On the correlation of Mercalli-Cancani-Sieberg intensity scale in Yugoslavia with the peaks of recorded strong earthquake ground motion

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SUMMARY – Amplitudes of the peaks of ground acceleration, velocity and displacement are presented for the recordings at 127 sites during 51 earthquakes in Yugoslavia, for the period between 1978 and 1983. Relative to the reported site intensity (Mercalli-Cancani-Sieberg, MCS), the logarithms of average peak amplitudes increase linearly for MCS ≥ V.

Grouping of all recording stations according to the site geology classification, as proposed by Trifunac and Brady (1975), allows an investigation of the site effects on the recorded peak amplitudes. The results suggest different trends from those found in the Western United States (WUS), implying slower high frequency attenuation (higher quality factor Q*) in Yugoslavia. This means that the transfer and use of the empirical scaling relationships on strong motion amplitudes from United States into other regions of the world may be more difficult and less direct than this has appeared to be so far.*

Grouping of all recording stations according to the site soil classification (Seed et al, 1976) indicates amplification of peaks by a factor ~ 3, on stiff soil sites relative to «rock» sites.

Introduction

In 1975 we studied the average trends of the recorded peaks of strong earthquake ground motion, for accelerograms in the WUS and for the site shaking described by the Modified Mercalli Intensity (MMI). Then, we discovered that for 187 records during 57 earthquakes, occurring between 1933 and 1971, peak accelerations have tendency to be larger on basement rock (see Trifunac and Brady, 1975, for detailed description of the sites on sediments, $s = 0$, basement rock, $s = 2$, and intermediate sites, $s = 1$) than on «softer» sites on sedimentary deposits ($s = 0$). These findings lead to numerous empirical studies which extended these results to the scaling of the complete Fourier and Response Spectrum amplitudes, and explained the observed trends as combined effects of overall amplification and high frequency attenuation (Trifunac, 1991).

To facilitate the use of this body of empirical results by researchers and engineers outside the WUS, we carried out other studies to compare the strong motion magnitude scales, which can be used in the respective regions, with the corresponding magnitudes in the WUS (Trifunac, 1991; Lee, 1991; Lee et al., 1990b). Such studies can help in relative calibration of the published catalogues on earthquake occurrence and in the eventual establishment of international standards for more uniform and common scaling conventions. As more data becomes available and as our understanding of the physical processes associated with earthquakes improves, it is inevitable that new and better «magnitude» and «intensity» scales will be developed. However, it should be remembered that for sound probabilistic estimation of earthquake risk, in engineering design applications, it is essential to work towards more complete, uniform and more homogeneous catalogues of earthquake occurrence covering longer observation periods. Since, in preparing such catalogues it is essential to go as far back in time as possible, it also becomes necessary to carefully account for, interpret and calibrate the differences in «new» versus «old» scales and methods.

It appears that careful relative calibration of magnitude and intensity scales in different geologic regions may not suffice. Such scaling results in averaging over many parameters which characterize the earthquake ground motion, and so must be viewed only as a first step in establishing more complete «translation equations». Systematic differences in the

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overall shape of the Fourier amplitude spectra of strong ground motion, for example, for two different geologic regions may not affect much the average overall amplitudes as sampled by the magnitude or intensity scales, but may lead to significant differences in relative amplitudes of short or of long period ground motion. The purpose of this paper is to show how such differences can be first evaluated, before more detailed scaling of the entire spectrum becomes possible (Trifunac, 1989a, b; Lee, 1990).

As description of the effects of strong earthquake shaking on man-made structures contributes to the selection of site intensities, it is also important to remember that in comparing the intensities in different regions one must consider the differences in the type of construction and in the distribution of the affected structures. In this work we choose to accept the reported site intensities and then we characterize those by the peaks of the recorded strong ground motion. The extent to which the nature of the buildings in the area then contributes to the results of this study should be evaluated in future analyses which deal with distribution and type of the observed damage.

Many different intensity scales were in use on the territory of Yugoslavia and its neighboring countries. The periods of their use, their mutual relationship and the proposed tables for their conversion, have been described by Shebalin (1969) and by Shebalin et al (1974). For example the levels of *MCS* intensity have been interpreted to be one half intensity level below the levels of the *MMI*, for $MMI \geq V$. For $MMI = I$, $MCS = II$, with linearly decreasing differences for $I \leq MMI \leq V$ until $MCS = IV - V$ for $MMI = V$. As we will show in this paper, strong motion data recorded in Yugoslavia suggests very different relationship between these two scales (see also the correlation proposed by Console et al. in 1972 and summarized by Ambraseys, 1975).

