Earthquake Engineering, Tenth World Conference © 1992 Balkema, Rotterdam. ISBN 90 5410 060 5

Expected ground motion evaluation for Italian sites

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ABSTRACT: The Italian accelerometric data base with M and distance determined by Ambraseys and Bommer (1991 b) were employed to predict Pga and Response Spectra. A two step regression analysis was performed. The obtained law is: $\ln Pga = 4.73 + 0.52M - \ln R - 0.002R$ $s=0.67$
M is the local Magnidute and $R=(d^2+h^2)^{1/2}$, d is the closest distance to the fault and h the hypocentral depth. The results are in good agreement with other investigations. As far as predicted Response Spectra are concerned the standard deviation increases according to T_0 from 0.69 at $T_0=0.04$ sec. to 0.9 at $T_0=3.0$ sec. The prediction of Response Spectra is reliable up to $T_0=2.0$ sec., for higher periods the accelerograms correction procedure strongly undermines the reliability of predicted values.

1 INTRODUCTION

Empirical attenuation laws of ground shaking are a fundamental tool in seismic hazard assessment. The dramatic increment of strong motion data available produced a lot of attenuation laws.

Three main aspects are concerned: the empirical relation to adopt, the parameters to predict, the identification of independent random variables.

The procedure is based on a statistical approach, generally the predicted strong motion is obtained by regression analysis of three random data considered independent (the strong motion data concerned, Magnitude and site to source distance).

More physical approaches which include statical and dynamical properties of the source have been attempted, but the lack of data undermines the statistical approach.

The predicted strong motion parameters, usually Pga and Pgv, are found lognormally distributed, regardless the Magnitude and the source to site distance used.

The adoption of the site condition as an additional independent data in the regression is rather controversial: all the authors agree about the strong influence of soil condition on the ground shaking; the difficulties arise in the assessing the reliability of soil condition coefficients of the strong motion data bases.

In the present work the Italian strong motion data were taken into account and the predicted parameters also include the response spectra, due to their importance for engineering application.

The relationship adopted, originally suggested by Joyner and Boore 1981, is:

$$\ln Pga = b_1 + b_2 M + b_3 R - \ln R \qquad (1)$$

Local magnitude M_l was adopted since our data range between 4 and 6.6.

The distance adopted is $R=(d^2+h^2)^{1/2}$, where d is the shortest distance from the station to the surface projection of the fault rupture (for M < 5.7 d is taken equal to the epicentral distance) and h is the mean focal depth of the group into which each earthquake is classified.

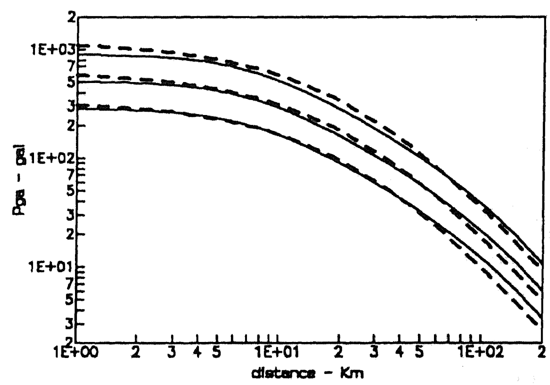

Figure 1. Results obtained by Joyner and Boore (1981) (continuous line) and appliyng Campbell formula (1981) (dashed line), with c constant, to the same data base.
M=5.5, 6.5, 7.5.

The distance d, adopted by several authors (e.g. Joyner and Boore 1981, Ambraseys and Bommer 1991 a, Sabetta and Pugliese 1987) avoids the distance overestimation for large earthquakes caused by the epicentral distance.

A comparison with other attenuation laws shows the relative scarse influence of the formula adopted (fig.1), while main problems arise from the reliability of available strong motion data bases, data qualification and kind of M and distance adopted. In addition, given that the most part of strong motion data are recorded by SMA-1 accelerographs (this is the case for the Italian data), the correction procedures plays a relevant role expecially for Pgv and response spectra (fig. 2).

