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Influence of the focal mechanism on the ground motion characteristics

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Abstract **– Synthetic ground motion parameters are usually adopted for the characterization of seismic signals, because of their effectiveness in synthesize the main information about amplitude, frequency and duration of earthquakes. The influence of focal mechanism on ground motion parameters and the differences or similarities for areas characterized by different prevalent faults will be discussed in this paper. The main aim of the study is to clarify the possibility of utilization of spectrum compatible accelerograms independently by their fault typology, to derive a set of design accelerograms for advanced structural and geotechnical analyses in given areas. Particularly, it will be demonstrate that care should be taken, because neglecting the source mechanism might lead to the loss of important information (i.e. duration and frequency content) about ground motion nature itself.**

I. INTRODUCTION

Ground motion synthetic parameters having a direct engineering significance are commonly derived from collection and analysis of recorded data that are, nowadays, widely available on websites. The number of these websites is increasing, providing an increasing number of information about seismic events all over the world, so that a wide number of recorded earthquakes with different tectonic origin and spatial distribution can be collected. In this research, in order to automatically analyze them, a MATLAB code has been created to calculate synthetic parameters and study their dependence by source mechanism.

In other words, one of the questions in the background of this work is: is it possible to study the seismicity of a given area using events recorded in other parts of the world maybe characterized by other source characteristics? The problem is particularly relevant in areas such as the center-south Italy, where the normal faults are predominant. There, due to the lack of strong motion records caused by normal faults, registrations from other earthquake source motion are usually employed for advanced analyses.

This document will deal with the following topics: selection criteria for the strong motion record database definition, synthetic parameters used for the analyses, regression analyses and results.

II. STRONG MOTION RECORD DATABASE

For the analyses, a strong motion record database has been created. It contains seismic events recorded in areas such as Europe, America and Japan, collected using the following websites: ITACA (Italian Accelerometric Archive), ESD (European Strong-Motion Database), CESMD (Center for Engineering Strong Motion Data), PEER (Pacific Earthquake Engineering Research Center), USGS (United States Geological Survey Earthquake Hazards Program), NSMP (National Strong-Motion Project Earthquake Data Sets), KIK-NET and K-NET (Strong-Motion Seismograph Network).

The two horizontal components of the recorded accelerograms are selected, diving them for geographical area and focal mechanism. Only acceleration records on bedrock and lowland sites (not ridges or steep slope) have been considered.

The database is composed of 1437 acceleration time histories divided as shown in Fig. 1.

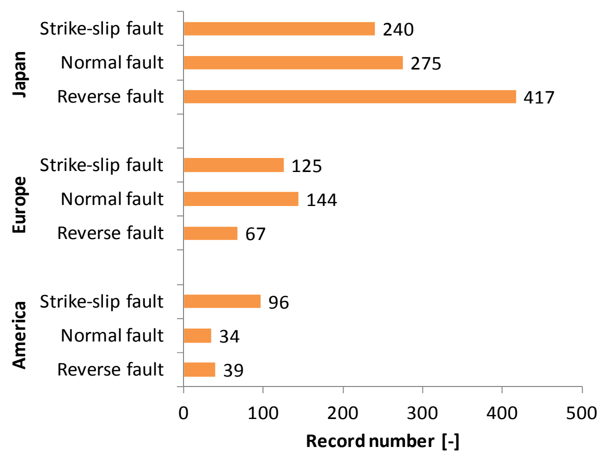

Fig. 1. Number of records divided for geographical area and focal mechanism.

These selected records are characterized by values of Peak Ground Acceleration (PGA), Magnitude (M), Epicentral distance (R) ranging between maximum and minimum value summerized in Table 1.

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Table 1. Threshold values.

	PGA (g)	M (-)	R (km)
Max	0.664	7.9	200.0
Min	0.001	5.0	3.1

Table 2. Values range of parameters.

