or $v_{s,H}$ is not available or it is incomplete, **Annex B** may be used.

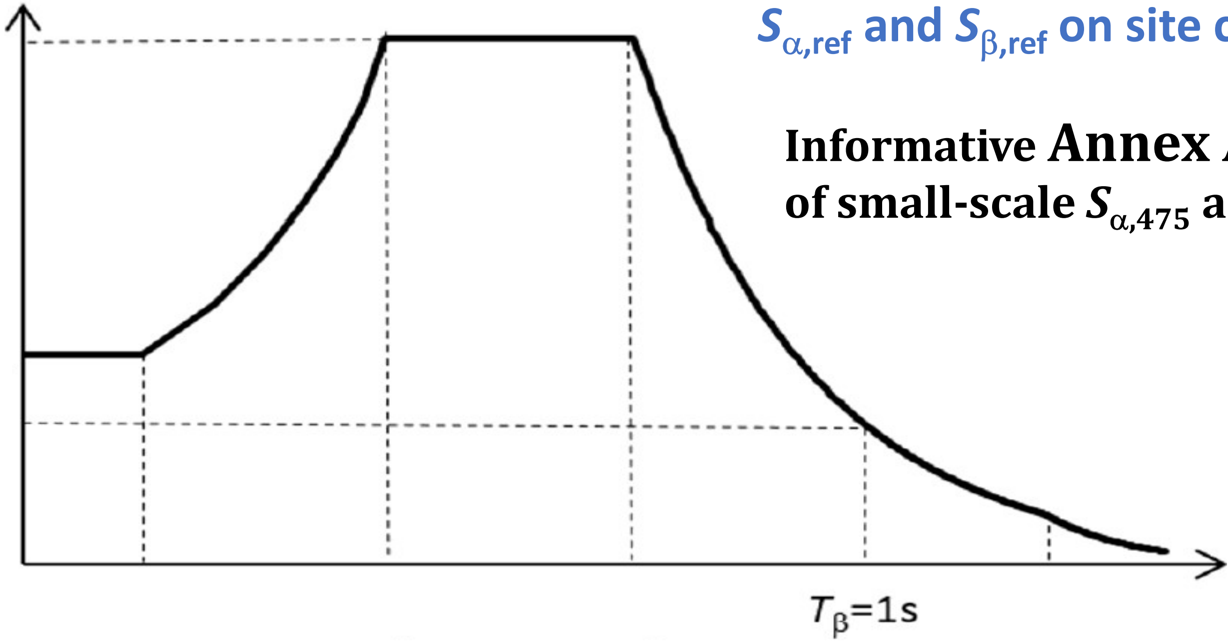
Seismic action, § 5.2 / Spectral acceleration maps, § 5.2.1

5.2.1 (1) For use of EN 1998, territories shall be mapped depending on the local seismic hazard.

NOTE …These parameters can also be grouped into seismic zones … .

NDP $S_{\alpha,ref}$

NDP $S_{\beta,ref}$



$S_{\alpha,ref}$ and $S_{\beta,ref}$ on site cat. A for return period T_{ref}

Informative Annex A gives a representation of small-scale $S_{\alpha,475}$ and $S_{\beta,475}$ maps of Europe.

Seismic action, § 5.2 / Spectral acceleration maps, § 5.2.1

➢ Seismicity levels, based on $S_{\alpha,475}$ values

Table 5.2 — Range of $S_{\alpha,475}$ values to define seismicity levels

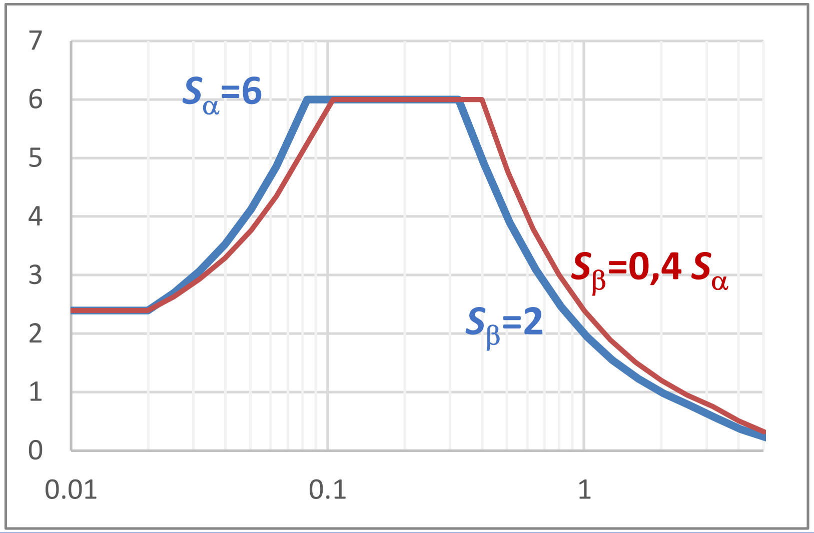
Seismicity level	$S_{\alpha,475}$ (m/s²)
Very low	< 1,0
Low	1,0 - 2,5
Moderate	2,5 - 5,0
High	≥ 5,0

(2) In case … of seismic zones, these zones should be delimited, and their seismicity levels qualified according to Table 5.2…

➢ Option for $S_{\beta,ref}$ determination

$$S_{\beta,ref} = f_h \, S_{\alpha,ref}$$

f_h = 0,2 for low and very low seismicity levels;
f_h = 0,3 for moderate seismicity levels;
f_h = 0,4 for high seismicity levels.



Seismic action, § 5.2 / Spectral acceleration maps, § 5.2.1

- Provisions in case T_{ref} is different from 475 years.
- Provisions in case the reference seismic hazard is established for site category other than A.
- Several pairs of $S_{\alpha,ref}$ and $S_{\beta,ref}$ may be considered.
- Provisions for calculation of $S_{\alpha,RP}$ and $S_{\beta,RP}$ at return periods other that T_{ref} .

Seismic action, § 5.2 / Basic representation of it, § 5.2.2

(1) Within the scope of EN 1998, the seismic action at a given location on the ground surface shall be represented by horizontal and vertical elastic pseudo-absolute acceleration response spectra, henceforth called "elastic response spectra".

NOTE A reduced spectrum for the application of the force-based approach is introduced in 6.4.1.

(4) Site-specific ground response studies may be used in view of the definition of the seismic action for performance verifications, for whatever the ground type and the consequence class of the structure. These studies should be carried out according to Annex C and to prEN 1998-5:2022, 7.5, and should provide site-specific elastic response spectra.

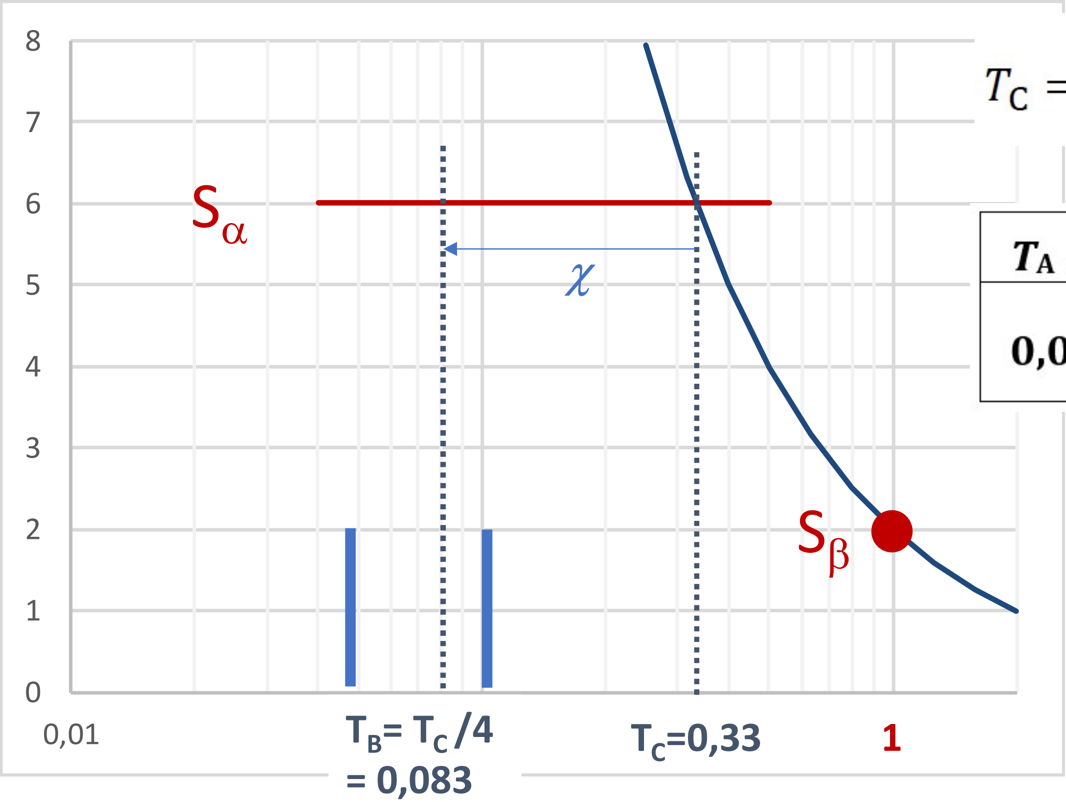
(5) Site-specific ground response studies should be carried out in case a) or b) apply:

a) in case of high seismic action class, with $v_{s,H} < 200$ m/s;

b) when site conditions cannot be associated with the standard site categories referred to in Table 5.1.

(6) Time-history representations of the seismic action may be used (see 5.2.3).

