Evaluation of site effects: development of the semiquantitative abacuses in Lazio Region (Italy)

F. Pergalani & M. Compagnoni
Politecnico di Milano-Dipartimento di Ingegneria strutturale, Milano, Italy

A. Colombi
Environmental Regional Department, Geologic and Seismic Survey, Regione Lazio, Roma, Italy

15 WCEE
LISBOA 2012

SUMMARY:
In this paper the procedure for the development of the regional abacuses (level 2), as prescribed in the Italian Guidelines for the Seismic Microzonation, is presented. These abacuses are finalized to obtain the values of the expected amplification, due to the presence of the deposits on bedrock. During the project the following steps have been performed: choice of the seismic inputs, choice of the numerical code, choice of the structure of the abacuses, analyses of the collected data, numerical analyses and construction of the abacuses. Therefore 5 abacuses, concerning to 5 geologic groups have been pointed out. The abacuses are constructed by table considering two inputs: the equivalent average velocity and the depth of the bedrock, the amplification is expressed in term of the FH value, calculated considering the elastic acceleration response spectra, as a ratio between the integral of output and input calculated in the period range between 0.1-0.5s.

Keywords:
Abacuses, Microzonation, Numerical analyses, Amplification factor, Lazio Region.

1. INTRODUCTION

The Italian Guidelines for the Seismic Microzonation (ICMS) (GdL MS, 2008) prescribe 3 levels for the microzonation studies: the Level 1 (L1) (qualitative approach) is dedicated to the individuation of the areas that can produce amplification and/or instability phenomena. The Level 2 (L2) (semiquantitative approach) consists in the definition of the expected amplification factors through the application of abacuses, that starting from the individuation of the thickness of the deposits (z) and the equivalent average velocity of the shear waves (Vs_H), gives the level of the expected amplification. The Level 3 (L3) (quantitative approach) prescribes an evaluation of the quantitative level of the amplification and instability through the application of numerical and experimental analyses. In Region Lazio codes (DGR 545/2010), the L1 must be performed for all municipality territory to define the seismic stable areas, the seismic amplification areas and the instable one's. The L2 studies will be carry out in the amplification and instable areas only, like defined by L1, while the L3 where the L2 shows an high level of amplification and for the Strategic and Relevant Structures for Civil Protection (barracks, schools, university and so on – DGR 387/09). So, the aim of the paper has been the point out of the regional abacuses, in the Lazio Region, for L2 studies, as prescribed in the ICMS. The requirement to have regional abacuses derived by the consideration that the ICMS abacuses is devoted to a general application for the entire Italian territory, so the specific regional geologic situations aren't sufficiently represented. Moreover, in Lazio Region, the recent regional codes, for the planning and the mitigation of seismic risk, prescribe the use of specific regional abacuses (DGR 490/2011).
The structure of the developed regional abacuses is similar to the structure of the ICMS abacuses, but just in term of input parameters, whereas it is different in term of output parameter and of some validation criteria of the abacuses itself. The requirement to modify the output parameter is linked to the new revisions of ICMS (Colombi et al., 2011). The applied procedure, through numerical analyses, to obtain the abacuses, has been structured in the following steps:

- choice of the seismic inputs;
- choice of the numerical code;
- choice of the abacuses structure;

- analysis of the collected data;
- numerical analyses;
- construction of the abacuses;
- use of the abacuses.

2. CHOICE OF THE SEISMIC INPUTS

To define the accelerograms used in the numerical analyses, the new seismic zonation of Lazio Region (DGR 387/2009) and the study of the ENEA (2009) have been considered.
In this new seismic zonation, the regional territory has been divided in 5 seismic subzones (1, 2A, 2B, 3A, 3B), considering the expected horizontal acceleration value (a_{rif}), characterized by a return period of 475 years. Moreover the study has been pointed out the recorded accelerogram sets assigned to each "*Unità Amministrativa Sismica*" (UAS) that correspond to a Municipality or to areas of itself. Each set is characterized by 5 recorded accelerograms, modified in according to the expected response spectrum of each UAS, deriving from the seismic hazard analysis performed by the ENEA study.
To have a sufficient representativeness of the regional seismic hazard in term of accelerograms, 4 reference UAS have been chosen, in particular:
Vallerotonda: for the maximum value of the a_{rif} of the seismic subzone 1;
Monte San Giovanni Campano: for the minimum value of the a_{rif} of the seismic subzone 2A;
Roma Municipio V: for the minimum value of the a_{rif} of the seismic subzone 3A;
Ponza: for the minimum value of the a_{rif} of the seismic subzone 3B.
The numerical analyses have been performed using all the 4 selected accelerogram sets, calculating the average results into each set and between the sets. In the Figure 1, as an example, for the Roma V UAS, the 5 used accelerograms, each relative elastic acceleration response spectrum, the average spectrum of the 5 accelerograms and the Municipality code spectrum for the subsoil A, considering as bedrock, (NTC, 2008) are shown.