	PGV (m/s)	Ia (m/s)	Ts (s)	Tm (s)
Max	0.6127	2.31	172.7	2.8
Min	0.0003	0.00001	1.4	0.07

III. SYNTHETIC PARAMETERS

Synthetic ground motion parameters reflect characteristics of ground motion of engineering significance: amplitude, frequency content and duration. For this study, with regard at all these three main factors, the selected ones are: PGA, Peak Ground Velocity (PGV), Arias Intensity (Ia), mean period (Tm) and significant duration (Ts). These parameters have been computed starting with the acceleration time histories of the events, thanks to the MATLAB routine developed for the specific purpose. In the following, the ground motion parameters are provided.

$$PGA = max\left|a\left(t\right)\right| \quad (1)$$

$$PGV = max\left|v\left(t\right)\right| \quad (2)$$

$$I_a = \frac{\pi}{2g}\int_0^{\infty}[\,a\left(t\right)]^2\,dt \quad (3)$$

$$T_m = \frac{\sum A^2 / f}{\sum A^2} \quad (4)$$

a(t) in equations (1) and (3) and v(t) in equation (2) are the acceleration and velocity time history respectively, for detailed information refer to [1]; A and f in equation (4) are the amplitude and frequency of the Fourier Spectra, according to [2].

Furthermore, the significant duration, which represents the interval of time between the 5% and 95% of the total Arias Intensity [3].

The choice of these synthetic parameters, instead of others, is related to these main reasons: PGA and PGV are useful parameters for the characterization of ground motion amplitude, moreover, since the velocity is less sensitive to the higher-frequency content of ground motion, PGV defines amplitude more accurately than PGA at intermediate frequencies; Tm is the best simplified frequency content characterization parameter; Ts is the best measure of duration, considering the continuous interval of time in which the earthquake can be significant from an energetic point of view; and, Ia gives information about the energy release of an earthquake and includes characteristics of amplitude, frequency and duration.

Appling these formulations on the database of 1437 records, parameters assume values within the range reported in Table 2.

IV. ANALYSES

Synthetic ground motion parameters have been analyzed using a multiple linear regression to fit data for each fault type and location. The multiple linear regression has been developed applying the MATLAB statistic toolbox. Linear regression is one of the fundamental models in statistics used to determine the relationship between dependent and independent variables. In particular, the multiple linear regression model is:

$$Y = X\beta + \varepsilon \quad (5)$$

where Y is an N x 1 vector of values of the response (dependent) variable, X is an N x p full-column rank matrix of known predictors, β is a px1 vector of unknown coefficients to be estimated, and ε is an N x 1 vector of independent random variables each with zero mean and unknown variance σ^2 [4].

The expression in MATLAB code to obtain coefficients is the (6):

$$\beta = regress\,(y, x) \quad (6)$$

which returns a p-by-1 vector b of coefficient estimates for a multilinear regression of the responses in y on the predictors in x. x is an n-by-p matrix of p predictors at each of n observations and y is an n-by-1 vector of observed responses.

The function used to evaluate the dependent variable is the (7):

$$y = exp[\,\beta_1 + \beta_2 log(x)] \quad (7)$$

The aim of the analyses is to make a comparison between multiple linear regression curves obtained for chosen parameters in different cases of faults and countries, searching for similarities and differences to validate the main idea of this study.

Figures from 2 to 16 show multiple linear regression curves obtained fitting American, European and Japanese synthetic parameters values, which are also shown in the graphs through various markers, using the epicentral distance as independent variable. Looking at the figures, differences for the same country can be observed between normal, reverse and strike-slip fault. This statement demonstrates that the focal mechanism influences synthetic ground motion parameters and consequently the characteristics of amplitude, frequency and duration of earthquakes. About data dispersion, sometimes parameters show a considerable scatter resulting from their own nature, in other cases it depends on the lack of data in the whole range of distances, which contributes to the presence of singular values. The standard deviation statistical indicators on the graphs, σ, quantify the amount of dispersion of the dataset values, assuming zero when data points are close to the mean of the set, and high value if are spread out over a wider range of values. Figures from 17 to 21 make a comparison between curves obtained for different focal mechanism and different geographic areas. In this case too, differences in the attenuation relationships for all parameters considered in the analyses are clear. It means that earthquake recorded in different parts of the world have characteristics of amplitude, frequency and duration dissimilar from each other. However, in many cases it is still very difficult to perform seismic assessment at a site by records of the same area, so accelerograms from other locations have to be considered.

