PRELIMINARY SPATIAL ANALYSIS AND COMPARISON BETWEEN RESPONSE SPECTRA EVALUATED FOR EMILIA ROMAGNA EARTHQUAKES AND ELASTIC DEMAND SPECTRA ACCORDING TO THE NEW SEISMIC ITALIAN CODE

20 and 29 May events

Luigi Petti, Alessio Lodato

petti@unisa.it, alessio_lodato@libero.it
Department of Civil Engineering, University of Salerno, Italy

Introduction

As widely known, seismic demand is generally described through Pseudo-Acceleration Spectra which lead to an analysis of the seismic response of a structure by means of equivalent static forces evaluated through the use of dynamic parameters, i.e. main modal shapes, periods and damping factors.

Seismic Codes usually define elastic spectra for each assigned performance target level by considering the seismic hazard of the station. Non-linear behavior, however, is considered by means of the "Structural Factor" taking into account the overall ductility capacities of structures.

In the case of New Design Italian Code (NTC '08), elastic spectra have been defined at bedrock (Soil Type A) by considering the Seismic Hazard evaluated for several occurrence probabilities according to each performance level and to the relevance of construction; i.e. for ordinary and strategic buildings, the demand spectra are evaluated by considering the following return periods.

Target Performance Levels	**Return Period T_R** [yrs]	
	Ordinary Constructions *(V_R=50 yrs)*	***Strategic Constructions*** *(V_R=200 yrs)*
Immediate Operative (**SLO**)	30	120
Damage Control (**SLD**)	50	201
Life Safety (**SLV**)	475	1898
Collapse Prevention (**SLC**)	975	2475

Please cite as: "L. Petti, A. Lodato (2012), *Preliminary spatial analysis and comparison between response spectra evaluated for Emilia Romagna earthquakes and elastic demand spectra according to the new seismic Italian Code*, available at http://www.reluis.it"

This report presents a comparison between the response spectra evaluated for the Emilia Romagna earthquakes (date: 20/05/2012 – 02:03:53 UTC – Magnitude 5.9; 29/05/2012 – 07:00:03 UTC – Magnitude 5.8) and the elastic demand spectra according to the new Italian seismic code (NTC2008) for ordinary (*reference period* V_R*=50 yrs*) and strategic constructions (*reference period* V_R*=200 yrs*).

In particular, the following records (1,2) have been taken into account:

- 20th may event – *station MRN*, Mirandola site
  Soil profile type C, Topography factor ST=1.0, Epicenter distance R=17 km
- 20th may event – *station NVL*, Novellara site
  Soil profile type C, Topography factor ST=1.0, Epicenter distance R=41 km
- 29th may event – *station MRN*, Mirandola site
  Soil profile type C, Topography factor ST=1.0, Epicenter distance R=2 km
- 29th may event – *station MOG0*, Moglia site
  Soil profile unknown, Topography factor unknown, Epicenter distance R=16 km

Soil parameters have been preliminarily estimated from data made available from the ITACA database (1), accelerometric RAN network (2) and (4).

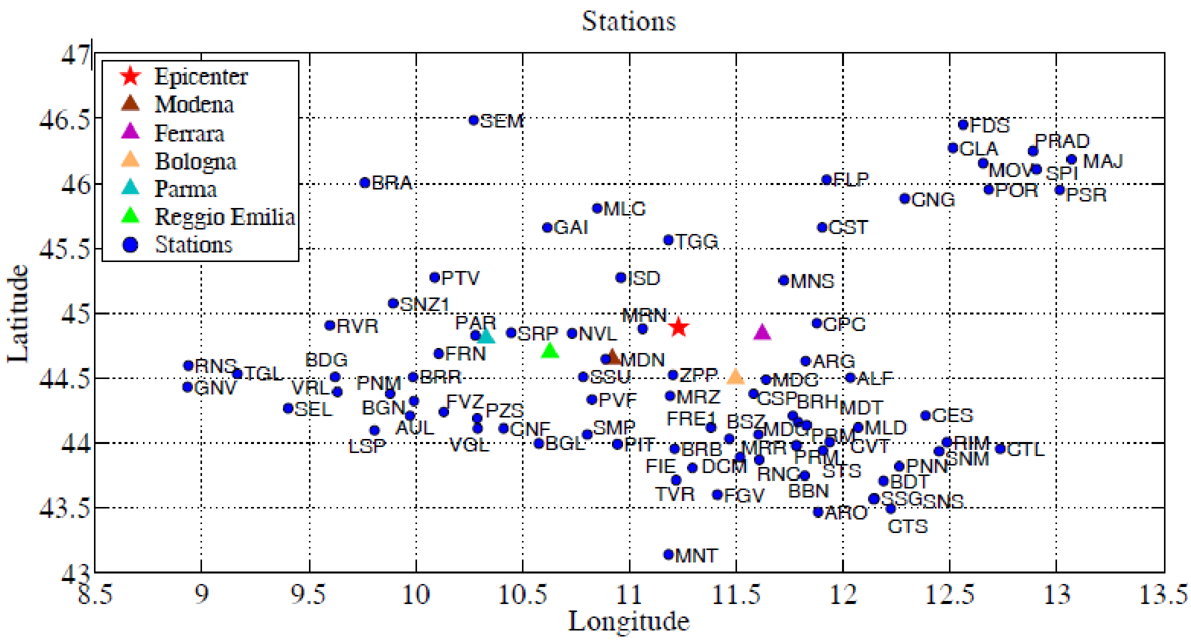


Figure 1. Map of the stations within 200 km from the epicentre (4)

In the following, Peak Ground Acceleration (PGA) for horizontal (X and Y) and vertical (Z) components are represented.

ID station/direction analysis	PGA [g]		
	EW – direction	NS – direction	Z - direction
MRN (20th may)	0.265	0.265	0.306
NVL (20th may)	0.048	0.052	0.030
MRN (29th may)	0.224	0.296	0.917
MOG0 (29th may)	0.245	0.173	0.133

The recorded horizontal and vertical Peak Ground Accelerations, for Mirandola and Moglia stations, the nearest station to the sources, present significant values. In the case of the MRN station vertical component reached very high peak values in the case of 29^{th} May event.

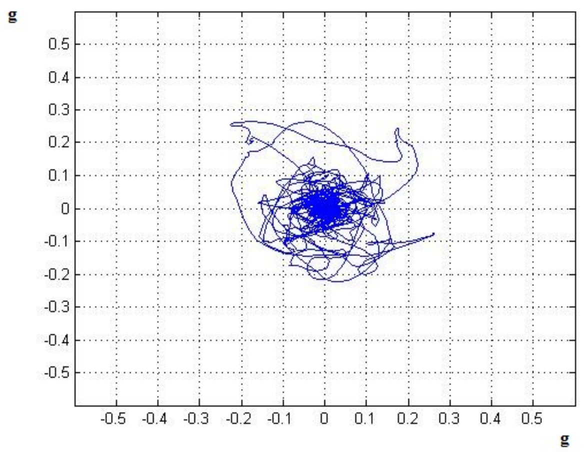
Spatial spectral analysis

To characterize horizontal seismic demand, pseudo-acceleration spectra for several in-plane directions have been evaluated. In particular, for each recording station the following have been represented:

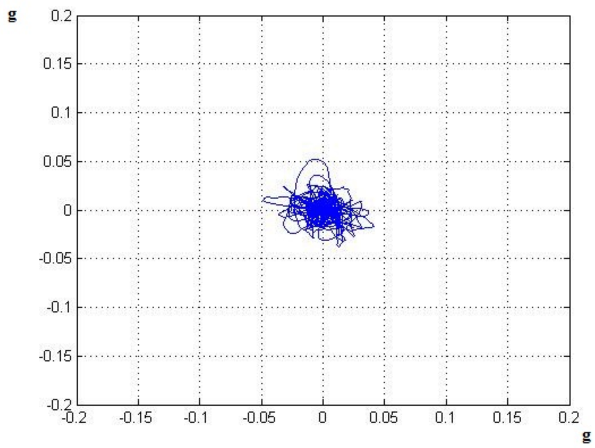
1. Plots of absolute acceleration path in terms of “g” in the NS-EW plan;
2. Overlapped spectra response in terms of pseudo-accelerations, evaluated for several directions in the horizontal plane;
3. Polar Spectra in terms of Pseudo-Acceleration, Pseudo-Velocities and Displacements.

In particular, the earthquake response spectra, for 40 in-plane directions (every 9°) in each recording station, have been evaluated by considering a 5% damping coefficient and logarithmic subdivision of the considered period range 0.0-5.0 sec.. The overlapped spectra figures compare the spectra evaluated in each direction by highlighting those evaluated for the main horizontal directions S_{ax} and S_{ay} and the envelope of all of them $S_{a,env}$.

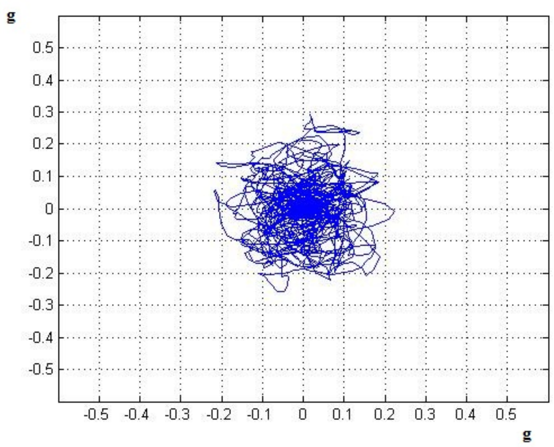
With regard to the Polar Spectra (5), the plots represent the seismic spectra demand in each horizontal directions by means of graduated color maps. In particular, the polar spectrum represents the projection on the horizontal plan of the spectral surface obtained by evaluating the spectra in each horizontal direction by considering the ground accelerations time histories just in these directions. To the scope, for each considered directions the accelerograms have been evaluated by considering the NS and EW recorded components of the seismic event. Each radius of the polar spectrum represents, thus, the response evaluated in that direction and each circumference, instead, the spectral demand for a fixed period in each directions. In the represented Polar Spectra, the periods 0.5, 1.0 and 1.5 are marked by black thin circumference, the origin corresponds to 0 sec. period.