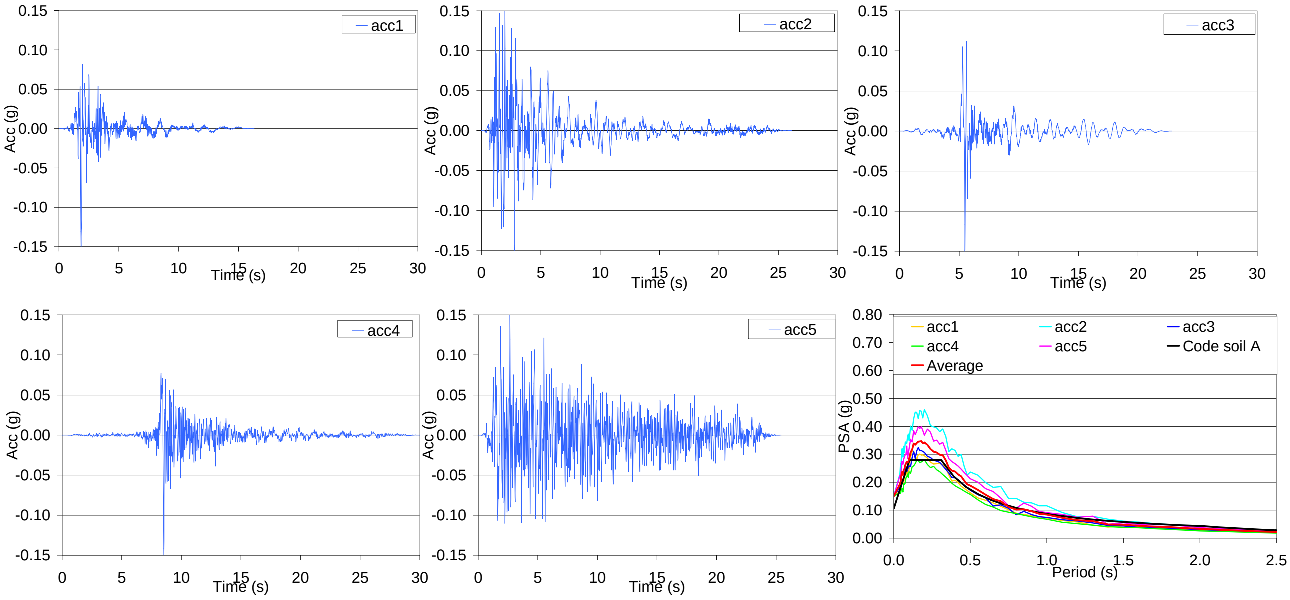


Figure 1. Accelerograms and response spectra for the Roma V UAS

3. CHOICE OF THE NUMERICAL CODE

Considering the objectives of this research, as the evaluation of the seismic amplification only due to geologic effects, a mono-dimensional numerical code has been chosen, finalized to compute the seismic response of horizontally layered soil deposits.
In the code the soil profile is idealized as a system of homogeneous, visco-elastic sub-layers of infinite

horizontal extent (Kelvin-Voigt). The response of this system is calculated considering vertically propagating shear waves: each layer is characterized by the thickness h, the density ρ, the initial shear modulus G0 or the velocity of the shear waves Vs and the initial damping ratio D0. The bedrock is considered deformable, to avoid the energy of reflection waves into the model, in fact a rigid layer reflects all the reflected waves from the surface, instead in the case of the deformable layer, the waves are spread into the bedrock, so the code requires the bedrock parameters as the density ρ, the velocity of the shear waves Vs and the damping ratio D. The code adopts the equivalent linear analysis using an iterative procedure to obtain, in each iteration, the characteristics of the soil compatible with the effective strain in each layer. Therefore the process is iterative and the code works in the frequency domain, using the Fourier analysis.

4. CHOICE OF THE ABACUSES STRUCTURE

As described in the introduction, the structure of the proposed abacuses is similar to that reported in the ICMS, in term of input parameters, on the contrary it is different for the output parameter and for some validity criteria. The input parameters of the regional abacuses are: the thickness of the deposits z and their average equivalent velocity Vs_H, calculated until the bedrock, using the following formula:

$$V_{SH} = z \Big/ \sum_{i=1}^{n} h_i / V_{Si}$$

where:
Vs_H = equivalent average velocity
z = thickness of the deposits
h_i = thickness of each layer of the deposits
Vs_i = shear wave velocity S of each layer of the deposits
n = number of the layers
In the abacuses of L2, the values of the input parameters z and Vs_H are divided by a range of 5-10 m for z and by a range of 50-100 m/s for Vs_H, excluding the values of 180 m/s and 360 m/s, that have been chosen as prescribed in NTC (2008).
The output parameter is represented by the amplification factor FH, defined using the elastic acceleration response spectra (PSA), considering a critical damping (ξ) of 5%, as a ratio between the integrals of output and input calculated in the period range T of 0.1-0.5 s (Colombi et al., 2011).
One or more graphics Vs-z, delimiting the validity area for the abacus application, are associated to each abacus.

5. ANALYSIS OF THE COLLECTED DATA

To perform the numerical analyses it is necessary to know, for each geophysical unit, the value of the thickness h, the density ρ, the velocity of the shear waves Vs, the initial damping ratio D0 and the relative decay curves of the normalized shear modulus G/G0 and the damping ratio D with the shear strain γ. An amount of 42 geophysical investigations (Down-Hole and MASW) have been collected, to have information on the thickness and velocity Vs. The different behaviours of the velocity Vs correlating to the depth z are represented in Figure 2. As shown in Figure 2 the variability of the behaviour Vs-z is sufficiently large and able to consider these data as statistically suitable.
Each behaviour is associated to a specific geologic contest and particularly the data have been subdivided in 5 different units:

- alluvial ad debris gravels: n. 8 investigations;
- weathering sands (sandstone – travertine and tuff): n. 8 investigations;
- pyroclastic deposits: n. 7 investigations;
- alluvial sands: n. 6 investigations;
- clays and silts: n. 13 investigations.

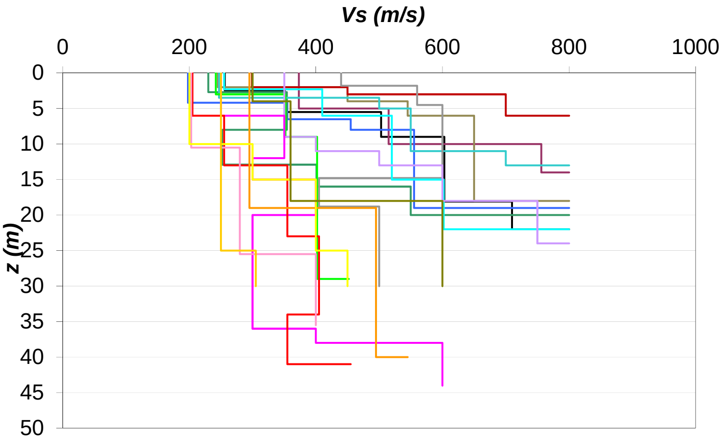


Figure 2. Behaviour of the collected Vs–z

The different units have been grouped on the basis of similar behaviour of Vs-z in 6 groups:

- alluvial gravels, debris gravels and weathering sands (sandstone – travertine and tuff);
- 3 groups for the alluvial sands and pyroclastic deposits;
- 2 groups for the clays and silts.

