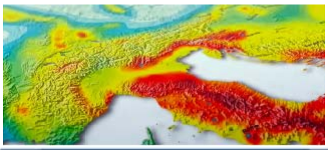

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Seismic action and site effects: work in progress for the revision of Eurocode 8

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PSHA Workshop

Future Directions for Probabilistic Seismic Hazard Assessment at a Local, National and Transnational Scale
5-7 September 2017
Lenzburg, Switzerland

Present EC8: seismic hazard representation

2

- seismic hazard defined in terms of a single parameter, PGA

- national territory subdivided in zones, differentiated by PGA

- each country identifies the normalized elastic spectra for design based on either the Type 1 (M>5.5) or Type 2 (M<5.5) spectral shapes

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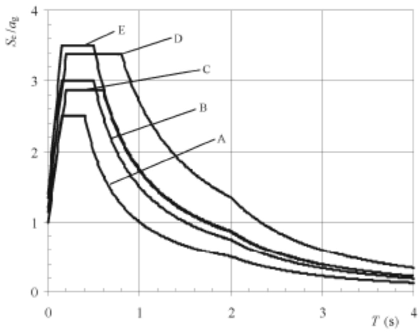
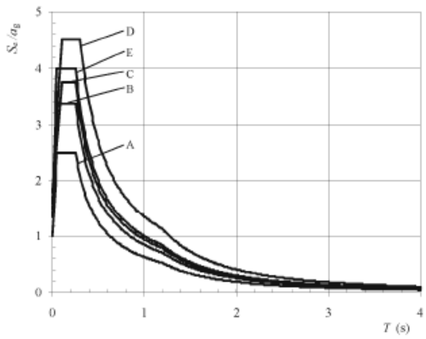
Present EC8: normalized elastic response spectra for design

3

Type 1



Type 2



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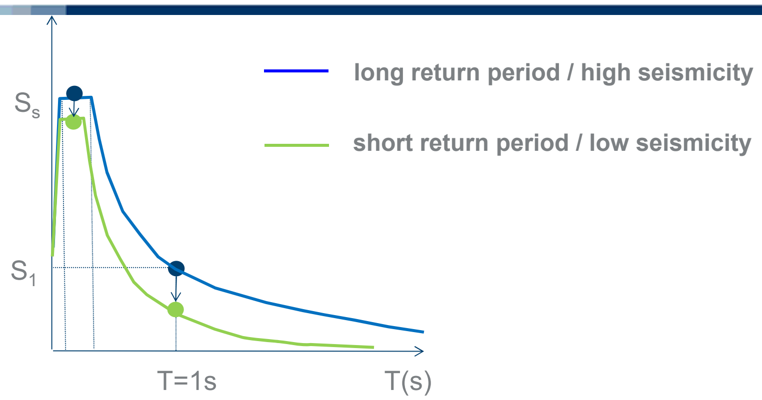
Definition of the Elastic Response Spectrum for Design

4



combination of S_s and S_1 parameters allows one:

- ✓ to tune the ERSD for high and low seismicity regions within a single country
- ✓ to tune the ERSD for long and short return periods within a single site

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Elastic response spectrum

3.1.1.1 Horizontal elastic response spectrum

(1)P For the horizontal components of the seismic action, the elastic response spectrum $S_e(T)$ is defined by the following expressions (see Figure. 3.1):

$$0 \le T \le T_A : S_e(T) = \frac{S_S}{F_0} \quad (3.2)$$

$$T_A \le T \le T_B : S_e(T) = \frac{S_S}{T_B - T_A}\left[\eta \cdot (T - T_A) + \frac{T_B - T}{F_0}\right] \quad (3.3)$$

$$T_B \le T \le T_C : S_e(T) = \eta \cdot S_S \quad (3.4)$$

$$T_C \le T \le T_D : S_e(T) = \eta \cdot \left[\frac{S_1}{T}\right] \quad (3.5)$$