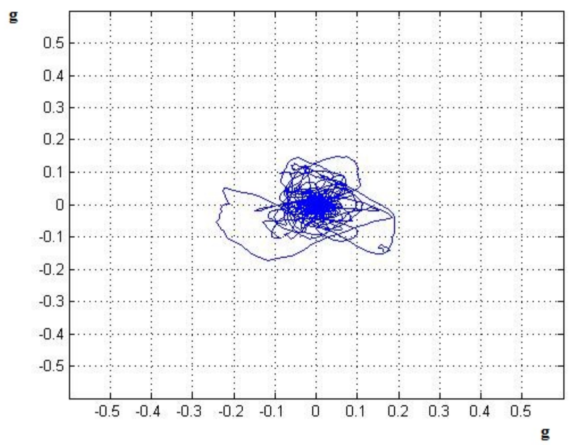
20th May event – station MRN



20th May – station NVL



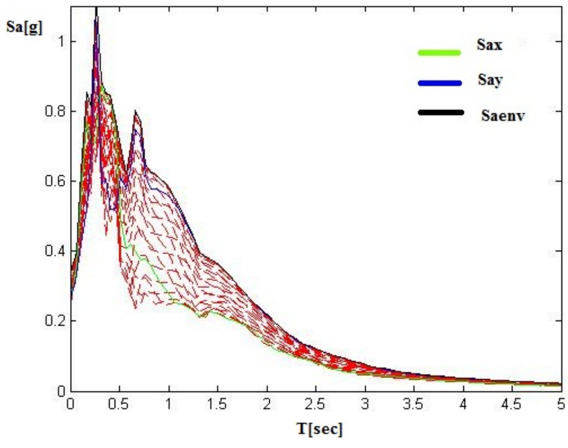
29th May event– station MRN



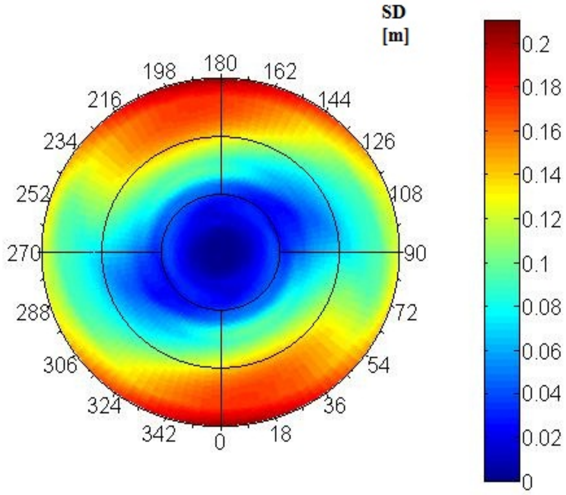
29th May event – station MOG0

Earthquake horizontal acceleration plot in the NS-EW directions (North at the Top of Figures)

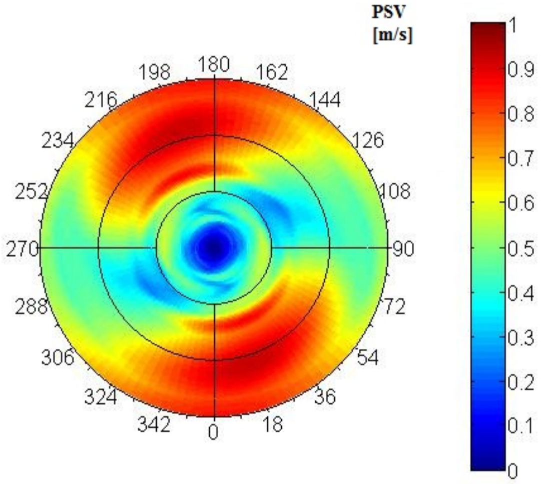
By analyzing the horizontal acceleration plot it is possible to observe a non-uniform seismic demand in the plane and is difficult to identify directivity effects.



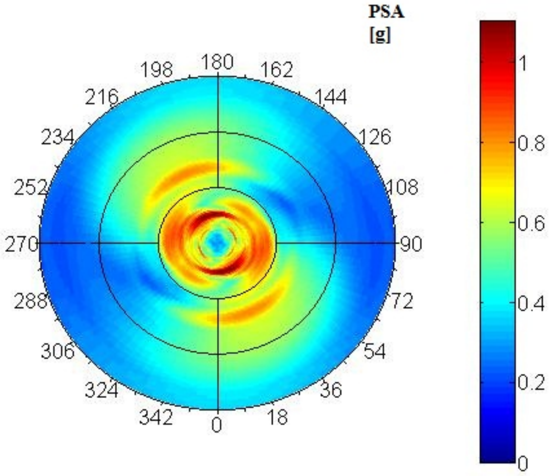
Overlapped Spectra Response in terms of Pseudo-Accelerations



Polar Spectrum – Displacements



Polar Spectrum – Pseudo Velocities



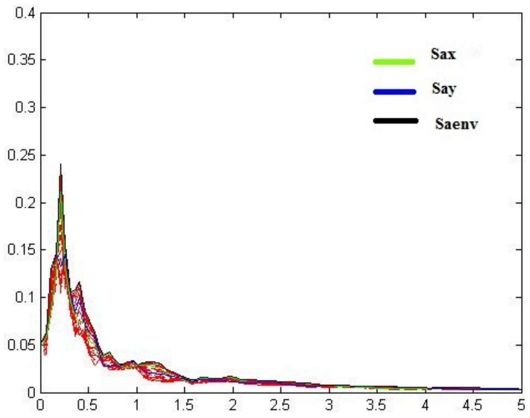
Polar Spectrum – Pseudo Accelerations

20th May event – Station MRN

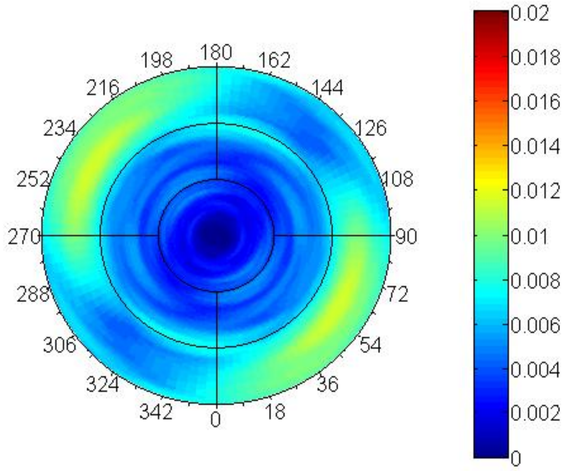
Spectra evaluated every 9° for several directions in the horizontal plane

Circular ring placed in polar spectra from inside to outside

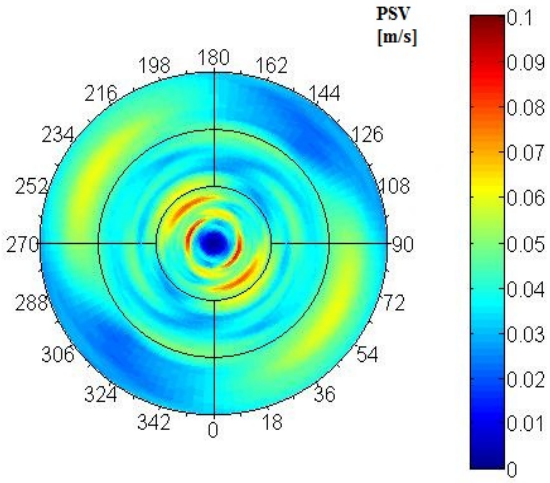
at 0.5,1.0 and 1.5 sec. vibration periods, 0° corresponds to the South



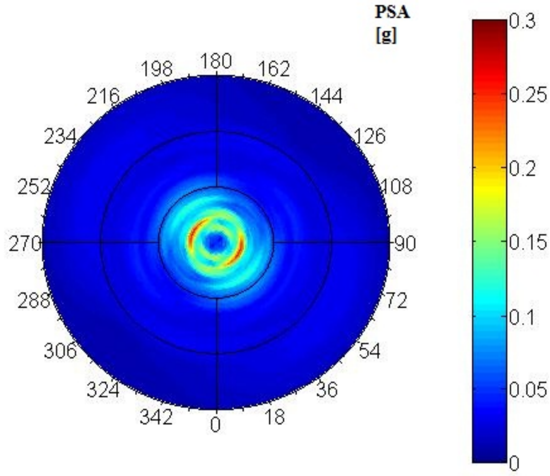
Overlapped Spectra Response in terms of Pseudo-Accelerations



Polar Spectrum – Displacements



Polar Spectrum – Pseudo Velocities



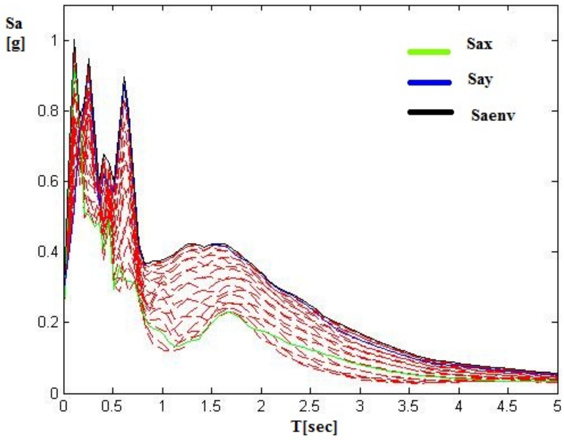
Polar Spectrum – Pseudo Accelerations

20th May event – station NVL

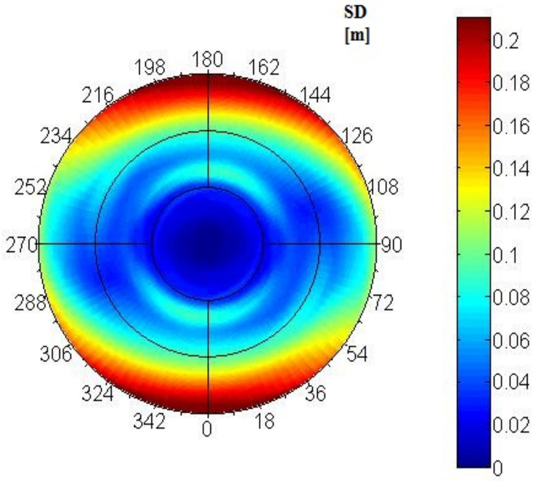
Spectra evaluated every 9° for several directions in the horizontal plane

