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SM-ROM-GL (STRONG MOTION ROMANIA GROUND LEVEL) DATABASE

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ABSTRACT

The SM-ROM-GL database includes data obtained by the processing of records performed at ground level by the Romanian seismic networks, namely INCERC, NIEP, NCSRR and ISPH-GEOTEC, during recent seismic events with moment magnitude $M_w \geq 5$ and epicenters located in Romania. All the available seismic records were re-processed using the same basic software (from Kinemetrics, Inc.) and the same procedures and options (filtering and baseline correction), in order to obtain a consistent dataset. The database stores computed parameters of seismic motions, i.e. peak values: PGA, PGV, PGD, effective peak values: EPA, EPV, EPD, control periods: T_B, T_C, T_D, spectral values of absolute acceleration, relative velocity and relative displacement, as well as of instrumental intensity (as defined in Sandi and Borcia, 2011a). The fields in the database include: coding of seismic events, stations and records, a number of associated fields (seismic event source parameters, geographical coordinates of seismic stations), links to the corresponding ground motion records, charts of the response spectra of absolute acceleration, relative velocity, relative displacement and instrumental intensity, as well as some other representative parameters of seismic motions. The conception of the SM-ROM-GL database allows for an easy maintenance; such that elementary knowledge of Microsoft Access 2000 is sufficient for its operation.

INTRODUCTION

The SM-ROM-GL database contains results obtained by the processing of earthquake ground motions, recorded by the seismic networks of Romania (INCERC - now part of the National Institute for Research and Development URBAN-INCERC, NIEP - National Institute for Research and Development in Earth Physics, NCSRR - now part of the National Institute for Research and Development URBAN-INCERC and ISPH-GEOTEC). The records were obtained at ground level, during strong seismic events with moment magnitude $M_w \geq 5$ and with epicenters situated in the Vrancea and Banat seismogenic zones. New numerical processing methodologies were developed and

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applied to the records of these earthquakes (i.e. instrumental intensity spectra averaged over different period intervals, response spectrum-based intensities, Arias intensities, destructiveness spectrum-based intensities), being used in defining the seismic action for building research and design and for a better understanding of the structural behaviour of buildings during strong Vrancea and Banat earthquakes.

ADVANCED PROCESSING OF SEISMIC RECORDS OBTAINED AT GROUND LEVEL

First, the initial processing of the recorded accelerograms was performed, i.e. the time-histories (corrected by using an Ormsby filter with 0.16 Hz as Corner Frequency and 25 Hz as Terminal Frequency) of acceleration, velocity and displacement were obtained. Then, the calculation of peak acceleration, *pga*, peak velocity, *pgv*, peak displacement, *pgd*, for the records obtained at ground level and the secondary processing of accelerographic information were performed. Consequently, response spectra (absolute acceleration response spectra, S_{aa}, relative velocity response spectra, S_{vr}, and relative displacement response spectra, S_{dr}) were computed.

Based on these spectra, the "effective" values were estimated, i.e. effective peak ground acceleration, *epa*, effective peak ground velocity, *epv*, effective peak ground displacement, *epd* (all as defined in the Romanian P 100-1/2013 seismic design code), according to the following relations:

$$epa = (\mathrm{S}_{\mathrm{aa}\,averaged\ \ on\ \ 0.4\mathrm{s}})_{\max} / 2.5 \tag{1}$$

$$epv = (\mathrm{S}_{\mathrm{vr}\,averaged\ \ on\ \ 0.4\mathrm{s}})_{\max} / 2.5 \tag{2}$$

$$epd = (\mathrm{S}_{\mathrm{dr}\,averaged\ \ on\ \ 0.4\mathrm{s}})_{\max} / 2.5 \tag{3}$$

The above quantities were obtained by averaging the response spectra computed for a damping ratio n=5%, where (0.4 s) represents the moving average for a 0.4 s time window, performed on the 0.1 s … 4.0 s range. Based on these quantities, the control periods, T_C and T_D, were computed as follows.

$$T_C = 2\pi(epv / epa) \tag{4}$$

$$T_D = 2\pi(epd / epv) \tag{5}$$

Additionally, instrumental intensity measures were computed, Sandi and Borcia (2011a), Sandi and Borcia (2014), as shown in the following.

