Empirical attenuation relationship for Arias Intensity in Mexico and their relation with the damage potential

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SUMMARY:
This paper presents empirical attenuation relationships for Arias Intensity (I_A), for interplate, intraslab and shallow crustal earthquakes with M_w>6.0, and for distances between 20 and 600 km. Empirical relationships were developed to estimate I_A as a function of magnitude, distance, fault mechanism, and site category based on 600 recorded ground motion data from 25 earthquakes in active zones in Mexico. Relationships were developed by regression analysis using a technique in two steps. We find that amplitudes of attenuation of I_A from intraslab earthquakes are lower than for interplate events, which produce I_A values about 25 percent larger than interslab events. In addition, predictive curves are estimated for PGA and PGV. In order to incorporate ground motion parameters related to earthquake damage into seismic hazard analysis, in the second part of this work, the new damage parameter ICI (*index of central intensity*) is established with basis in I_A and the mean period, T_m, this index is calibrated with acceleration records of strong earthquakes occurred in the world.

Keywords: Attenuation relationship, Arias Intensity, Damage potential index, Mexico.

1. INTRODUCTION

In seismic risk studies is essential to count on quantitative parameters for different levels of expected strong ground motions; so it is important to propose attenuation functions that allow to predict effectively the peak ground acceleration, and other important parameters such as velocity, Arias Intensity and displacement, during earthquakes.

The parameter widely used in strong ground motion studies, is the absolute peak ground acceleration (PGA). Attenuation relations have traditionally used empirical methods for the prediction of maximum acceleration. While many attenuation relationships have been proposed based on accelerographic information (Si and Midorikawa, 2000; Youngs, et al., 1997; Campbell, 1997; Boore et al.; 1997, among others), there are still many aspects to clarify and to resolve. In the case of Mexico, we can mention some problems related to the source, the wave path and local effects. In relation to the source, there is a scarcity of near field records, and it is clear that there are some particular characteristics for each earthquake, therefore the effects of the source cannot be simulated completely only with its magnitude. Secondly, in relation to the wave path, the near field distance to the source has always been a debatable topic. Finally, the criterion of assigning qualitative factors to every type of soil is not enough to simulate the local effects of the soils.

Arias Intensity is an important ground motion parameter that contains the destructiveness potential of an earthquake, because it is able to simultaneously reflect multiple characteristics of the motion in question. Correlation between I_A and ductility demands of single degree of freedom system was established for earthquakes occurred in Mexico City (Gómez-Bernal *et al*, 1991); an important conclusion was that the values of I_A in stations located in the very compressible soil of Mexico City underestimate the damage, in comparison with all other types of soil. In recent years, the effectiveness of I_A as a predictor of the likelihood of damage to short-period structures has been demonstrated, I_A

has been applied in both geotechnical and structural problems. Besides, I_A has been considered as a ground-motion measure suitable for use in probabilistic seismic hazard analysis and earthquake loss estimation. Results obtained in this research show good correlation for firm and rock soils, while the damage potential was underestimated for soft soils.

2. REGRESSION MODEL

Attenuation relations for Arias intensity were assessed from regression analysis using selected data. The results are compared with other intensity parameter (accelerations, velocities, and displacements). This information corresponds to earthquakes with enough stations distributed along a path of several hundred of kilometers from the source, 23 events and their data were used. These events are shown in Table 1, which specifies the number of stations used for this study, we did not consider data from stations in Lakebed zone of Mexico City, as well as those located on very compressible soil, like the one in Chilpancingo city; i.e., this study only considers stations located on rock and firm soil.

The regression model used is based on the fault distance, and is given by:

$$\log A = b - \log (DX + c) - k\,DX \tag{2.1}$$

where, A is the parameter of interest (I_A, PGA, or PGV), DX is the distance from the fault, in km. The coefficient b is a factor of counterweight for each earthquake. While, the second and third term consider respectively, the geometric attenuation, and the attenuation for damping. The k coefficient was assigned different for each parameter (0.0015 for I_A, and PGA, and 0.0003 for PGV). On the other hand, the coefficient c takes into account the saturation of the amplitude due to proximity to the source and considers an effective distance which increases with the magnitude, and it is proposed as:

$$c = 0.0055\ 10^{0.525Mw} \tag{2.2}$$

In the development of attenuation functions, we followed a two stages method, according to Si and Midorikawa (2000). First, we applied to each of the 17 events a regression analysis using equations (2.1) and (2.2), in order to define the value of coefficient b. Later, with the moment magnitude, M_w, with the type of failure, and with the focal depth, we defined the coefficient b in a second regression, using the following equation:

$$b = a\,Mw + d\,H + e_1 S_1 + e_2 S_2 + e_3 S_3 + f + \varepsilon \tag{2.3}$$

where H is the focal depth in km, S_i is the type of failure, ε the standard deviation, a, d, e_1, e_2, e_3, and f are regression coefficients, S_i is a factor that is set to 1 for each type of failure and 0 for all others.