Circular ring placed in polar spectra from inside to outside

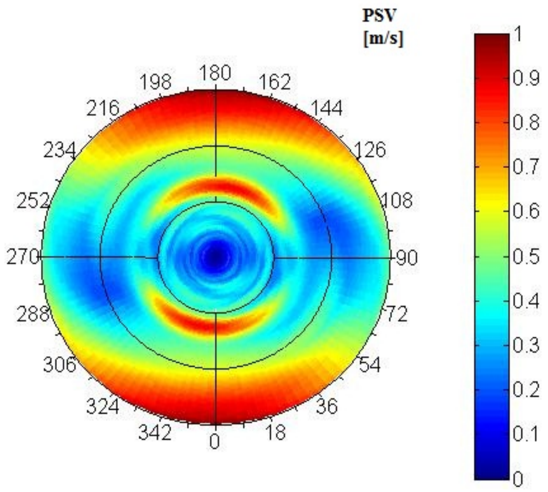
at 0.5,1.0 and 1.5 sec. vibration periods, 0° corresponds to the South



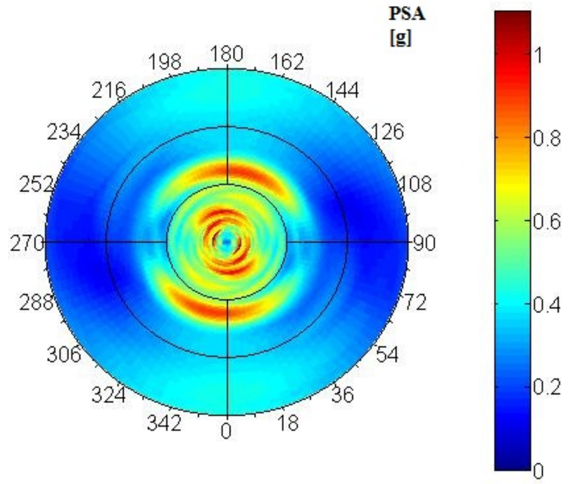
Overlapped Spectra Response in terms of Pseudo-Accelerations



Polar Spectrum – Displacements



Polar Spectrum – Pseudo Velocities



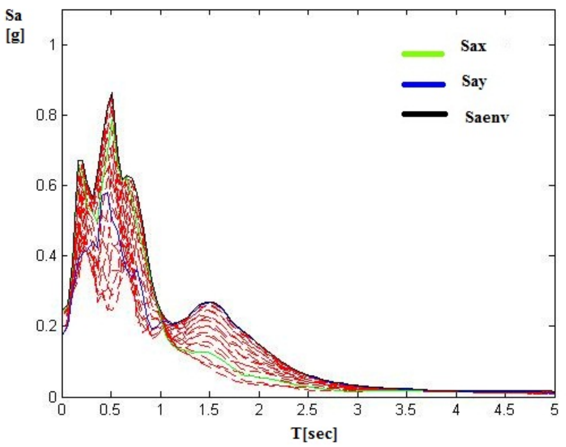
Polar Spectrum – Pseudo Accelerations

29th may event– station MRN

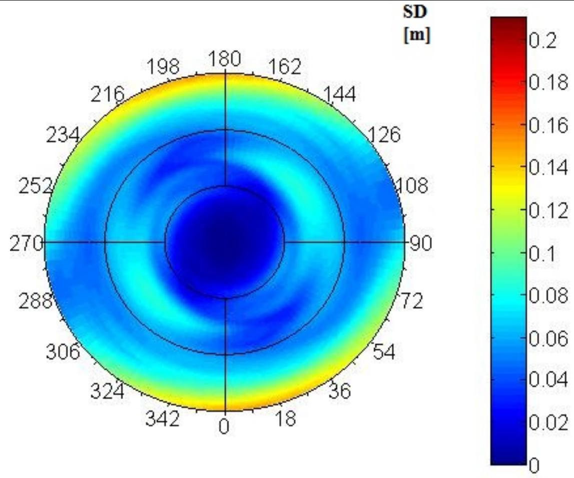
Spectra evaluated every 9° for several directions in the horizontal plane

Circular ring placed in polar spectra from inside to outside

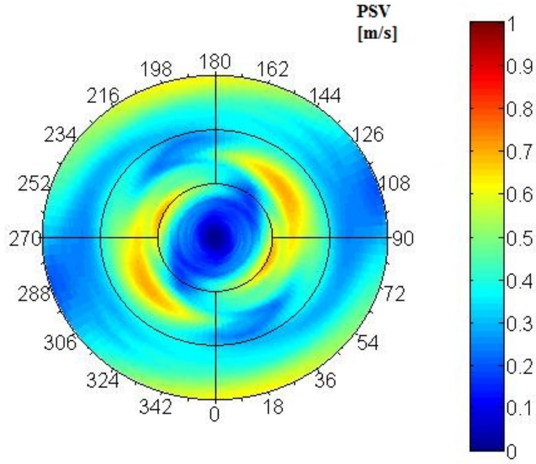
at 0.5,1.0 and 1.5 sec. vibration periods, 0° corresponds to the South



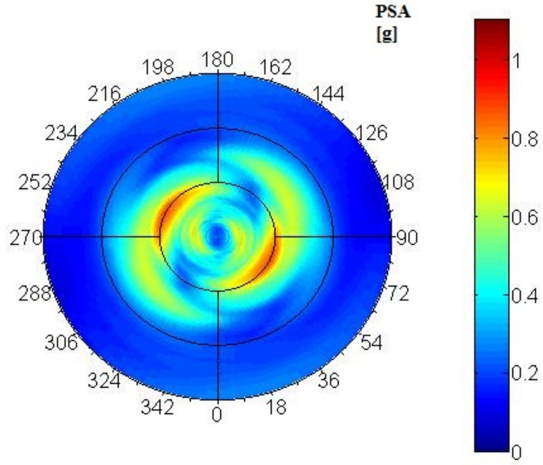
Overlapped Spectra Response in terms of Pseudo-Accelerations



Polar Spectrum – Displacements



Polar Spectrum – Pseudo Velocities



Polar Spectrum – Pseudo Accelerations

28th May event – station MOG0

Spectra evaluated every 9° for several directions in the horizontal plane
Circular ring placed in polar spectra from inside to outside
at 0.5,1.0 and 1.5 sec. vibration periods, 0° corresponds to the South

Results show that in the case of recording station MRN, for the 20th May event, spectral responses are generally characterized by the highest values in the NNW-SSE direction. More complex appears the seismic demand in terms of PSA in the range 0.3÷0.7 sec: for lower and higher period the maximum response is attained in the NNW-SSE direction, in medium period in the E-W direction.

In the case of recording station NVL, for the 20th May event, it is possible to observe larger spectral demand in the NW-SE direction. Maximum values are reached in range of periods 0.25 and 0.4 sec for PSA and PSV.

Please cite as: "L. Petti, A. Lodato (2012), *Preliminary spatial analysis and comparison between response spectra evaluated for Emilia Romagna earthquakes and elastic demand spectra according to the new seismic Italian Code*, available at http://www.reluis.it"

Results show that in the case of recording station MRN, for the 29th May event, spectral responses are generally characterized by the highest values in the N-S direction. More complex appears again the seismic demand in terms of PSA in the range 0.1÷0.7 sec where the maximum response attained recursively from NNW-SSE and NNE-SSW directions by increasing the periods. PSV present high values around 0.65 sec and 1,0 sec.

In the case of recording station MOG0 it is possible to observe larger spectral demand in the NNW-SSE direction for SD. More complex seems to be the response in terms of PSA and PSV which presents maximum values in the NE-SW and in the NWW-SEE directions respectively for periods around 0.75 and 0.5 sec.

The results analysis leads to the following main comments:

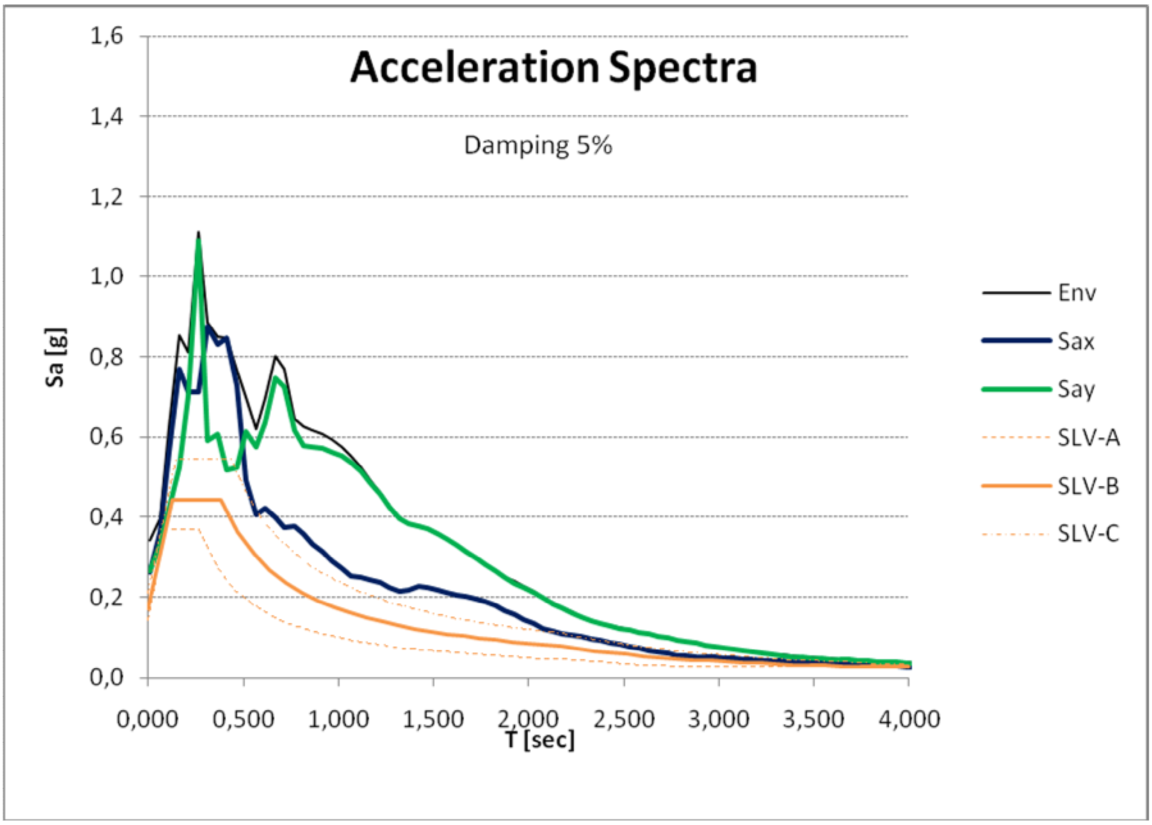
- The spectra evaluated along the main directions NS and EW do not always represent the highest seismic demand;
- The spectral demand in the main horizontal direction does not provide a satisfactory evaluation of the seismic demand as a polar spectrum which, instead, better describes the spatial features of the seismic demand. In particular, analysis of the polar spectra shows that the seismic shaking generally presents non-uniform seismic demand for a fixed vibration period by varying directions.