For each group one or more velocity gradients have been associated, that defines the field in which the experimental data are present:

- alluvial gravels, debris gravels and weathering sands (sandstone – travertine and tuff) characterized by a unique velocity gradient, reported in Figure 3;
- alluvial sands and pyroclastic deposits characterized by 3 velocity gradients, reported in Figure 4;
- clays and silts characterized by 2 velocity gradients, reported in Figure 5.

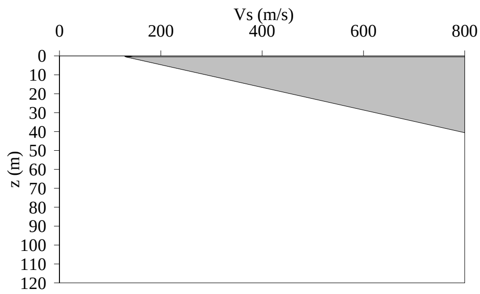


Figure 3. Boundary field of experimental data for the alluvial and debris gravels and weathering sands (in grey)

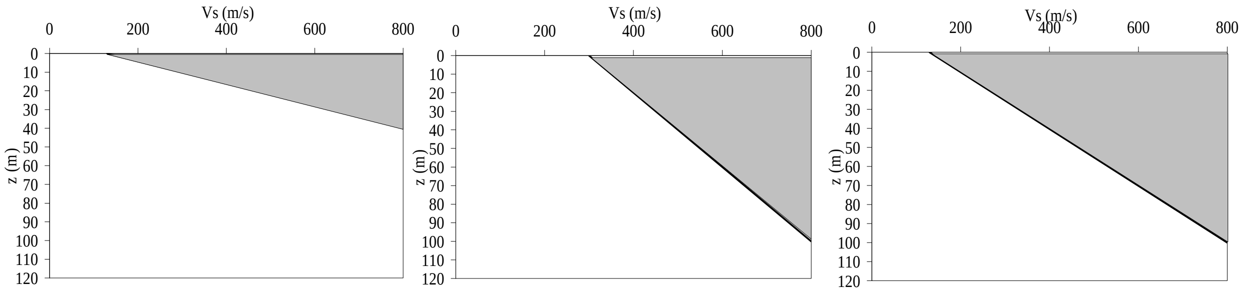


Figure 4. Boundary field of experimental data for the alluvial sands and pyroclastic deposits (in grey)

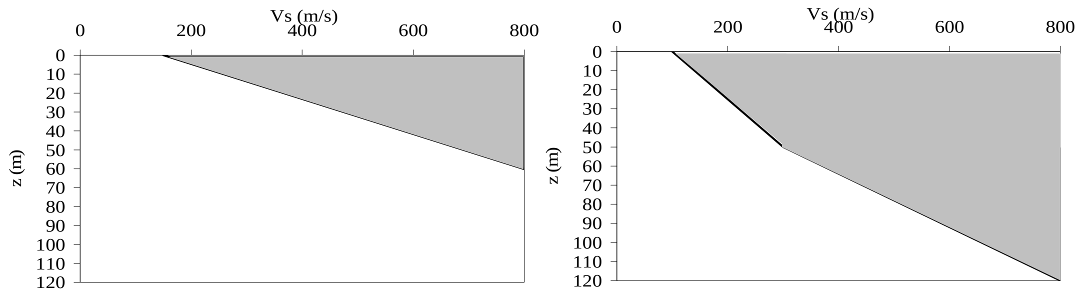


Figure 5. Boundary field of experimental data for the clays and silts (in grey)

The values of the initial damping ratio (D0) of each group and the relative decay curves (G/G0 and D correlating with γ) have been selected by bibliographic data, chosen into the available rich database, on the basis of geologic and geotechnical similarity.
In particular, for each group the following decay curves have been applied (Figure 6):

- alluvial ad debris gravels: Rollins (1998);
- weathering sands and pyroclastic deposits: Pergalani et al. (1999);
- alluvial sands: Seed & Idriss (1970);
- clays and silts: Working Group MS-AQ (2010).

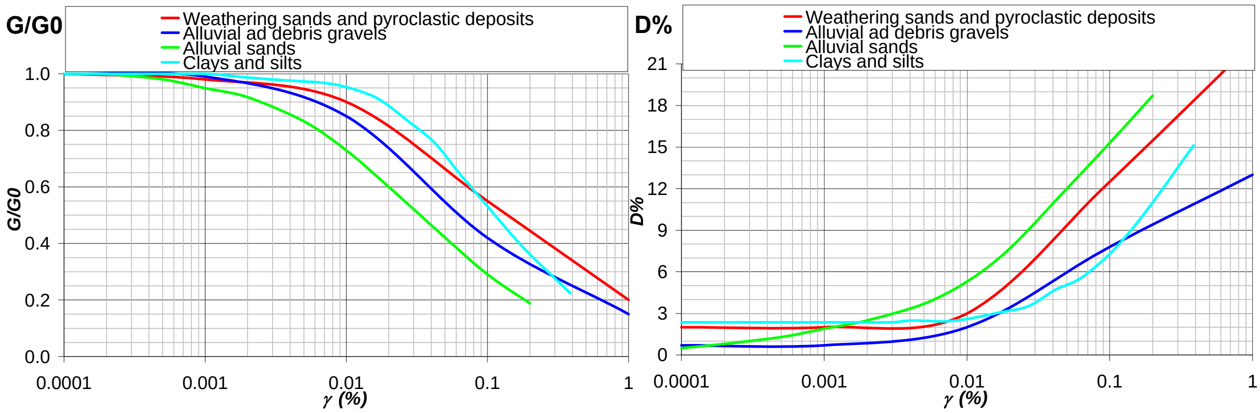


Figure 6. Decay curves for each examined group

Due to the lack of direct data, for the values of the density of each group, an increasing value, correlating to the depth z and to the V_S values, has been considered; in particular:

- 1.7 and 1.8 g/cm^3 in the interval of Vs between 200 and 300 m/s
- 1.8 and 1.9 g/cm^3 in the interval of Vs between 300 and 500 m/s
- 1.9 and 2.0 g/cm^3 in the interval of Vs between 500 and 600 m/s
- 2.0 and 2.1 g/cm^3 in the interval of Vs between 600 and 700 m/s
- 2.2 g/cm^3 for Vs 800 m/s.