Strong motion data in Yugoslavia

In 1984, a joint project between University of Southern California and Institute of Earthquake Engineering and Engineering Seismology (IZIIS) was organized to digitize and the process all strong motion data recorded in Yugoslavia (Jordanovski et al 1987). This project was completed in 1987, resulting in 449 digitized records. Most digitized accelerograms could be associated with 204 earthquakes occurring between 1975 and 1983. At present, some earthquakes contributing to this data base remain unidentified. However, as more basic results on this data become available, in particular the regional attenuation and scaling relationships (Trifunac and Todorovska, 1989; Lee et al., 1990b) it is expected that more of the remaining records will be identified and assigned to typically smaller local events.

For this study the data was selected for those sites for which we could gather the reported intensities at the recording stations. Also all data was classified according to the type of the site geology. All sites on sediments were grouped into category $s = 0$. Those sites which are near the boundary of $s = 0$ (sediments) and $s = 2$ (basement rock), or are located in a complex geologic setting, which could not be identified as $s = 0$ or $s = 2$, were grouped into intermediate category $s = 1$. All sites on the basement rock were identified with $s = 2$. This selection of the site geologic parameters was carried out in the same way as described by Trifunac and Brady (1975). This provided continuity in this approach and facilitated direct comparison with other similar studies in the WUS. The international team consisting of experienced geologists and earthquake engineers carefully interpreted the descriptions of the site geology and voted on how to choose $s = 0$, 1 or 2. This resulted in the data base with site classification parameters at 121 sites which recorded strong motion during 51 earthquakes.

For most sites we were also able to gather enough information to make a determination of the local soil site classification, following the procedure described by Seed et al. (1976). All sites with thickness of soil $d <$ 10m, over deposits with shear wave velocity $v_s > 800$ m/sec, were identified as «rock» sites ($SS_L = 3$). Soil deposits with thickness $d =$ 15m to 70m were grouped under $SS_L = 2$, as «stiff soil» sites, and for $d >$ 100m under $SS_L = 1$ «deep soil» sites. We note that $SS_L = 1,2$ and 3 used here corresponds to $S_L = 2,1$ and 0 respectively in our analyses of strong motion spectral amplitudes (Trifunac, 1989a,b; Lee, 1990).

For many small earthquakes and for many aftershocks of the Monte Negro, 1979, event, it was not possible to identify the site intensities. Some of this information may never be recovered. Looking back at these recordings in Yugoslavia and in many other countries, one cannot but wonder why most agencies and organizations, engaged in gathering and publishing intensity maps in most countries around the world, do not have a systematic policy of identifying the intensity of shaking at the stations with operating strong motion accelerographs, even when this intensity is not small. Gathering such information would contribute invaluable data for future studies, with only minor, perhaps insignificant additional effort.

Average trends of the peaks of acceleration, velocity and displacement with respect to M.C.S. intensity

Following the examples in our previous studies we have assigned linearly progressing numerical values to the levels of *MCS* scale and labeled these levels by I_{MCS}. Thus, in this work, $MCS = VIII$ will correspond to $I_{MCS} = 8$, which will be used as a «variable» in subsequent «calculations». These is, of course, no direct physical basis for doing so, but the practical considerations, the end results and numerous previous observations, all indicate that this may be a useful «working» hypothesis.

For 30 sites of 127 in our data base, the intensity levels have been reported as $VIII - IX$, for example. Rather than to work with $I_{MCS} = 8.5$, we chose to create two data sets, one where $VIII - IX \rightarrow VIII$ and the other where $VIII - IX \rightarrow IX$. In the first case the

Table 1 – Mean Values and Standard Deviations of Peak Acceleration, Velocity and Displacement for Different Mercalli-Cancani-Sieberg Intensities in Yugoslavia.