$$T \ge T_D : S_e(T) = \eta \cdot T_D \left[\frac{S_1}{T^2}\right] \quad (3.6)$$

short period factor

$$S_s = F_T \cdot F_s \cdot S_{sRP}$$

$$S_1 = F_T \cdot F_1 \cdot S_{1RP}$$

topography factor

long period factor

Elastic response spectrum

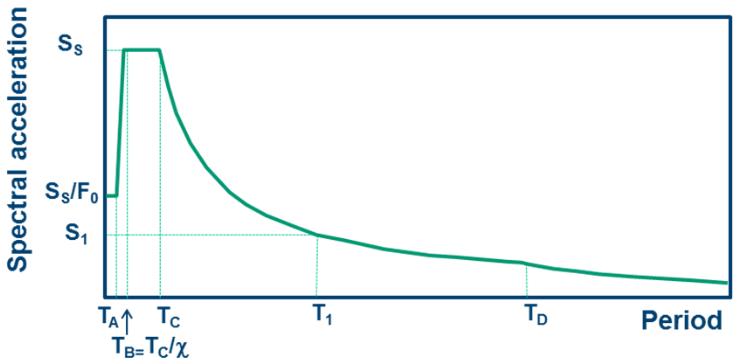


Table 3.3: Recommended values for seismic hazard parameters defining the elastic response spectrum

T_A (s)	T_C/T_B	F_0	T_D (s)
0,03	4	2,5	2 if $S_{1RP} \le 0{,}1g$ $1+10 \cdot S_{1RP}$ if $S_{1RP} > 0{,}1g$

Elastic displacement spectrum

for $T \le T_E$: $S_{De}(T) = S_e(T)\left[\frac{T}{2\pi}\right]^2$

for $T_E \le T \le T_F$: $S_{De}(T) = S_{De}(T_D)\left[1 + \left(\frac{F_L}{F_1} - 1\right) \cdot \frac{T - T_E}{T_F - T_E}\right]$

for $T > T_F$: $S_{De}(T) = S_{De}(T_D) \cdot \frac{F_L}{F_1}$

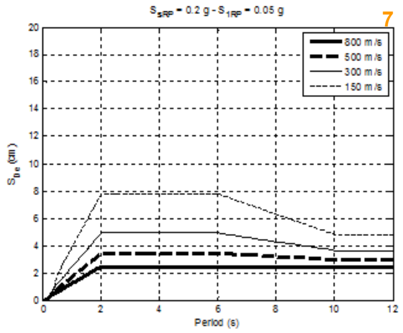
where:

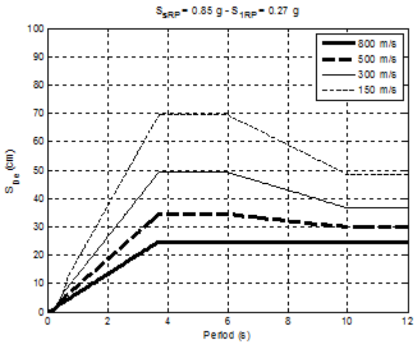
$S_e(T)$ is given in (1) of the present clause;

$T_E = 6$ s, $T_F = 10$ s;

F_L is the long period site amplification factor given by

$$F_L = \left(\frac{v_{s,30}}{800}\right)^{-0.40}$$





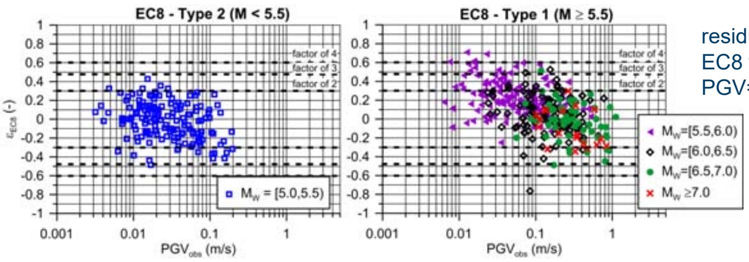
Design peak values of ground motion

$$PGA_e = \frac{S_s}{F_0} \tag{3.22}$$

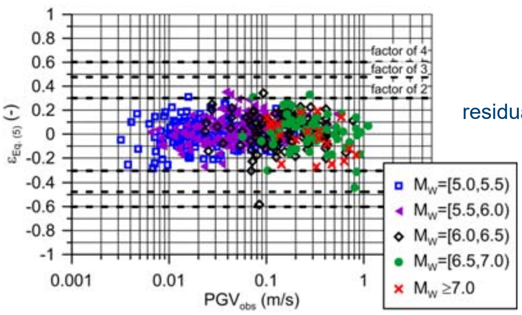
$$PGV_e = 0{,}75 \cdot \left(\frac{S_s}{g} \cdot \frac{S_1}{g}\right)^{0{,}55} \tag{3.23}$$

$$PGD_e = S_{De}(T_F) = \begin{cases} 0{,}5 F_L \frac{S_{1RP}}{g}, \; if \; \frac{S_{1RP}}{g} \le 0{,}1 \\ 0{,}25 F_L \frac{S_{1RP}}{g}\left(1 + 10\frac{S_{1RP}}{g}\right), if \; \frac{S_{1RP}}{g} > 0{,}1 \end{cases} \tag{3.24}$$