6. NUMERICAL ANALYSES

On the basis of the collected data, the numerical analyses have been performed, using the selected numerical code and applying in each geophysical column the 4 sets of accelerograms, characterized by 5 accelerograms each one.
For each individuated velocity gradient, the geophysical columns, correlated to the available geophysical investigation (DH and MASW), have been analyzed; then an amount of geophysical columns, varying the thickness h and the velocity Vs into the validity area, have been constructed and analyzed. Each analyzed geophysical column has been defined in term of the couple Vs_H–z and the results of the analyses are expressed in term of amplification factor FH, calculated as average between the FH derived by the application of the 5 accelerograms of each set and than as average between the FH of the 4 sets.
The results show a negligible difference between the application of the more energetic sets of accelerograms (Vallerotonda e Monte San Giovanni Campano) and the lesser ones (Roma V e Ponza); therefore it was possible to analyzed these results into an unique database, to obtain abacus of L2 independent of the level of the seismic hazard and applicable in all the regional territory. The analyses show an expected shear strain level γ into the range 0.01-0.05%, which can be considered relatively low, compatible to the used numerical code.

7. CONSTRUCTION OF THE ABACUSES

The choice to have the regional abacuses similar to the abacuses of ICMS has prescribed the use of only two input parameters (Vs_H and z).

The analyses have been shown that the same couple Vs_H–z values can be generated by different combination of thickness h and velocity Vs of the geophysical unit, and consequently, to the same couple Vs_H–z, different values of FH are associated. To obtain a correlation considering only two parameters as the FH value (output parameter of the abacus) and the couple Vs_H–z values (input parameters of the abacus), the parameter T (dominant period of the geophysical column) has been introduced, so defined:

$$T = 4\sum_{i=1}^{n} h_i \Bigg/ \left(\sum_{i=1}^{n} V_{Si} h_i \Big/ \sum_{i=1}^{n} h_i \right)$$

where:

T = dominant period of the column

h_i = thickness of the geophysical unit

Vs_i = velocity of the geophysical unit

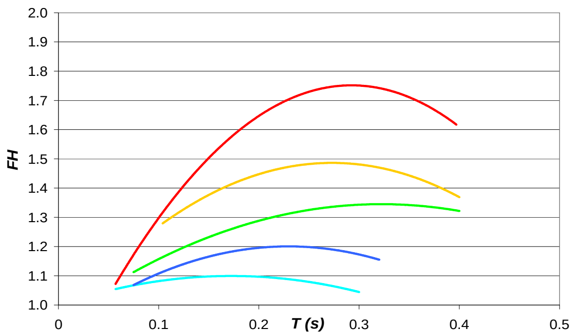
Each analyzed geophysical column has been described by the relative couple Vs_H–z, the relative T and the relative FH.

Different correlations of FH-T, using polynomial functions of 2° and 3° order, have been individuated and to each correlation (FH-T) some different couple Vs_H–z have been associated.

So each abacus has been constructed using the FH values obtained by the correlation curves FH-T in the correspondent table Vs_H-z, characterized by a specific T value.

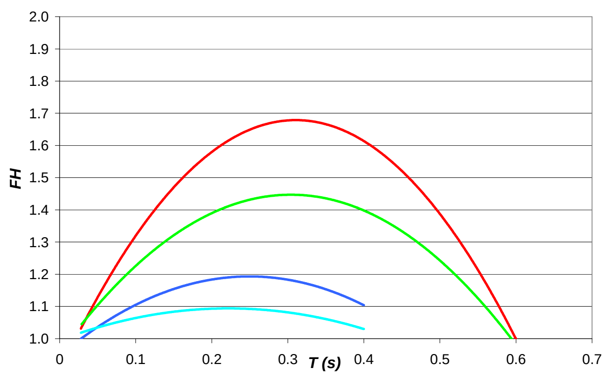
In the Figures 7, 8, 9, 10 and 11, for each group, the correlation curves FH-T and the relative associations in the table of the abacus are reported. In the Figures the table fields in grey correspond to the not applicable area of abacus.

In the Figures 12, 13, 14, 15 and 16 the abacuses, related to the 5 groups characterized by different velocity gradient and suitable for the entire regional territory, are presented. The abacuses are formed by tables considering two inputs (Vs_H and z), one output (FH) and graphics of validity areas.



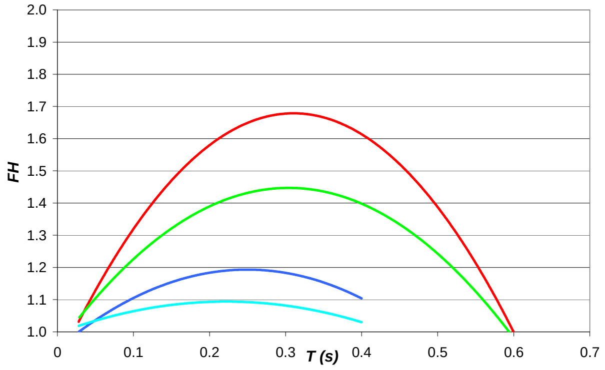
$FH_{0.1-0.5}$		V_{SH} (m/s)								
z (m)		180	250	300	360	400	450	500	600	700
	5	1.3	1.2	1.1	1.1	1.1	1.1	1.0	1.0	1.0
	10			1.4	1.4	1.2	1.2	1.1	1.1	1.0
	15			1.6	1.5	1.3	1.3	1.2	1.1	1.1
	20			1.7	1.6	1.4	1.3	1.2	1.1	1.1
	25			1.6	1.5	1.5	1.4	1.3	1.2	1.1
	30			1.5	1.5	1.5	1.4	1.3	1.2	1.1
	35				1.4	1.4	1.3	1.3	1.2	1.1
	40					1.4	1.3	1.3	1.2	1.1
	45						1.3	1.2	1.2	1.1