I_{MCS} M.C.S. intensity	Component	Number of Data	acceleration (cm/s²) $\bar{a}$	σ	velocity (cm/s) $\bar{v}$	σ	displacement (cm) $\bar{d}$	σ
IV^{-}_{+}	vert.	2	15.74	4.01	0.60	0.22	0.03	0.01
		1	21.42	–	0.91	–	0.05	–
	hor.	4	37.86	14.31	1.38	0.48	0.08	0.03
		2	55.86	9.25	2.05	0.12	0.12	0.03
V^{-}_{+}	vert.	36	11.97	5.84	0.60	0.46	0.08	0.14
		25	11.99	7.02	0.59	0.55	0.09	0.17
	horis	72	22.59	18.29	1.21	1.01	0.15	0.18
		50	24.82	21.91	1.32	1.21	0.18	0.22
VI^{-}_{+}	vert.	60	23.61	21.34	0.91	0.67	0.09	0.12
		63	20.72	21.66	0.83	0.74	0.08	0.12
	hor.	120	41.14	38.09	2.15	2.10	0.22	0.26
		126	35.40	38.97	1.83	2.16	0.19	0.27
VII^{-}_{+}	vert.	21	51.20	23.53	2.69	1.57	0.67	0.55
		22	32.52	22.70	1.74	1.67	0.33	0.55
	hor.	42	105.66	53.32	6.90	4.26	1.80	1.61
		44	58.47	47.64	4.10	4.26	0.76	1.54
$VIII^{-}_{+}$	vert	4	118.46	51.79	7.40	3.42	1.67	0.94
		12	90.54	57.58	4.79	3.29	1.22	1.62
	hor.	8	186.45	72.02	14.55	7.78	3.32	2.44
		24	177.44	113.34	11.46	7.77	3.06	4.25
IX^{-}_{+}	vert.	4	241.01	83.97	16.41	2.69	6.93	1.68
		4	241.01	83.97	16.41	2.69	6.93	1.68
	hor.	8	297.25	85.06	37.95	12.94	11.04	4.51
		8	297.25	85.06	37.95	12.94	11.04	4.51