Seismic action, § 5.2 / Standard response spectrum, § 5.2.2.2

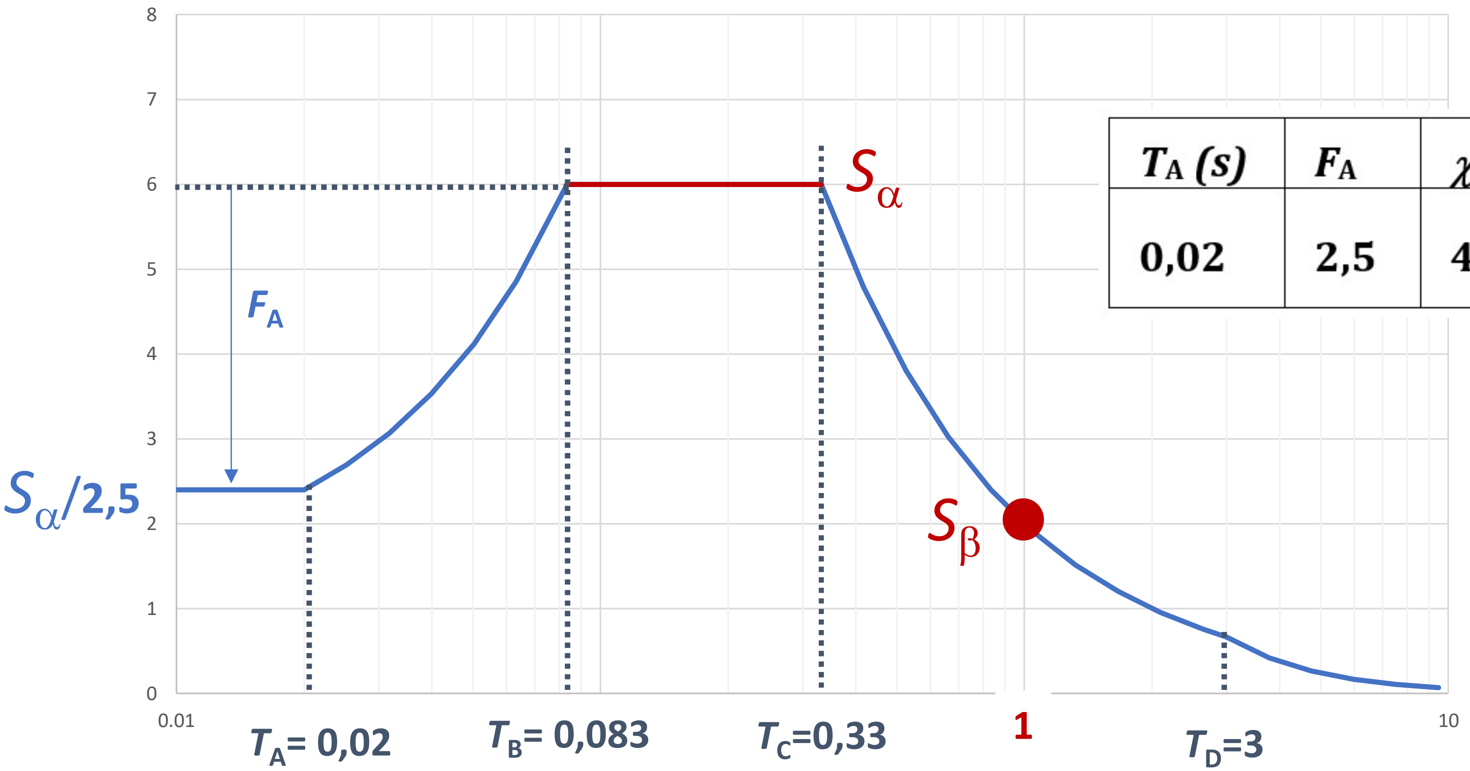


$$T_C = \frac{S_\beta T_\beta}{S_\alpha}$$

NDPs

T_A (s)	F_A	χ	T_D (s)
0,02	2,5	4	2 if $S_{\beta,RP} \leq 1\text{m/s}^2$ $1+S_{\beta,RP}$ if $S_{\beta,RP} > 1\text{m/s}^2$

Seismic action, § 5.2 / Standard response spectrum, § 5.2.2.2



NDPs

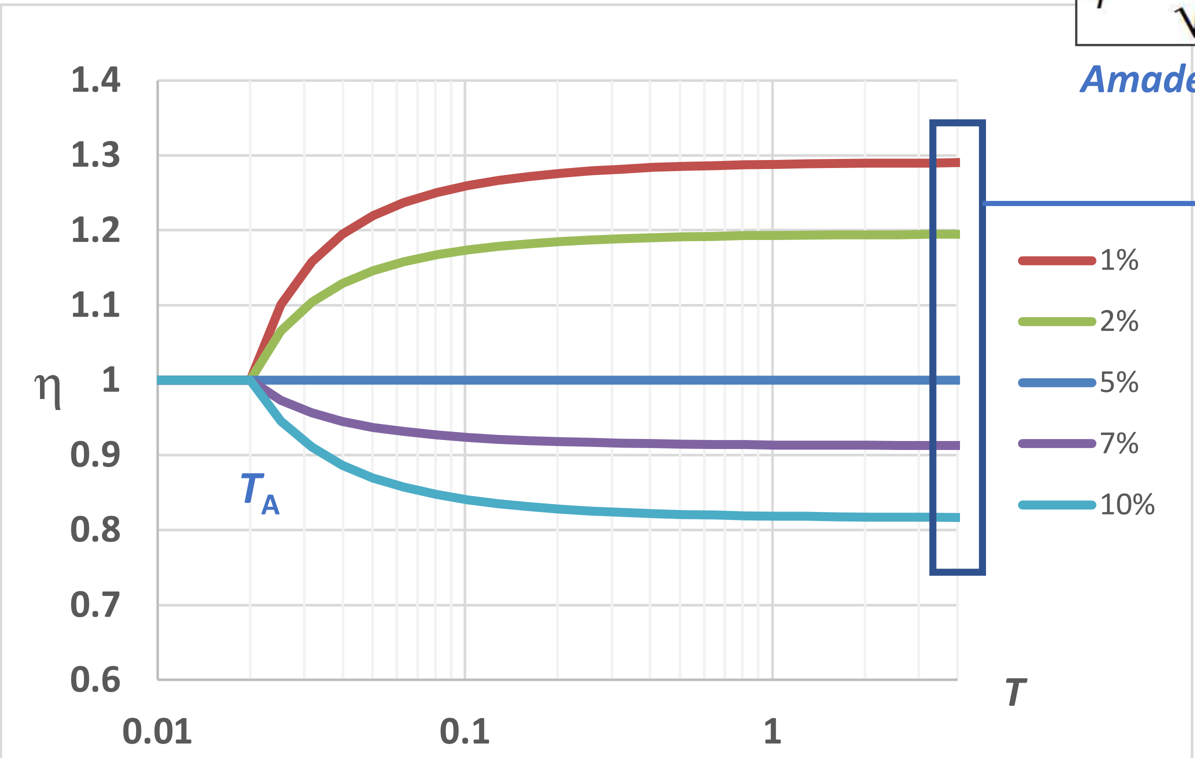
T_A (s)	F_A	χ	T_D (s)
0,02	2,5	4	2 if $S_{\beta,RP} \leq 1 m/s^2$ $1+S_{\beta,RP}$ if $S_{\beta,RP} > 1 m/s^2$

Seismic action, § 5.2 / Standard response spectrum, § 5.2.2.2

Damping correction factor

$$\eta = \sqrt{\left(10 + \frac{T_C(\xi - 5)}{T_C + 30\,(T - T_A)}\right) / (5 + \xi)} \quad T \leq 4\text{s}$$

Amadeo Benavent-Climent



Current EC8 values

Seismic action, § 5.2 / Site amplification factors, § 5.2.2.2

$S_\alpha = F_T \, F_\alpha \, S_{\alpha,RP}$
$S_\beta = F_T \, F_\beta \, S_{\beta,RP}$

RP is the return period associated to the CC and LS under consideration. For instance the RP default value for a CC3-a bridge verified at the NC limit state is 2500 y.

- $S_{\alpha,RP}$ and $S_{\beta,RP}$ can be obtained from hazard maps at the considered return period RP,

- or by applying:
  $S_{\alpha,RP} = \gamma_{SD,CC} \, S_{\alpha,Ref}$
  $S_{\beta,RP} = \gamma_{SD,CC} \, S_{\beta,Ref}$
  ($\gamma_{SD,CC}$ =1,8 for the above bridge case)

e.g. Part 2 table of return periods

	CC1	CC2	CC3-a	CC3-b
NC	800	1600	2500	5000
SD	250	475	800	1600
DL	50	60	100	200

e.g. Part 2 table of $\gamma_{SD,CC}$

NC	1,2	1,5	1,8	2,2
SD	0,8	1,0	1,25	1,5
DL	0,5	0,5	0,6	0,7

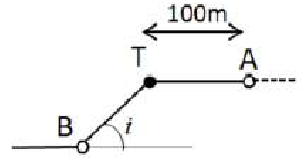
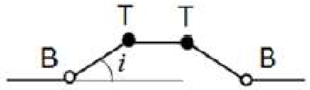
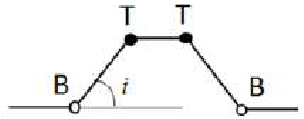
$S_{\alpha,Ref} = S_{\alpha,475}$ in the vast majority of countries.

Seismic action, § 5.2 / Site amplification factors, § 5.2.2.2

F_T is the topography amplification factor;

F_α is the short period site amplification factor;

F_β is the intermediate period ($T = T_\beta$) site amplification factor;

F_T	Simplified sketch*
1,0	
1,2	
1,2	
1,4	

According to current Part 5

Scientific background documentation for F_α and F_β :

See background document as well as
Paolucci, R., Aimar, M., Ciancimino, A. *et al.* Checking the site categorization criteria and amplification factors of the 2021 draft of Eurocode 8 Part 1–1. *Bull Earthquake Eng* 19, 4199–4234 (2021).