In the analysis conducted in the first phase we found that the original model is applicable for the prediction of acceleration and Arias intensity; while it is necessary to adjust the value of k, because we also examined the influence of the coefficients in the regression process, hence we concluded that parameter k is suitable for velocity and displacement predictions.

In the second stage of regression we considered the type of failure, therefore, attenuation functions were proposed for each type of seismogenic source. It was noted that earthquakes with intraplate origin would produce greater values of I_A, PGA and PGV for the same distance and size; if we compared them with the interplate origin events. Meanwhile, shallow earthquakes produced smaller values in all cases. We also verify directly the influence of the depth in the results of I_A and PGA, as well as the PGV parameter. We observed that when the depth is increased, the parameter values was also augmented, so that the more superficial is the earthquake the value of the parameter (I_A, PGA and PGV) will be.

3. DATABASE

In this research 17 events were used, which occurred between 1979 and 1999, all of them with one magnitude greater than 6.0. In Table 3.1 such events are listed, showing the depth, the coordinates of the epicenter, the number of stations used, and the source mechanism type of all earthquakes.

Table 3.1. Earthquakes used in the first part of this study

Event	Date	Magnitude M_W	Depth (Km)	Lat. N., Long W.	Stations	Mech. Type
1	79/03/14	7.4	26.7	17.490, -101.26	11	Interplate
2	85/09/19	8.1	21.3	18.081, -102.942	30	Interplate
3	85/09/21	7.5	20.8	18.021, -101.479	26	Interplate
4	86/04/30	6.9	20.7	18.024, -103.057	15	Interplate
5	89/04/25	7.0	15.0	16.603, -99.400	43	Interplate
6	93/05/15	6.0	38.5	16.430, -98.740	30	Interplate
7	93/09/10	7.2	29.1	14.140, -92.820	10	Interplate
8	93/10/24	6.6	21.8	16.540, -98.980	44	Interplate
9	94/12/10	6.4	54.0	18.020, -101.56	53	Intraslab
10	95/09/14	7.4	21.8	16.310, -98.880	36	Interplate
11	95/10/09	8.0	5.0	18.740, -104.67	34	Superficial
12	95/10/21	7.2	163.8	16.920, -93.620	19	Intraslab
13	96/02/25	7.1	5.0	15.830, -98.250	20	Superficial
14	96/07/15	6.8	22.4	17.450, -101.16	54	Interplate
15	97/01/11	7.2	40.0	17.910, -103.04	55	Intraslab
16	99/06/15	7.0	69.2	18.180, -97.510	67	Intraslab
17	99/09/30	7.5	46.8	15.950, -97.030	60	Intraslab

No data from stations located on very compressible sedimentary soil (Lakebed and transition zones of Mexico City) were used, i.e. only rock and firm ground stations were included. The stations reported in Table 3.1 correspond to the data we used in this work, even though many more stations recorded the events.

The acceleration records belong to the *Base Mexicana de Datos de Sismos Fuertes, BMDSF*, (Mexican Data Base of Strong Motions). We use bandpass filters and the respective correction per line basis for each component (one vertical and two horizontal) for each record of the earthquakes; as well as an adjustment of frequencies depending on the sampling interval. Once the correction was made, the parameters of interest were obtained, i.e.: I_A, PGA and PGV.

4. EMPIRICAL ATTENUATION RELATIONSHIPS

The regression analysis was performed in two stages: first, variation of each parameter (I_A, PGA and PGV) with the magnitude was separately determined for each event; in the second stage, final functions for each parameter were defined. In this second stage the failure type was also included.

The first step in the first stage was the calculation of coefficient ***b*** for each parameter, one for the vertical component and another for the horizontal component. The maximum value of both horizontal components was used in each parameter. Thus, from equation 1, we obtained the values of ***b***, one for each station, and we calculated the average of all of them, we finally obtained 6 values per event for the coefficient ***b***, that is 2 for each parameter.

Attenuation functions were calculated according to equations 2.1 and 2.2 from earthquake data of Table 3.1. The results obtained for the September, 19, 1985 earthquake are shown in Figure 1 as an example. In the curves of this figure, the horizontal axis represents the hipocentral distance, while the vertical axis the parameter in study. Dispersion values illustrated in blue and red points respectively, correspond to the original values of horizontal and vertical components of I_A, and PGA.