Spectra Comparison

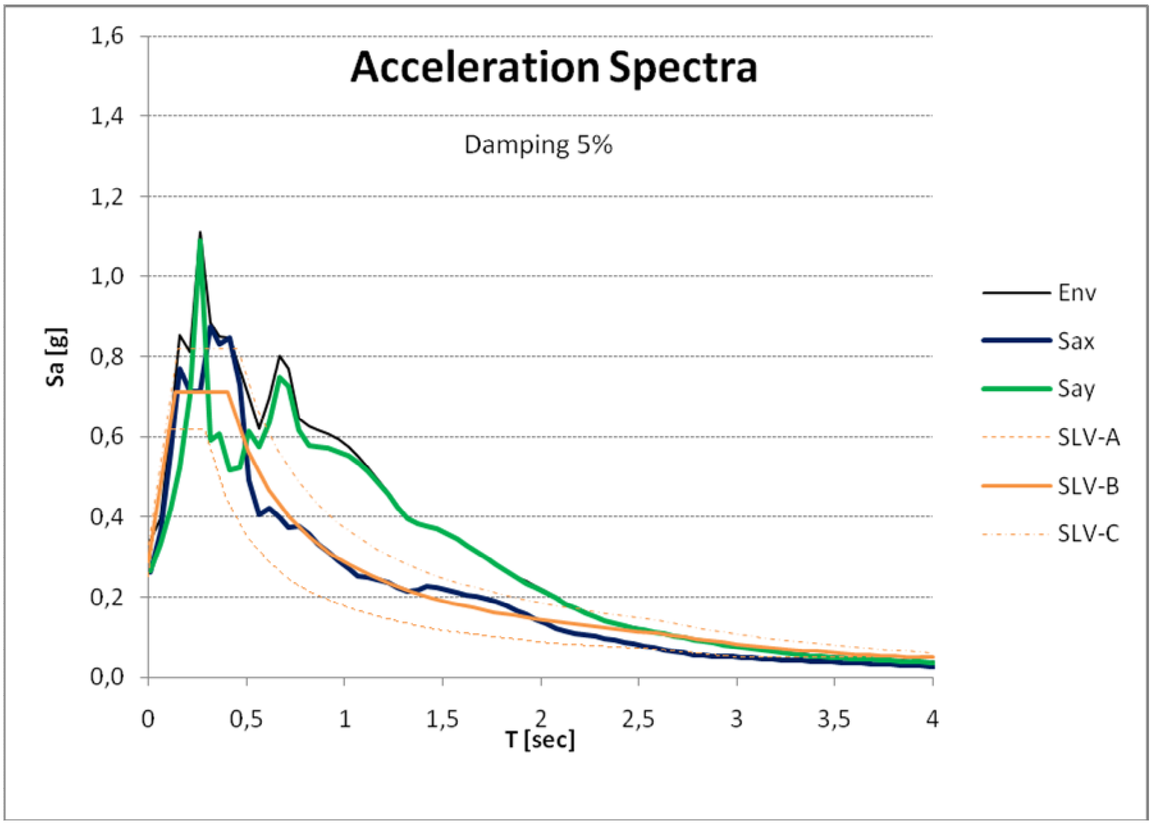
In the following, the obtained spectra for the main horizontal direction S_{ax} and S_{ay} and the envelope spectra(Env) have been compared with the elastic demand spectra according to the new Italian seismic code (NTC2008). In the case of NTC2008, the demand spectra are evaluated, for soil types A, B and C, by considering the following return periods:

Target Performance Levels NTC2008	**Return Period T_R** [yrs]	
	Ordinary Constructions *(V_R=50 yrs)*	***Strategic Constructions*** *(V_R=200 yrs)*
Life Safety (**SLV**)	475	1898

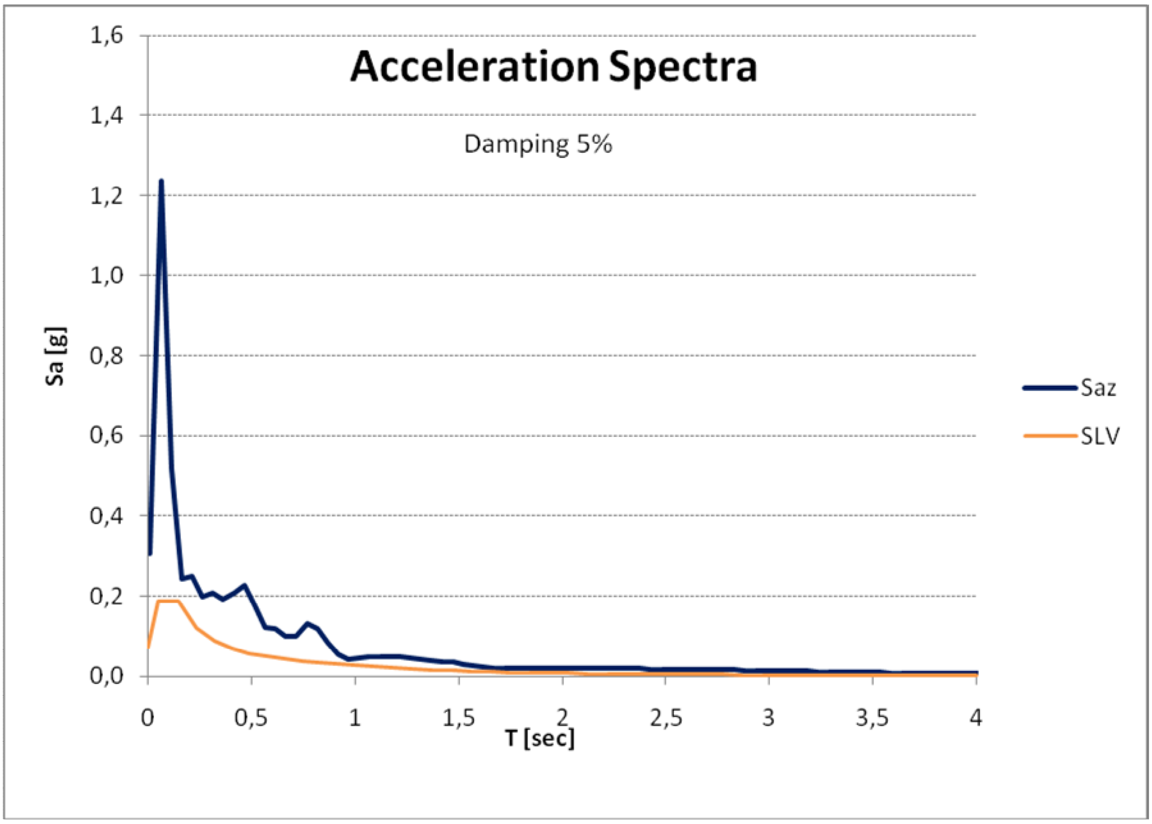
Moreover, for each station, the obtained spectra for the vertical direction S_{az} have been compared with the elastic demand spectra according to the new Italian seismic code (NTC2008), which, in this case, assumes the same spectrum response for each soil category.



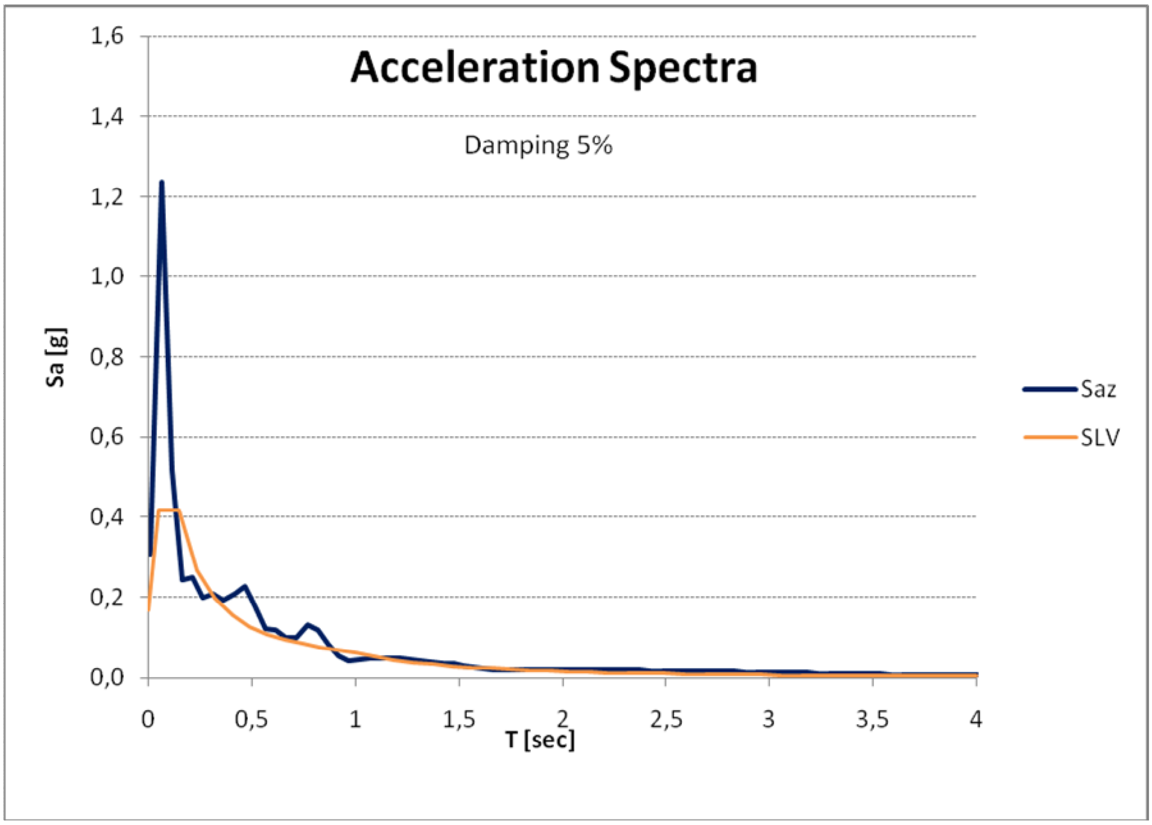
20th May event – station MRN – Earthquake Spectra Resp. vs. NTC2008 Elastic Spectra for Ordinary Const.