Figure 7. Association between the FH-T and the relative fields Vs_H–z of the abacus for the alluvial and debris gravels and weathering sands



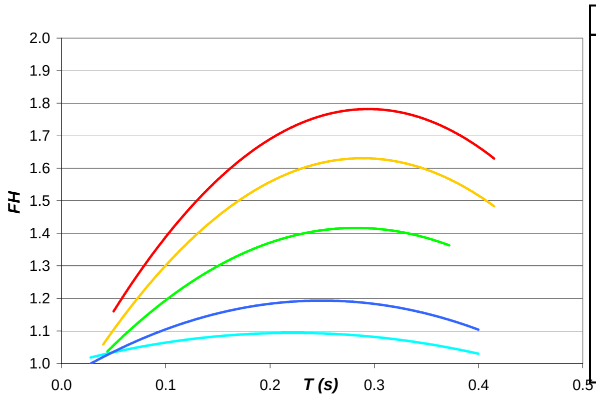
$FH_{0.1-0.5}$		V_{SH} (m/s)								
z (m)		180	250	300	360	400	450	500	600	700
	5	1.3	1.3	1.2	1.2	1.1	1.1	1.1	1.0	1.0
	10		1.5	1.4	1.4	1.2	1.2	1.2	1.1	1.0
	15		1.6	1.6	1.5	1.3	1.3	1.3	1.1	1.1
	20			1.7	1.6	1.4	1.4	1.3	1.1	1.1
	25			1.7	1.6	1.5	1.4	1.4	1.2	1.1
	30			1.5	1.5	1.5	1.4	1.4	1.2	1.1
	35				1.4	1.4	1.4	1.4	1.2	1.1
	40					1.4	1.4	1.4	1.2	1.1
	45						1.4	1.3	1.2	1.1
	50						1.3	1.3	1.2	1.1
	55						1.2	1.2	1.1	1.1
	60						1.2	1.2	1.1	1.1
	70							1.1	1.0	1.0
	80							1.0	1.0	1.0
	90								1.0	1.0
	100									1.0

Figure 8. Association between the FH-T curves and the relative fields Vs_H–z of the abacus for the alluvial sands and pyroclastic deposits characterized by minimum velocity gradient



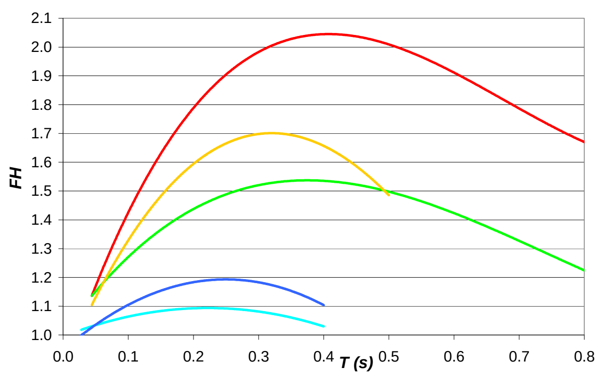
$FH_{0.1\text{-}0.5}$		V_{SH} (m/s)								
		180	*250*	*300*	*360*	*400*	*450*	*500*	*600*	*700*
z (m)	***5***	1.3	1.3	1.2	1.2	1.1	1.1	1.1	1.0	1.0
	10	1.6	1.5	1.4	1.4	1.3	1.3	1.2	1.1	1.0
	15	1.7	1.6	1.6	1.5	1.5	1.4	1.3	1.1	1.1
	20	1.6	1.7	1.7	1.6	1.6	1.5	1.3	1.1	1.1
	25	1.4	1.6	1.7	1.7	1.6	1.6	1.4	1.2	1.1
	30		1.4	1.6	1.7	1.6	1.6	1.4	1.2	1.1
	35		1.3	1.5	1.6	1.5	1.5	1.4	1.2	1.1
	40			1.4	1.6	1.5	1.5	1.4	1.2	1.1
	45			1.4	1.5	1.5	1.5	1.4	1.2	1.1
	50			1.4	1.4	1.5	1.5	1.4	1.2	1.1
	55			1.3	1.4	1.5	1.4	1.3	1.1	1.1
	60			1.2	1.3	1.4	1.4	1.3	1.1	1.1
	70				1.2	1.3	1.3	1.1	1.0	1.0
	80				1.1	1.2	1.2	1.0	1.0	1.0
	90					1.1	1.1	1.0	1.0	1.0
	100						1.1	1.0	1.0	1.0

Figure 9. Association between the FH-T curves and the relative fields Vs_H–z of the abacus for the alluvial sands and pyroclastic deposits characterized by maximum velocity gradient



$FH_{0.1\text{-}0.5}$		V_{SH} (m/s)								
		180	*250*	*300*	*360*	*400*	*450*	*500*	*600*	*700*
z (m)	***5***	1.6	1.4	1.3	1.2	1.1	1.1	1.1	1.0	1.0
	10	1.8	1.7	1.6	1.4	1.3	1.2	1.2	1.1	1.0
	15		1.9	1.7	1.5	1.4	1.3	1.2	1.1	1.1
	20		1.8	1.8	1.7	1.5	1.4	1.3	1.1	1.1
	25			1.7	1.7	1.6	1.5	1.4	1.2	1.1
	30			1.7	1.7	1.6	1.5	1.4	1.2	1.1
	35				1.6	1.5	1.4	1.4	1.2	1.1
	40				1.5	1.5	1.4	1.4	1.2	1.1
	45					1.4	1.3	1.3	1.2	1.1
	50					1.3	1.3	1.3	1.2	1.1
	55						1.2	1.2	1.1	1.1
	60							1.2	1.1	1.1