PGV

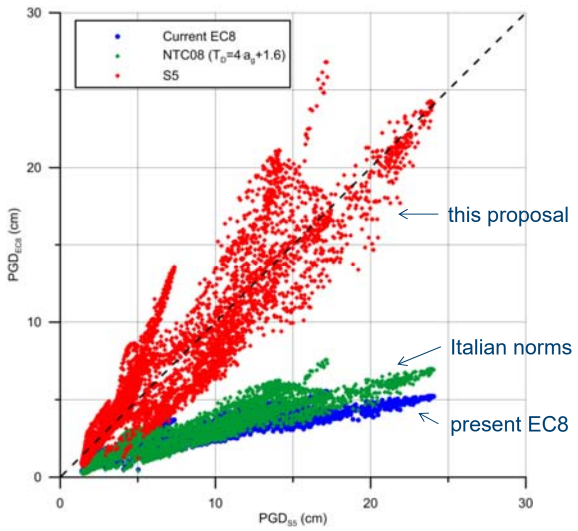


residuals using the EC8 formula: $PGV=0.16 \cdot PGA \cdot T_C$



residuals using this draft

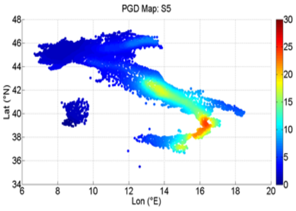
PGD values on rock in Italy according to this proposal

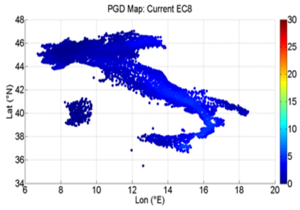


reference values from long period PSHA

Spatial distribution of PGD in Italy

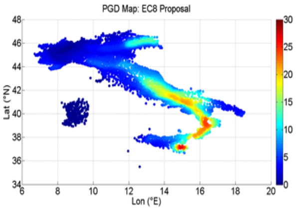
according to long period PSHA →

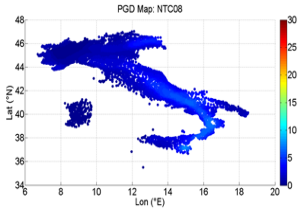




← according to present EC8

according to EC8 draft →





← according to NTC 08

Vertical spectra

(1) The vertical component of the seismic action is represented by an elastic response spectrum (Figure 3.5), $S_{ve}(T)$, using the same expressions (3.4) to (3.8) used for the horizontal elastic spectrum, where the parameters S_s, S_1, T_B and T_C are replaced by the corresponding parameters S_{sv}, S_{1v}, T_{Bv} and T_{Cv}, as follows:

$$S_{sv} = f_{vhs} \cdot S_s \tag{3.16}$$

$$S_{1v} = f_{vh1} \cdot S_1 \tag{3.17}$$

$$T_{Cv} = \left[\frac{S_{1v} \cdot T_1}{S_{sv}}\right], \ (T_1 = 1\text{s}) \tag{3.18}$$

$$T_{Bv} = 0.05 \tag{3.19}$$

$$f_{vhs} = \begin{cases} 0.6 & if \ S_s(g) < 0.25 \\ 0.4 \cdot S_s + 0.5 & if \ 0.25 \le S_s(g) \le 0.75 \\ 0.8 & if \ S_s(g) > 0.75 \end{cases} \tag{3.20}$$

short-period V/H

$$f_{vh1} = 0.6 \tag{3.21}$$

long-period V/H

Vertical spectra

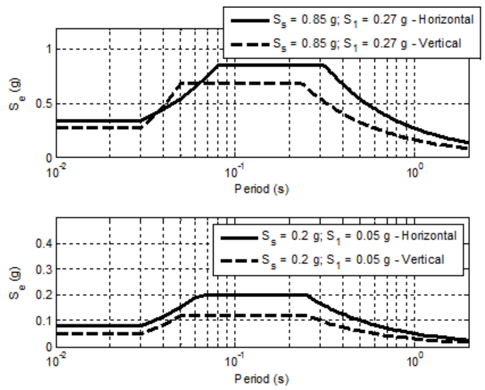


Figure 3.5: Horizontal and Vertical elastic response spectra for ground type A and two different pairs (S_s, S_1), resulting from eqs. (3.19) to (3.24). T_A = 0,03s, F_0=2,5, κ = 4.