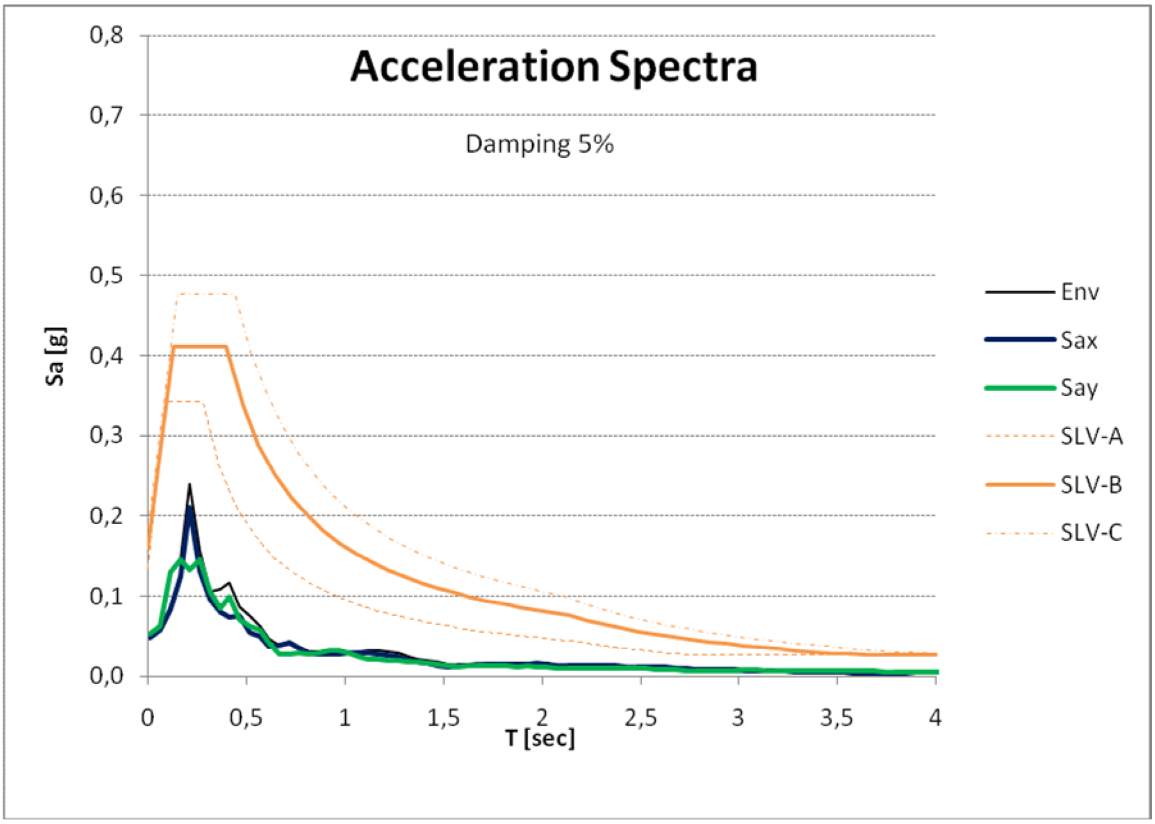
20th May event – station MRN – Earthquake Spectra Resp. vs. NTC2008 Elastic Spectra for Strategic Const.



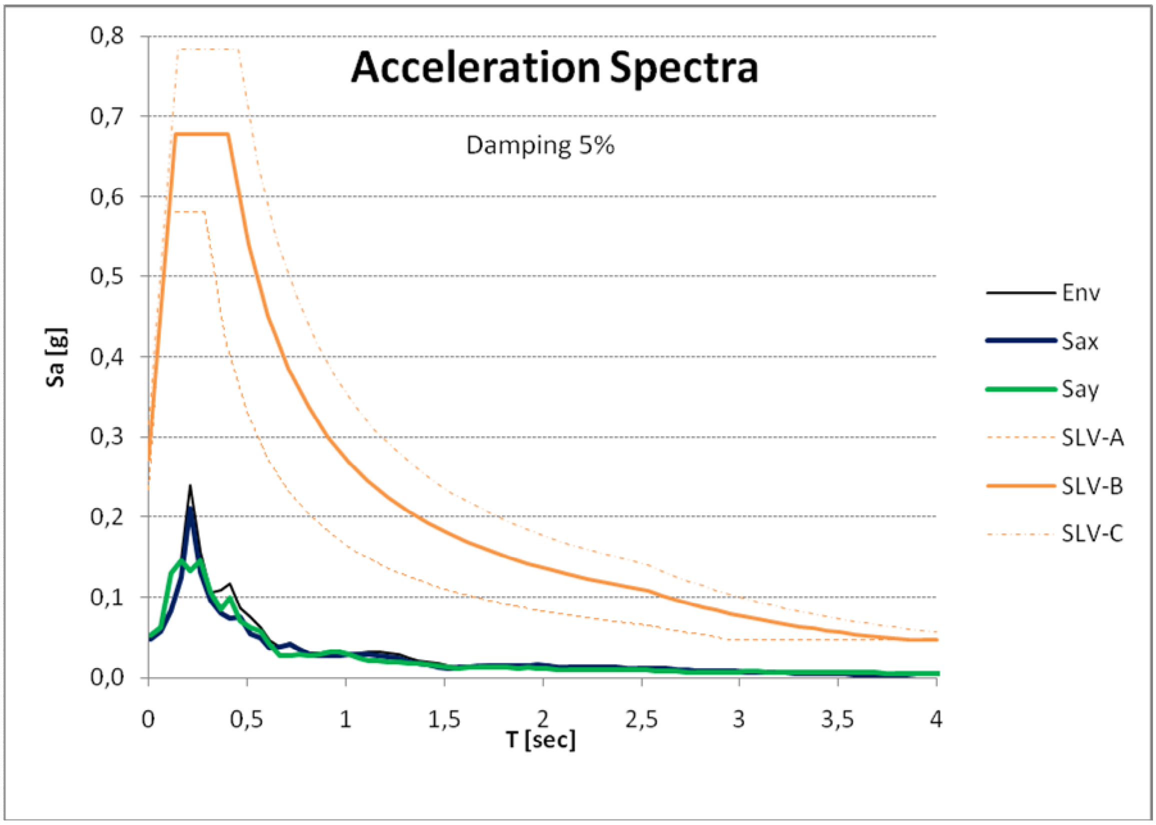
20th May event – station MRN – Earthquake Spectra Resp. vs. NTC2008 Elastic Spectra for Ordinary Const.



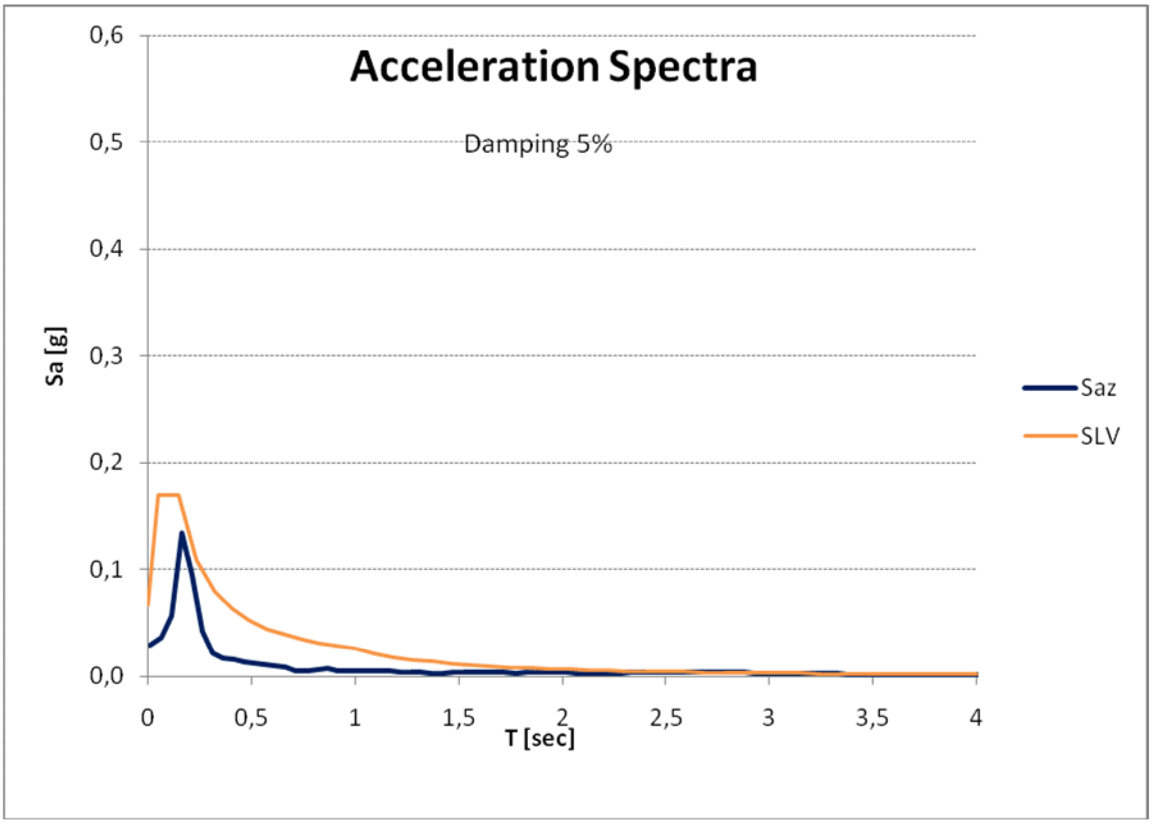
20th May event – station MRN – Earthquake Spectra Resp. vs. NTC2008 Elastic Spectra for Strategic Const.