1. Global instrumental intensities

1.1. The global intensity based on response spectrum, I_S, a measure of ground motion severity, is defined by using the following parameters:

$$EPAM\,(m/s^2) = \max_T S_{aa}\ (T,0.05)/2.5 \tag{6}$$

$$EPVM\,(m/s^2) = \max_T S_{va}\ (T,0.05)/2.5 \tag{7}$$

$$EPDM\,(m/s^2) = \max_T S_{dr}\ (T,0.05)/2.5 \tag{8}$$

where:

- $S_{aa}(T,n)$ is the absolute acceleration response spectrum and $S_{va}(T,n)$ is the absolute velocity spectrum, both expressed as functions of period and damping ratio;
- $S_{dr}(T,n)$ is the relative displacement spectrum, expressed as a function of period; n is the damping ratio, and max_T is the maximum spectral value, for periods, T, between 0.0625 s and 4.0 s.

$$I_S = \log_6(EPAM \cdot EPVM) + 8.0 \tag{9}$$

1.2. The Arias-type intensity:

$$I_A = \log_6 \int [w_g]^2 dt + 7.05 \tag{10}$$

where $w_g(t)$ is the ground acceleration on a horizontal direction.

2. The following quantities were computed, as well, for intensities depending on the frequency φ(Hz).

2.1. Response spectrum-based intensity, $i_s(\varphi)$:

$$i_s(\varphi) = \log_6[S_{aa}(\varphi,0.05) \cdot S_{va}(\varphi,0.05)] + 7.75 \tag{11}$$

2.2. Destructivity spectrum-based intensity, $i_d(\varphi)$, determined from the (absolute) accelerogram $w_a(t,\varphi,0.05)$, for a pendulum having the natural (undamped) frequency φ and a damping ratio of 0.05,

$$i_d(\varphi) = \log_6[\int w_a^2(t,\varphi,0.05)\, dt] + 6.25 \tag{12}$$

3. Intensities based on the application of the averaging rule on a specified frequency band (φ', φ") were computed as well, using the following expressions.

3.1. For the response spectrum-based intensity, $i_s(\varphi)$:

$$i_s^*(\varphi',\varphi'') = \log_6\{1/\ln(\varphi',\varphi'')\int[S_{aa}(\varphi,0.05)d\varphi \cdot S_{va}(\varphi,0.05)d\varphi/\varphi]\} + 7.75 \tag{13}$$

3.2. For the destructivity-based intensity, $i_d(\varphi)$:

$$i_d^*(\varphi',\varphi'') = \log_6\left\{1/\ln(\varphi',\varphi'')\int[(\int w_a^2(t,\varphi,0.05)\, dt)d\varphi/\varphi]\right\} + 6.25 \tag{14}$$

4. Averaging rules for the two horizontal orthogonal directions were also provided.

The following notations were used, as shown in the tables below: Id1 = i_d*(0.25 Hz, 16.0 Hz), for averaging on the whole interval (0,0625 sec – 4,0 sec), Id31= i_d*(0.25 Hz, 1.0 Hz), Id32= i_d*(1.0 Hz, 4.0 Hz), Id33= i_d*(4.0 Hz, 16.0 Hz) for averaging on 3 periods interval (i.e. (1 - 4 sec), (0.25 - 1 sec) and (0.0625 - 0.25 sec)), similar notation conventions being used for averaging on 6 and 12 intervals, respectively.

Table 1. Averaging intervals for instrumental intensities

		Frequency intervals		**Period intervals**	
Is12x	**Id12x**	**Hz**		**sec.**	
Is121	Id121	0,25	0,354	2,825	4
Is122	Id122	0,354	0,5	2	2,825
Is123	Id123	0,5	0,707	1,414	2
Is124	Id124	0,707	1	1	1,414
Is125	Id125	1	1,414	0,707	1
Is126	Id126	1,414	2	0,5	0,707
Is127	Id127	2	2,828	0,354	0,5
Is128	Id128	2,828	4	0,25	0,354
Is129	Id129	4	5,657	0,177	0,25
Is1210	Id1210	5,657	8	0,125	0,177
Is1211	Id1211	8	11,314	0,088	0,125
Is1212	Id1212	11,314	16	0,0625	0,088