These findings lead to pay attention in the choice of records for structural and geotechnical purposes.

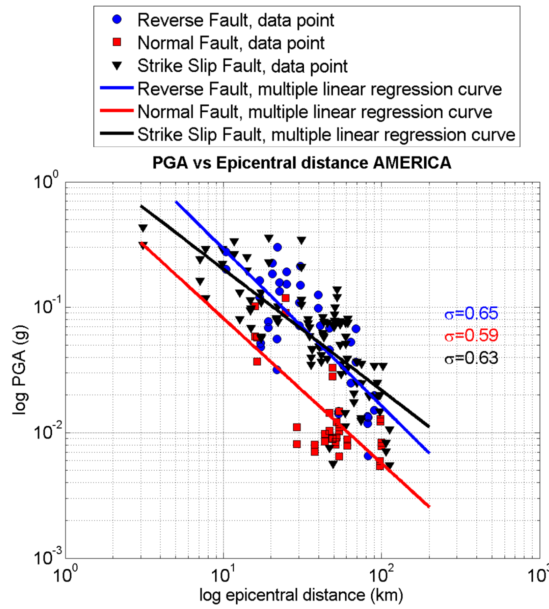

Fig. 2. PGA vs Epicentral distance for American data.

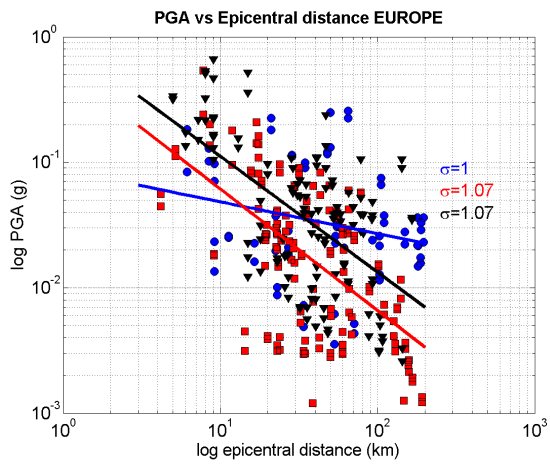

Fig. 3. PGA vs Epicentral distance for European data.

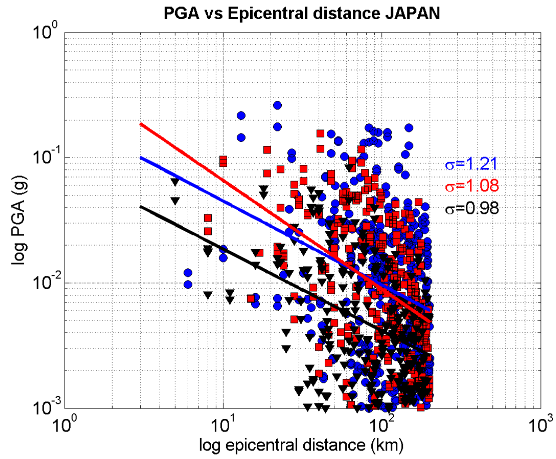

Fig. 4. PGA vs Epicentral distance for Japanese data.

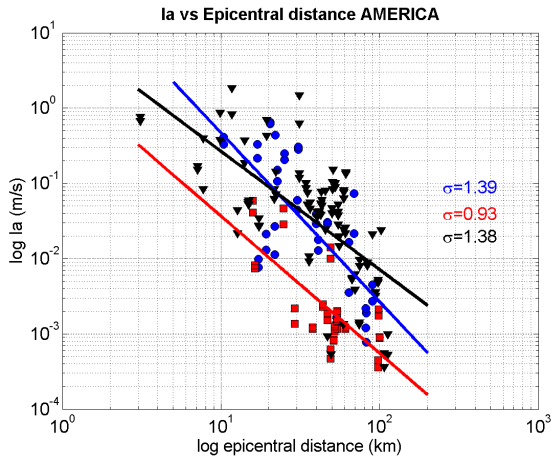

Fig. 5. Ia vs Epicentral distance for American data.