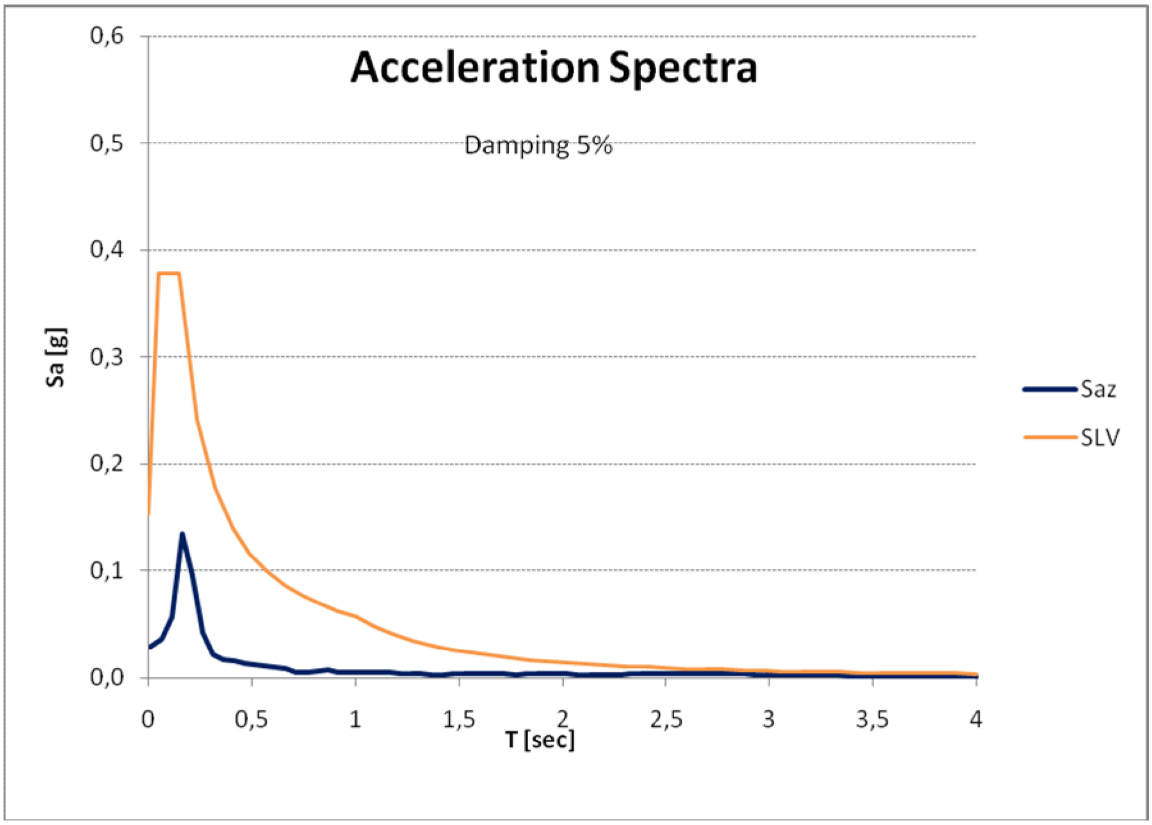
20th May event – station NVL – Earthquake Spectra Resp. vs. NTC2008 Elastic Spectra for Ordinary Const.



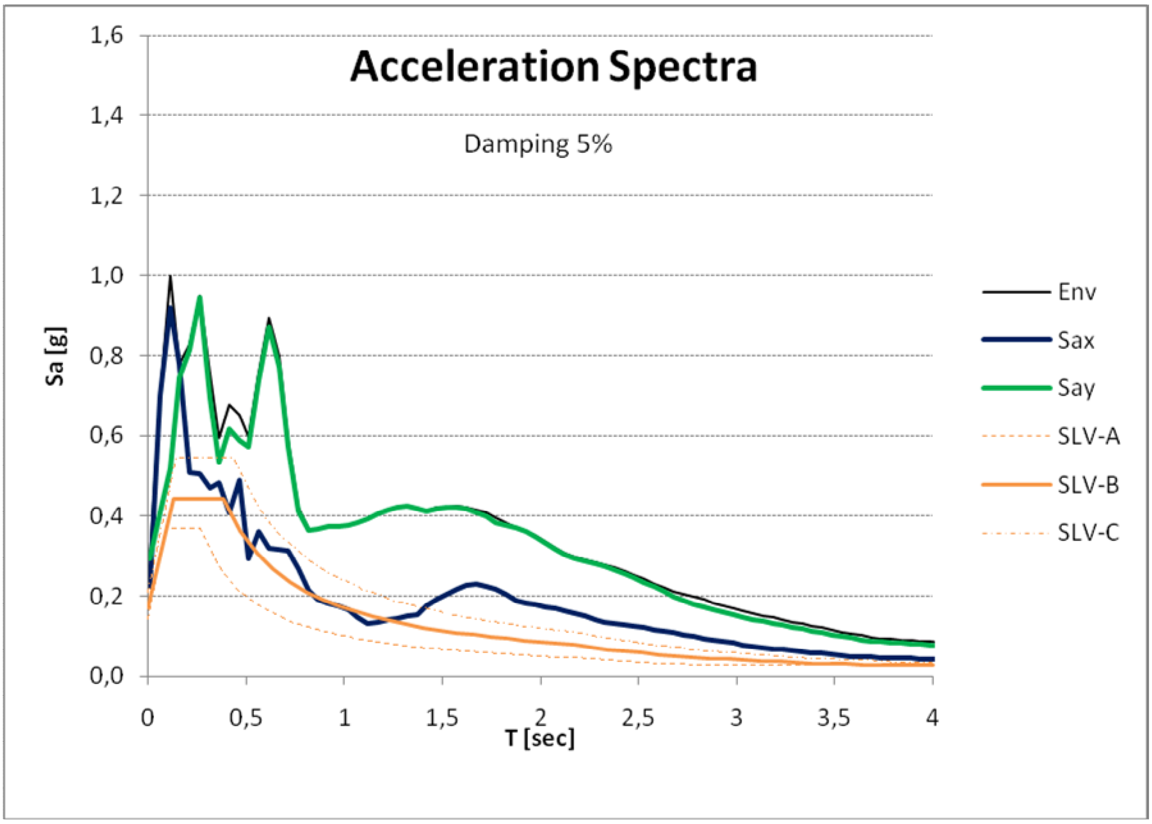
20th May event – station NVL – Earthquake Spectra Resp. vs. NTC2008 Elastic Spectra for Strategic Const.



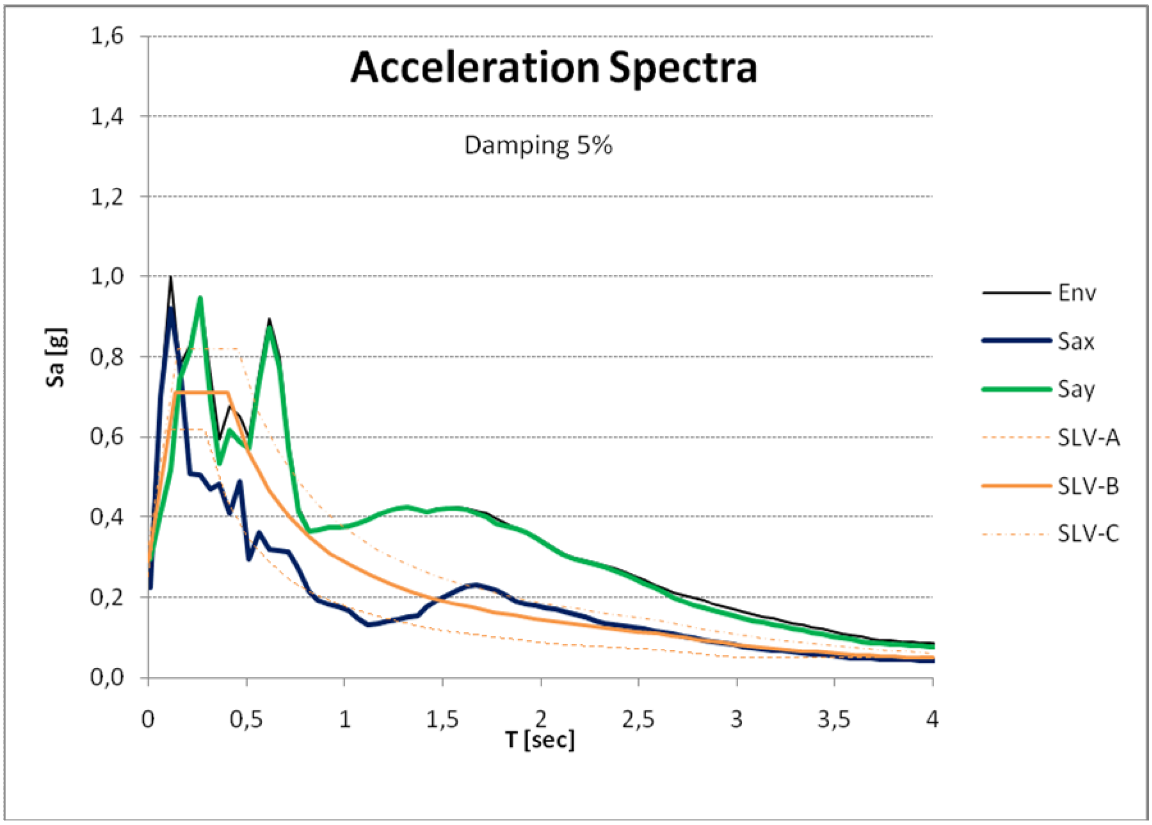
20th May event – station NVL – Earthquake Spectra Resp. vs. NTC2008 Elastic Spectra for Ordinary Const.



20th May event – station NVL – Earthquake Spectra Resp. vs. NTC2008 Elastic Spectra for Strategic Const.