Table 1 (cont'd). Averaging intervals for instrumental intensities

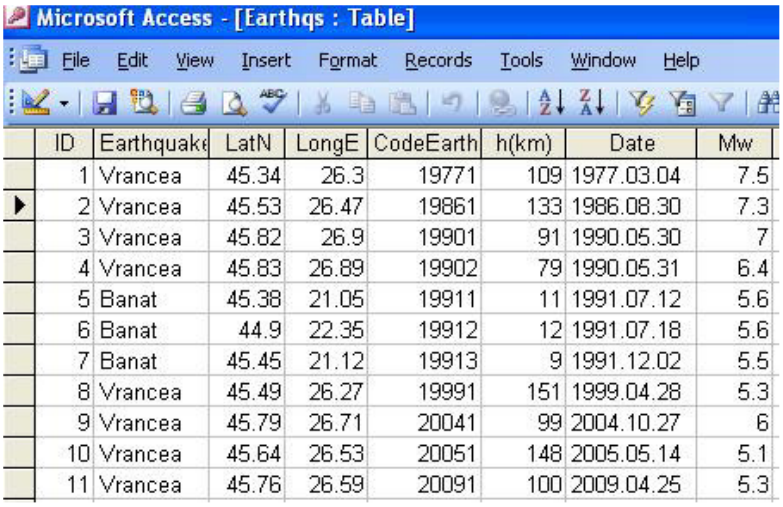
Is6x	**Id6x**	**Hz**		**sec.**	
Is61	Id61	0,25	0,5	2	4
Is62	Id62	0,5	1	1	2
Is63	Id63	1	2	0,5	1
Is64	Id64	2	4	0,25	0,5
Is65	Id65	4	8	0,125	0,25
Is66	Id66	8	16	0,0625	0,125
Is3x	**Id3x**	**Hz.**		**sec.**	
Is31	Id31	0,25	1	1	4
Is32	Id32	1	4	0,25	1
Is33	Id33	4	16	0,0625	0,25
Is1	**Id1**	**Hz.**		**sec.**	
Is1	Id1	0,25	16	0,0625	4

Numerical values for the seismic records of Vrancea and Banat earthquakes with moment magnitude $M_w \geq 5$, obtained from seismic networks in Romania (INCERC, NIEP, NCSRR and ISPH-GEOTEC), were determined by using software applications developed at INCERC. The numerical values and the graphical information thus obtained were used to create four MS Excel tables (SM-ROM-GL.xls) and a MS Access database (SM-ROM-GL.mdb).

DATABASE STRUCTURE

The adopted codifications and the fields associated with various information in the database are given in the following.

- Seismic events (source parameters) are given in table *SM-ROM-GL Earthquakes* (containing information on the 11 earthquakes with $M_w \geq 5$ that occurred between 1977 and 2009, 8 with epicenters located in Vrancea seismogenic zone and 3 with epicentres located in Banat seismogenic zone) (Fig. 1).



ID	Earthquake	LatN	LongE	CodeEarth	h(km)	Date	Mw
1	Vrancea	45.34	26.3	19771	109	1977.03.04	7.5
2	Vrancea	45.53	26.47	19861	133	1986.08.30	7.3
3	Vrancea	45.82	26.9	19901	91	1990.05.30	7
4	Vrancea	45.83	26.89	19902	79	1990.05.31	6.4
5	Banat	45.38	21.05	19911	11	1991.07.12	5.6
6	Banat	44.9	22.35	19912	12	1991.07.18	5.6
7	Banat	45.45	21.12	19913	9	1991.12.02	5.5
8	Vrancea	45.49	26.27	19991	151	1999.04.28	5.3
9	Vrancea	45.79	26.71	20041	99	2004.10.27	6
10	Vrancea	45.64	26.53	20051	148	2005.05.14	5.1
11	Vrancea	45.76	26.59	20091	100	2009.04.25	5.3

Figure 1. Screenshot of table *SM-ROM-GL Earthquakes*

- Seismic stations (geographical coordinates, station code) are given in table *SM-ROM-GL Stations* (containing information on the 166 stations that provided at least one record in one of the earthquakes listed in table *SM-ROM-GL Earthquakes*) (Fig. 2).
- Seismic records are given in table *SM-ROM-GL Records* (Fig. 3), containing information on the 307 records obtained from the networks in Romania, Bulgaria and Moldova. The records were obtained at the above seismic stations during the mentioned earthquakes. For these records, charts are provided for absolute acceleration response spectra, relative velocity spectra and displacement spectra, as well as for instrumental intensity spectra.
- Representative parameters of seismic motion (peak values and "effective" values of acceleration, velocity and displacement, global instrumental intensities and intensities averaged on various period intervals and spectral values for periods whit $\Delta T = 0.05$ sec.) are given in table *SM-ROM-GL Components* (Fig. 4), containing information on the 920 components of the records in table *SM-ROM-GL Records*.