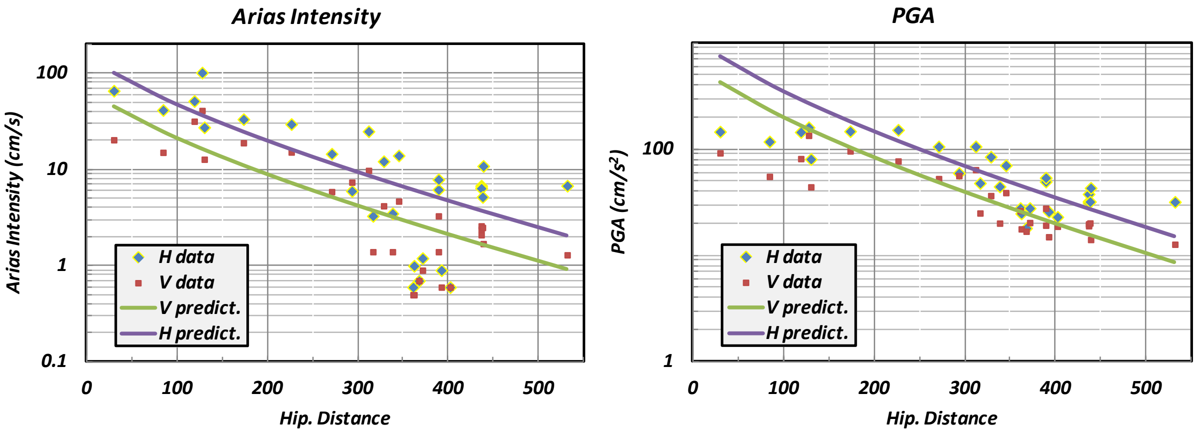

Figure 1. Median prediction of Arias Intensity (I_A) and PGA, plotted against the data for the September, 19, 1985 earthquake (Mw=8.1) in the first stage of regression (a reverse or interplate earthquake were considered).

Figures 2-4 illustrates the results of the second stage, for each failure type. Trend lines were calculated for several magnitudes. For example, for interplate earthquakes 5 different magnitudes are plotted: from 6.1 to 8.1 in Table 1, the same range of Magnitude values were used for this type of failure. In the case of shallow events, only two earthquakes were used (events 11 and 13 of table 3.1). The magnitudes are 8.0 and 7.1, respectively, so that the graphics of shallow earthquakes show 3 lines, for magnitudes 7.1, 7.6 and 8.1. A similar approach was followed to define the magnitudes with trend lines that represent intraslab earthquakes. For shallow earthquakes we considered a constant depth of 5 km, while for interplate and intraslab events we considered a constant depth of 20 and 50 km respectively.

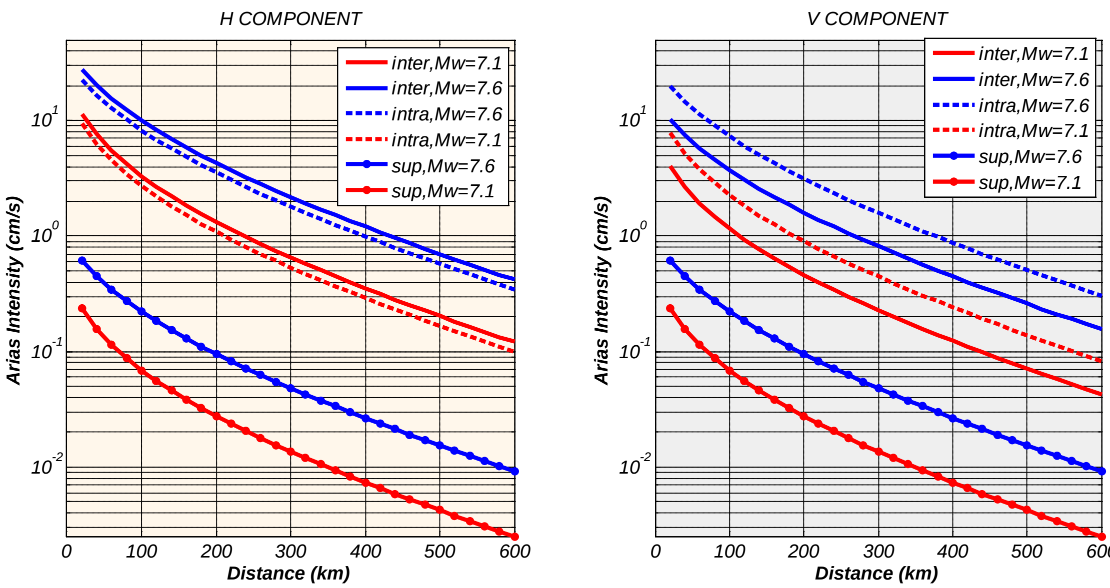

Figure 2. Median prediction of Arias Intensity (I_A) in the second stage of regression (interplate, intraslab and superficial earthquakes).

The predicted curves for the median Arias Intensity, I_A, are plotted against distance in Figure 2(a) for the three mechanism faults types, and for two different magnitude events on horizontal (H) components. Figure 2(b) illustrates the curves of the predicted median value of I_A at vertical (V) components. Normal or Intra faults produce approximately 25% smaller I_A values than Inter-plate faults, while shallow crustal or superficial faults result in approximately 500% smaller I_A values than the ones predicted for other faults.