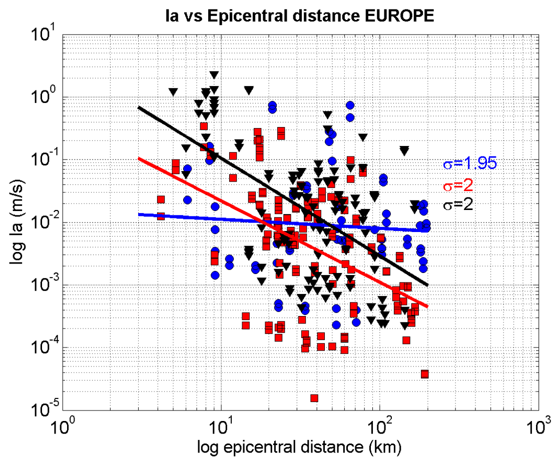

Fig. 6. Ia vs Epicentral distance for European data.

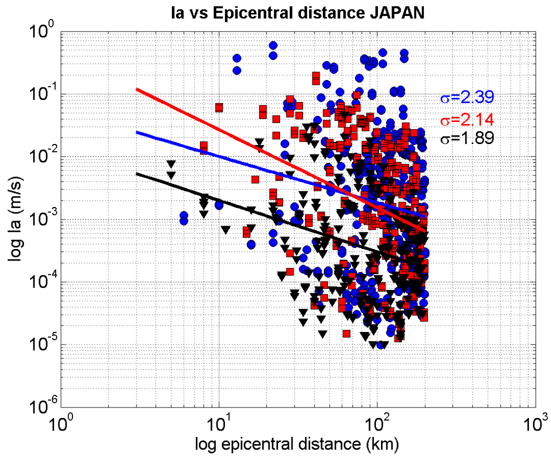

Fig. 7. Ia vs Epicentral distance for Japanese data.

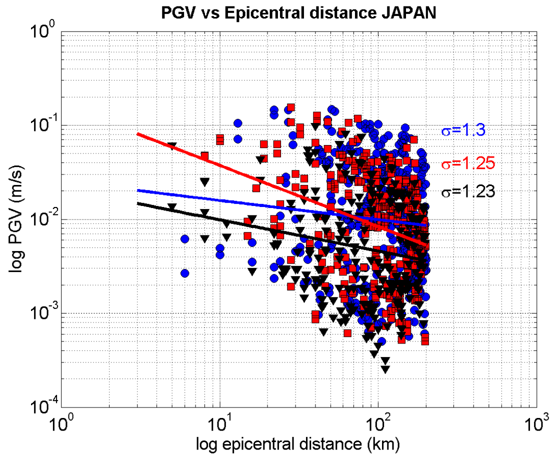

Fig. 10. PGV vs Epicentral distance for Japanese data.

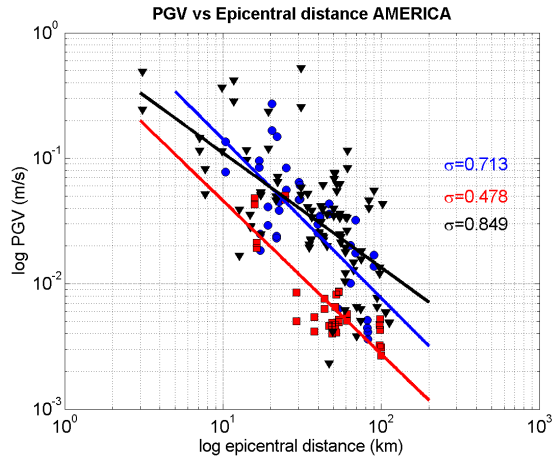

Fig. 8. PGV vs Epicentral distance for American data.

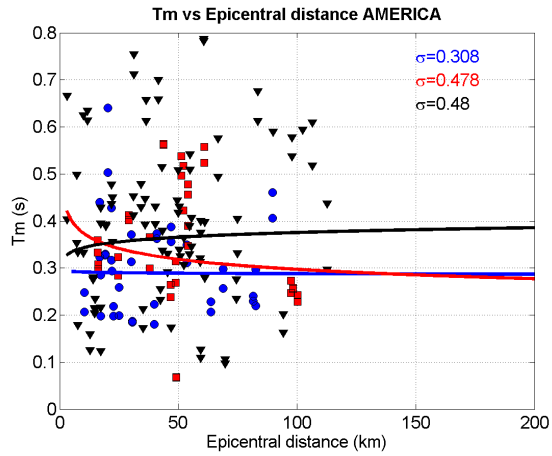

Fig. 11. Tm vs Epicentral distance for American data.