Microsoft Access - [Stations : Table]

ID	Station	Address	CodeStation	LatN	LongE	BuildingHeight	Owner
1	Adjud	ADJUD, 1 Mai 12, Adm Financiara	ADJ	46.095	27.181	GF	INCERC
2	Alexandria	ALEXANDRIA, Libertatii 200A,Proiect SA subsol	ALX	43.965	25.337	GF+2S	INCERC
3	Amara	Amara, boys camp	AMR	44.610	27.335	GF	NIEP
4	ARGES	ARGES	ARR	45.368	24.633	GF	NIEP
5	Bacau	BACAU, Cornisa Bistritei, bl 7B, locuinte	BAC1	46.554	26.916	GF+10S	NIEP
6	BACAU	BACAU	BAC2	46.567	26.9	GF	NIEP
7	Bacau-Prot. Civ.	BACAU, Protectia Civila, Str. George Bacovia	BAC3	46.57	26.902	GF	INCERC
8	Baia –Tulcea	BAIA, Republicii, Scoala	BAA	44.723	28.679	GF+1S	INCERC
9	Baicoi	Ploiesti-Baicoi, collin ab.	PBA	45.037	25.853	GF	NIEP
10	Banloc	Primărie	BNL	45.397	21.131	GF	INCERC
11	Barlad	BARLAD, Epureanu 2, Adapost ALA	BIR1	46.228	27.666	GF	INCERC
12	BARLAD-NIEP	BARLAD	BIR2	46.266	27.626	GF	NIEP
13	Berezeni	Berezeni,Cellar within Loess	BER	46.359	28.150	GF	NIEP
14	Bolintin Vale	BOLINTIN VALE, Primarie	BLV	44.444	25.757	GF	INCERC
15	Botosani	BOTOSANI, Teatrului 1, Teatru Eminescu, Adapost ALA	BTS	47.742	26.663	GF+1S	INCERC
16	BOZVELI	BOZVELI	BOZ	43.105	27.479	GF	Blg
17	Braila	BRAILA, Unirii 72,Bloc turn, locuinte	BRL1	45.269	27.966	GF+10S	INCERC
18	Braila-Prot. Civ.	BRAILA, Protectia Civila, Str. Gradinii publice 13	BRL2	45.273	27.977	GF	INCERC
19	Branesti	BRANESTI, 23 August 4, Liceu silvic	BRN	44.46	26.329	GF	INCERC
20	Brasov	BRASOV, Iuliu Maniu 43,SC Proiect Brasov	BRS1	46.656	25.652	GF+8S	INCERC
21	Brasov-Prot. Civ.	BRASOV, Protectia Civila, Str. Scolii 4	BRS2	45.657	25.584	GF	INCERC
22	Buc. Pipera	Bucharest Pipera , priv.house	PIP	44.514	26.114	GF	NIEP
23	Buc.-Agropul	Bucharest Agropul	POP	44.355	26.203	GF	NIEP

Figure 2. Screenshot of table *SM-ROM-GL Stations*

Microsoft Access - [Records : Table]