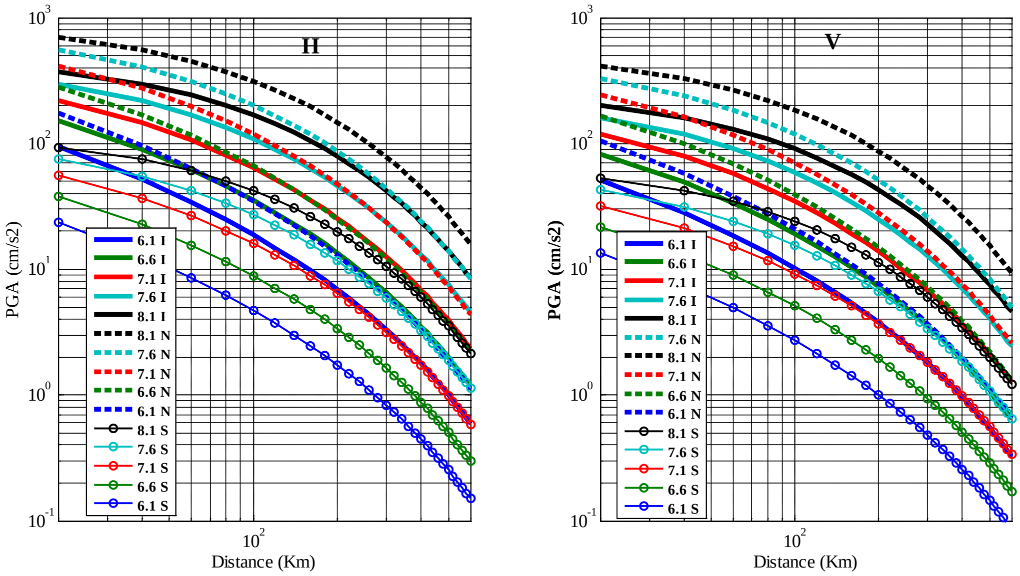

Figure 3. Median prediction of PGA in the second stage of regression (I-interplate, N- Normal or intraslab and S-superficial type).

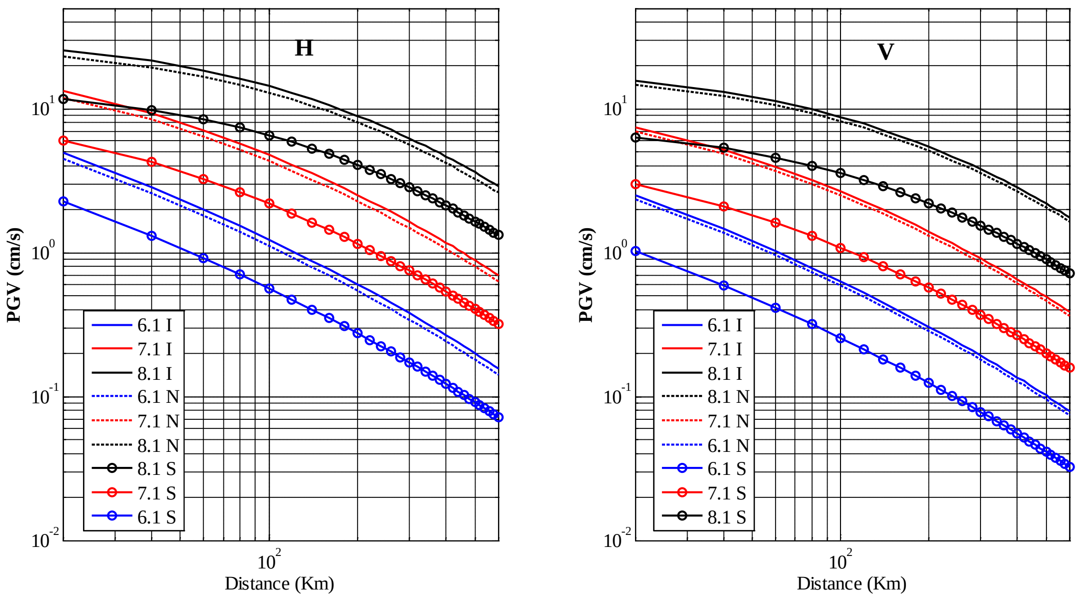

Figure 4. Median prediction of PGV in the second stage of regression (I-interplate, N- Normal or intraslab, and S-superficial type).

The predicted curves for median values of the other parameters (PGA and PGV), are illustrated in Figures 4 and 5 for three faults types and for five different magnitude events on horizontal (H) and vertical (V) components. In the case of PGA, normal or Intraslab faults approximately produce 80% larger values than Inter-plate faults, while PGA values in cortical or superficial faults result in approximately 300% smaller values than the ones predicted for other faults. Nevertheless, predicted curves of PGA indicated that there is no significant difference between intraslab and interplate cases; again, predicted values for superficial events are very low.