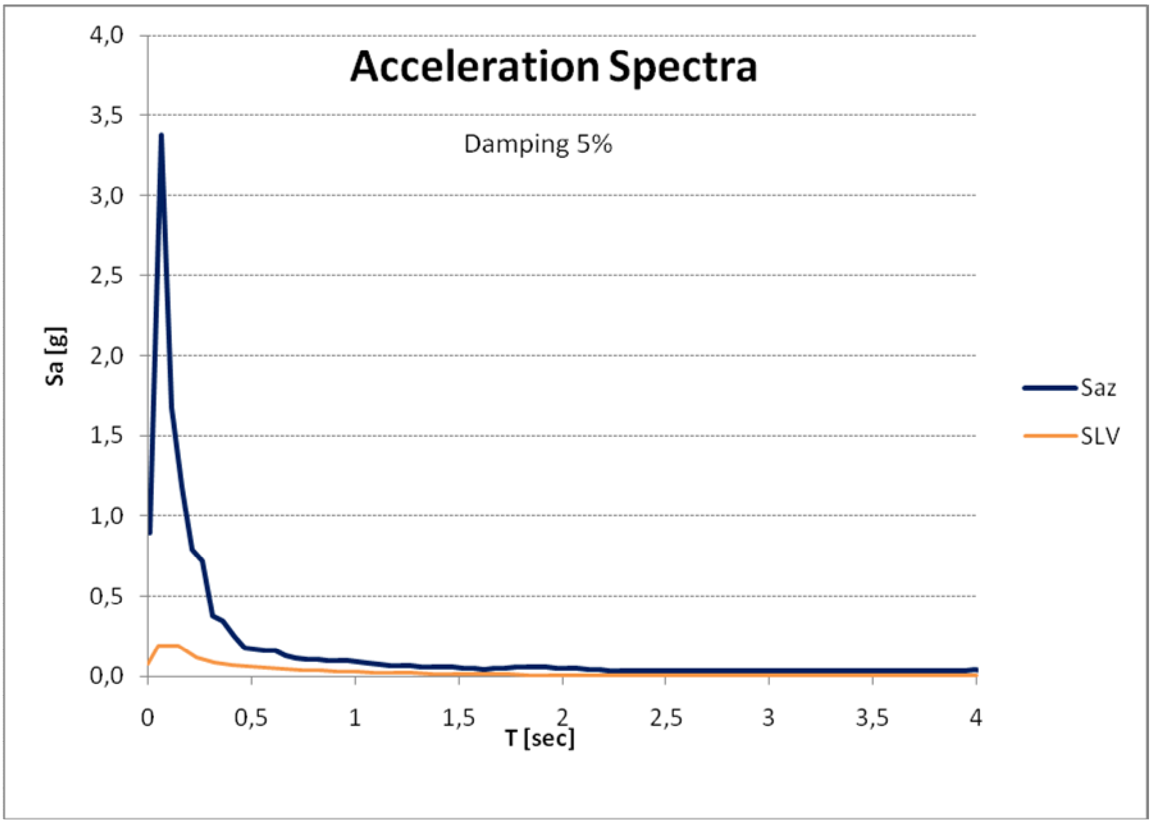


29th May event – station MRN – Earthquake Spectra Resp. vs. NTC2008 Elastic Spectra for Ordinary Const.

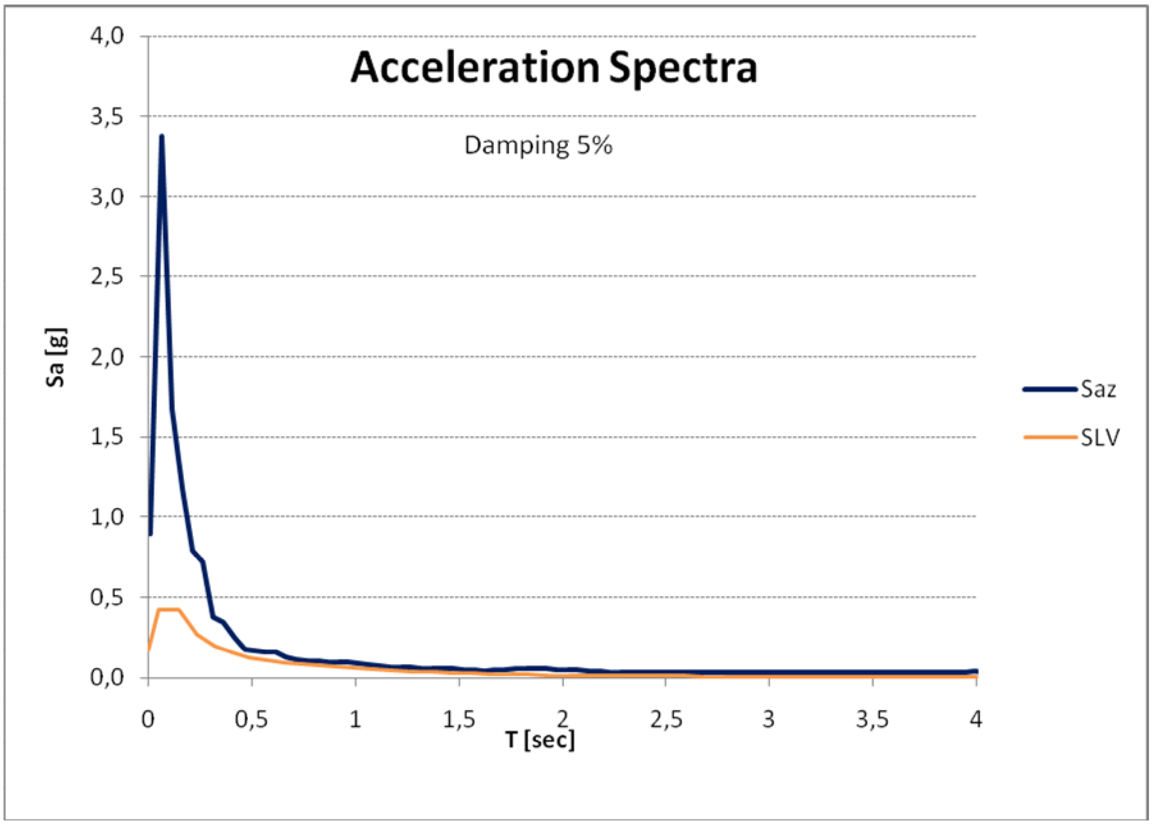


29th May event – station MRN – Earthquake Spectra Resp. vs. NTC2008 Elastic Spectra for Strategic Const.

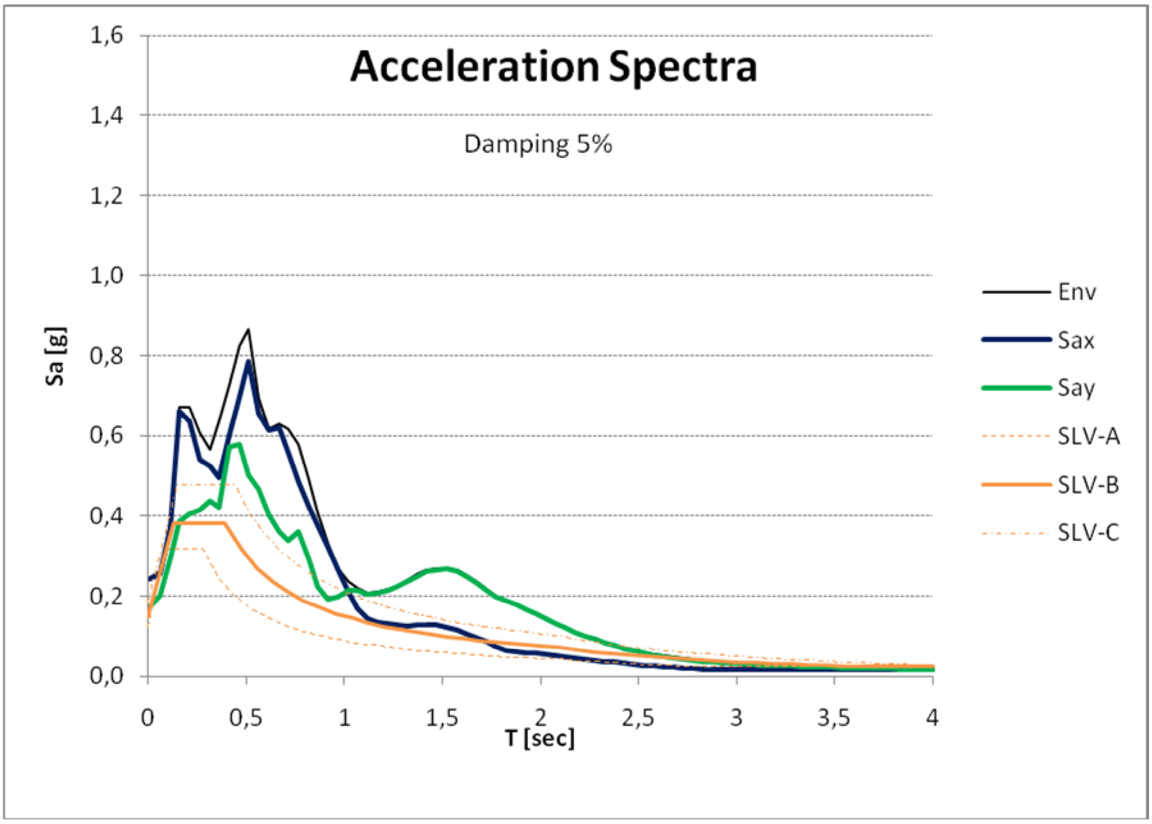
Please cite as: "L. Petti, A. Lodato (2012), *Preliminary spatial analysis and comparison between response spectra evaluated for Emilia Romagna earthquakes and elastic demand spectra according to the new seismic Italian Code*, available at http://www.reluis.it"