ID	Station	CodeEarthq	CodeStation	Saa	Saaln	Srv
1	Adjud	19901	ADJ	19901ADJ1Saa.jpg	19901ADJ1Saaln.jpg	19901ADJ1Srv.jpg
2	Adjud	19902	ADJ	19902ADJSaa.jpg	19902ADJSaaln.jpg	19902ADJSrv.jpg
3	Alexandria	20041	ALX	20041ALXSaa.jpg	20041ALXSaaln.jpg	20041ALXSrv.jpg
4	Buc.-Prot. Civ.	20041	APC	20041APC1Saa.jpg	20041APCSaaln.jpg	20041APCSrv.jpg
5	Buc.-Prot. Civ.	20091	APC	20091APCSaa.jpg	20091APCSaaln.jpg	20091APCSrv.jpg
6	Buc.-Armeneasca	19901	ARM	19901ARMSaa.jpg	19901ARMSaaln.jpg	19901ARMSrv.jpg
7	Buc.-Armeneasca	19902	ARM	19902ARMSaa.jpg	19902ARMSaaln.jpg	19902ARMSrv.jpg
8	ARGES	19901	ARR	19901ARRSaa.jpg	19901ARMSaaln.jpg	19901ARRSrv.jpg
9	Baia –Tulcea	19861	BAA	19861BAASaa.jpg	19861BAASaaln.jpg	19861BAASrv.jpg
10	Baia –Tulcea	19901	BAA	19901BAASaa.jpg	19901BAASaaln.jpg	19901BAASrv.jpg
11	Baia –Tulcea	19902	BAA	19902BAASaa.jpg	19902BAASaaln.jpg	19902BAASrv.jpg
12	Bacau	19861	BAC1	19861BAC1Saa.jpg	19861BAC1Saaln.jpg	19861BAC1Srv.jpg
13	BACAU	19861	BAC2	19861BAC2Saa.jpg	19861BAC2Saaln.jpg	19861BAC2Srv.jpg
14	BACAU	19901	BAC2	19901BAC2Saa.jpg	19901BAC2Saaln.jpg	19901BAC2Srv.jpg
15	BACAU	19902	BAC2	19902BAC2Saa.jpg	19902BAC2Saaln.jpg	19902BAC2Srv.jpg
16	Bacau-Prot. Civ.	20041	BAC3	20041BAC3Saa.jpg	20041BAC3Saaln.jpg	20041BAC3Srv.jpg
17	Barlad	19861	BIR1	19861BIR1Saa.jpg	19861BIR1Saaln.jpg	19861BIR1Srv.jpg
18	Barlad	19901	BIR1	19901BIR1Saa.jpg	19901BIR1Saaln.jpg	19901BIR1Srv.jpg
19	Barlad	19902	BIR1	19902BIR1Saa.jpg	19902BIR1Saaln.jpg	19902BIR1Srv.jpg
20	Barlad	19991	BIR1	19991BIRSaaln.jpg	19991BIRSaaln.jpg	19991BIRSrv.jpg

Figure 3. Screenshot of table *SM-ROM-GL Records*

Microsoft Access - [Components : Table]