Pitilakis K, Riga E, Anastasiadis A (2013) New code site classification, amplification factors and normalized response spectra based on a worldwide ground-motion database. Bull Earthq Eng 11(4):925–966

Seismic action, § 5.2 / Site amplification factors, § 5.2.2.2

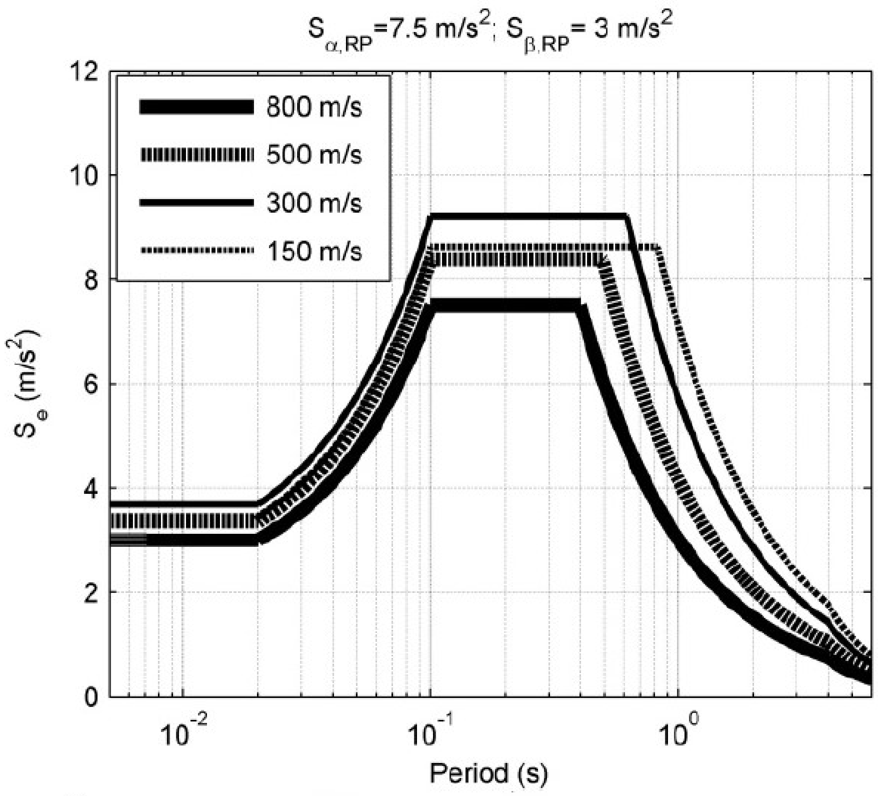
Limited jumps at boundaries.

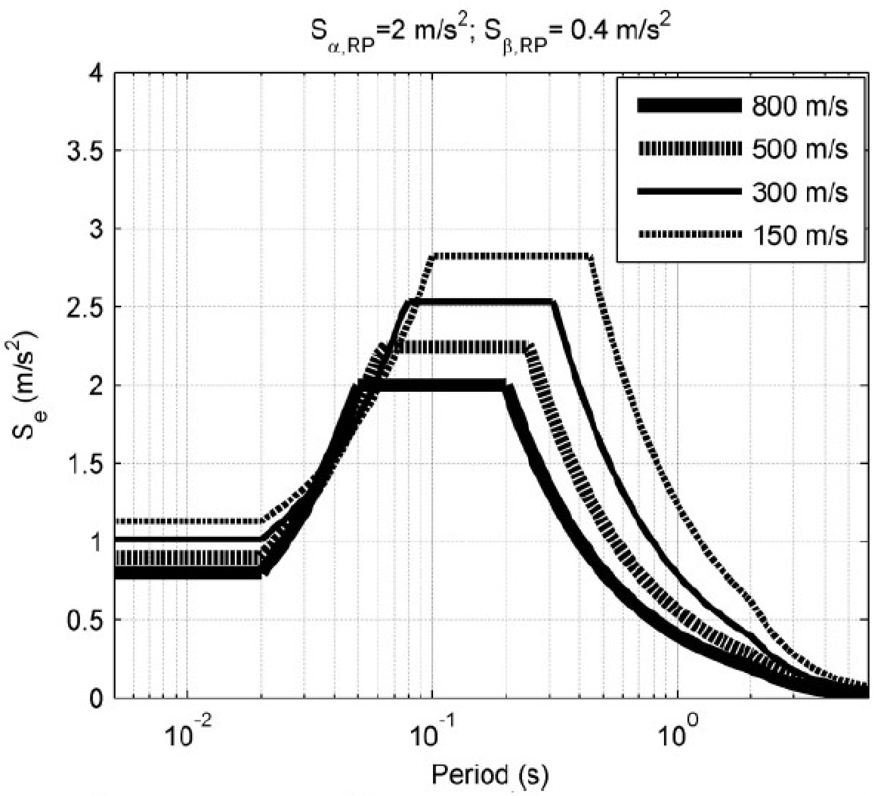
H **dependent for cat. E sites.**

Table 5.4 — Site amplification factors F_α and F_β for the standard site categories

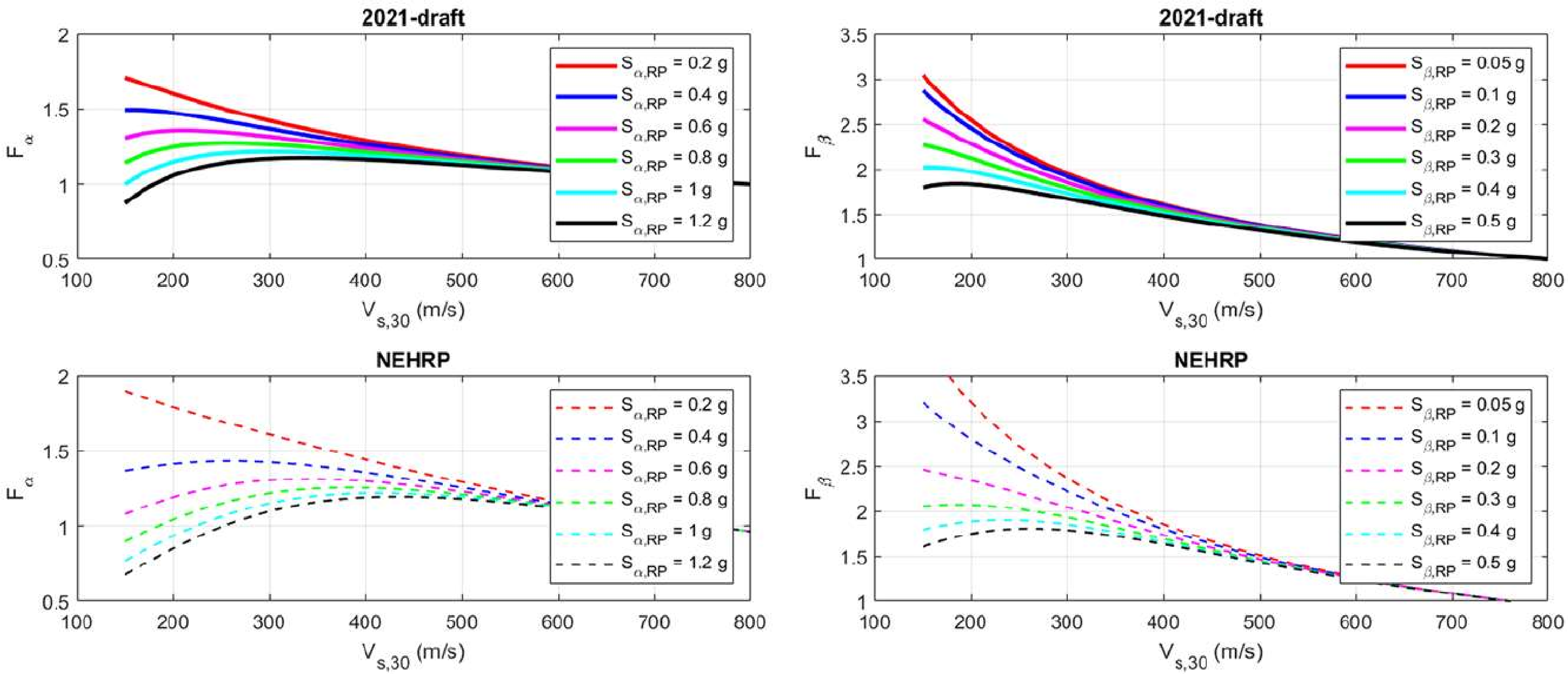
Site category	F_α		F_β	
	H_{800} and $v_{s,H}$ available	Default value	H_{800} and $v_{s,H}$ available	Default value
A	1,0	1,0	1,0	1,0
B		$1,3\ (1-0,1\ S_{\alpha,RP}/g)$		$1,6\ (1-0,2\ S_{\beta,RP}/g)$
C	$\left(\frac{v_{s,H}}{800}\right)^{-0,40\ r_\alpha}$	$1,6\ (1-0,2\ S_{\alpha,RP}/g)$	$\left(\frac{v_{s,H}}{800}\right)^{-0,70\ r_\beta}$	$2,3\ (1-0,3\ S_{\beta,RP}/g)$
D		$1,8\ (1-0,3\ S_{\alpha,RP}/g$		$3,2\ (1-S_{\beta,RP}/g)$
E	$\left(\frac{v_{s,H}}{800}\right)^{-0,40\ r_\alpha \frac{H}{30}\left(4-\frac{H}{10}\right)}$	$2,2\ (1-0,5\ S_{\alpha,RP}/g)$	$\left(\frac{v_{s,H}}{800}\right)^{-0,70\ r_\beta \frac{H}{30}}$	$3,2\ (1-S_{\beta,RP}/g)$
F	$0,90\ \left(\frac{v_{s,H}}{800}\right)^{-0,40\ r_\alpha}$	$1,7\ (1-0,3\ S_{\alpha,RP}/g)$	$1,25\cdot\left(\frac{v_{s,H}}{800}\right)^{-0,70\ r_\beta}$	$4,0\ (1-S_{\beta,RP}/g)$
	with $r_\alpha = 1 - \frac{S_{\alpha,RP}/g}{v_{s,H}/150}$ and $r_\beta = 1 - \frac{S_{\beta,RP}/g}{v_{s,H}/150}$			