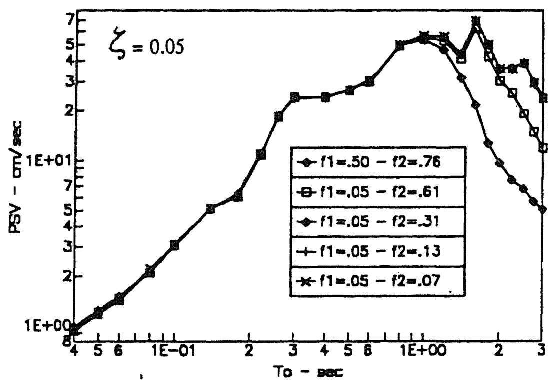

Figure 2. Pseudo Velocity Response Spectrum of 23/11/1980 Southern Italy earthquake, recorded at Calitri (NS component). f_1 and f_2 are the roll-on and cut-on frequencies of Orsmby filter.

2 DATA

137 accelerograms recordings of the Enea Enel accelerometric data base (Commissione Enea Enel 1981,1984) were selected, 125 were automatically digitized using high resolution (400 sps) optical scanner (Basili 1987) and the restant manually digitized.

For these latter a linear interpolation routine was applied to achieve a constant time interval sampling.

In the present work the following selection criteria were applied: recordings not complete (e.g. started during the strong motion phase) were disregarded, only recordings in free field condition were taken into account, exclusion of recordings of stations the epicentral distance is greater than that of the first operational station not triggered, only $M_l \geqslant 4$ earthquakes were considered.

The obtained data refer to 40 earthquakes recorded in Italy, the M_l and R distances taken from Ambraseys and Bommer (1991 b), range respectively 4-6.6 and 3.2-170 Km. Fig. 3 shows the distribution of recordings with respect to Magnitude and distance.

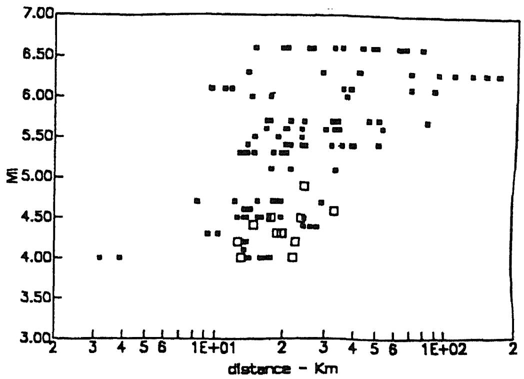

Figure 3. Magnitude and distance scattergram. Open squares refer to earthquakes recorded only in one station.

Caltech correction procedure was adopted (Trifunac 1971; Trifunac and Lee 1973); roll-on and cut-on frequencies of Orsmby filter were selected by adopting a record dependent criteria (Basili and Brady 1978).

In particular the selected cut-on frequencies range between 0.13 Hz and 1.18 Hz with a median of 0.38 Hz.

3 PROCEDURE

Following Joyner and Boore (1981), a two step procedure to regress the (1) has been adopted to allow the decoupling of the determination of magnitude dependence from the determination of distance dependence.

In a first step the following formula was applied:

$$Ln(Pga \cdot R) = \sum_{j=1}^{N} E_j A_j + b_3 R \qquad (2)$$

where:

N is the umber of earthquakes
$E_j=1$ for earthquake j
$E_j=0$ otherwise

The obtained A_i were used in the second regression:

$$A = b_1 + b_2 M \qquad (3)$$

$$s^2 = s_1{}^2 + s_2{}^2$$

s is the standard deviation of the predicted strong motion parameter and s_1 and s_2 are the standard deviation of first step and second step.

In order to obtain better estimates of the parameters, earthquakes associated with only one strong-motion record in the data set were excluded from the second regression; therefore 11 recordings were barred (see fig. 3).

Results concerning the first step is shown in fig. 4, while fig. 5a shows those for the second step.

In fig. 5b it is possible to observe that the use of distance *d* causes a greater scatter of the data (the error of the coefficient b_2 of the regression is 0.16 against 0.10 for *R* distance).

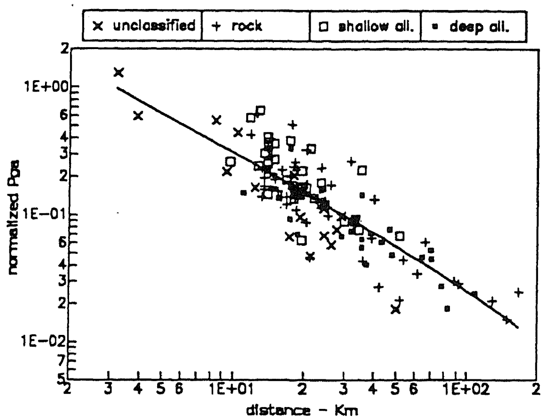

Figure 4. Results of the regression of formula (2). Different symbols according to soil classification (after Sabetta and Pugliese 1987).