File Edit View Insert Format Records Tools Window Help

ID	Station	CodeEarthq	CodeStation	CodeAxis	NrAxis	pga	pgv	pgd	epa	epv	epd	Tc	Td	Is	Is1	Is31	Is32	Is33
1	Adjud	19901	ADJ	N50E	1	0.8214	0.09919	0.0238	0.8037	0.09736	0.03158	0.76	2.04	7.00	6.95	6.77	7.06	6.99
2	Adjud	19901	ADJ	N40W	2	0.8959	0.1044	0.0275	0.9687	0.09505	0.03612	0.62	2.39	7.20	7.09	6.74	7.13	7.27
3	Adjud	19901	ADJ	V	3	1.05	0.04192	0.0068	0	0	0	0	0	7.11	7.03	6.75	7.1	7.15
4	Adjud	19902	ADJ	N40W	1	0.3514	0.0204	0.0035	0.3212	0.02138	0.00651	0.42	1.91	5.81	5.79	4.98	6.06	5.84
5	Adjud	19902	ADJ	N50E	2	0.3646	0.0263	0.003	0.3350	0.01737	0.00643	0.33	2.33	5.99	5.88	5.09	5.87	6.17
6	Adjud	19902	ADJ	V	3	0.3301	0.01061	0.0027	0	0	0	0	0	5.91	5.84	5.04	5.97	6.03
7	Alexandria	20041	ALX	0	1	0.176	0.00625	0.0008	0.1038	0.00629	0.00142	0.38	1.42	4.82	4.75	3.37	4.88	4.99
8	Alexandria	20041	ALX	0	2	0.15559	0.00692	0.0005	0.1143	0.00579	0.00143	0.32	1.55	4.75	4.74	3.02	4.87	5
9	Alexandria	20041	ALX	V	3	0.11288	0.00357	0.0007	0	0	0	0	0	4.79	4.75	3.22	4.87	5
10	Buc.-Prot. Civ.	20041	APC	0	1	0.37059	0.02021	0.0021	0.2531	0.01287	0.00163	0.32	0.8	5.66	5.63	4.16	5.73	5.9
11	Buc.-Prot. Civ.	20041	APC	0	2	0.3314	0.01099	0.001	0.228	0.01017	0.00107	0.28	0.66	5.64	5.51	3.7	5.42	5.89
12	Buc.-Prot. Civ.	20041	APC	V	3	0.22771	0.00551	0.0004	0	0	0	0	0	5.65	5.57	3.98	5.6	5.9
13	Buc.-Prot. Civ.	20091	APC	EW	1	0.09955	0.00323	0.0003	0.0643	0.00257	0.00033	0.25	0.82	4.31	4.23	2.66	4.02	4.64
14	Buc.-Prot. Civ.	20091	APC	NS	2	0.1185	0.00422	0.0008	0.07	0.00351	0.00061	0.32	1.08	4.5	4.42	3.32	4.26	4.80
15	Buc.-Prot. Civ.	20091	APC	V	3	0.12212	0.00322	1E-05	0	0	0	0	0	4.42	4.33	3.09	4.16	4.73
16	Buc.-Armeneasca	19901	ARM	0	1	0.25097	0.81503	0.0815	0.0996	0.00323	0.00029	0.12	0.004	6.91	6.91	6.51	7.18	6.81
17	Buc.-Armeneasca	19901	ARM	0	2	0.31563	1.08346	0.1083	0.0643	0.00257	0.00033	0.07	0.004	6.45	6.45	5.98	6.64	6.52
18	Buc.-Armeneasca	19901	ARM	V	3	0.31563	1.08346	0.1083	0	0	0	0	0	6.73	6.73	6.31	6.98	6.68
19	Buc.-Armeneasca	19902	ARM	0	1	0.2217	0.02048	0.0020	0.2896	0.01897	0.00524	0.41	1.74	5.73	5.73	5.03	6.06	5.65
20	Buc.-Armeneasca	19902	ARM	0	2	0.2342	0.02469	0.0025	0.2510	0.01992	0.00803	0.5	2.53	5.68	5.68	5.19	5.95	5.64
21	Buc.-Armeneasca	19902	ARM	V	3	0.2342	0.02469	0.0025	0	0	0	0	0	5.71	5.71	5.11	6.01	5.64
22	ARGES	19901	ARR	NS	1	0.24632	0.03829	0.0201	0.2653	0.02966	0.01799	0.70	3.81	6.07	5.81	5.25	6.11	5.75
23	ARGES	19901	ARR	EW	2	0.11535	0.02859	0.022	0.1092	0.02031	0.01232	1.17	3.81	5.37	5.26	5.16	5.45	5.11
24	ARGES	19901	ARR	V	3	0.0682	0.02575	0.0205	0	0	0	0	0	5.83	5.61	5.21	5.88	5.53
25	Baia –Tulcea	19861	BAA	N175W	1	0.3127	0.02552	0.0042	0.3591	0.02708	0.00716	0.47	1.66	6.00	5.90	5.07	6.27	5.72
26	Baia –Tulcea	19861	BAA	N85W	2	0.3294	0.03174	0.0058	0.4258	0.03172	0.00723	0.47	1.43	6.26	6.07	5.20	6.45	5.86
27	Baia –Tulcea	19861	BAA	V	3	0.1554	0.0125	0.0033	0	0	0	0	0	6.15	5.99	5.14	6.37	5.79

Figure 4. Screenshot of table *SM-ROM-GL Components*

EXAMPLES OF USE OF THE SM-ROM-GL DATABASE

The use of the information stored in the SM-ROM-GL database is first illustrated by an example that demonstrates the use of the provided spectral charts for observing differences between ground motion frequency content recorded on distinct types of sites.

According to previous studies of Sandi and Borcia (2011b), it was shown that, for seismic stations located in areas affected by strong subcrustal Vrancea earthquakes, the following classification of sites is adequate:

- type (a) sites, where a layer interface with a marked contrast of shear wave propagation velocity is identified; for these sites, a relatively stable spectral content is observed, for several strong events; a representative station for this site type is Cernavoda Town Hall;
- type (b) sites, where such an interface cannot be identified and a variability of spectral content characteristics is observed, from an event to another; a representative station for this site type is INCERC Bucharest.

The absolute acceleration spectra of ground motion records obtained during the strong Vrancea earthquakes of 1977, 1986 and 1990 are shown in Fig. 5, as provided in the SM-ROM-GL database for the two representative stations above.

Due to the inclusion of the geographical coordinates of seismic stations, the spatial distribution of the values provided in the database can also be easily obtained. Examples are given in Fig. 6, where the map of effective peak ground acceleration values (EPA) for the Vrancea earthquake of October 27, 2004 (M_w = 6.0) is shown, and in Fig. 7, where the map of effective peak ground acceleration values (EPA) is presented, for the same earthquake.