Seismic action, § 5.2 / Site amplification factors, § 5.2.2.2





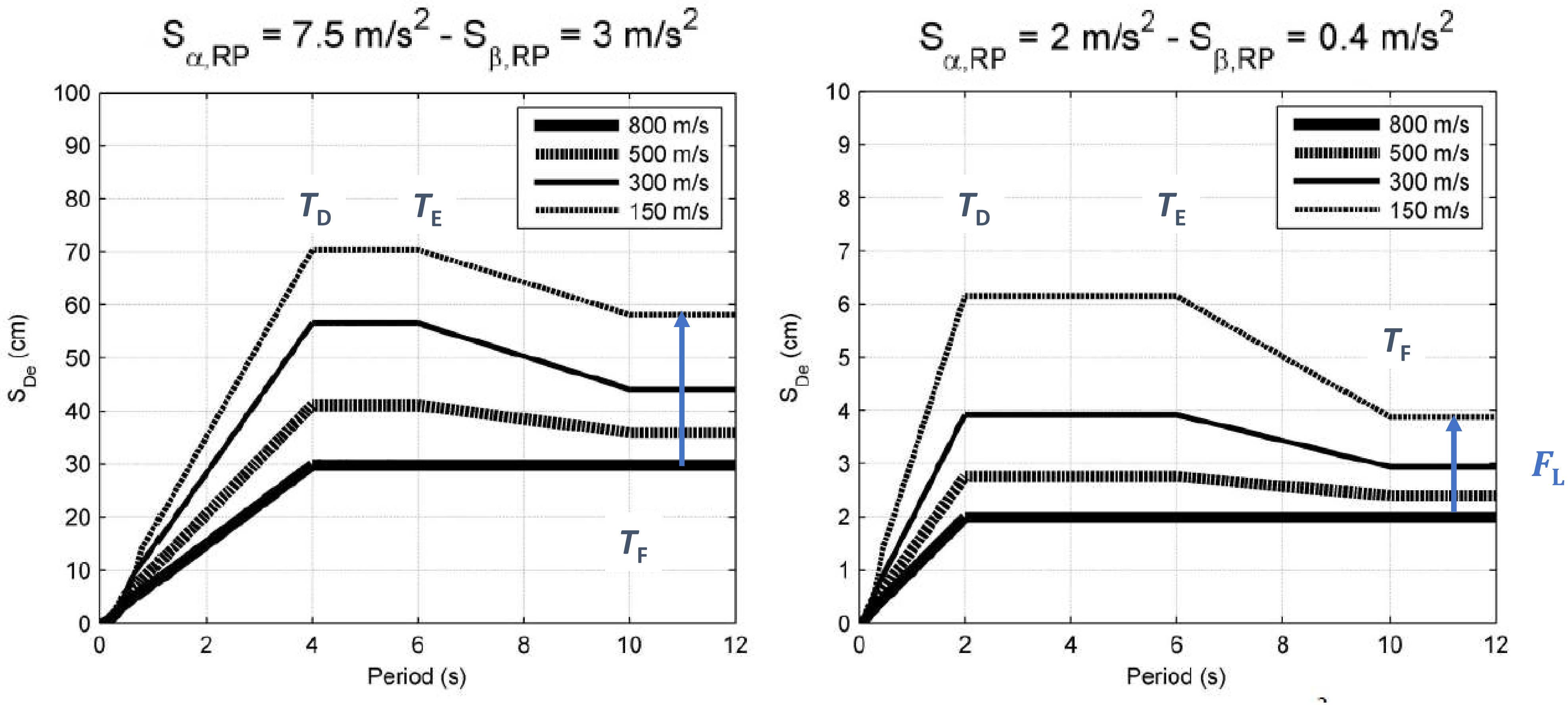
Seismic action, § 5.2 / Site amplification factors, § 5.2.2.2



F_α F_β

Paolucci, R., *et al.* 2021

Seismic action, § 5.2 / Elastic displacement response spectrum, § 5.2.2.2



Seismic action, § 5.2 / Design peak values, § 5.2.2.4

❑ Displacement

$$PGD_e = S_{De}(T_F) = 0,025\, T_\beta T_D F_L\, F_T\, S_{\beta,RP}$$

F_L **is the long period site amplification factor** $F_L = \left(\frac{v_{s,H}}{800}\right)^{-0,4}$

Considerations on displacement and velocity are not anymore disseminated in other Parts.

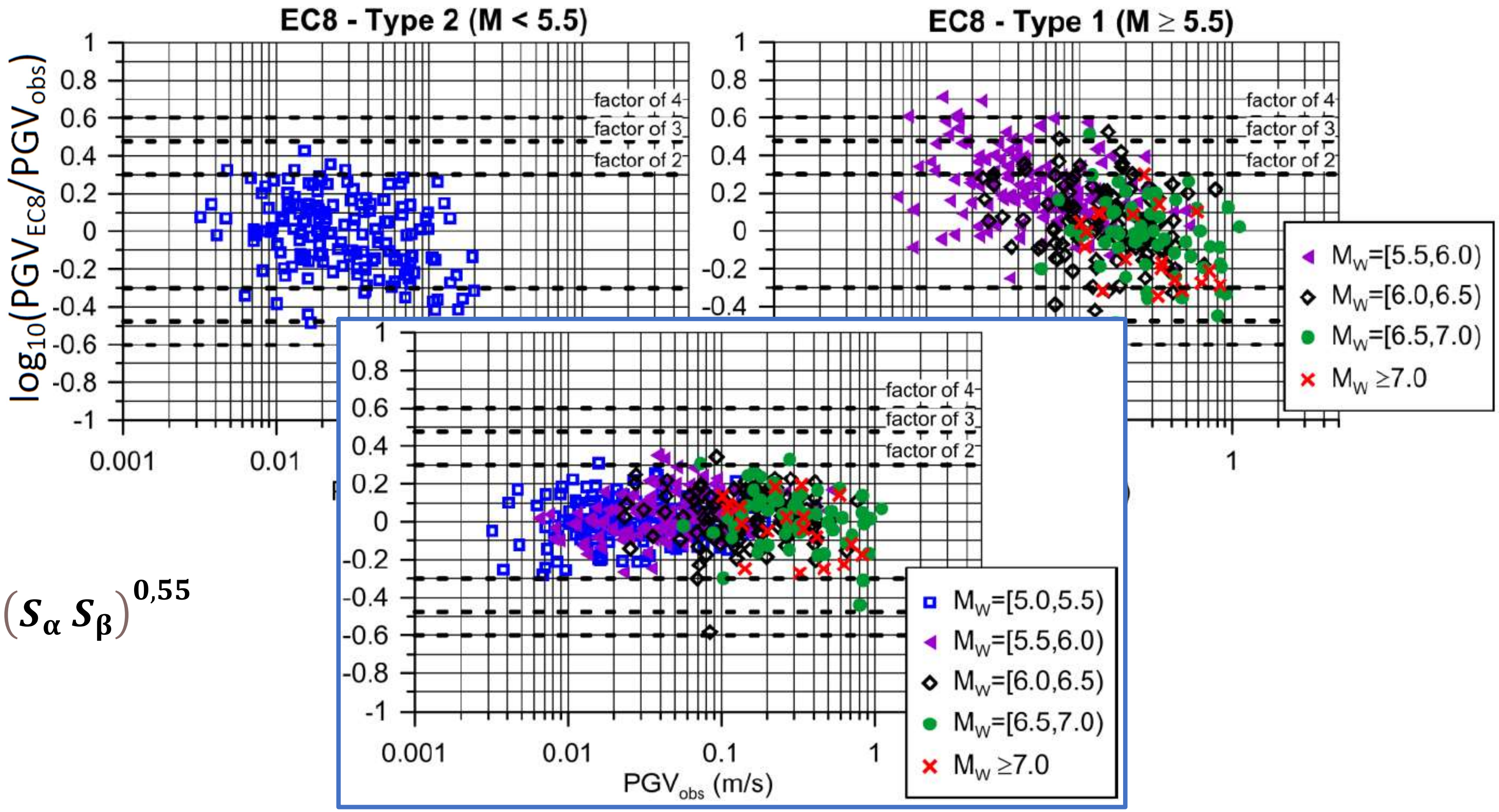
Replaces the current formula, built on a non-observed correlation between PGA and PGD:

$$d_g = 0,025 \cdot a_g \cdot S \cdot T_C \cdot T_D$$

Paolucci R., C. Smerzini (2018). Empirical evaluation of peak ground velocity and displacement as a function of elastic spectral ordinates for design. Earthquake Engineering and Structural Dynamics, 47: 245-255.

Seismic action, § 5.2 / Design peak values, § 5.2.2.4

- ❑ Velocity



$$PGV_e = 0,06\left(S_\alpha\, S_\beta\right)^{0,55}$$

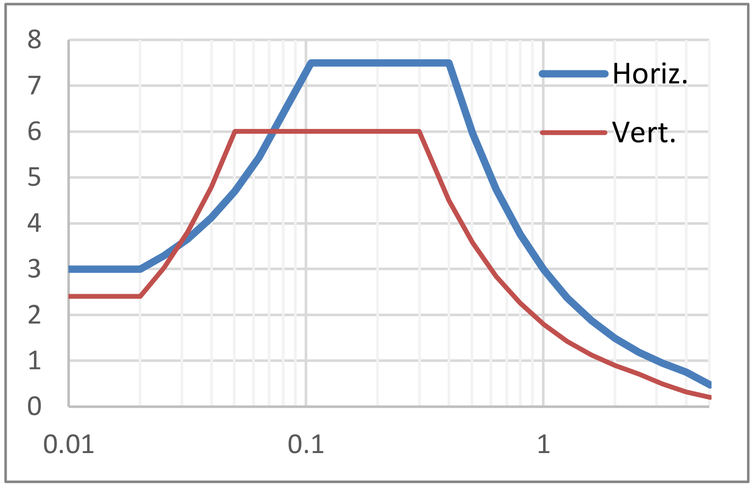
Seismic action, § 5.2 / Vertical elastic response spectrum, § 5.2.2.3

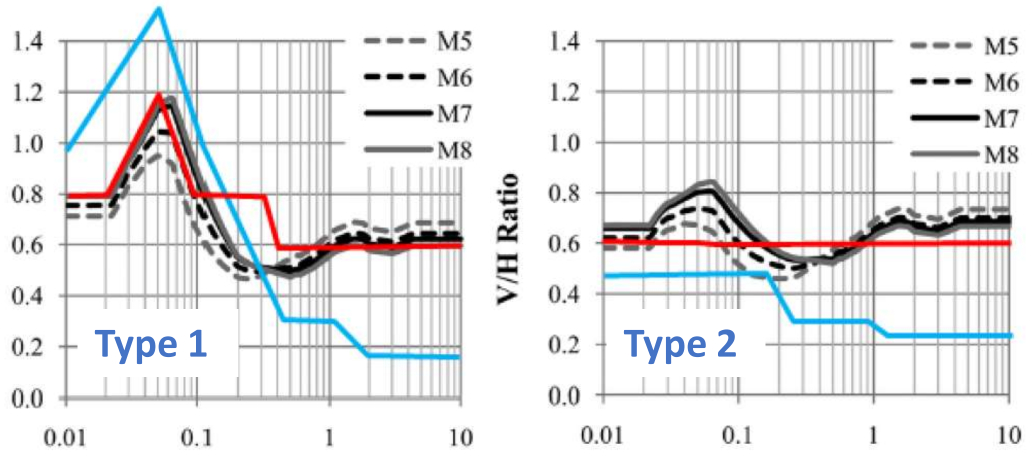
Similar to horizontal, except:

$$S_{\alpha v} = f_{v\alpha}\, S_\alpha \qquad f_{v\alpha} = \begin{cases} 0,6 & \text{if } S_\alpha < 2,5\ \text{m/s}^2 \\ 0,04\, S_\alpha + 0,5 & \text{if } 2,5\ \text{m/s}^2 \le S_\alpha \le 7,5\ \text{m/s}^2 \\ 0,8 & \text{if } S_\alpha > 7,5\ \text{m/s}^2 \end{cases}$$

$$S_{\beta v} = f_{v\beta}\, S_\beta \qquad f_{v\beta} = 0,6$$

$$T_{Bv} = 0,05\ \text{s}$$





Current EC8
2021 draft

Gülerce Z., N.A. Abrahamson (2011). Site-Specific Design Spectra for Vertical Ground Motion. Earthquake Spectra, 27: 1023–1047.