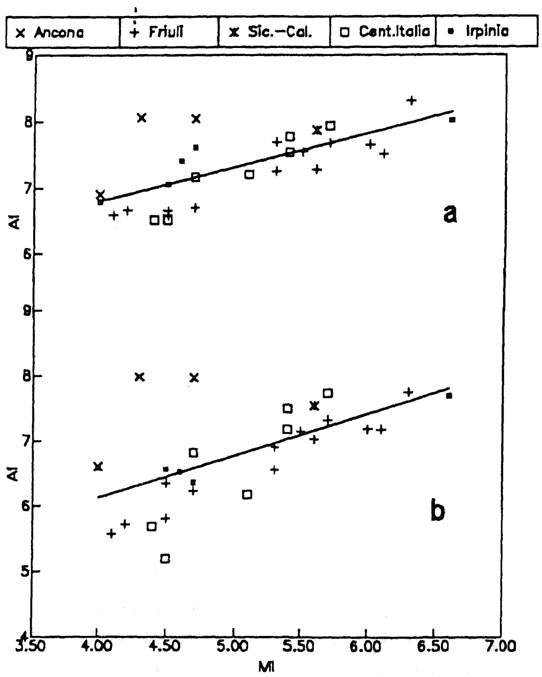

Figure 5. Results of the regression of formula (3):5a considering distance=*R*, 5b distance=*d*. Symbols refer to different seismotectonic environments.

Expected horizontal response spectra were obtained adopting the same procedure, as for horizontal Pga; spectral ordinates were regresseded indipendently.

Only the maximum of the two components was considered.

4 DISCUSSION

Table 1 reports the obtained coefficients of the regressions and fig. 6 the results in term of predicted horizontal *Pga* for 50% and 84% probability of not exceedence for selected values of magnitude and fault distances considering a hypocentral depth of 10 Km.

Table 1. Coefficients of equation 1, Pga in gal, PSV in cm/s ($\zeta = 0.05$).

Parameter	b_1	b_2	b_3	s
Pga	4.73	0.52	-0.00216	0.67
PSV at $T_0 = 0.04$ s	0.49	0.41	-0.00258	0.69
PSV at $T_0 = 0.06$ s	1.11	0.40	-0.00245	0.68
PSV at $T_0 = 0.10$ s	1.78	0.43	-0.00168	0.68
PSV at $T_0 = 0.18$ s	1.68	0.58	-0.00044	0.69
PSV at $T_0 = 0.26$ s	1.37	0.70	-0.00254	0.74
PSV at $T_0 = 0.40$ s	0.70	0.82	-0.00249	0.87
PSV at $T_0 = 0.60$ s	-0.92	1.11	-0.00449	0.78
PSV at $T_0 = 1.00$ s	-2.77	1.41	-0.00380	0.73
PSV at $T_0 = 1.40$ s	-3.54	1.51	-0.00219	0.74
PSV at $T_0 = 1.80$ s	-3.95	1.54	-0.00154	0.87
PSV at $T_0 = 2.25$ s	-4.23	1.57	-0.00305	0.92
PSV at $T_0 = 2.75$ s	-4.43	1.57	-0.00460	0.87

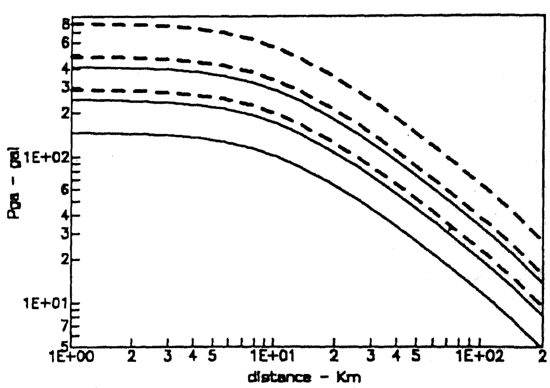

Figure 6. 50% predicted *Pga* (continuous line) and 84% predicted *Pga* (dashed line); *M*=5, 6, 7; depth=10 Km.

The predicted *Pga* do not exibit significant biases (fig. 7 and 8) but a moderate understimation for low magnitude in nearfield and for high magnitude in farfield.