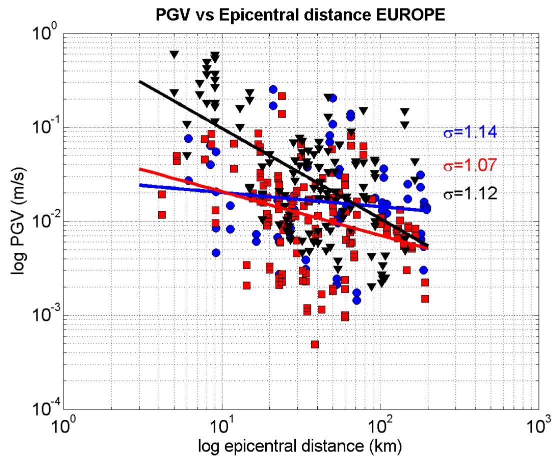

Fig. 9. PGV vs Epicentral distance for European data.

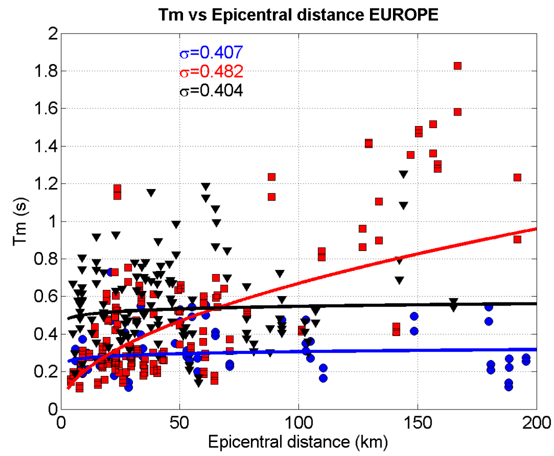

Fig. 12. Tm vs Epicentral distance for European data.

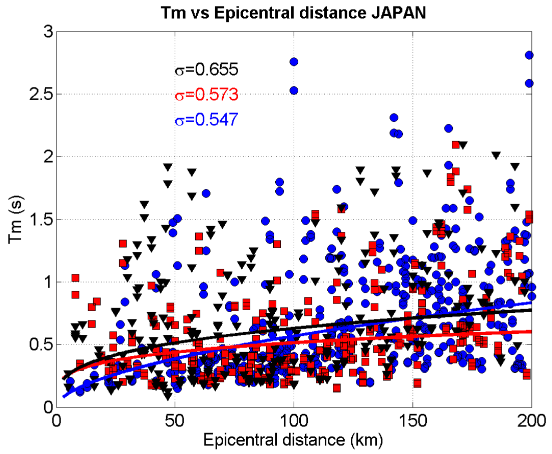

Fig. 13. Tm vs Epicentral distance for Japanese data.

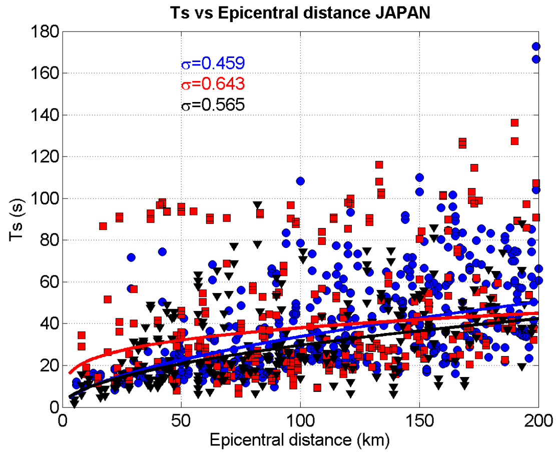

Fig. 16. Ts vs Epicentral distance for Japanese data.