Seismic action, § 5.2 / Conventional magnitudes and strong motion duration

§ 5.2.2.5

Range of $S_{\beta,RP}$ (m/s²)	M_w	D_R (s)		
		Site category A	Site cat. B and C	Other site categories
≤ 0,08	4,5	0,5	0,6	0,75
$0,08 < S_{\beta,RP} \leq 0,2$	5,0	1,0	1,2	1,5
$0,2 < S_{\beta,RP} \leq 0,5$	5,5	2,0	2,4	3,0
$0,5 < S_{\beta,RP} \leq 1,2$	6,0	4,0	4,8	6,0
$1,2 < S_{\beta,RP} \leq 2,5$	6,5	8,0	9,6	12
$2,5 < S_{\beta,RP} \leq 4,0$	7,0	16	19	24
$S_{\beta,RP} > 4,0$	7,5	32	38	48

Values of epicentral distances less than about 20 km are implicitly assumed …

Possible NDPs

Seismic action, § 5.2 / Alternative representations § 5.2.3

Input motions for time-history analysis §5.2.3.1

(2) Depending on the nature of the application and on the information actually available, the input motion may consist of recorded accelerograms, simulated accelerograms, or artificial accelerograms.

NOTE 1 Criteria for selection and scaling of input motions are given in Annex D.

NOTE 2 The minimum number of accelerograms to be considered for different seismic action classes is specified in 6.6.

Seismic action, § 5.2 / Alternative representations § 5.2.3

Spatial model of the seismic action §5.2.3.2

For the purpose of Part 2, it is necessary that the correlation coefficient between input motion at two distant supports be introduced.

$$\rho_{\mathrm{kl}} = \exp\left(-\frac{2\,L_{\mathrm{kl}}}{a_{kl}\left(L_{\mathrm{g,k}} + L_{\mathrm{g,l}}\right)}\right) \qquad a_{\mathrm{kl}} = exp\left(-\frac{L_{\mathrm{g,k}} - L_{\mathrm{g,l}}}{500}\right)$$

L_{kl} is the distance between supports *k* and *l*;

$L_{\mathrm{g,k}}$ and $L_{\mathrm{g,l}}$ are characteristic lengths given in Table 5.7 as functions of the site category of the considered supports *k* and *l*, respectively;

Site category	A	B	C	D	E	F
L_g (m)	400	300	250	200	300	200

In case of time-history analysis, the normalized cross-correlation between input motions at two different supports should not exceed the largest of ρ_{kl} and 0,2.

Seismic action, § 5.2 / Alternative representations § 5.2.3

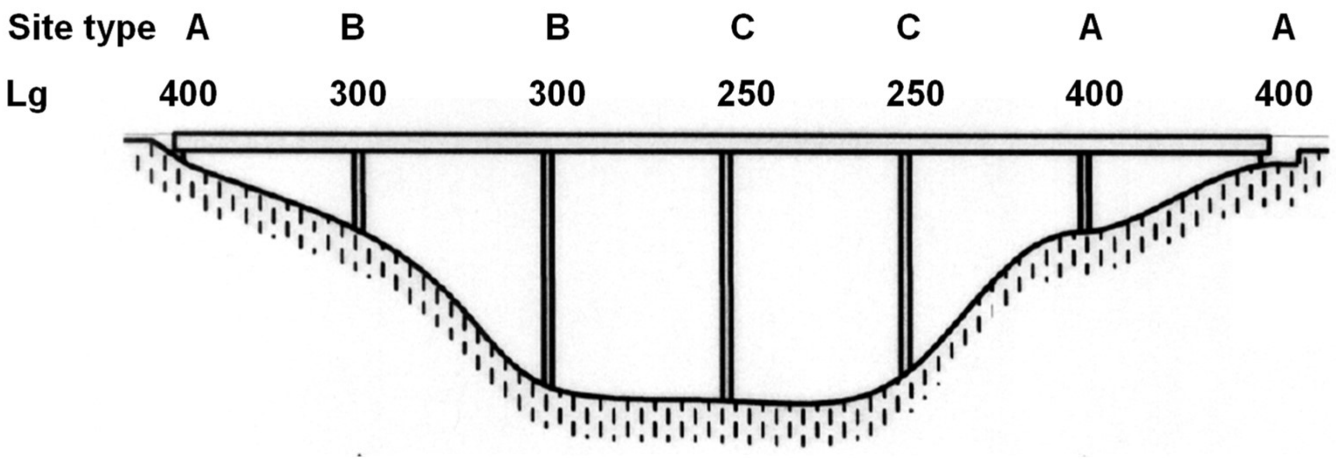
Spatial model of the seismic action §5.2.3.2

The between support correlation effect was addressed in a common PT6-PT4 meeting. Two causes of variability were identified:

- **a) Distance between supports and travelling wave effect.**
- **b) Filtering effect through soil profiles.**

It was recognized that b) prevails. Taking it into account is very easy through soil profiles features and CQC formula. However it might result in high correlation coefficient for distant supports.

Therefore distance dependance was introduced as expressed in formulas (5-29) and (5-30).



Contribution Anastasios Sextos

Seismic action in Clause 6
Modelling, analysis and verification

Generalities on seismic action, § 6.3

(1) The horizontal components of the seismic action (see 5.2.2.2), and, if relevant, the vertical component (see 5.2.2.3), should be taken as acting simultaneously.

(3) The elastic response spectra given in 5.2.2.2 and 5.2.2.3, or the corresponding input motions selected in accordance with 5.2.3.1, should be used as representation of the seismic action except when the force-based approach is applied, in which case the reduced response spectrum should be used (see 6.4.1).

Reduce spectrum for the force-based approach § 6.4.1

$q = q_R\, q_S\, q_D$

q_R is the behaviour factor component accounting for overstrength due to the redistribution of seismic action effects in redundant structures;

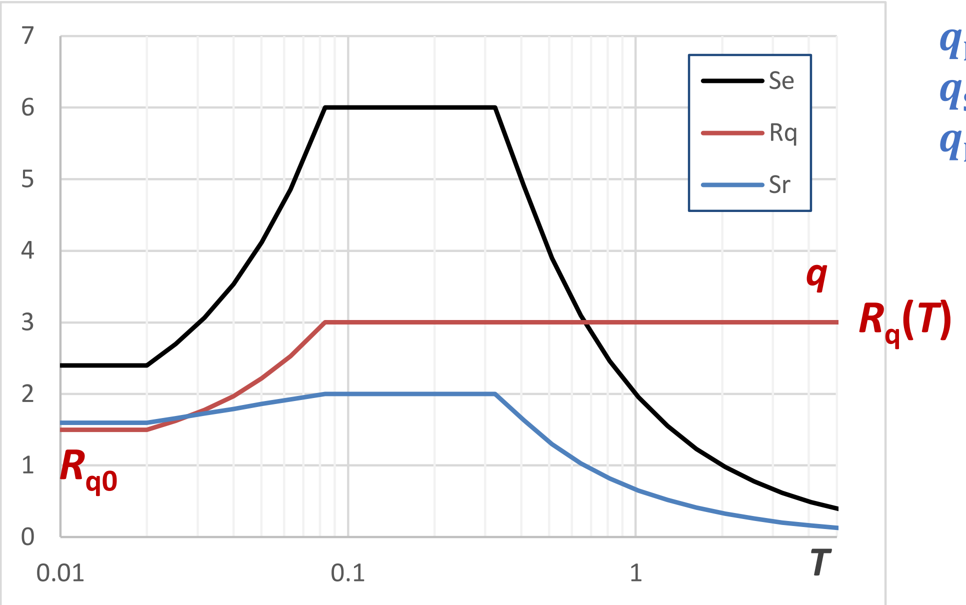
q_S is the behaviour factor component accounting for overstrength due to all other sources;

R_{q0}

q_D is the behaviour factor component accounting for the deformation capacity and energy dissipation capacity.

$$S_r(T) = \frac{S_e(T)}{R_q(T)} \geq \beta S_{\alpha,475}(T)$$

$$S_{vr}(T) = \frac{S_{ve}(T)}{q_v} \qquad q_v = 1{,}5$$



$q_R = 1$

$q_S = 1{,}5$

$q_D = 2$

Response history analysis, § 6.6

(3) Unless (4) is applied, a minimum of seven sets of input motions should be used. The average peak response should be considered for estimating the seismic action effects.

(4) For low and very low seismic action classes, the minimum number of input motions may be reduced to three. In this case, the most unfavourable peak response should be considered.

Annex A (informative)
European hazard maps

Spectral acceleration maps

A2 (1) This Informative Annex contains small-scale maps of $S_{\alpha,475}$ and $S_{\beta,475}$ values as defined in 5.2.1.