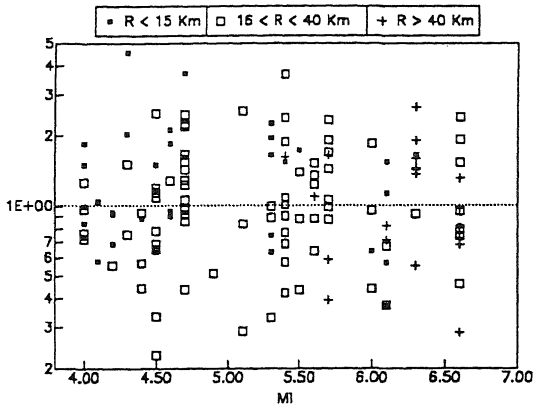

Figure 7. *Pga* observed - *Pga* predicted (50%) ratio against Magnitude.

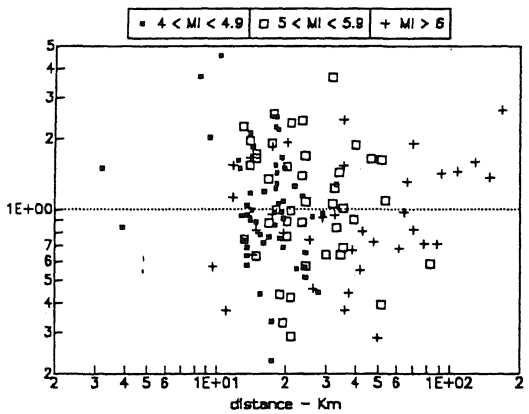

Figure 8. *Pga* observed - *Pga* predicted (50%) ratio against distance.

A comparison of the results with other investigation (fig. 9) shows a significant agreement with Ambraseys and Bommer (1991 a) who adopted the same regression formula, but $\mathcal{M}_s$ instead of $\mathcal{M}_l$ and whose data base consists by accelerograph recordings of several earthquakes occurred in the Alpide belt region.

Therefore in evaluating such a figure, it should be noted that the value of magnitude employed for prediction should be consistent with the scale adopted in deploying the attenuation law.

Fig. 10 shows the relation between $\mathcal{M}_s$ and $\mathcal{M}_l$ (of the Italian earthquakes employed in this analysis) which seems to be slightly different from the overall trend found for the Alpide belt data set.

The results obtained by Sabetta and Pugliese (1987) who perform the regression analysis on Italian data (date set very close to the one adopted in the present work) are somewhat different due to a greater bending of our curves (fig.9).

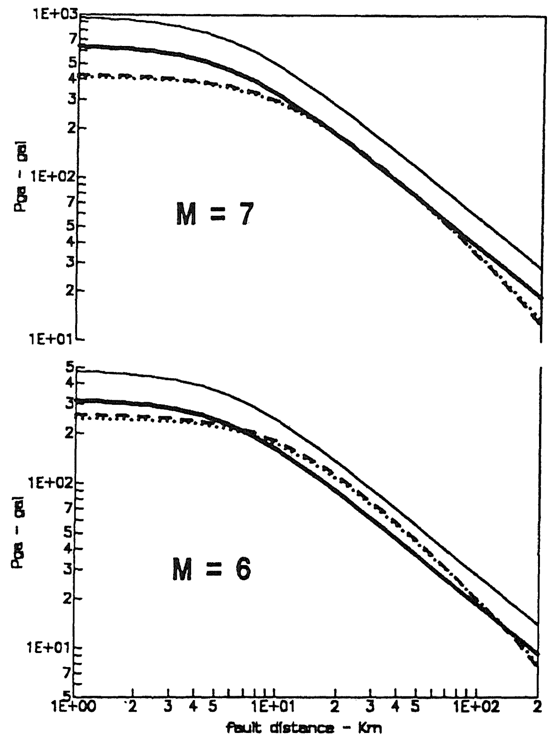

Figure 9. Results obtained by: 1. Ambraseys and Bommer (dashed line), 2. Sabetta and Pugliese - rock sites (heavy continous line), 3. Sabetta and Pugliese - soils sites (continous line), 4. this study (dotted line) distance=d for 2 and 3, for 1 and 4 a depth of 10 Km was assumed.