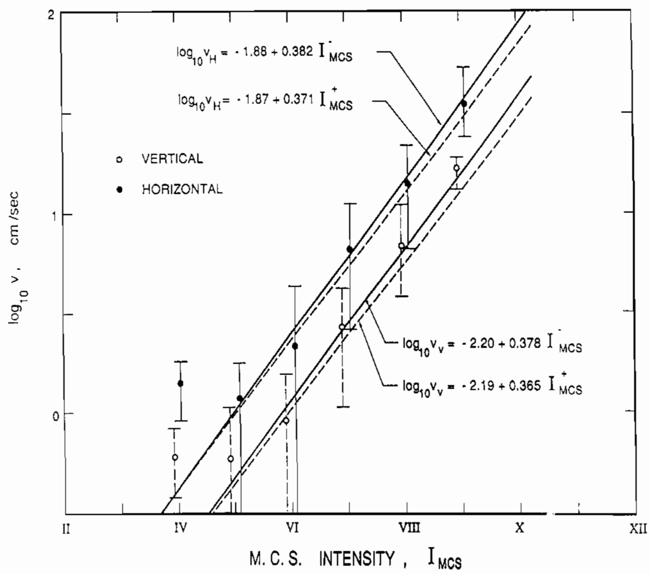

Fig. 2

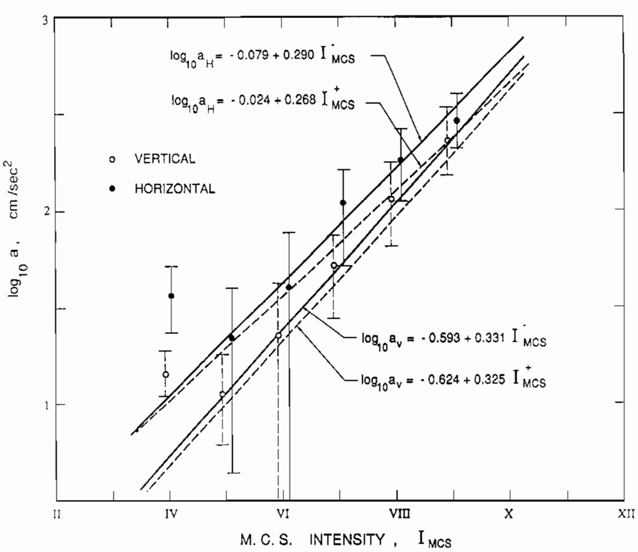

Fig. 1

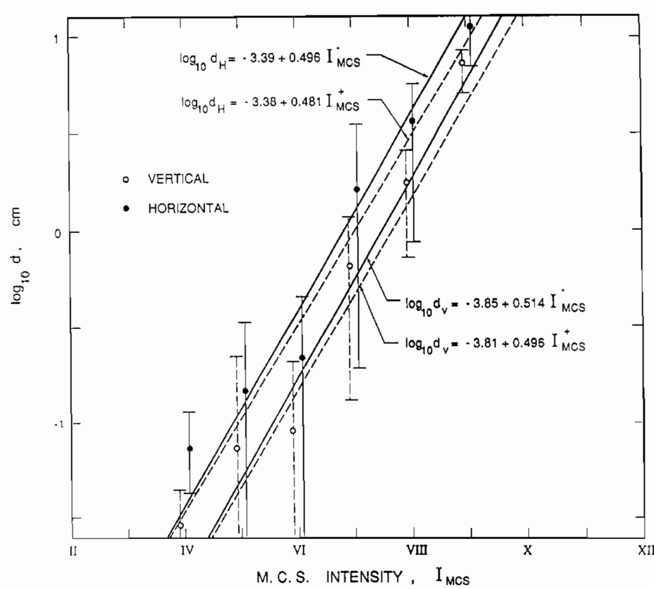

Fig. 3

resulting levels are labeled as $VIII^{-}$ or as I^{-}_{MCS}, and in the second as I^{+}_{MCS}. It was also felt that this «perturbation» might serve to suggest how sensitive our results are to such variations in the data base.

Table 1 presents averages and standard deviations and the number of the contributing observations, for the recorded peak accelerations and computed velocity and displacement of ground motion versus $I^{\mp}_{MCS}$. It is seen that the data is essentially available only for $MCS = V$, VI and VII. To avoid cluttering, only the data for I^{-}_{MCS} has been plotted, using the logarithmic amplitude scale, in Figures 1, 2 and 3. Horizontal peaks have been identified with solid points, while vertical peaks are shown with open circles.

The trends of the average peak amplitudes in Table 1 also can be described by

$$\log_{10} f = a_0 + b_0\, I^{\mp}_{MCS} \pm \sigma \tag{1}$$

where f stands for peak accelerations a_V and a_H (cm/sec²), peak velocities v_v, v_H (cm/sec) and peak displacements d_V, d_H (cm), with V and H identifying vertical and horizontal components of motion. a_0 and b_0 are regression coefficients and σ is the standard deviation. Table 2 presents the results of this regression with two sets of coefficients corresponding to «−» and «+» in the two data sets as described above.

It is interesting to compare the results in Table 2 with corresponding results in Trifunac and Brady (1975). It is seen that both a_0 and b_0 are very similar in there two studies for $\log_{10} a_{V,H}$. However, this study of Yugoslav data shows that peak velocities and peak displacements grow faster with respect to MCS scale

Table 2 – Coefficients a_0 and b_0 in equation $\log_{10} f_{H,V} = a_0 + b_0 I^{\mp}_{MCS} \pm \sigma$.

		a_0	b_0	σ
$f = a_V$	−	-0.593	0.331	0.016
	+	-0.624	0.325	0.081
$f = a_H$	−	0.079	0.290	0.049
	+	0.024	0.268	0.070
$f = v_V$	−	-2.20	0.378	0.066
	+	-2.19	0.365	0.107
$f = v_H$	−	-1.88	0.382	0.048
	+	-1.87	0.371	0.104
$f = d_V$	−	-3.85	0.514	0.158
	+	-3.81	0.496	0.203
$f = v_H$	−	-3.39	0.496	0.143
	+	-3.38	0.481	0.157

$- : I^{-}_{MCS} = VII - VIII \rightarrow VII$
$+ : I^{+}_{MCS} = VII - VIII \rightarrow VIII$