Figure 10. Association between the FH-T curves and the relative fields Vs_H–z of the abacus for the clays and silts characterized by minimum velocity gradient



$FH_{0.1\text{-}0.5}$		V_{SH}								
		180	*250*	*300*	*360*	*400*	*450*	*500*	*600*	*700*
z (m)	***5***	1.6	1.4	1.3	1.2	1.1	1.1	1.1	1.0	1.0
	10	1.8	1.7	1.6	1.5	1.3	1.3	1.2	1.1	1.0
	15	2.0	1.9	1.8	1.6	1.5	1.4	1.3	1.1	1.1
	20	1.7	2.0	1.9	1.7	1.6	1.5	1.3	1.1	1.1
	25	1.5	1.7	1.7	1.7	1.6	1.6	1.4	1.2	1.1
	30	1.4	1.5	1.7	1.7	1.6	1.6	1.5	1.2	1.1
	35	1.3	1.5	1.6	1.6	1.5	1.5	1.5	1.2	1.1
	40		1.4	1.5	1.6	1.5	1.5	1.5	1.2	1.1
	45		1.3	1.4	1.5	1.5	1.5	1.4	1.2	1.1
	50		1.2	1.4	1.4	1.5	1.5	1.4	1.2	1.1
	55			1.3	1.4	1.5	1.5	1.4	1.1	1.1
	60			1.2	1.3	1.4	1.4	1.4	1.1	1.1
	70				1.2	1.3	1.4	1.3	1.1	1.1
	80				1.2	1.2	1.3	1.2	1.1	1.1
	90					1.2	1.2	1.2	1.1	1.0
	100						1.1	1.1	1.0	1.0
	110						1.1	1.1	1.0	1.0
	120						1.1	1.1	1.0	1.0

Figure 11. Association between the FH-T curves and the relative fields Vs_H–z of the abacus for the clays and silts characterized by maximum velocity gradient

$FH_{0.1-0.5}$	V_{SH} (m/s)								
z (m)	***180***	***250***	***300***	***360***	***400***	***450***	***500***	***600***	***700***
5	1.3	1.2	1.1	1.1	1.1	1.1	1.0	1.0	1.0
10			1.4	1.4	1.2	1.2	1.1	1.1	1.0
15			1.6	1.5	1.3	1.3	1.2	1.1	1.1
20			1.7	1.6	1.4	1.3	1.2	1.1	1.1
25			1.6	1.5	1.5	1.4	1.3	1.2	1.1
30			1.5	1.5	1.5	1.4	1.3	1.2	1.1
35				1.4	1.4	1.3	1.3	1.2	1.1
40					1.4	1.3	1.3	1.2	1.1
45						1.3	1.2	1.2	1.1

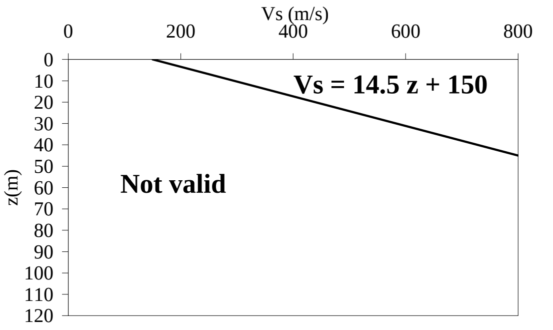


Figure 12. Abacus for the alluvial and debris gravels and weathering sands

$FH_{0.1-0.5}$	V_{SH} (m/s)								
z (m)	***180***	***250***	***300***	***360***	***400***	***450***	***500***	***600***	***700***
5	1.3	1.3	1.2	1.2	1.1	1.1	1.1	1.0	1.0
10		1.5	1.4	1.4	1.2	1.2	1.2	1.1	1.0
15		1.6	1.6	1.5	1.3	1.3	1.3	1.1	1.1
20			1.7	1.6	1.4	1.4	1.3	1.1	1.1
25			1.7	1.6	1.5	1.4	1.4	1.2	1.1
30			1.5	1.5	1.5	1.4	1.4	1.2	1.1
35				1.4	1.4	1.4	1.4	1.2	1.1
40					1.4	1.4	1.4	1.2	1.1
45						1.4	1.3	1.2	1.1
50						1.3	1.3	1.2	1.1
55						1.2	1.2	1.1	1.1
60						1.2	1.2	1.1	1.1
70							1.1	1.0	1.0
80							1.0	1.0	1.0
90								1.0	1.0
100									1.0

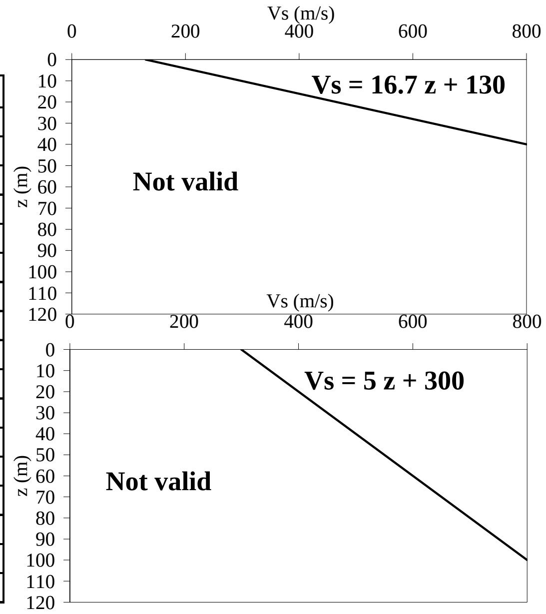


Figure 13. Abacus for the alluvial sands and pyroclastic deposits characterized by minimum velocity gradient