The new empirical equation for Arias Intensity does include saturation of this parameter at short distance with increasing magnitude. This decision was made based on a number of observations. After experimenting with several models, we decided that saturation should be incorporated in the final empirical relationship. The new empirical relationship accounts for the non-linear scaling of Arias Intensity, with magnitudes at all distances through the use of equation 2.2.

Table 4.1. Coefficients of empirical equation for I_A, PGA and PGV.

Parameter	A	d	e_1	e_2	e_3	F
I_A (H)	1.1505	0.0006	-2.8394	-2.7882	-4.0207	-2.5633
I_A (V)	1.1168	-0.0003	-2.9466	-2.7944	-4.1870	-2.6477
PGA (H)	0.6066	0.0021	-0.4083	-0.2019	-0.9771	0.1270
PGA (V)	0.6042	0.0019	-0.5420	-0.2891	-1.0899	0.0154
PGV (H)	0.6635	-0.0016	-1.1109	-1.0836	-1.4752	-0.7457
PGV (V)	0.7030	-0.0025	-1.3737	-1.2878	-1.8029	-0.9989

5.2 Comparison with existing relationships

Figure 5a compares the median Arias Intensity predicted values for two different magnitude earthquakes on a reverse fault (interplate) and sites class ‘B’ (or ‘rock’) and C, as computed from two attenuation relationships: the one proposed in this study, and those of Travasarou *et al.* (2003). Despite the difference in the amount of data that these relationships have been based on, they predict similar values of Arias Intensity for the intermediate magnitude range (M ≈7). For larger magnitudes, the proposed relationship predicts very similar I_A values (in the range 100–500 km and class C) than these from existing relationships. This coincidence in the results with the already existing empirical equations at larger magnitudes is primarily attributed to a non-linear magnitude term used in both models. For all magnitudes and short distances (1 to 50 km), the proposed relationship predicts I_A values only 2 to 3 times lower than these from existing relationships. Nevertheless, in Figure 5b when comparison of predicted curves is made in normal fault events, we found a major difference in the I_A values respect the comparison of Figure 5a. In general, the existing relationship of Travasarou et al. (2003) predicts I_A values between 1 to 2 times lower than these from our proposed relationships. This short difference of the empirical equations at normal faults is primarily attributed to the significantly smaller amount of data on which this work is based on.

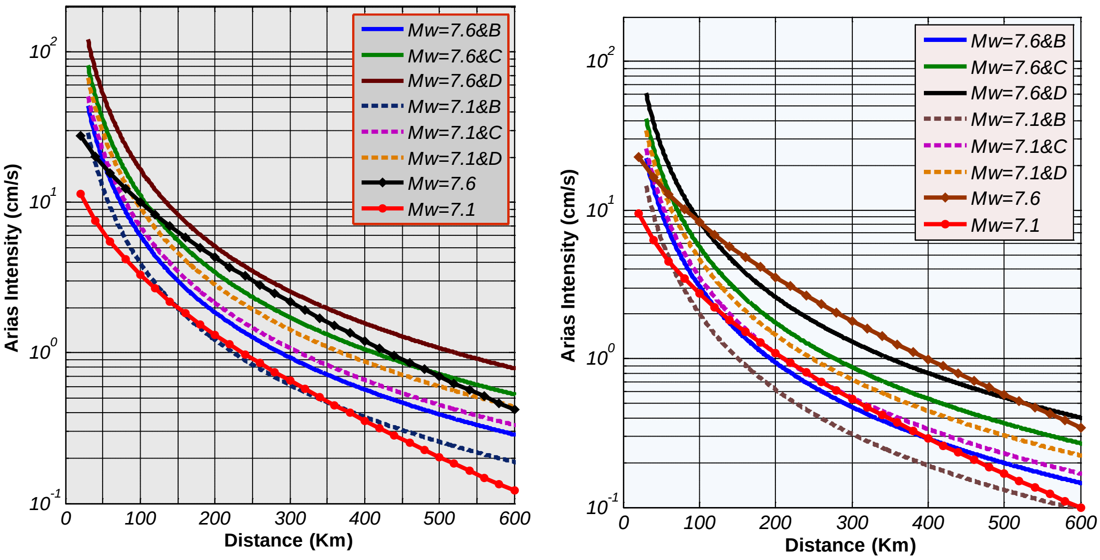

Figure 5. Comparison of proposed attenuation relationship with existing relationships for two different magnitude earthquakes: on a reverse or inter-plate fault (right); and on normal or inter-slab fault (left).

5. PART II: A NEW DAMAGE POTENTIAL INDEX

Data from stations located on lacustrine zone of Mexico City (situated at more than 350 km of epicenters) were not included in the analysis of regression of the first part of this work because they generate very high Arias intensity values, including those stations located close to epicentral areas. In the other hand, Arias Intensity underestimate the potential damage in the soils of Mexico City basically due to the low frequency content observed during strong ground motions, this result in an underestimation of the real damage in structures during earthquakes.