Vertical spectra

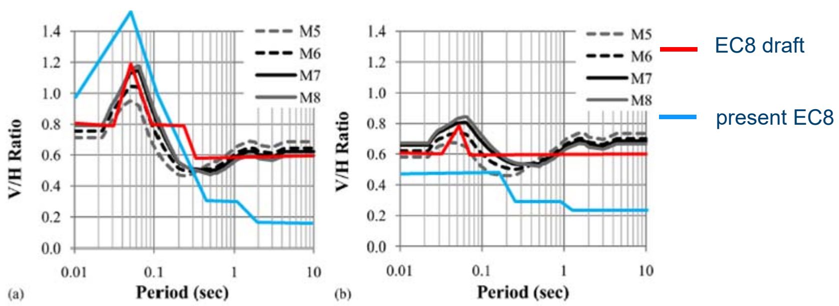


Figure 6. V/H ratio for $v_{s,30}$=800 m/s for the current version of EC8 (blue line: Type 1 on the left side, Type 2 on the right side) and for this proposal (red line: S_s=0.85g, S_1=0.27g on the left side; S_s=0.20g, S_1=0.05g, on the right side). Plot are superimposed to Fig. 8 of Gülerce and Abrahamson (2011) referring to $v_{s,30}$=760 m/s and R=5km (left side), R=30 km (right side).

Vertical spectra

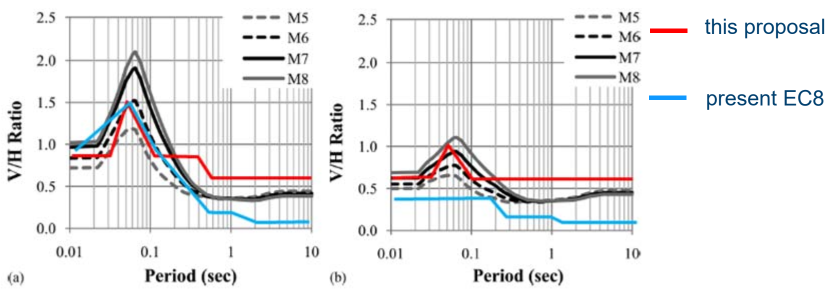


Figure 7. V/H ratio for $v_{s,30}$=270 m/s for the current version of EC8 (blue line: Type 1 on the left side, Type 2 on the right side) and for this proposal (red line: S_s=0.85g, S_1=0.27g on the left side; S_s=0.20g, S_1=0.05g, on the right side). Plot are superimposed to Fig. 9 of Gülerce and Abrahamson (2011) referring to $v_{s,30}$=270 m/s and R=5km (left side), R=30 km (right side).

Present EC8: Site classification and site amplification factors

EC8 Site classification

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			

EC8 Site amplification factors – Type 1

Ground type	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

EC8 Site amplification factors – Type 2

Ground type	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

Site categorization

(1) **The profile of the shear wave velocity v_s in the ground should be regarded as the most reliable predictor** of the site-dependent characteristics of the seismic action at stable sites.

(2) To account for the influence of local conditions on the seismic action, the **ground materials should be characterised at least down to 30 m depth**, except if the bedrock formation is at a smaller depth.