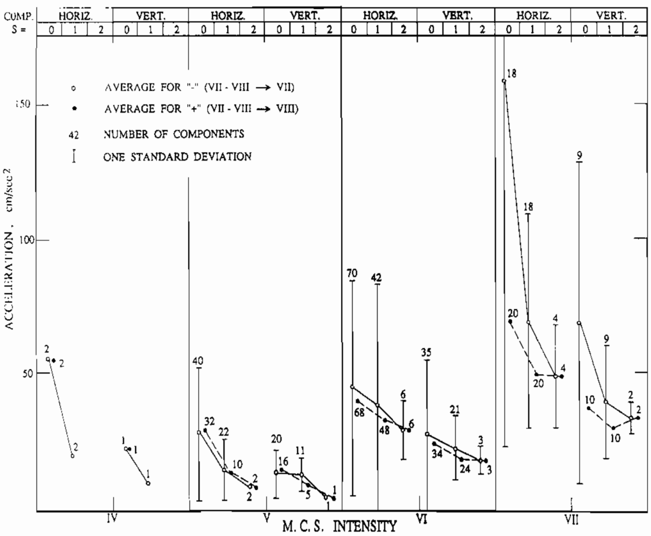

Fig. 4

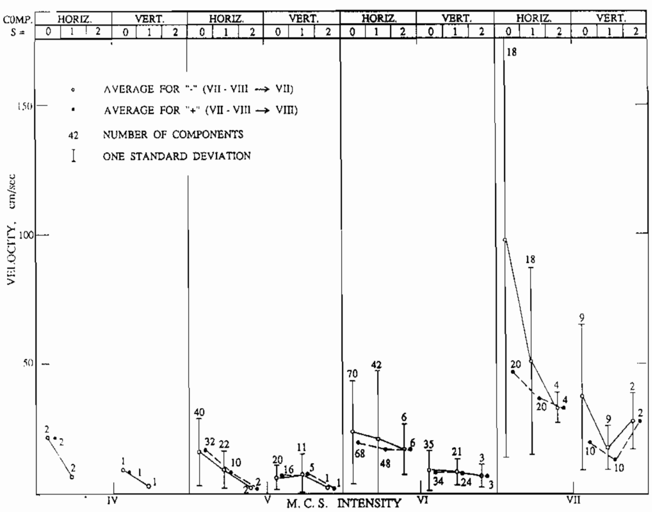

Fig. 5

than the corresponding peaks in the WUS with respect to MMI. In performing the regression analyses for equation (1), we omitted the data for $I_{MCS} = 4$. For this intensity the observations are not complete and approach the noise level of recording, detection and intensity assignment.

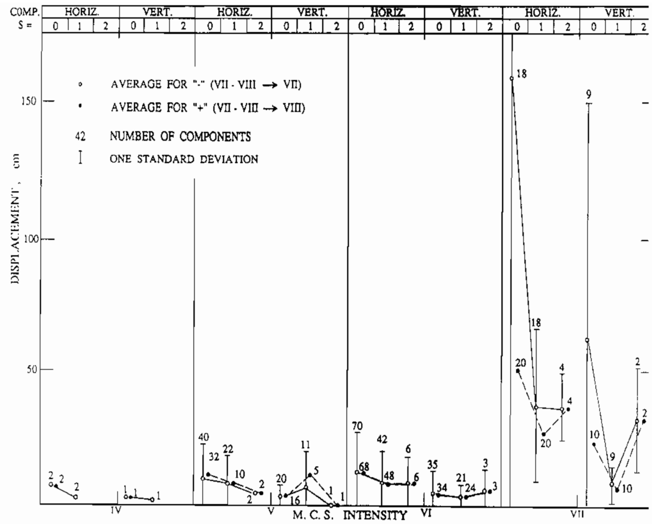

Fig. 6

Variations of peak amplitudes for different site conditions

In this investigation we followed the steps of Trifunac and Brady (1975) in selecting the geological site classification s = 0, 1 or 2. Descriptions of site geology were distributed to 14 experts from Yugoslavia, Bulgaria, U.S.S.R., China and United States. The variations among expert classifications and their consistency were very similar to those found by Trifunac and Brady (1975). Distribution of the current data base between s = 0, 1 and 2 is 67 (55%), 48 (40%) and 6(5%) respectively, for the total of 121 sites. For six additional recordings considered in Table 1 we could not obtain the data on the local site geology. It is seen that most recording stations in Yugoslavia are on the sedimentary sites (55%) with only small number on the basement rock. This distribution is similar to the one in the Western United States. In this respect it may be noted that many investigators and organizations in charge of strong motion observation programs are perhaps not aware of the need to consider the site geology on the scale as used here. Instead, in typical considerations on how to deploy recording stations, one finds mainly the consideration of the local soil conditions only (Trifunac, 1990). The consequence of this is that, after many years of laborious observational programs and considerable expenditures, we still have no adequate data on strong motion on sound basement rock (s = 2). Perhaps this paper could serve as yet another example of the extent and of the detail one should consider, in optimizing the siting and performance of strong motion recording networks, in general.

Tables 3a, b and c present averages and standard deviations of peak amplitudes of acceleration, velocity and displacement, again for two data groups designated by «−» and «+», as described above. Figures 4, 5 and 6 present the same data with open circles for averages and vertical bars for standard deviations for the data set in group «−». To avoid clutter in these figures the data

Table 3a – Mean Values and standard deviations of peak acceleration (cm/sec^2), velocity (cm/sec) and displacement (cm) for different Mercalli-Cancani-Sieberg Intensities in Yugoslavia recorded on sediments (s = 0).