5.1 Accelerations recorded from Mexico Earthquakes

With the purpose of detecting the most destructive accelerograms recorded in México, Gómez Bernal and Sordo (2004), analyzed more than 200 strong ground motion records with the highest accelerations. The acceleration records containing the most energy were selected for the analyses; they were ordered according to PGA values. The station labels used was according to *Base Mexicana de Sismos Fuertes* (BMSF, 2000). Corrected PGA, PGV, and peak displacement, were correlated with other parameters as I_A, and Destructive Potential, P_{dh}, of Araya-Saragoni (1984).

It is well-known, that one high acceleration is not necessarily related to greater damage. Gómez Bernal and Sordo (2004), found that outside Mexico City the accelerograms with the greater energies, according to I_A corresponds, in sequence decreasing, to stations MZ01, RIXC, DELS, ACAS and ZACA; the first four sites with energies greater than those observed in SCT. Stations outside of Mexico City, with the greater values of P_{dh}, are, in sequence of decreasing values, CHI1, ZACA, MZ01, DELS and SICC. It was observed, a strong correspondence between PGV and P_{dh}. The first four stations with greater P_{dh}, contain values of PGV greater than 25 cm/s. Nevertheless, when the strong ground motion records in Mexico City were analyzed, as expected, they contained the highest energies values of all the records, although they have relatively low PGA value levels, but they still preserved the highest PGV values, and also with the highest damage potential. In conclusion, P_{dh}, it is a parameter that overestimate the damage potential in acceleration records with frequencies lower than 1.0 Hz (T>1.0 s), and I_A is a index that underestimate the damage in the same range of frequencies.

Table 5.1. Mexican earthquakes used in the second part of this study

Earthquake	Station	PGA	PGV	PGD	I_A	Tm	SMA	ICI
MEX97	CALE	400.70	11.73	3.45	204.80	0.25		102.40
MEX85	SCT-EW	167.10	59.09	20.20	223.80	2.12	133.73	923.82
MEX85	SCT-NS	98.30	32.95	16.19	120.50	2.08	93.95	493.14
MEX85	CDAO2	78.26	34.06	22.03	102.00	3.04	69.24	440.51
MEX85	CDA03	61.59	29.97	19.86	130.00	3.09	58.58	560.01
MEX85	TLHB-NS	142.07	52.57	44.84	146.90	2.56	114.68	638.11
MEX85	TLHBEW	100.13	49.09	37.81	108.70	2.67	80.54	473.37
MEX2012	TH35-EW	88.18	40.48	20.33	54.60	2.75	75.00	237.81
MEX1989	CO56NS	62.89	22.96	8.38	42.2	2.26	52.00	178.67
MEX85	CHI1NS	171.80	25.29	9.30	152.00	1.17	156.66	192.36
MEX85	CHI1EW	187.54	36.47	9.72	129.00	1.24	135.70	178.12
MEX85	ZACA	174.77	19.44	6.43	158.24	0.42	162.90	102.55
MEX85	ZACA-C3	273.16	35.96	13.10	250.00	0.53	200.22	182.00
MEX	VIC15	500.31	20.79	8.43	99.00	0.39	290.00	61.83
MEX	VICT45	598.41	33.48	9.94	195.00	0.51	410.00	139.12
MEX	MZ01	395.90	32.07	9.23	440.00	0.42	349.15	285.15
MEX	MZ01-C3	421.07	34.05	9.20	466.00	0.44	376.13	309.11
MEX	DELS	343.64	32.98	20.10	324.20	0.69	250.00	269.30
MEX	SICC-C1	309.61	23.05	2.75	124.90	0.42	89.69	80.94
MEX	SICC-C3	261.98	21.02	2.37	164.80	0.37	100.32	100.24

5.2 Acceleration records from earthquakes in the world

In this second part, we included data from several important earthquakes recorded in the world, the stations were chosen considering that they posses great energy values, most stations are classified as near field stations. The selected stations are shown in Table 5.2, and the most representative parameters of these intense acceleration records were calculated. For each one of the channels, are indicated PGA, PGV, PGD, I_A, T_m and the Peak Sustained Acceleration (SMA, according to Nuttli, 1978). Note that Tar090 component, of station TAR (Tarzana), has the highest values of PGA, and I_A.