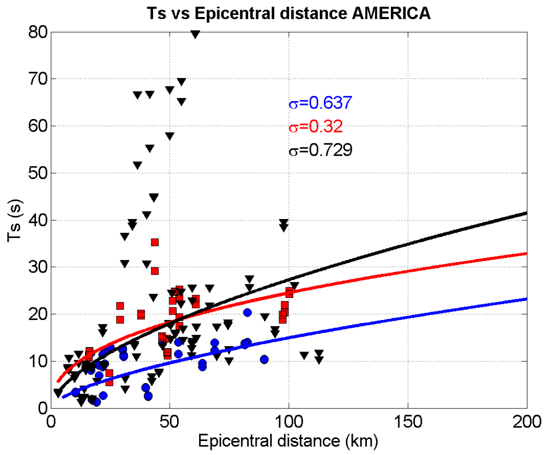

Fig. 14. Ts vs Epicentral distance for American data.

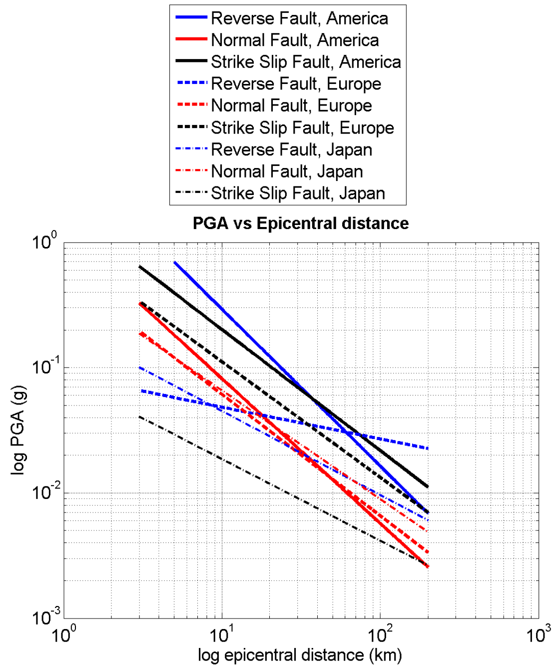

Fig. 17. Curves comparison in terms of PGA.

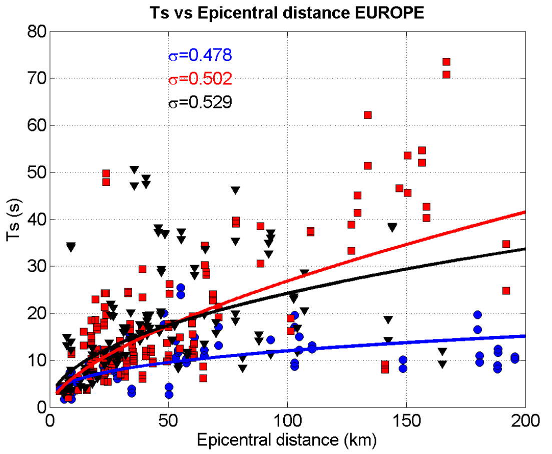

Fig. 15. Ts vs Epicentral distance for European data.

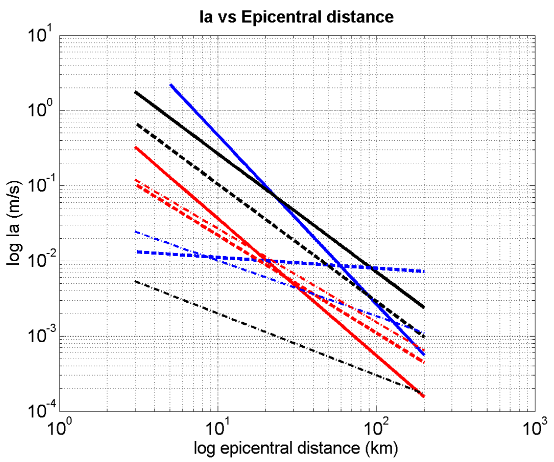

Fig. 18. Curves comparison in terms of Ia.