MCS	COMP.	N	$\bar{a}$	σ	$\bar{v}$	σ	$\bar{d}$	σ
IV^-	ver.	1	21.42	—	.91	—	.05	—
	hor.	2	55.86	9.25	2.05	.12	.11	.03
IV^+	ver.	1	21.42	—	.910	—	.05	—
	hor.	2	55.86	9.25	2.05	.12	.11	.03
V^-	ver.	20	12.83	8.72	.60	.47	.06	.07
	hor.	40	27.31	24.34	1.53	1.43	.19	.22
V^+	ver.	16	13.27	8.18	.63	.41	.0	.07
	hor.	32	28.42	23.72	1.64	1.36	.22	.22
VI^-	ver.	35	26.34	26.87	.95	.85	.09	.15
	hor.	70	44.85	38.78	2.30	2.08	.24	.31
VI^+	ver.	34	23.94	26.82	.86	.81	.08	.14
	hor.	68	39.65	36.86	2.00	1.97	.21	.30
VII^-	ver.	9	68.89	59.03	3.74	2.82	1.23	1.77
	hor.	18	158.13	137.11	9.79	8.36	3.17	5.00
VII^+	ver.	10	35.35	27.23	2.00	2.18	.47	.74
	hor.	20	69.65	58.97	4.67	5.24	1.00	2.18
$VIII^-$	ver.	–	—	—	—	—	—	—
	hor.	–	—	—	—	—	—	—
$VIII^+$	ver.	4	104.62	65.02	4.88	2.56	1.77	2.34
	hor.	8	259.92	131.30	14.53	7.73	5.03	6.26
IX^-	ver.	2	310.17	59.84	17.88	1.04	7.24	.01
	hor.	4	307.54	57.76	48.53	6.86	13.77	2.92
IX^+	ver.	2	310.17	59.84	17.88	1.04	7.24	.01
	hor.	4	307.54	57.76	48.53	6.86	13.77	2.92

Table 3b – Mean Values and standard deviations of peak acceleration, velocity and displacement for different Mercalli-Cancani-Sieberg Intensities in Yugoslavia recorded on intermediate geologic sities (s = 1).

MCS	COMP.	N	$\bar{a}$	σ	$\bar{v}$	σ	$\bar{d}$	σ
IV^-	ver.	1	10.07	—	.28	—	.01	—
	hor.	2	19.86	—	.71	—	.04	—
IV^+	ver.	–	—	—	—	—	—	—
	hor.	–	—	—	—	—	—	—
V^-	ver.	11	11.98	7.41	.81	.89	.15	.25
	hor.	22	14.52	10.46	.93	.83	.14	.21
V^+	ver.	5	9.46	2.64	.80	.90	.21	.33
	hor.	10	12.66	6.37	.88	.58	.17	.24
VI^-	ver.	21	20.49	13.96	.87	.52	.08	.07
	hor.	42	37.20	46.13	2.04	2.62	.18	.22
VI^+	ver.	24	17.66	13.01	.82	.65	.08	.09
	hor.	48	31.65	44.19	1.73	2.53	.16	.22
VII^-	ver.	9	38.87	22.78	1.70	.83	.18	.12
	hor.	18	69.39	40.46	5.02	3.49	.75	.56
VII^+	ver.	10	29.84	19.13	1.27	.77	.12	.11
	hor.	20	49.22	34.78	3.69	3.43	.51	.53
$VIII^-$	ver.	4	118.45	51.79	7.39	3.42	1.67	.94
	hor.	8	186.45	72.02	14.55	7.78	3.32	2.44
$VIII^+$	ver.	7	89.47	53.04	5.13	3.70	1.05	1.01
	hor.	14	145.15	75.48	10.63	7.55	2.22	2.26
IX^-	ver.	2	171.84	30.90	14.94	3.01	6.61	2.33
	hor.	4	286.95	104.51	27.36	7.98	8.31	4.16
IX^+	ver.	2	171.84	30.90	14.94	3.01	6.61	2.33
	hor.	4	286.95	104.51	27.36	7.98	8.31	4.16

Table 3c – Mean Values and standard deviations of peak acceleration, velocity and displacement for different Mercalli-Cancani-Sieberg Intensities in Yugoslavia recorded on basement rock (s = 2).

MCS	COMP.	N	$\bar{a}$	σ	$\bar{v}$	σ	$\bar{d}$	σ
V^-	ver.	1	4.29	—	.09	—	—	—
	hor.	2	7.87	.87	.19	.02	.010	—
V^+	ver.	1	4.29	—	.09	—	—	—
	hor.	2	7.87	.87	.19	.02	.010	—
VI^-	ver.	3	17.26	3.40	.75	.63	.12	.15
	hor.	6	27.42	12.79	1.18	1.01	.16	.21
VI^+	ver.	3	17.26	3.40	.75	.63	.12	.15
	hor.	6	27.42	12.79	1.18	1.01	.16	.21
VII^-	ver.	2	31.79	7.39	2.72	1.16	.630	.380
	hor.	4	48.79	19.76	3.30	.61	.717	.280
VII^+	ver.	2	31.79	7.39	2.72	1.16	.630	.380
	hor.	4	48.79	19.76	3.30	.61	.717	.280

for «+» group is shown only by solid points. A number over the standard deviation bar (same as N in Tables 3a, b and c) shows the number of contributing components.