(3) As a minimum requirement for seismic characterisation, the site should be classified according to a simplified description of the shallow geological materials. **Parameters retained by EN 1998 for site categorization are**:

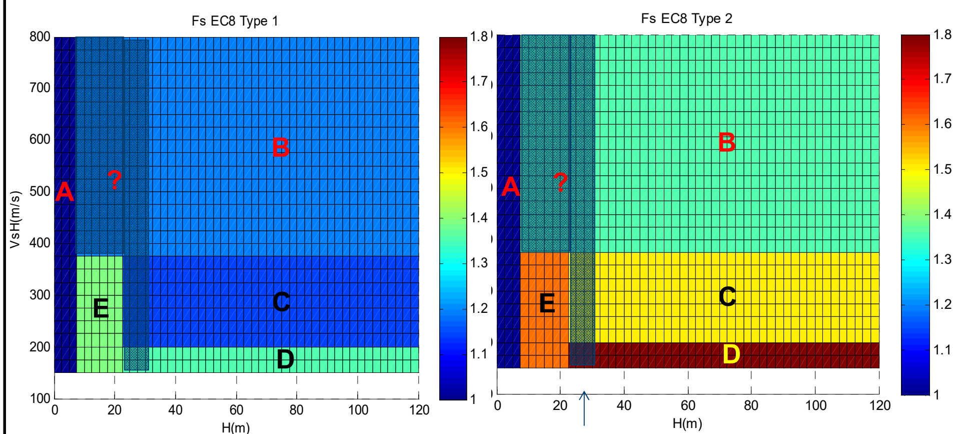
- **H_{800}**, the depth of the bedrock formation identified by v_s larger than 800m/s,

- **$v_{S,H}$**, the average superficial shear wave velocity, between the surface and the depth H defined by

H= 30 m if $H_{800} \geq 30$m ($v_{S,H}$ is then designated as $v_{S,30}$.)
H= H_{800} if $H_{800} < 30$m.

Present EC8: Site classification and site amplification factors

S values for Type 1 EC8 S values for Type 2 EC8



"at least several tens of m"

Site categorization in the EC8 draft

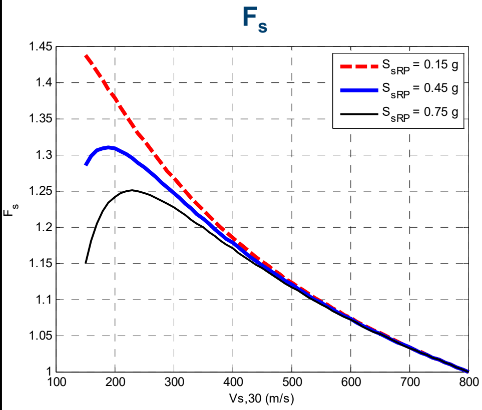
Table 3.1 Standard site categorisation

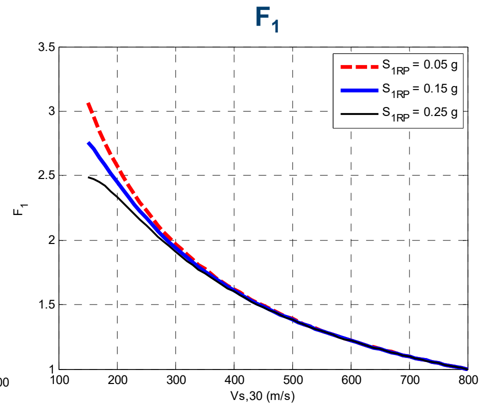
	$v_{S,H}$ **class**	high	medium	low
Depth class		800 m/s> $v_{S,H}$ > 400 m/s	400 m/s> $v_{S,H}$ > 250 m/s	250 m/s> $v_{S,H}$ > 150 m/s
very shallow	H_{800} < 5 m	A	A	E
shallow	5 m < H_{800} < 30 m	B	E	E
intermediate	30 m < H_{800} < 100 m	B	C	D
Deep	100 m < H_{800} < 200 m	B	F	F
very deep	H_{800} > 200 m	B	F	F

Recommended site amplification factors

Site category	F_s		F_1	
	H and $v_{s,H}$ available	Default value	H and $v_{s,H}$ available	Default value
A	1,0	1,0	1,0	1,0
B	$\left(\frac{v_{s,H}}{800}\right)^{-0,25\cdot\alpha_s}$	1,20	$\left(\frac{v_{s,H}}{800}\right)^{-0,70\cdot\alpha_1}$	1,60
C		1,35		2,25
D		1,50		3,20
E	$\left(\frac{v_{s,H}}{800}\right)^{-0,25\cdot\alpha_s\cdot\frac{H}{30}\left(4-\frac{H}{10}\right)}$	1.7	$\left(\frac{v_{s,H}}{800}\right)^{-0,70\cdot\alpha_1\cdot\frac{H}{30}}$	3,0
F	$0,90\cdot\left(\frac{v_{s,H}}{800}\right)^{-0,25\cdot\alpha_s}$	1,35	$1,25\cdot\left(\frac{v_{s,H}}{800}\right)^{-0,70\cdot\alpha_1}$	4,0
	$\alpha_s = 1-2\cdot10^3\cdot S_{sRP}/v_{s,H}^2$ $\alpha_1 = 1-2\cdot10^3\cdot S_{1RP}/v_{s,H}^2$			