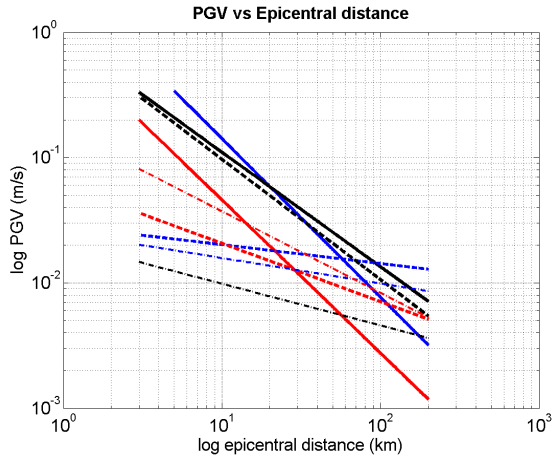

Fig. 19. Curves comparison in terms of PGV.

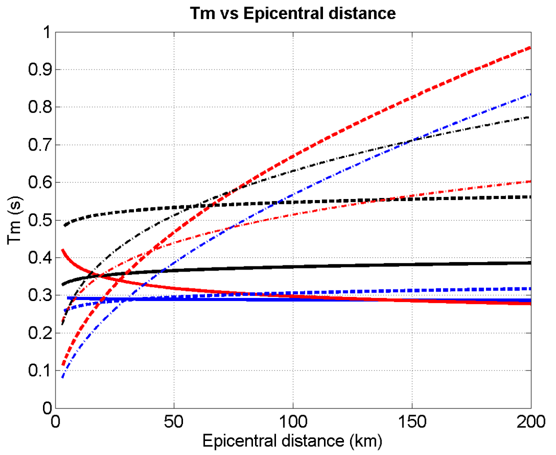

Fig. 20. Curves comparison in terms of Tm.

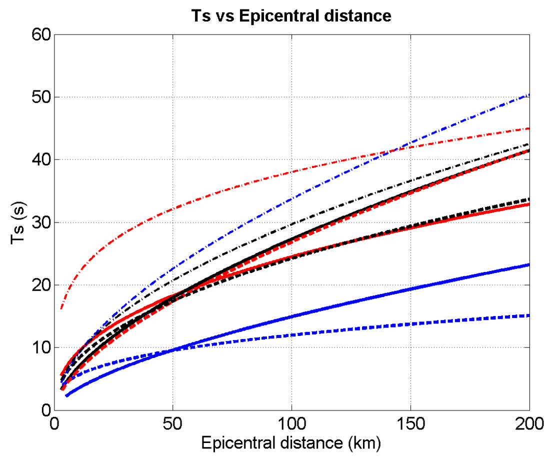

Fig. 21. Curves comparison in terms of Ts.

V. DISCUSSION AND CONCLUSIONS

In seismic design codes, guidance are usually given on how to select appropriate real records on the base of the compatibility with the response spectrum rather than following other synthetic parameters [5]. Therefore, records are selected on the basis of strong-motion parameters to match a design response spectrum. Real strong ground motion accelerograms contain a wealth of information about the nature of the ground shaking and reflect the characteristics of source, path, and site. Earthquake-resistant design and seismic analysis often require the action to be represented in the form of acceleration time histories, since accessible waveform databases are available, a limited number of criteria have to be considered in selection, and simple procedures have been developed to link the real ground motion to the earthquake scenario (e.g. linear amplitude scaling). The search of a set of spectrum compatible accelerograms for a given area usually takes into account the same PGA, magnitude and epicentral distance expected to give the major contribute to the seismicity of the site, other than the same site condition (site class and topographic factors), but it not refers to focal mechanism requirements too. The accelerograms selected without considering focal mechanism could contribute to make the average spectrum compatible with the elastic spectrum of the given seismogenic zone, but they are not really representative of the seismicity of the site. This way, it loses some important information about seismic signals, which is to say frequency content and duration.

This problem is firstly related to the lack of acceleration records which satisfy all the conditions mentioned before, secondly to the improper use of real record selection codes for seismic analysis, in which the choice of focal mechanism is not even implemented [6].

Considerations resulting in this work do not take into account the variability of site class and topographic condition, another main factor to be studied in detail.

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