It spite of the fact that the number of data available for s = 2 is clearly inadequate, it seems clear that the amplitudes of peaks decrease as one moves from s = 0, to s = 1 and from s = 1 to s = 2. This observation may prove to be important well beyond the aspect of local scaling of strong ground motion on the territory of Yugoslavia. Trifunac and Brady (1975) found the opposite trend for strong motion acceleration peaks in the WUS, and numerous later studies (e.g. Trifunac, 1990) confirmed their findings. The present result for Yugoslav data suggests that such trends may be sensitive to regional geology, inelastic attenuation (Q), typical thickness of sediments, shape of the source spectrum and on the regional dependence of amplitude attenuation.

To investigate the combined effects of geological and of soil site conditions, the available data (Tables 3a, b and c) was further subdivided into sub-groups corresponding to SS_L = 1,2 and 3. For each of these sub-groups, the observed peak amplitudes were averaged and presented in Tables 4a, b and c. It is seen that the available data is not adequate to provide this information on all combinations of the site parameters. However, for a limited group of site parameter combinations, typically SS_L = 2 and 3, for s = 0 and 1, and for MCS = V − VII, the trends appear to be fairly consistent (with only few exceptions). The peak amplitudes for SS_L = 2 (stiff soil sites) relative to SS_L = 3 («rock» sites) are on the average about 3 times larger. For shear wave velocities of 300 m/sec, for example, and for the corresponding wave lengths of 30 m (for T = 0.1 sec) to 600 m (for T = 2 sec), the thin and stiff soil layers (with thickness from say 10 to 50 m), should indeed result in mainly amplification, with inelastic attenuation playing an insignificant role in the amplitude range corresponding to the data presented here (Trifunac, 1990).

Table 4a – Vertical and horizontal peack accelerations on different geologic (S = 0, 1, 2) and soil (SS_L = 1, 2, 3) site conditions, versus MCS intensities in Yugoslavia.
AVERAGE ACCELERATION PEAKS (cm/sec^2)

		$S = 0$				$S = 1$				$S = 2$			
MCS	SS_L	N^-	VERT. HOR.	N^+	VERT. HOR.	N^-	VERT. HOR.	N^+	VERT. HOR.	N^-	VERT. HOR.	N^+	VERT. HOR.
	1												
IV	2	1	21.4 55.8	1	21.4 55.8	1	10.1 19.9						
	3												
	1												
V	2	8	19.79 42.83	7	18.45 39.35	1	33.23 44.16	1	10.07 19.86	1	4.29 7.87	1	4.29 7.87
	3	7	6.89 17.55	4	8.28 24.65	9	9.76 11.87	3	8.83 11.54				
	1	2	7.50 14.04	2	7.50 14.04								
VI	2	28	30.42 52.48	24	30.37 50.99	12	25.46 50.87	12	24.73 50.76	2	18.11 34.96	2	18.11 34.96
	3	3	11.69 15.62	6	8.36 11.86	9	13.87 18.98	12	10.6 12.6	1	15.54 12.34	1	15.54 12.34
	1												
VII	2	5	38.9 80.9	9	35.9 72.6	2	52.8 97.9	2	57.8 92.1				
	3	4	106.4 254.7	1	30.43 43.01	7	34.9 61.2	8	22.8 38.5	2	31.8 48.8	2	31.8 48.8
	1												
VIII	2			1	23.54 64.07	2	111.4 139.8	3	84.9 112.3				
	3			3	131.6 325.2	2	125.5 233.0	4	92.9 169.8				
	1												
IX	2	2	310.2 307.5	2	310.2 307.5	1	202.7 375.6	1	202.7 375.6				
	3					1	140.9 198.4	1	140.9 198.4				

Table 4b – Vertical and horizontal peack velocities on different geologic (S = 0, 1, 2) and soil (SS_L = 1, 2, 3) site conditions, versus MCS intensities in Yugoslavia.
AVERAGE VELOCITY PEAKS (cm/sec)