Recommended site amplification factors

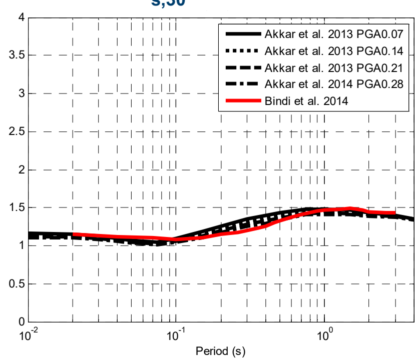


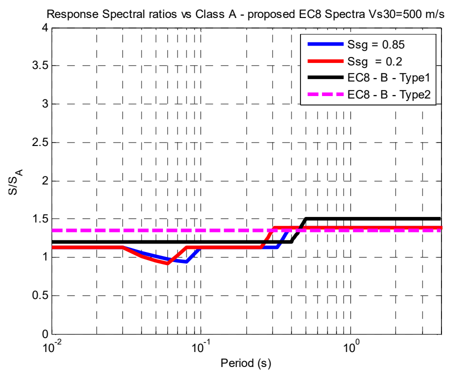


Recommended site amplification factors

comparison with European GMPEs

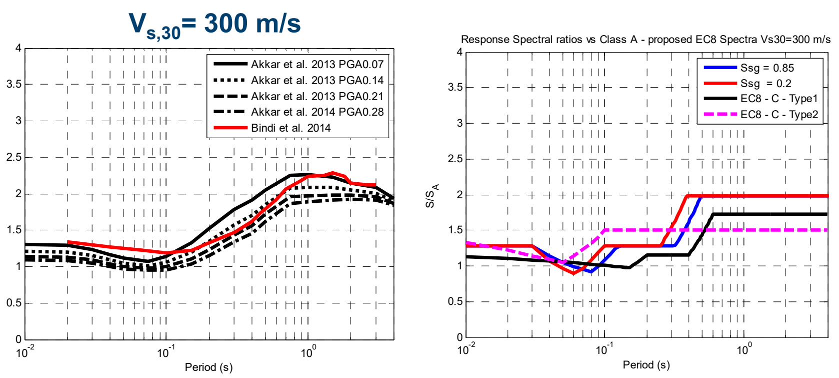
$V_{s,30}$= 500 m/s





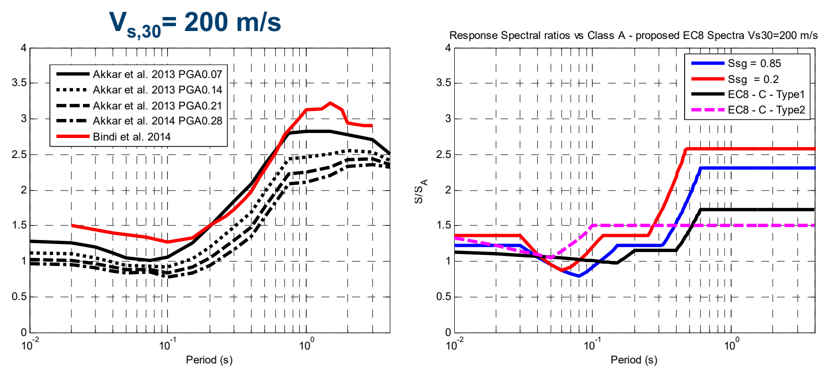
Recommended site amplification factors

comparison with European GMPEs

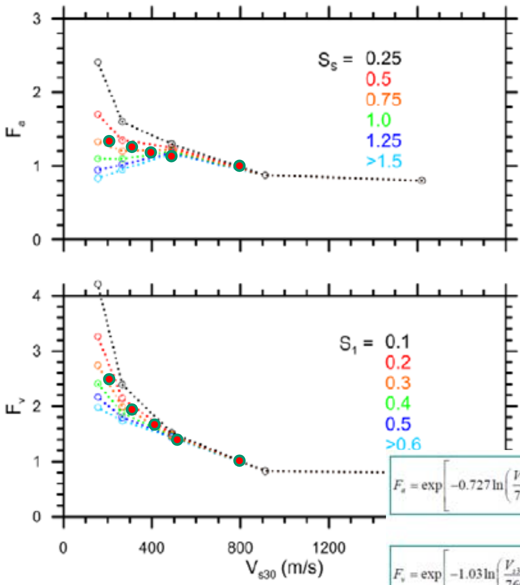


Recommended site amplification factors

comparison with European GMPEs



Recommended site amplification factors



comparison with NEHRP 2015

● EC8 proposal
(Ss=0.45g – S1= 0.15g)

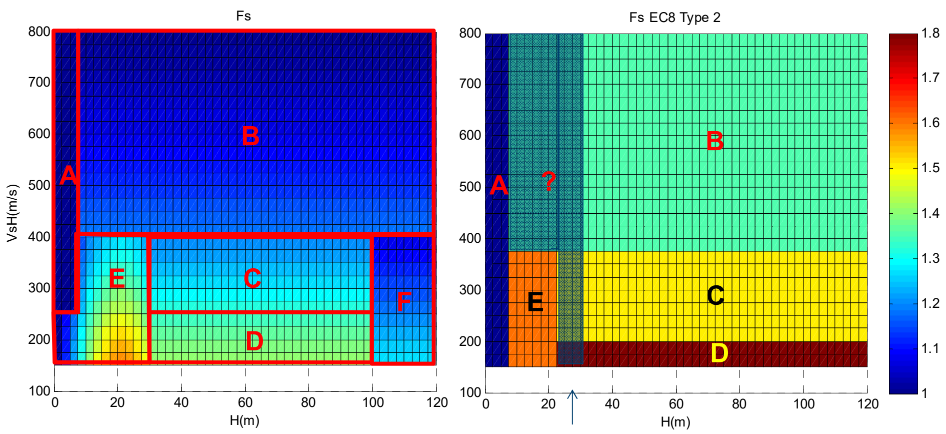