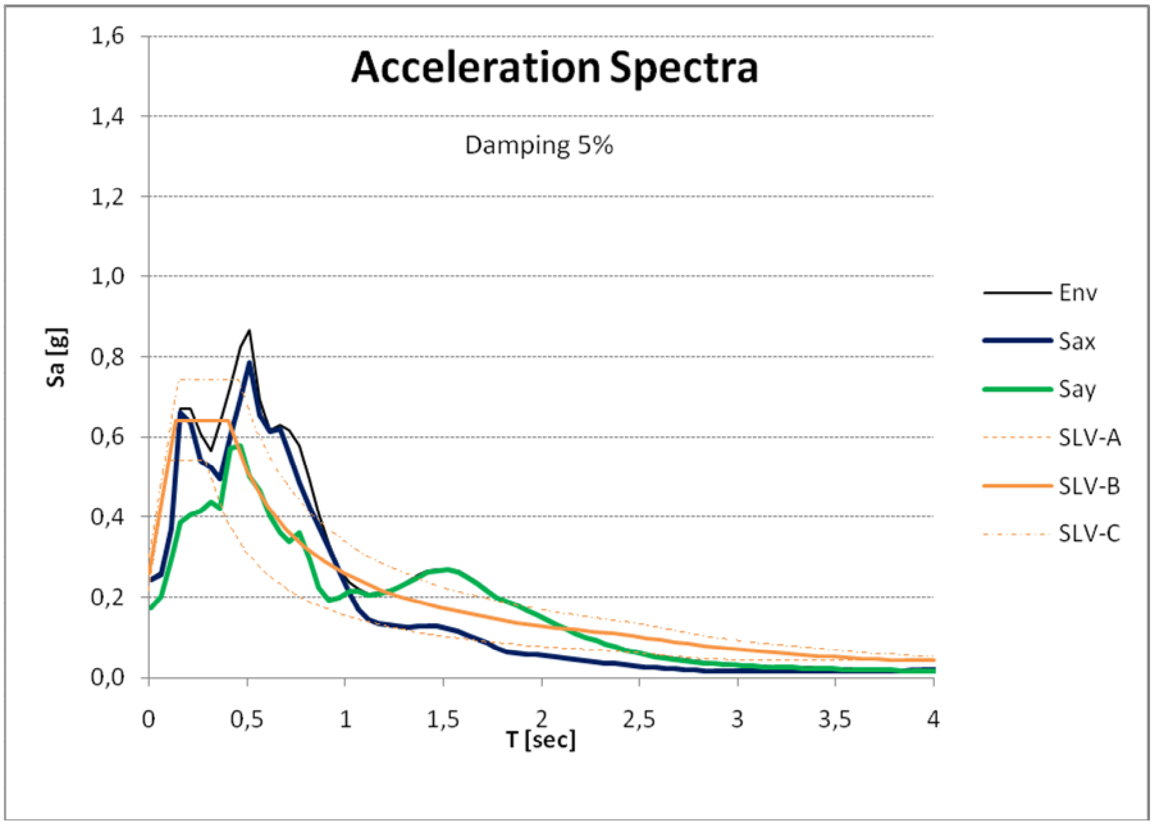
29th May event – station MRN – Earthquake Spectra Resp. vs. NTC2008 Elastic Spectra for Ordinary Const.



29th May event – station MRN – Earthquake Spectra Resp. vs. NTC2008 Elastic Spectra for Strategic Const.

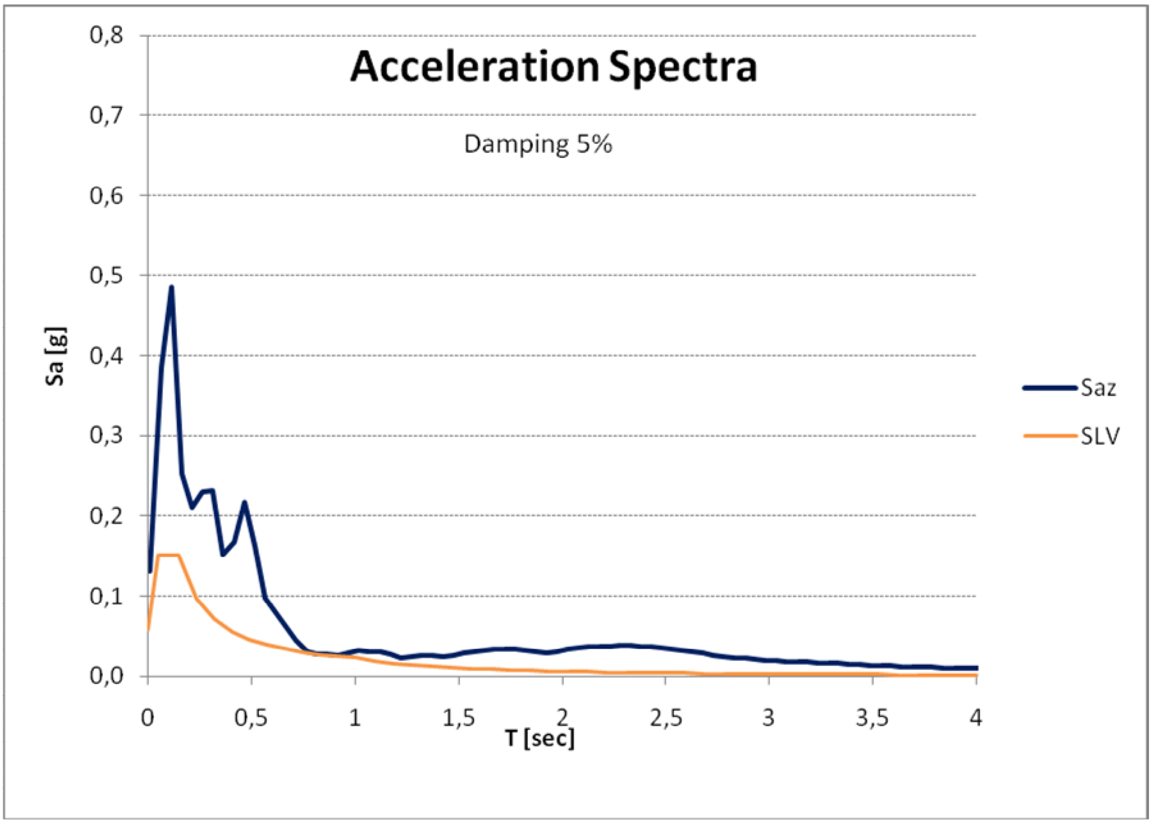


29th May event –station MOG0 –Earthquake Spectra Resp. vs. NTC2008 Elastic Spectra for Ordinary Cons.

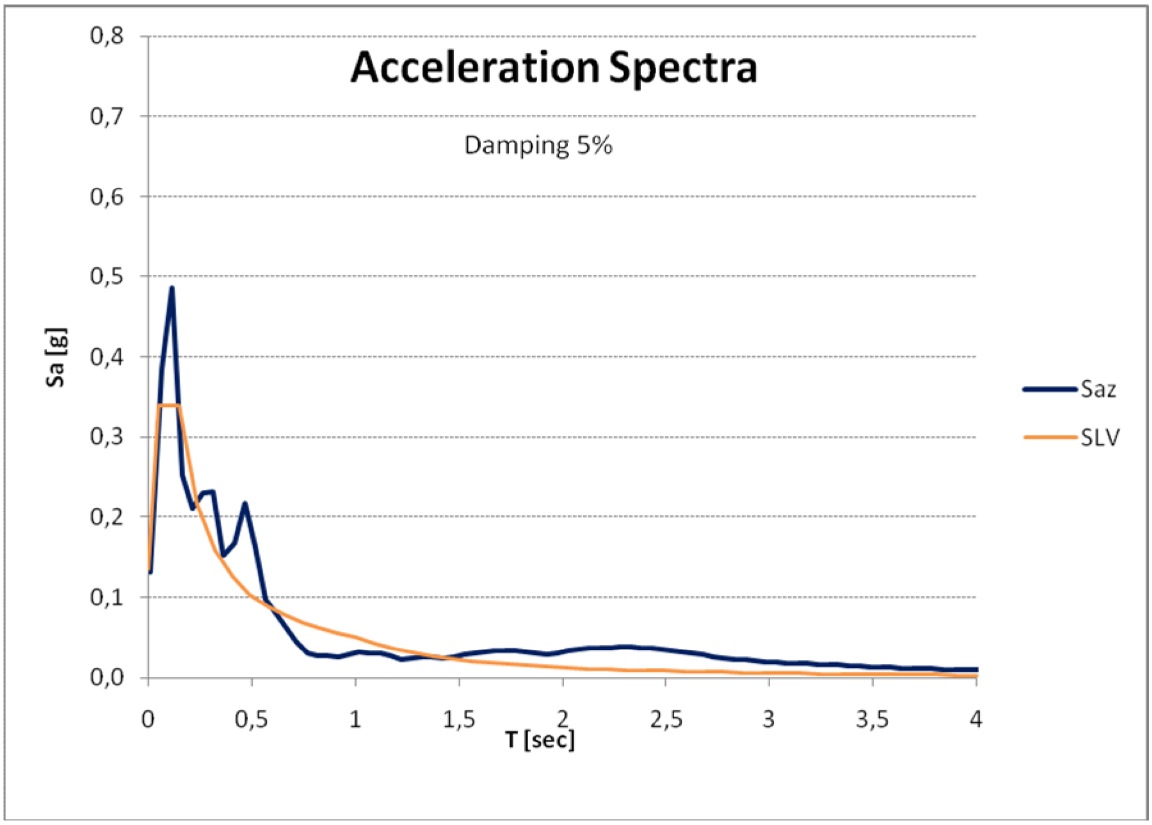


29th May event –station MOG0 –Earthquake Spectra Resp. vs. NTC2008 Elastic Spectra for Strategic Const.

Please cite as: "L. Petti, A. Lodato (2012), *Preliminary spatial analysis and comparison between response spectra evaluated for Emilia Romagna earthquakes and elastic demand spectra according to the new seismic Italian Code*, available at http://www.reluis.it"



29th May event –station MOG0 –Earthquake Spectra Resp. vs. NTC2008 Elastic Spectra for Ordinary Cons.



29th May event –station MOG0 –Earthquake Spectra Resp. vs. NTC2008 Elastic Spectra for Strategic Const.

The analysis of the results leads to the following main considerations:

- The horizontal and vertical seismic demands evaluated by means of pseudo-acceleration spectral response are particularly severe for the MRN and MOG0 sites;
- The horizontal seismic demands for MRN site are notable higher than the ones considered by the NTC 2008 for the Life Safety (SLV) performance target over the whole range of considered periods for ordinary constructions;
- In a wide range of periods the considered control damage target is greatly exceeded for the strategic constructions as well;
- In the short range periods the vertical components for MRN site attain values notable higher than the ones considered by the NTC.

Moreover, analyses show that the vertical spectral demand, although not generally considered in the design, played an important role for this event having, in some cases, recorded vertical accelerations much higher than the horizontal ones.

References

(1) ITACA, Italian Accelerometric Archive (http://itaca.mi.ingv.it/ItacaNet)

(2) RAN – National Accelerometric Network – DPC Dipartimento di Protezione Civile (http://www.protezionecivile.it)

(3) NTC2008, *Norme tecniche per le costruzioni*, D.M. 14 Gennaio 2008

(4) E. Chioccarelli, F. De Luca, I. Iervolino (2012), *Preliminary study of Emilia (May 20th 2012) Earthquake Ground Motion Records V2.1*

(5) L. Petti, I. Marino, *The polar spectrum: a new spatial representation of seismic demand*, 14 ECEE European Conference on Earthquake Engineering, Horid 2010