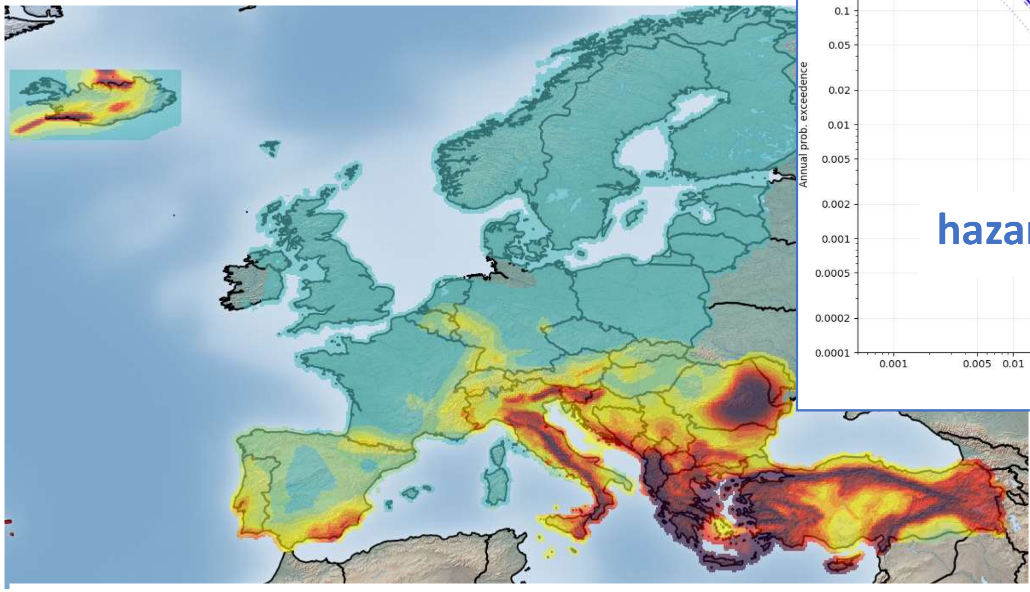
NOTE 1 ... the seismic hazard maps issued from deliverable ESHM20 of the SERA research project (...), which received funding from the EU Horizon 2020 research and innovation programme in order to provide updated information on the seismic hazard in Europe, are included in this annex.

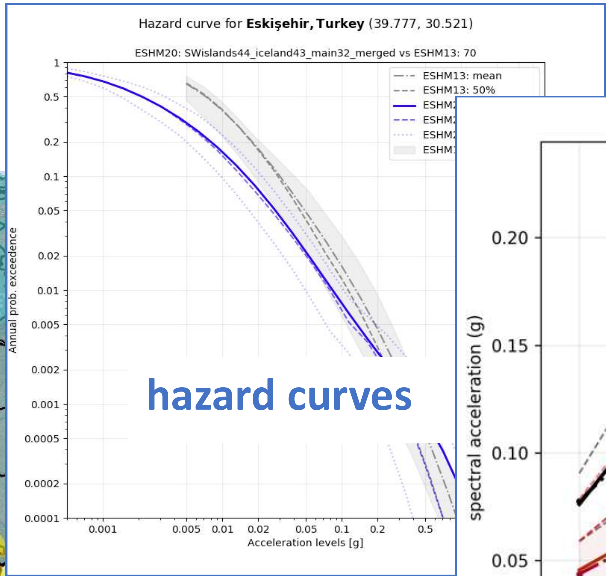
A specific SC8 Ad hoc Group "Seismic hazard" (P. Labbé convenor) was established in order to achieve a consensus on $S_{\alpha,475}$ and $S_{\beta,475}$ maps to be included in Annex A on the basis of ESHM20 model.

Exchanges with ESHM20 team, namely with Laurentiu Danciu, developed in an excellent spirit of cooperation.

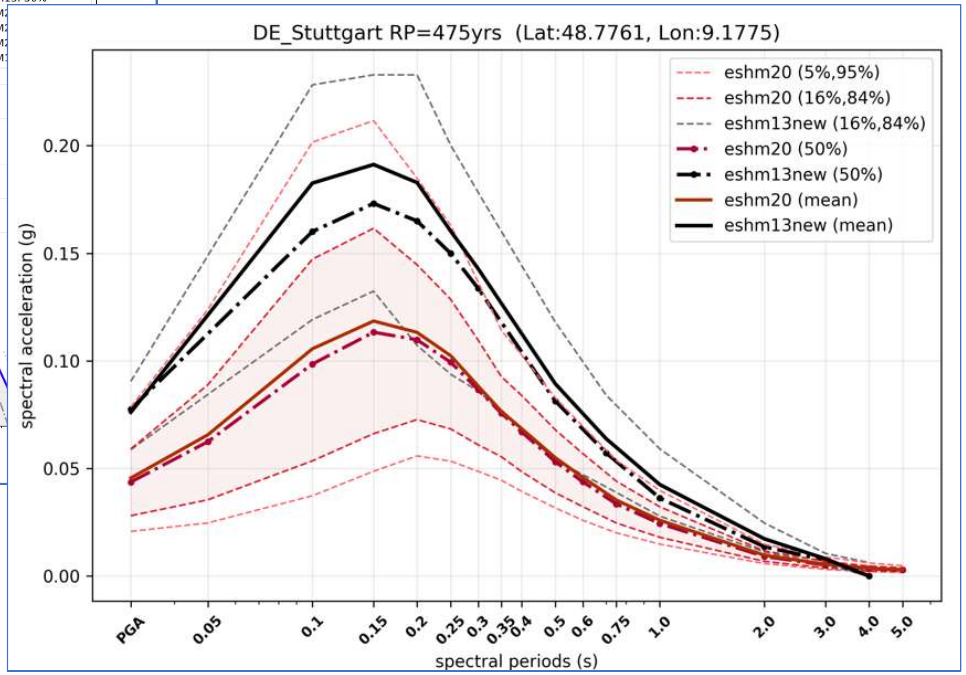
Spectral acceleration maps

ESHM20 model





hazard curves



Seismic hazard maps; different return periods, fractiles, spectral periods including PGA.

Uniform hazard response spectra

All results are available online at hazard.EFEHR.org

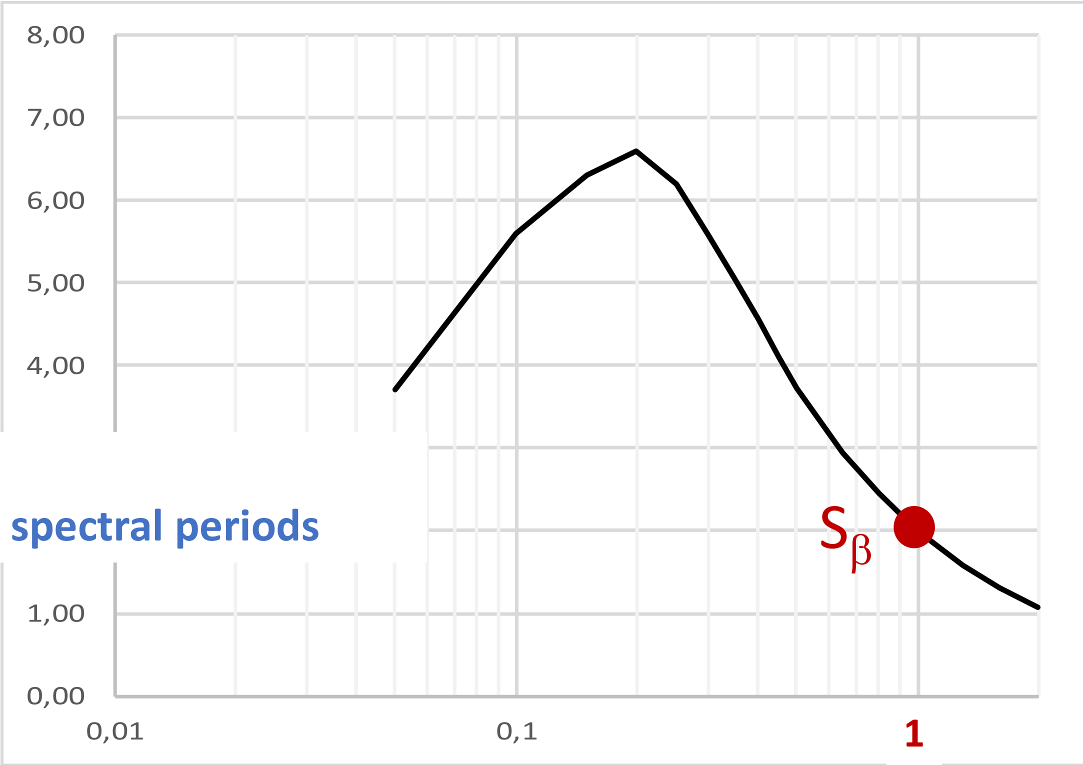
Spectral acceleration maps

NOTE 2 These maps are considered by CEN as an acceptable representation of the seismic hazard in Europe for the return period of 475 years. CEN does not pass judgment on other results obtained in the context of their development.