$$F_a = \exp\left[-0.727\ln\left(\frac{V_{s30}}{760}\right) - 0.2298\left[\begin{array}{l}\exp\{-0.00638(\min(V_{s30},760)-360)\}- \\ \exp\{-0.00638\times 400\}\end{array}\right]\ln\left(\frac{(S_s/2.3)+0.1}{0.1}\right)\right] \quad (C11.4\text{-}1)$$

$$F_v = \exp\left[-1.03\ln\left(\frac{V_{s30}}{760}\right) - 0.118\left[\begin{array}{l}\exp\{-0.00756(\min(V_{s30},760)-360)\}- \\ \exp\{-0.00756\times 400\}\end{array}\right]\ln\left(\frac{(S_1/0.7)+0.1}{0.1}\right)\right] \quad (C11.4\text{-}2)$$

Recommended site amplification factors

F_s values for low seismicity
S_s=0.20g S_1=0.05g

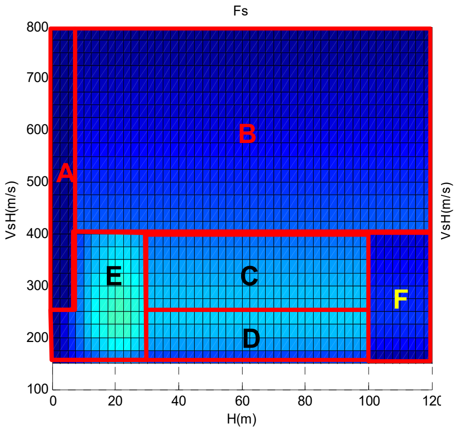
F_s (≡ S) values for Type 2 EC8



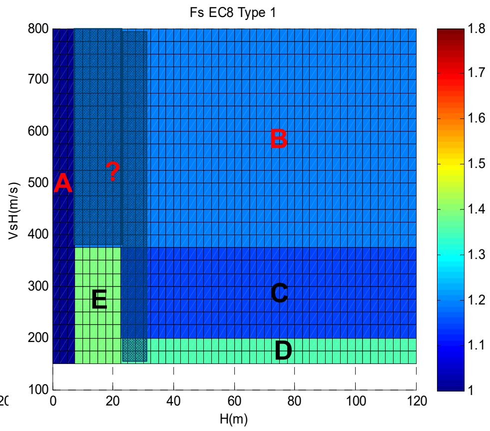
"at least several
tens of m"