Table 5.2. Earthquakes used in the second part of this study

Earthquake	Station	PGA	PGV	PGD	I_A	T_m	SMA	ICI
Taiwan	TCU068N	551.13	180.23	205.37	301.56	1.27	245.05	433.79
Taiwan	TCU068W	593.80	146.42	151.48	318.50	1.51	361.40	589.22
Cape Mendocino	CPM000	1601.38	110.83	31.14	595.41	0.36	404.86	358.48
Tabas Iran	TAB-TR	902.81	131.93	83.82	1152.97	0.47	550.54	792.12
Tabas Iran	TAB.LN	816.29	94.56	37.54	1154.00	0.47	722.21	792.99
Turkey	DZC270	498.94	73.09	51.20	293.11	0.83	330.60	266.65
Turkey	ATS-long	251.69	30.87	26.92	104.60	0.87	161.84	97.56
Turkey	ATS-trans	183.91	30.55	17.85	128.90	0.98	165.30	127.60
Turkey	YPT-TR	349.65	61.63	50.99	167.54	1.20	203.60	220.24
Turkey	EZR-NS	495.70	87.43	27.13	151.00	1.33	268.79	231.61
Nicaragua 1972	MN358G3	331.43	25.37	7.52	210.00	0.40	318.70	133.48
Peru	PRQ66C2	274.38	16.31	9.32	88.30	0.25	207.55	44.15
Peru	PRQ74C1	181.97	19.09	4.94	135.33	0.32	162.66	76.55
PERU	MOQ011C1	292.80	23.53	5.10	284.00	0.54	240.52	208.70
Russia	gaz090	740.00	54.03	28.65	500.00	0.41	620.00	320.16
Luce	luce27	703.70	98.71	69.75	716.50	0.32	651.00	405.31
Luce	luce360	788.16	32.93	16.50	687.20	0.17	629.00	280.83
Petronia	petronia90	701.81	94.45	26.83	382.90	0.67	295.43	313.42
Northridge	Tar090	1745.50	113.60	33.22	2120.60	0.36	1268.00	1272.36
Northridge	Tar360	971.50	77.60	30.45	1570.30	0.41	819.00	1005.48
Northridge	Syl090	593.05	78.20	16.05	255.20	0.77	300.00	223.94
Northridge	Syl360	827.28	129.60	32.68	490.00	0.74	305.00	421.51
Northridge	Jen022	416.37	106.20	43.06	262.90	1.27	282.00	376.27
Northridge	Jen292	581.30	99.30	24.00	556.30	0.98	411.00	550.71
Northridge	Wpi046	446.29	92.80	56.64	154.10	1.54	190.00	294.50
Northridge	Wpi316	319.25	67.40	16.11	97.04	1.21	228.00	129.16
Northridge	Rrs228	821.65	166.10	28.78	735.80	0.73	657.00	628.67
Northridge	Rrs318	463.44	73.00	19.76	394.50	0.61	420.00	308.11
Chile	Llol010	664.43	35.69	10.42	1505.80	0.37	603.30	915.94
Chile	Llol100	385.05	24.14	3.98	680.84	0.37	323.50	414.14
Chile	Vm290	212.04	24.81	3.58	298.41	0.54	193.70	219.29
Chile	Vm200	322.84	32.75	4.94	548.50	0.62	276.40	431.89
Japan	Kob-ew	581.42	75.27	19.24	543.80	0.64	599.80	435.04
Japan	Kob-ns	802.07	80.42	17.84	838.80	0.24	296.40	410.93
Japan	tak00	589.00	125.65	36.39	870.00	1.10	495.00	1003.71
Japan	tak90	588.00	104.68	34.84	813.00	0.96	563.00	796.57
MOQ	Moq1ew	292.80	23.53	5.10	510.00	0.53	203.15	371.29
Moq	Moq1ns	228.79	30.70	7.31	247.02	0.34	151.66	144.04
El Centro	00-1940	315.13	31.48	12.62	182.20	0.57	199.93	137.56
El Centro	090-1940	204.31	37.90	20.69	129.10	0.64	171.80	103.28
El Centro79	HE06230	455.00	95.20	69.76	175.40	1.31	265.00	262.99
El Centro79	HE06140	440.00	65.22	27.56	148.70	0.91	283.00	141.85

5.3 A new parameter for estimating the destructiveness of earthquakes

Arias intensity alone cannot be used as an index of destructiveness, because in several cases this parameter can underestimate the damage level. This can be exemplify clearly with the case of accelerograms in lakebed zone of Mexico City from the destructive earthquake of September 19, 1985, containing Arias intensity values less than 224 cm/s. If this intensity value in SCT station is compared with values from other large-scale events such as the earthquakes of table 5.2 (Kobe, Northridge, Tabas, etc.), we can conclude that it is two to five times lower. However the destruction caused by the 1985 earthquake in the Mexico City was very extensive and severe, in many cases it was greater than the damage observed in other earthquakes of the Table 5.2.