		$S=0$				$S=1$				$S=2$			
MCS	SS_L	N^-	VERT. HOR.	N^+	VERT. HOR.	N^-	VERT. HOR.	N^+	VERT. HOR.	N^-	VERT. HOR.	N^+	VERT. HOR.
	1												
IV	2	1	.91 2.05	1	.91 2.05	1	.28 .71						
	3												
	1												
V	2	8	.75 2.25	7	.63 2.04	1	2.73 3.12	1	.28 .71	1	.09 .19	1	.09 .19
	3	7	.13 .34	4	.14 .44	9	.40 .58	3	.38 .59				
	1	2	.15 .51	2	.15 .51								
VI	2	28	.94 2.47	24	.92 2.34	12	1.03 2.66	12	1.17 2.73	2	.96 1.62	2	.96 1.62
	3	3	1.25 1.68	6	.69 .94	9	.65 1.22	12	.47 .73	1	.33 .31	1	.33 .31
	1												
VII	2	5	2.33 5.95	9	1.83 4.69	2	2.74 8.77	2	2.13 7.73				
	3	4	5.50 14.60	1	3.63 4.45	7	1.40 3.95	8	1.06 2.69	2	2.73 3.30	2	2.73 3.30
	1												
VIII	2			1	1.16 4.16	2	5.30 15.99	3	4.28 12.11				
	3			3	6.12 17.99	2	9.49 13.11	4	5.76 9.53				
	1												
IX	2	2	17.88 48.53	2	17.88 48.53	1	17.95 32.61	1	17.95 32.61				
	3					1	11.93 22.13	1	11.93 22.13				

Table 4c – Vertical and horizontal peack displacements on different geologic (S = 0, 1, 2) and soil (SS_L = 1, 2, 3) site conditions, versus MCS intensities in Yugoslavia.
AVERAGE DISPLACEMENT PEAKS (cm)

		$S=0$				$S=1$				$S=2$			
MCS	SS_L	N^-	VERT. HOR.	N^+	VERT. HOR.	N^-	VERT. HOR.	N^+	VERT. HOR.	N^-	VERT. HOR.	N^+	VERT. HOR.
	1												
IV	2	1	.05 .12	1	.05 .12	1	.01 .04						
	3												
	1												
V	2	8	.06 .23	7	.06 .21	1	.39 .50	1	.01 .04	1	.00 .01	1	.00 .01
	3	7	.00 .01	4	0.1 0.1	9	.04 .05	3	.06 .06				
	1	2	.01 .02	2	0.1 0.2								
VI	2	28	.07 .21	24	.05 .19	12	.09 .22	12	.12 .25	2	.17 .23	2	.17 .23
	3	3	.30 .40	6	.15 .20	9	.05 .13	12	.04 .07	1	.01 .02	1	.01 .02
	1												
VII	2	5	.54 1.54	9	.36 1.00	2	.32 1.33	2	.20 .96				
	3	4	2.09 5.21	1	1.39 1.07	7	.14 .58	8	.11 .40	2	.63 .72	2	.63 .72
	1												
VIII	2			1	.10 .36	2	1.07 3.79	3	.82 2.83				
	3			3	3.33 6.59	2	2.67 2.85	4	1.22 1.77				
	1												
IX	2	2	7.24 13.77	2	7.24 13.77	1	8.94 8.32	1	8.94 8.32				
	3					1	4.28 8.31	1	4.28 8.31				

Discussion and conclusions

The trends observed in Figures 4, 5 and 6, showing that all peak amplitudes are amplified by soft geologic site conditions will, of course have to be further confirmed by additional data and by further studies of spectral shapes and their dependence on I_{MCS}, similar to what has been done for the WUS data (Trifunac, 1990). If the observed trends are indeed representative (and can be repeated in future observations of strong motion), this means that the average shape of Fourier spectra of earthquake excitations recorded in Yugoslavia, for the same local magnitude (Lee et al., 1991), and for the same site intensity of shaking, are different from the shape of the spectra of strong earthquake motion in California. It appears now that Fourier and Response Spectra may have larger high frequency amplitudes in Yugoslavia. This must be carefully studied in future analyses for several reasons. First, detailed description and characterization of the observed differences between Yugoslav and WUS data should help in understanding how much are our inferences about the nature of strong ground motion just the accidental consequence of the particular data set and of the parameters describing the geologic environment, earthquake sources and wave attenuation in the WUS. Understanding such differences will help to extrapolate many results and empirical scaling relationships from the WUS to those regions where there is little or no data at present, but correctly and using sound physical principles, which can be verified in this type of a comparative study. Second, careful understanding of these differences shall be of importance to many analyses in earthquake resistant design of important structures. This could mean that the use of attenuation equations of peak acceleration, velocity and displacement, developed with the WUS data and the «standard» shapes of the design spectra, already frequently used in many countries, could be inappropriate and in some instances not conservative.

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