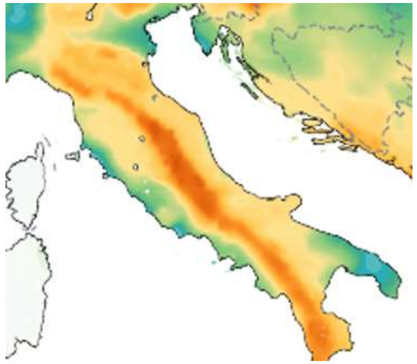
**In other words, CEN does not endorse ESHM20 hazard maps at other return periods.
(not even at 475 y return period)**

Spectral acceleration maps

Derivation of $S_{\alpha,475}$ and $S_{\beta,475}$ from the ESHM20 model

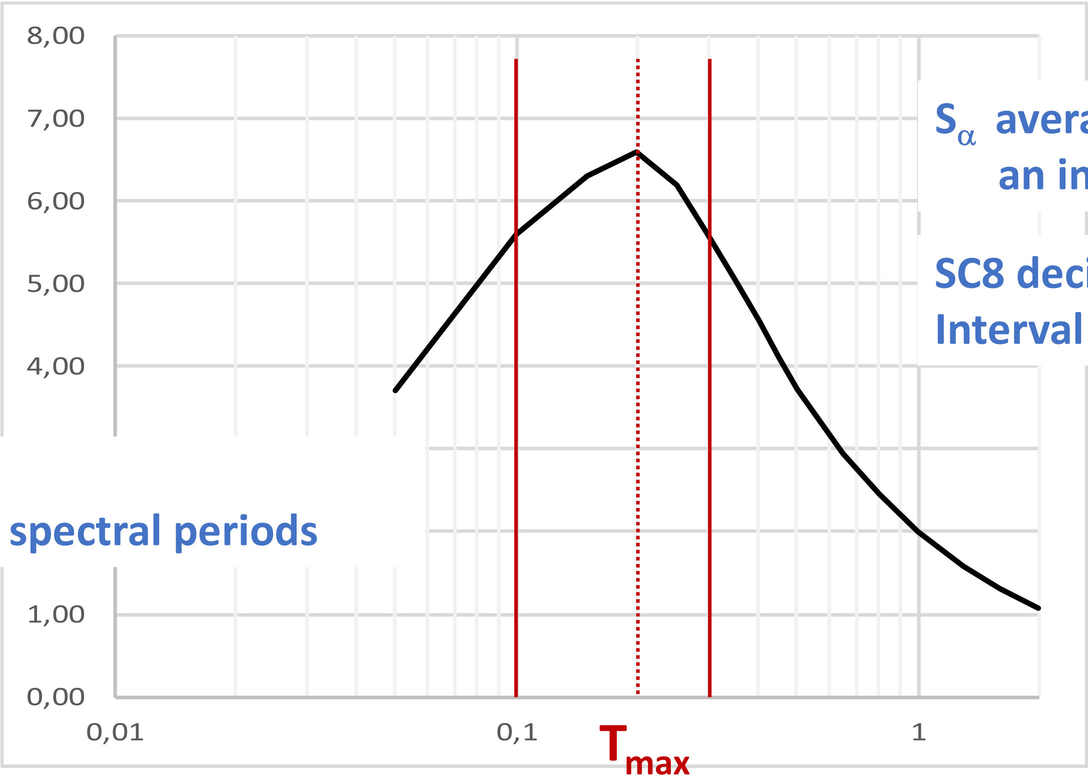


ESHM20 output:
U(T) spectrum at discrete spectral periods



Spectral acceleration maps

Derivation of $S_{\alpha,475}$ and $S_{\beta,475}$ from the ESHM20 model



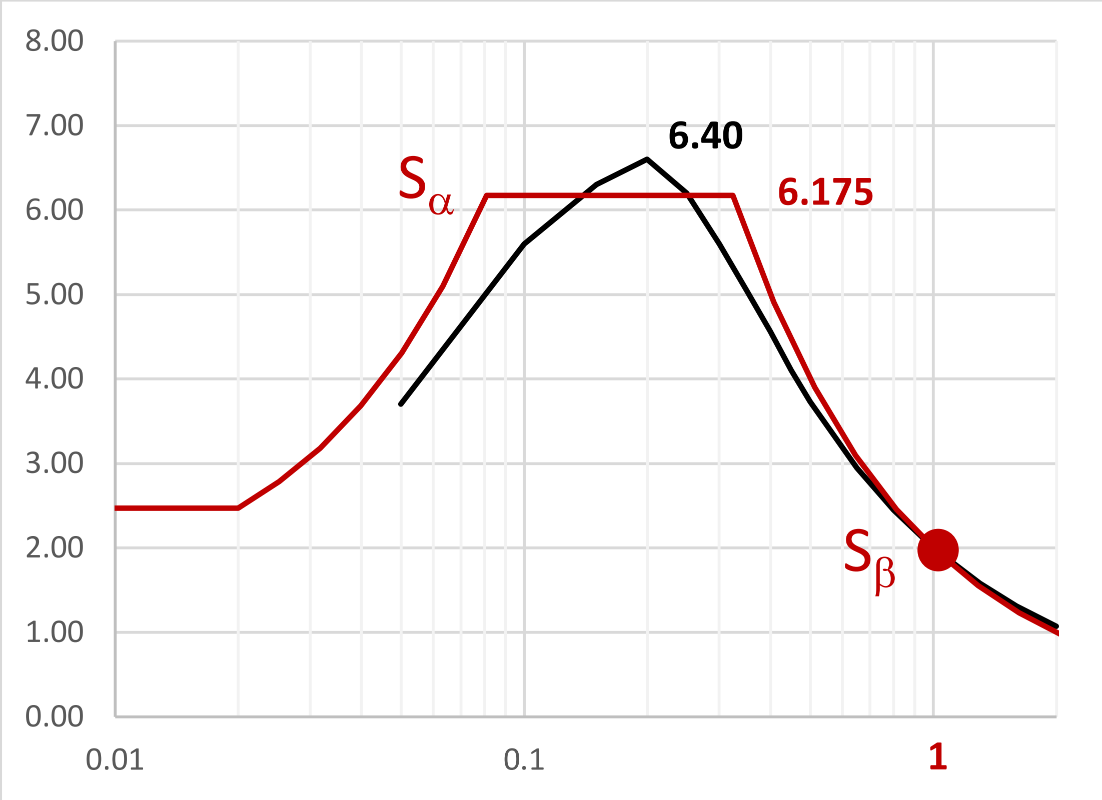
S_α average value of U(T) on an interval to be decided.

SC8 decision:
Interval {0.5 T_{max} – 1.5 T_{max} }

ESHM20 output:
U(T) spectrum at discrete spectral periods

Spectral acceleration maps

Derivation of $S_{\alpha,475}$ and $S_{\beta,475}$ from the ESHM20 model



Spectral acceleration maps

Median *vs* mean hazard maps

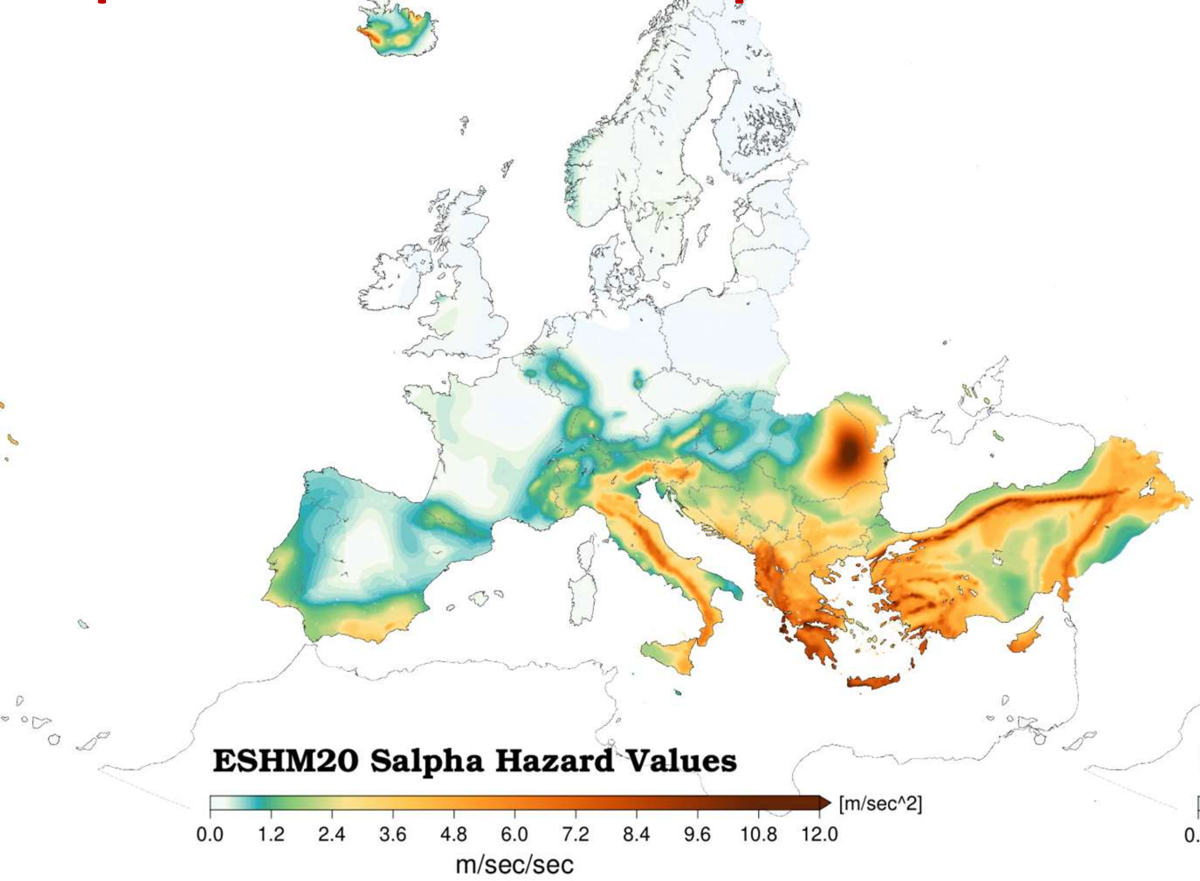
This point was deeply discussed in the Ad hoc Group.