$FH_{0.1-0.5}$	V_{SH} (m/s)								
z (m)	***180***	***250***	***300***	***360***	***400***	***450***	***500***	***600***	***700***
5	1.3	1.3	1.2	1.2	1.1	1.1	1.1	1.0	1.0
10	1.6	1.5	1.4	1.4	1.3	1.3	1.2	1.1	1.0
15	1.7	1.6	1.6	1.5	1.5	1.4	1.3	1.1	1.1
20	1.6	1.7	1.7	1.6	1.6	1.5	1.3	1.1	1.1
25	1.4	1.6	1.7	1.7	1.6	1.6	1.4	1.2	1.1
30		1.4	1.6	1.7	1.6	1.6	1.4	1.2	1.1
35		1.3	1.5	1.6	1.5	1.5	1.4	1.2	1.1
40			1.4	1.6	1.5	1.5	1.4	1.2	1.1
45			1.4	1.5	1.5	1.5	1.4	1.2	1.1
50			1.4	1.4	1.5	1.5	1.4	1.2	1.1
55			1.3	1.4	1.5	1.4	1.3	1.1	1.1
60			1.2	1.3	1.4	1.4	1.3	1.1	1.1
70				1.2	1.3	1.3	1.1	1.0	1.0
80				1.1	1.2	1.2	1.0	1.0	1.0
90					1.1	1.1	1.0	1.0	1.0
100						1.1	1.0	1.0	1.0

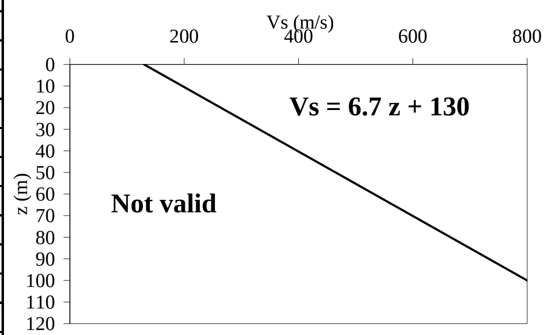


Figure 14. Abacus for the alluvial sands and pyroclastic deposits characterized by maximum velocity gradient

$FH_{0.1-0.5}$		V_{SH} (m/s)								
		180	***250***	***300***	***360***	***400***	***450***	***500***	***600***	***700***
z (m)	***5***	1.6	1.4	1.3	1.2	1.1	1.1	1.1	1.0	1.0
	10	1.8	1.7	1.6	1.4	1.3	1.2	1.2	1.1	1.0
	15		1.9	1.7	1.5	1.4	1.3	1.2	1.1	1.1
	20		1.8	1.8	1.7	1.5	1.4	1.3	1.1	1.1
	25			1.7	1.7	1.6	1.5	1.4	1.2	1.1
	30			1.7	1.7	1.6	1.5	1.4	1.2	1.1
	35				1.6	1.5	1.4	1.4	1.2	1.1
	40				1.5	1.5	1.4	1.4	1.2	1.1
	45					1.4	1.3	1.3	1.2	1.1
	50					1.3	1.3	1.3	1.2	1.1
	55						1.2	1.2	1.1	1.1
	60							1.2	1.1	1.1

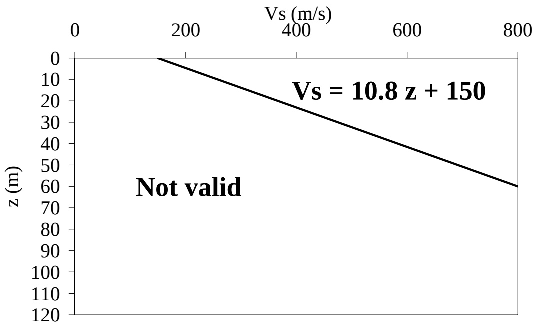


Figure 15. Abacus for the clays and silts characterized by minimum velocity gradient

$FH_{0.1-0.5}$		V_{SH}								
		180	***250***	***300***	***360***	***400***	***450***	***500***	***600***	***700***
z (m)	***5***	1.6	1.4	1.3	1.2	1.1	1.1	1.1	1.0	1.0
	10	1.8	1.7	1.6	1.5	1.3	1.3	1.2	1.1	1.0
	15	2.0	1.9	1.8	1.6	1.5	1.4	1.3	1.1	1.1
	20	1.7	2.0	1.9	1.7	1.6	1.5	1.3	1.1	1.1
	25	1.5	1.7	1.7	1.7	1.6	1.6	1.4	1.2	1.1
	30	1.4	1.5	1.7	1.7	1.6	1.6	1.5	1.2	1.1
	35	1.3	1.5	1.6	1.6	1.5	1.5	1.5	1.2	1.1
	40		1.4	1.5	1.6	1.5	1.5	1.5	1.2	1.1
	45		1.3	1.4	1.5	1.5	1.5	1.4	1.2	1.1
	50		1.2	1.4	1.4	1.5	1.5	1.4	1.2	1.1
	55			1.3	1.4	1.5	1.5	1.4	1.1	1.1
	60			1.2	1.3	1.4	1.4	1.4	1.1	1.1
	70				1.2	1.3	1.4	1.3	1.1	1.1
	80				1.2	1.2	1.3	1.2	1.1	1.1
	90					1.2	1.2	1.2	1.1	1.0
	100						1.1	1.1	1.0	1.0
	110						1.1	1.1	1.0	1.0
	120						1.1	1.1	1.0	1.0

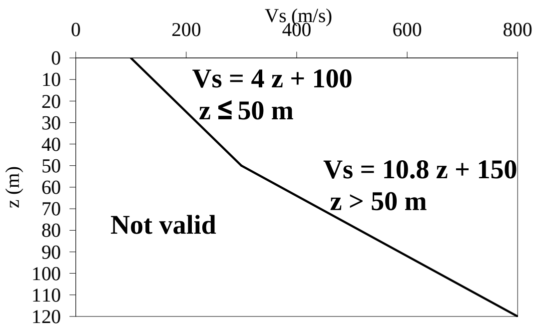


Figure 16. Abacus for the clays and silts characterized by maximum velocity gradient

9. USE OF THE ABACUSES

As mentioned, the regional territory has been subdivided in UAS, that correspond to a Municipality or a part of itself, particularly if the Municipality is characterized by a large territory (Roma, Rieti, Pescorocchiano).