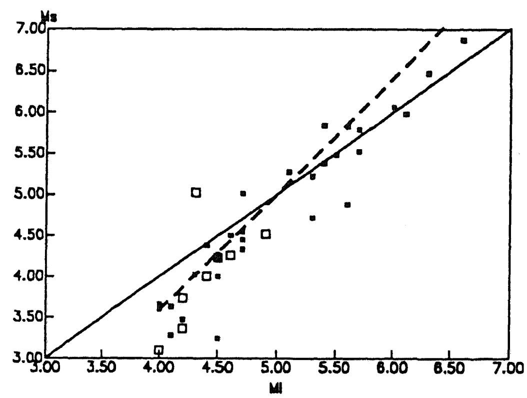

Figure 10. $\mathcal{M}_s$ vs $\mathcal{M}_l$ relative to data base adopted in this study. Dashed line represents Ambraseys and Bommer 1990 $\mathcal{M}_s$-$\mathcal{M}_l$ relationship. Open squares refer to earthquakes recorded only in one station.

Expected Pseudo Velocity Response Spectra are shown in fig. 11 and 12: their shape seems to be distance independent, at least for $\mathcal{R}$<80 km, as is better evidenced by the expected Dynamic Amplification Factor (fig. 13 and 14).

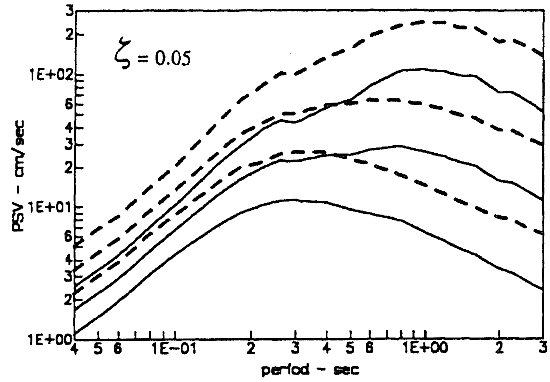

Figure 11. 50% (continous line) and 84% (dashed line) predicted Pseudo Velocity Response Spectra: fault distance=5 Km (depth=10 Km); $\mathcal{M}$=5,6,7.

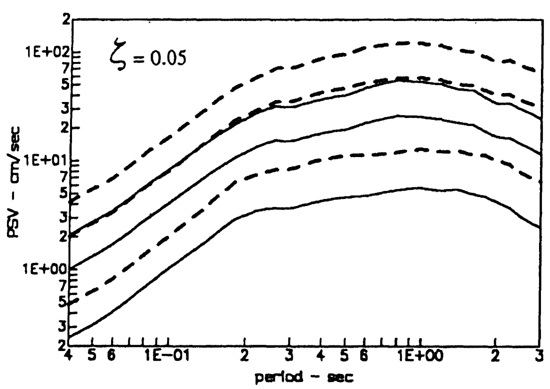

Figure 12. 50% (continous line) and 84% (dashed line) predicted Pseudo Velocity Response Spectra: $\mathcal{M}$=6.5, fault distance=5,20,80 Km (constant depth=10 Km).

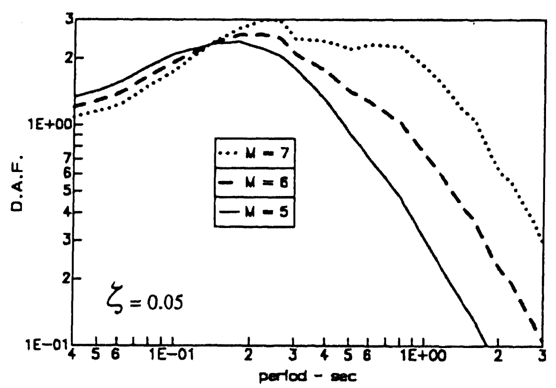

Figure 13. DAF of 50% predicted Response Spectra, fault distance=5 Km (10 Km depth) for different Magnitudes.

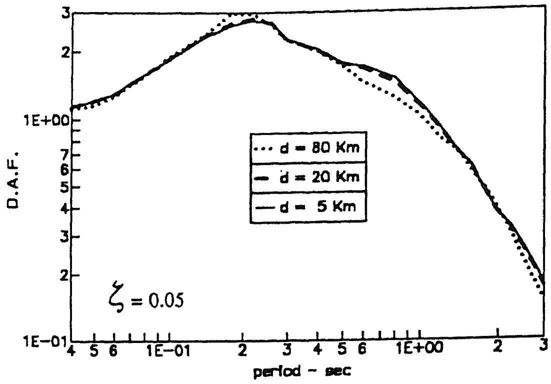

Figure 14. DAF of 50% predicted Response Spectra, $\mathcal{M}$=6.5, for different fault distances (depth=10 Km).