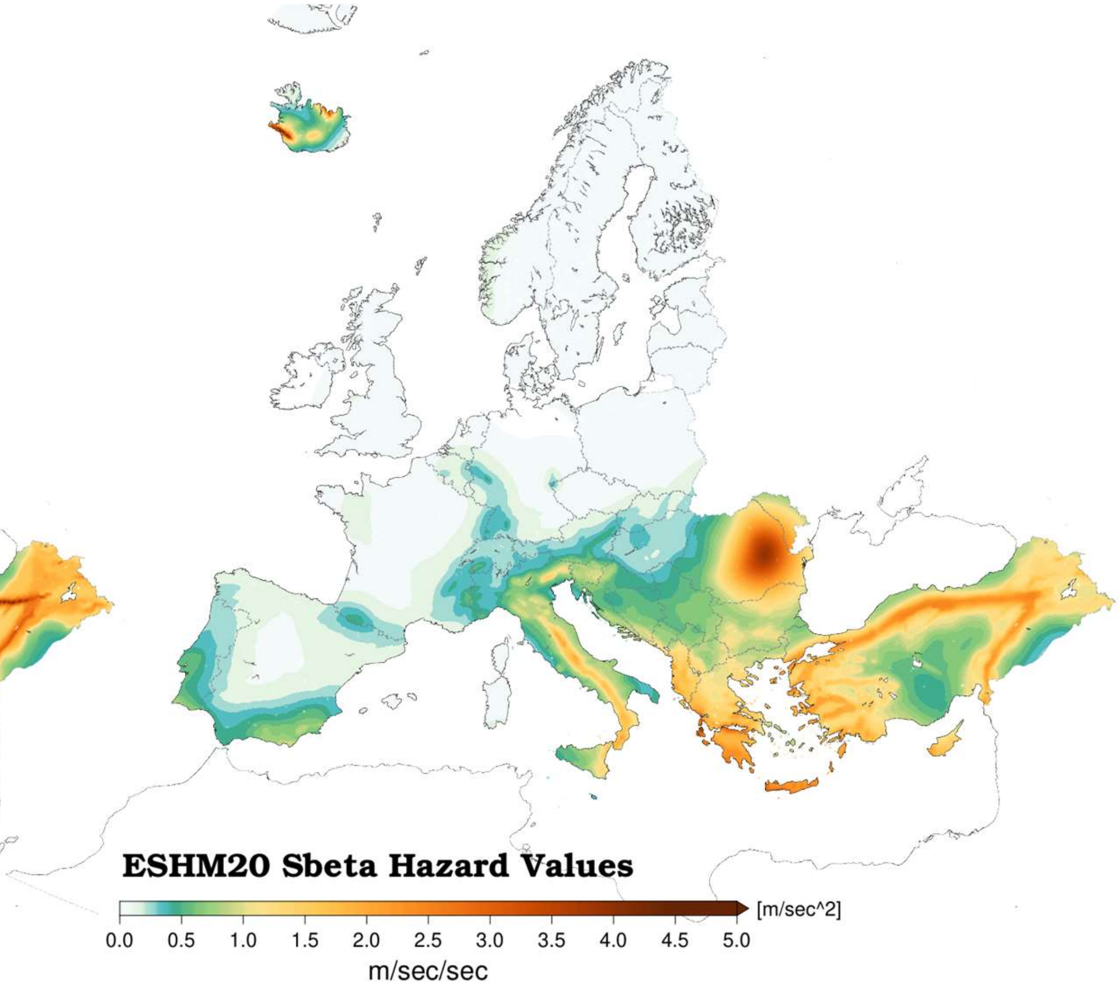
Regarding the mean, pro and cons of geometric *vs* arithmetic mean ; probability mean for a given spectral acceleration *vs* spectral acceleration mean for a given probability were discussed.

Eventually, a consensus was achieved, with the exception of one country (out of 10), in favour of the median.

Maps presented in Annex A are median maps, but they are not qualified as such, neither in the narrative, nor in the legends.

Spectral acceleration maps





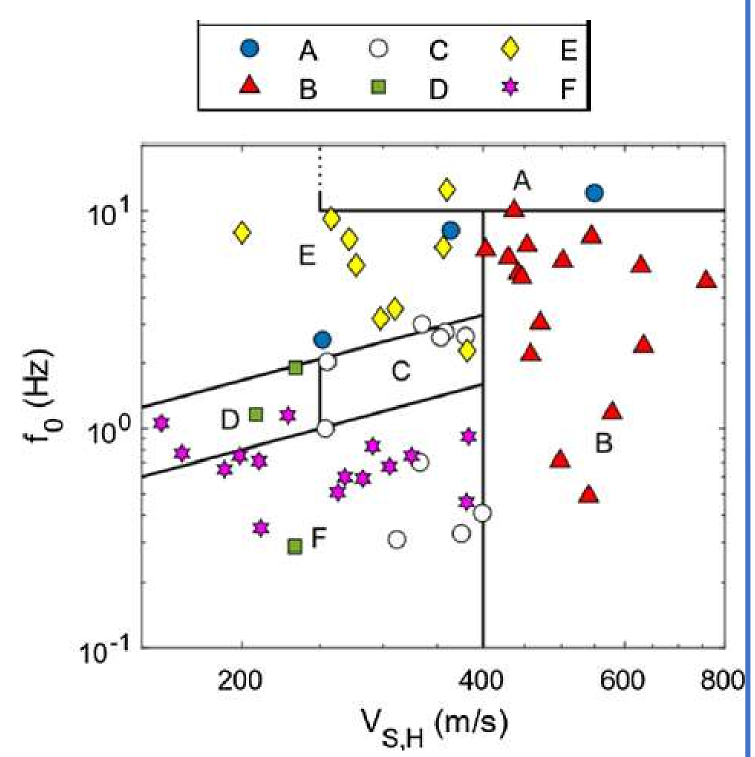
Annex B (normative)
Alternative identification of site categories

Case of incomplete quantitative information

- v_{sH} is not documented ; using correlations or v_{sz} is possible.

- H_{800} is not documented ; using f_0 is possible.

Combination of f_0 (Hz) and $v_{s,H}$ (m/s)	Site cat.
$f_0 \geq 10$ and $v_{s,H} \geq 250$	A
$f_0 < 10$ and $400 \leq v_{s,H} < 800$	B
$v_{s,H}/250 \leq f_0 < v_{s,H}/120$ and $250 \leq v_{s,H} < 400$	C
$v_{s,H}/250 \leq f_0 < v_{s,H}/120$ and $150 \leq v_{s,H} < 250$	D
$v_{s,H}/120 \leq f_0 < 10$ and $150 \leq v_{s,H} < 400$, or $f_0 \geq 10$ and $150 \leq v_{s,H} < 250$	E and $H = \dfrac{v_{s,H}}{4f_0}$
$f_0 < v_{s,H}/250$ and $150 \leq v_{s,H} < 400$	F



Paolucci, R., *et al.* 2021

=> Continuous formulations of site amplification factors may be used.

Simplified identification of site categories

Table B.1 — Simplified description of site categories (excerpt)

Site category	Description
A	Rock or other rock-like geological material, including very shallow layers of very dense, dense or medium-dense sand, gravels, very stiff or stiff clay.
B	Deposits consisting prevalently of very dense sand, gravel, or very stiff clay, with representative values of the geotechnical parameters in the range defined in Table B.2 for stiff ground.
C	Intermediate-depth deposits consisting prevalently of dense or medium-dense sand, gravel or stiff clay, with representative values of the geotechnical parameters in the range defined in Table B.2 for medium ground.

Table B.2 — Correspondence between ground class and geotechnical parameters (excerpt)

Test	Parameter	Ground class		
		stiff	medium	soft
SPT	N_{60} (SPT, ER = 60%) [blows/30 cm]	> 60	30-60	15-30
CPT	q_c – sands (MPa)	> 30	15-30	5-15
	q_c – clays (MPa)	> 6	3-6	1,5-3
FVT or lab tests	c_u (kPa)	> 300	150-300	50-150

=> Default values of site amplification factors should be used

Annex C (normative)
Site specific elastic response spectra

❑ Mandatory site specific analyses

5.1.1(5) Specific analyses to account for the vicinity to well identified seismically active faults should be made if all the conditions a) to c) apply:

a) the return period, $T_{LS,CC}$, under consideration is longer than 1 000 years;

b) the maximum earthquake that the fault can generate has an expected moment magnitude M_w > 6,5;

c) the minimum distance of the site from the segment obtained by projecting the top edge of the fault to the ground surface is less than 5 km. (scheme in the background document)

C.5(1) In case the conditions stated above apply, the site-specific elastic response spectrum should not be lower than the horizontal elastic response spectrum defined in 5.2.2.2 for the corresponding return period and for the same $v_{s,H}$ and site category.

❑ Volunteer site specific analyses

C.5(2) For all cases other than those addressed in (1), the site-specific elastic response spectrum should not be lower than 75% of the horizontal elastic response spectrum obtained from 5.2.2.2, for the same $v_{s,H}$ and site category and for the corresponding return period, at least in the period ranges defined in D.3(2).

Annex D (normative)
Criteria for selection and scaling of input motions

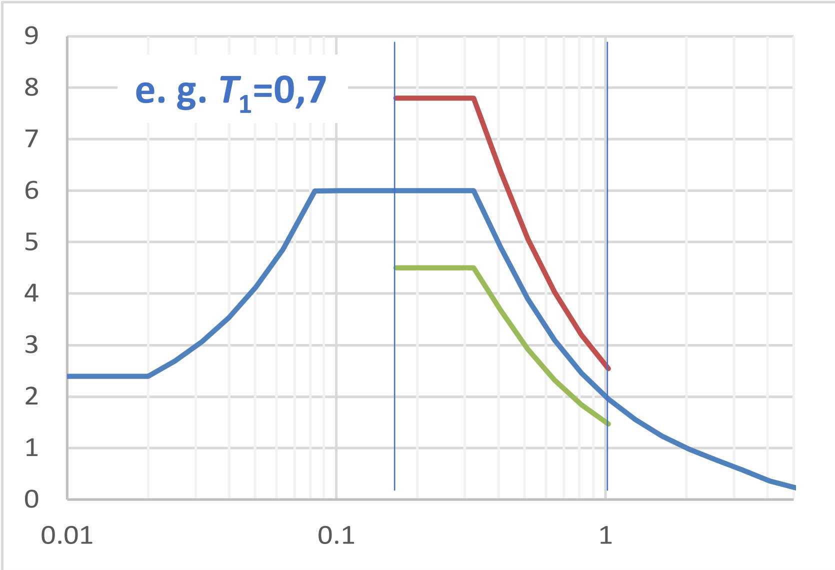
D3.1 Recorded accelerograms, available from qualified strong motion databases, should be the preferred representation of the seismic action for analyses in the time domain.

For structural analyses, the spectral accelerations of the selected accelerograms should approach the elastic response spectrum defined in the 0,2 T_1 to 1,5 T_1 period range.

D3 (8) Compatibility of the suite of selected and scaled accelerograms may be considered as satisfied if conditions a) and b) apply concurrently:

a) in the range defined in (2), the ratio to the target spectrum of the average 5%-damped response spectrum of the set falls within the band from 0,75 to 1,3 and has an average value larger than 0,95;

b) in the same range, the 5%-damped response spectrum of each accelerogram of the suite does not fall below 50% of the target spectrum.



In the current EC8, the ratio should not go below 90% of the target in the period range.

Thank you for your attention