Recommended site amplification factors

F_s values for high seismicity
S_s=0.75g S_1=0.25g

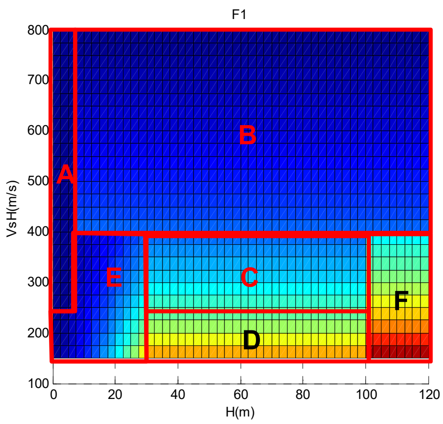


F_s (≡ S) values for Type 1 EC8

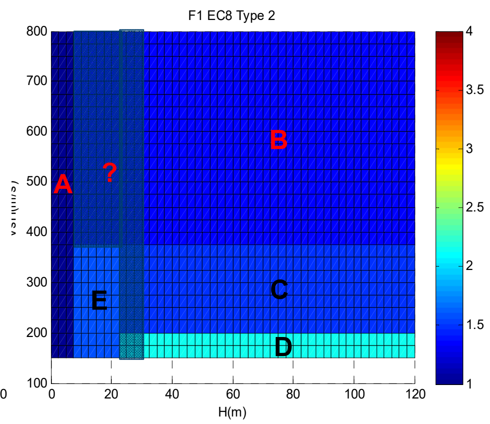


Recommended site amplification factors

F_1 values for low seismicity
S_s=0.20g S_1=0.05g

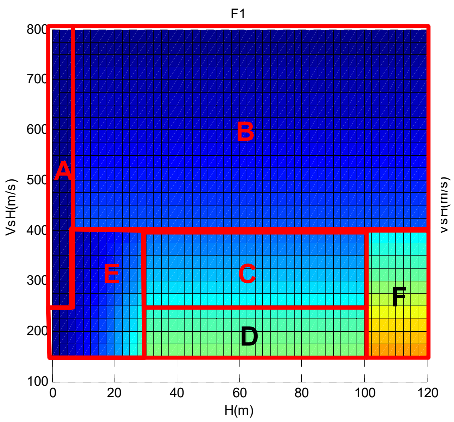


F_1 (≡ ST_C/T_{CA}) values for Type 2 EC8

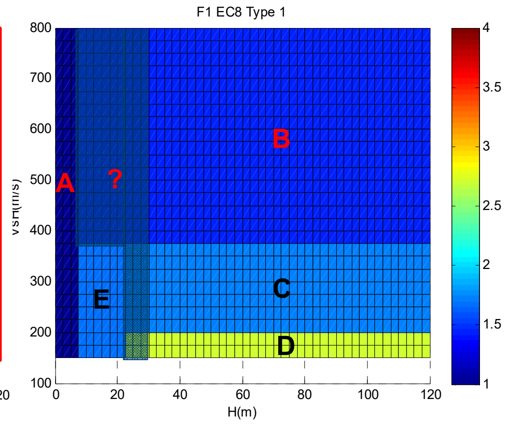


Recommended site amplification factors

F_1 values for high seismicity
S_s=0.75g S_1=0.25g



F_1 ($\equiv ST_C/T_{CA}$) values for Type 1 EC8



Conclusions

(1) Recall that seismic norms address **generic sites**: a recipe suitable for whatever specific-site is impossible. Site-specific analyses should be encouraged (or enforced in some cases)

(2) Drafting European norms implies a **compromise between** very different points of view and constraints from **Countries having conflicting interests and different approaches to the seismic problem**.

(3) Also, a **compromise between ease-of-use and scientific soundness** should be found. This implies **smoothing complexity** and pinpointing those elements that, although extremely interesting from the scientific point of view, are costly to be quantified and do not imply major variations in the design solution.

(4) Finally, the **compromise between safety and costs**, that is at the actual basis of any seismic norm.

With so many compromises, the **optimum solution is not possible**!

Thank you !