Taking into account that dominant periods during strong ground motion in Mexico City are located between 2 and 5 seconds, it is possible to use a parameter that in addition to using the total energy of the record, as does the Arias intensity, we can also include the effect of soil dominant period. Because structures with low period (T < 1.0 sec), have more over-strength than structures with high period, we are proposing the *index of concentrated intensity*, ICI, as an index of destructiveness:

$$\mathbf{ICI = I_A{*}(T_m)^{\alpha}} \qquad (5.1)$$

Where:

$$\propto = \begin{cases} 0.5, & if\ T_m < 1.0 \\ 1.5, & if\ 1.0 \le T_m < 2.0 \\ \dfrac{4}{T_m}, & if\ T_m \ge 2.0 \end{cases}$$

And T_m, is the average period of the record. According to Rathje *et al* (1988) T_m is calculated like $\Sigma Ci^2{*}fi/\ \Sigma Ci^2$, where Ci are the Fourier amplitudes, and fi represent the discrete Fourier transform frequencies between 0.25 and 20 Hz. According to Rathje *et al.* (1998) the mean period, T_m, is the best simplified frequency content characterization parameter. In figure 6, we compared this new parameter with PGA, PGV and SMA.

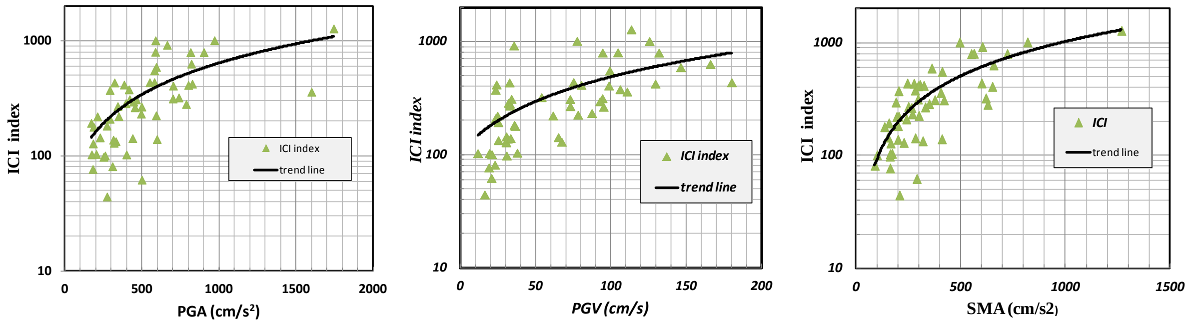

Figure 6. Variation of the ICI parameter with PGA, PGV and SMA, for the Table 5.2 records.

6. CONCLUSIONS

A new suite of predictive equations for the estimation of Arias Intensity, PGA and PGV, from earthquakes in Mexico has been presented for three fault types: interplate, intraslab and crustal. Dataset correspond only to stations located on rock and firm soil (B and C soil type). Relationships were developed by regression analysis using a two steps technique. Differences in the amplitudes of predicted ground motions associated with different fault types are shown to be significant, and therefore care must be taken into consideration when applying the equations to ensure that, the most appropriate functional is adopted. We find that the horizontal PGA parameter is considerably greater in intraslab or normal events than in interplate earthquakes; nevertheless, this difference changes in the case of the horizontal I_A: the amplitudes for intraplate events are about 25 % greater than those for intraslab events. In the case of PGV, the predicted curves for interplate and interslab events are very similar. In all parameters studied, predicted curves are very lower in superficial events than the ones observed for the other two types.

When the predicted values of I_A proposed in this study for interplate events, are compared with the attenuation relationships of Travasarou *et al.* (2003), on a reverse fault, for different magnitude earthquakes, we observed similar Arias Intensity values for the intermediate magnitude range (M ≈7), despite the difference in the amount of data that these relationships, have been based. For larger magnitudes, the proposed relationship predicts very similar I_A values (in the range 100–500 km and class C) than these from existing relationships. This coincidence in the results with existing empirical equations at larger magnitudes is primarily attributed to a non-linear magnitude term used in both models. Nevertheless, when comparison of predicted curves is made in normal fault events, we found a major difference in the I_A values than those with interplate faults.

I_A is a simple intensity measure that correlates to the damage of a number of engineering systems. The fact that I_A is independent of the fundamental period of the engineering systems, does restricts its applicability in some cases, like in the problem of the dynamic response of structures, and their relationship with the damage. This point can be illustrated with the case of the strong ground motion observed in Mexico City during earthquakes occurred to very long distances (over 400 km). This can be exemplify clearly if I_A values, from accelerograms in the lake bed area of Mexico City during the destructive earthquake of September 19, 1985, are compared with I_A values from other large-scale events such as the earthquakes of Kobe, Northridge, Tabas, etc. We can conclude that I_A values for Mexican earthquakes are between two and five times lower than those events. However the destruction caused by the 1985 earthquake in Mexico City was extended and severe. I_A underestimates the potential damage in the Mexico City soils basically due to the low frequency content observed during earthquakes, this results in an underestimation of the real damage in structures.

In order to incorporate ground motion parameters related to earthquake damage into seismic hazard analysis, in the second part of this work, a new damage index is established, which uses the I_A parameter and the mean period, T_m, this new index of destructiveness is defined as ICI, index of central intensity, and was calibrated with several acceleration records of strong earthquakes occurred all over the world.

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