The use of the abacuses considers the values, for each UAS, of a thresholds Ss (Stratigraphic coefficient) derived by the national seismic hazard and by the elastic acceleration response spectra prescribed by the national code (NTC, 2008). In particular the national code considers 4 types of soils that can produce amplification phenomena (B-C-D-E soils) and a bedrock (A soil), for each soil the national code gives an acceleration response spectrum, relating to different points of seismic hazard.

So 4 different threshold values Ss, for each UAS, have been calculated as a ratio, considering the acceleration response spectra, between the integral of the output (B-C-D-E soils) and of the input (A soil) in the period range of 0.1-0.5 s.

The comparison between the Ss value and FH value, obtained by the abacuses, permits to distinguish the areas where it is necessary to perform seismic analyses of L3 of the ICMS, as described in the integration of ICMS (Colombi et al., 2011), and prescribed in the regional codes, when the FH>Ss+0,1, from the areas where it is possible to apply the acceleration response spectra derived by the national code.

10. CONCLUSION

The aim of the project has been the development of regional abacuses, finalized to the evaluation of the expected amplifications, using a semiquantitative approach (L2), as prescribed by the ICMS. The requirement to have regional abacuses derived by the consideration that the ICMS abacuses are devoted to a general application for the entire Italian territory, so the specific regional geologic situations aren't sufficiently represented. Moreover, in Lazio Region, the recent regional codes, for the planning and the mitigation of seismic risk, prescribe the use of specific regional abacuses.
During the project the following steps have been performed: choice of the seismic inputs, choice of the numerical code, choice of the structure of the abacuses, analyses of the collected data, numerical analyses and construction of the abacuses.
The application of the abacuses, defining the value of the expected amplification FH, allows, in urban planning phase, to:

- perform a list of areas, characterized by different hazards due to different values of expected amplifications;
- define the suitability of the investigated areas, during the planning phase (DGR 2649/99);
- define the areas where it is necessary to apply the L3 of ICMS, because the FH values is higher than the Ss threshold, derived by the national code, to obtain more adequate acceleration response spectra.

REFERENCES

Colombi, A., Compagnoni, M., Pergalani, F. (2011). Risposta sismica locale: la MS come strumento discriminante per l'utilizzo di approcci semplificati o di specifiche analisi. *Ingegneria Sismica*, **2**, 65-68.

DGR Lazio n. 2649 del 18 Maggio (1999). Linee guida e documentazione per l'indagine geologica e vegetazionale estensione dell'applicabilità della legge 2 febbraio 1974 n. 64 ai comuni individuati tra quelli ad alto rischio sismico in base all'ordinanza n. 2788 del 12 Giugno 1998 della Presidenza del Consiglio Dipartimento della Protezione Civile. Bollettino Ufficiale Regione Lazio n. 24 del 22 settembre 1999 Supplemento 103.

DGR Lazio n. 387 del 18 Maggio (2009). Nuova riclassificazione sismica del territorio della Regione Lazio in applicazione dell'OPCM n. 3519/2006. Bollettino Ufficiale Regione Lazio n. 24 del 27 giugno 2009 Supplemento 106.

DGR Lazio n. 545 del 26 Novembre (2010). Approvazione delle Linee Guida per l'utilizzo degli Indirizzi e Criteri generali per gli studi per gli studi di Microzonazione Sismica nel territorio della Regione Lazio di cui alla Deliberazione 387/09. Bollettino Ufficiale Regione Lazio n. 48 del 28 dicembre 2010. Supplemento 212.

DGR Lazio n. 490 del 21 Ottobre (2011). Approvazione degli Abachi Regionali per gli studi di Livello 2 di Microzonazione Sismica ai sensi della DGR Lazio n. 545 del 26 dicembre 2010 e delle relative procedure di applicazione nell'ambito del rilascio del parere ai sensi dell'art. 89 del DPR del 6 giugno 2001 n. 380. Modifica alla DGR 545/10. Bollettino Ufficiale Regione Lazio n. 43 del 21 novembre 2011.

ENEA (2009). Analisi della sismicità regionale ai fini dell'individuazione di classi di comuni con situazioni omogenee di scuotibilità in occasione di eventi sismici. Report interno.

GdL MS (2008). Indirizzi e Criteri per la Microzonazione Sismica. Conferenza delle Regioni e delle Province autonome – Dipartimento della Protezione Civile, Roma, 3 vol. e DVD.

NTC (2008). Norme Tecniche per le Costruzioni. DM 14 gennaio 2008. Gazzetta Ufficiale, n. 29 del 4 febbraio 2008, Supplemento Ordinario n. 30, Istituto Poligrafico e Zecca dello Stato, Roma (*www.cslp.it*).

Pergalani, F., Romeo, R., Luzi, L., Petrini, V., Pugliese, A., Sanò, T. (1999). Seismic microzoning of the area struck by Umbria-Marche (central Italy) Ms 5.9 earthquake of the 26 september 1997. *Soil Dynamics and Earthquake Engineering*, Elsevier Science, **18:4**, 279-296.

Rollins, K.M. (1998). Shear modulus and damping relationship for gravels. *Journal of Geotechnical and Geoenvironmental Engineering.*

Seed, H.B., Idriss, I.M. (1970). Soil moduli and damping factors for dynamic response analyses. EERC Report 70-10, University of California, Berkeley.

Working Group MS-AQ (2010). Microzonazione sismica per la ricostruzione dell'area aquilana. Regione Abruzzo - Gruppo di lavoro coordinato dal Dipartimento della protezione civile, L'Aquila, 3 vol. and Cd-rom.