Mean predicted values and moreover the standard deviation have to be considered very carefully. In particular the correction procedure (fig. 3) affects significantly the results for $\mathcal{T}_0 > 2$ sec. This limit does not depend on the correction methodology itself: signal to noise ratio, duration of the signal and frequency content, that are different from record to record, introduce both dishomogeneity and errors due to subjectivity of the choice of low frequencies filter limits. That is to say usual statistical predictive models fail in high periods.

5 CONCLUSIONS

It is possible to summarize the results in the following way.

- The $\mathcal{P}ga$ predicted in this work is not significantly different respect to other authors. For practical application a multiplication by a factor of two of the 50% $\mathcal{P}ga$ can be considered as an upper limit of the 84% $\mathcal{P}ga$, according also to results obtained by other investigators.
- The attenuation formula adopted is not decisive, anyway two steps approach seems preferable.
- The qualification of the data set is the most crucial point.

As far as the prediction of the Response Spectra is concerned, the correction procedure expecially for low level strong-motion, can play a primary role.

In particular it seems very cumbersome to do prediction for $\mathcal{T}o > 2.0$ sec. (as far as Italian data are concerned).

Finally a critical aspect is the instability of the obtained laws for nearfield and farfield due to the lack of data.

AKNOWLEDGEMENTS

We tank L. Faravelli for the comments on the adopted statistical approach, R. Daminelli for the preparation of manuscript.

The research was carried out under CNR-GNDT grant.

REFERENCES

Ambraseys, N.N. & J.J. Bommer 1990. Uniform magnitude re-evaluation for the strong-motion database of Europe and adjacent areas. *Int. J. of Earthquake Engineering and Engineering Seismology* 2: 3-16.

Ambraseys, N.N. & J.J. Bommer 1991 a. The attenuation of ground accelerations in Europe. *Earthquake Engineering & Structural Dynamics* 20.

Ambraseys, N.N. & J.J. Bommer 1991 b. Database of European strong-motion records. *Int. J. of Earthquake Engineering and Engineering Seismology* V,2: 18-37.

Basili, M. 1987. Data acquisition and processing in strong Ground Motion Seismology. In M.O. Erdik & M.N. Toksoz (eds.), *NATO Advanced Study Institute on Strong Ground Motion Seismology:* 251-331. Dordrecht, The Netherlands: D. Reidel Publishing Company.

Basili, M. & G. Brady 1978. Low frequency filtering and the selection of limits for accelerogram corrections. *Proc. 6th European Conference on Seismic Engineering, Dubrovnic, Jugoslvia* I: 251-258.

Campbell, K.W. 1981. Near-source attenuation of peack horizontal acceleration. *Bullettin of the Seismological Society of America* 71: 2039-2070.

Commissione ENEA-ENEL per lo studio dei problemi sismici connessi con la realizzazione di impianti nucleari 1981. Contributo alla caratterizzazione della sismicità del territorio italiano. *Convegno annuale del Progetto Finalizzato Geodinamica, Udine, Italy.*

Commissione ENEA-ENEL per lo studio dei problemi sismici connessi con la realizzazione di impianti nucleari 1984. Prime registrazioni attuate dalle stazioni accelerometriche installate da ENEA ed ENEL in occasione del terremoto dell'Umbria del 29/4/84 e del terremoto d'Abruzzo del 7/5/84. *Commissione ENEA-ENEL, Technical Report, Rome, Italy.*

Joyner, W.B. & D.M. Boore 1981. Peak horizontal acceleration and velocity from strong-motion records from the 1979 Imperial Valley, California, earthquake. *Bullettin of Seismological Society of America* 71, 4: 2011-2038.

Sabetta, F. & A. Pugliese 1987. Attenuation of peak horizontal acceleration and velocity from Italian strong-motion records. *Bullettin of the Seismological Society of America* 77, 5: 1491-1513.

Trifunac, M.D. 1971. Zero base-line correction of strong-motion accelerograms. *Bullettin of the Seismological Society of America* 61: 1201-1211.

Trifunac M.D. & V. Lee 1973. *Routine Computer Processing of Strong Motion Accelerograms.* Earthquake Engineering Lab., Cal. Inst. of Technology, Pasadena, California.