CONCLUDING REMARKS

The maintenance of the SM-ROM-GL database and the addition of new records to be obtained in the future will be provided by the developers. The database, along with the users' guide, will be soon available on the BIGSEES project website (http://infp.infp.ro/bigsees/default.htm), becoming thus accessible to any potential user.

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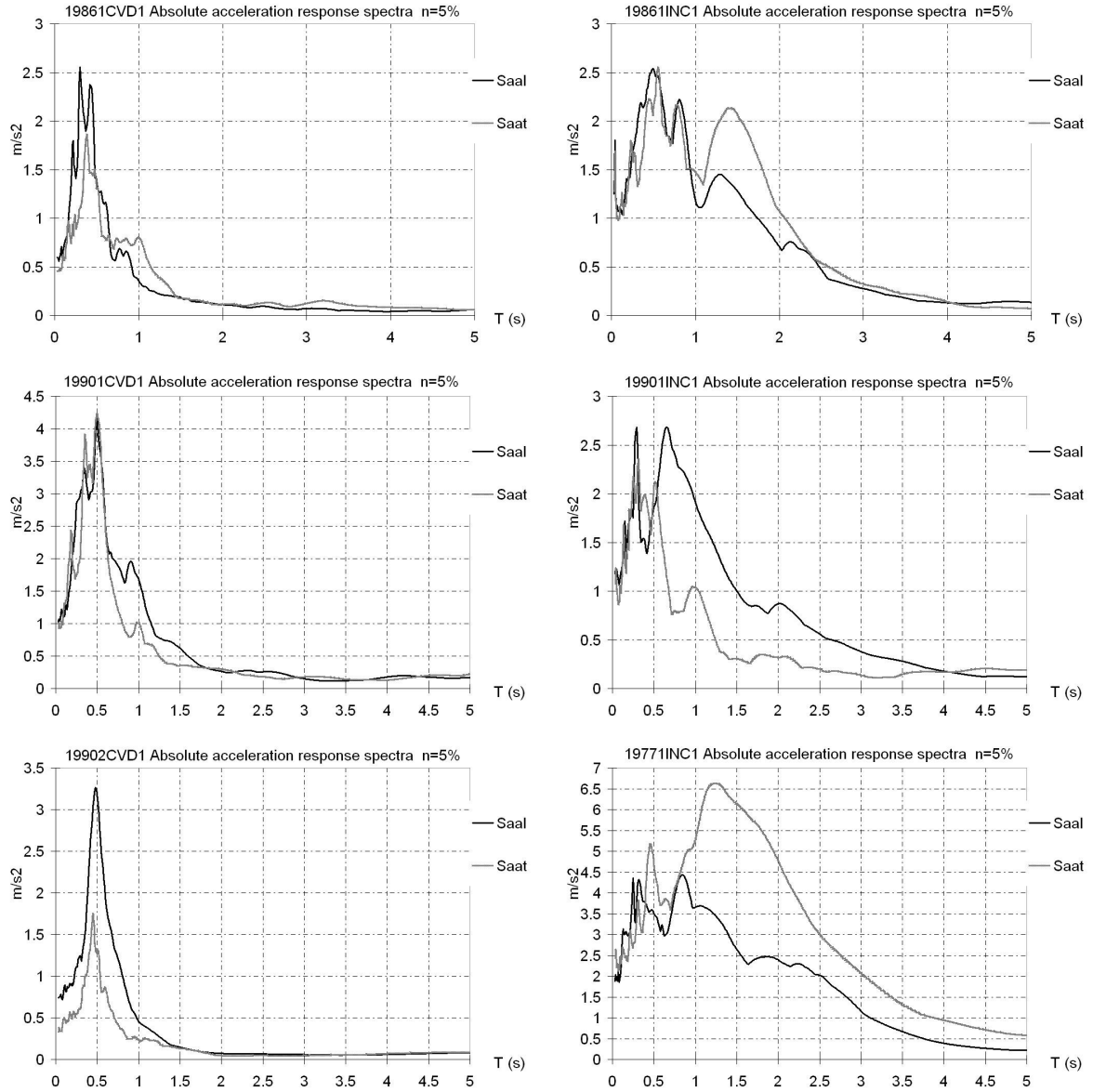

Type (a) station: Cernavoda Town Hall Type (b) station: INCERC Bucharest

Figure 5. Absolute acceleration response spectra for two distinct types of sites, computed for ground motion records obtained during the strong Vrancea earthquakes of 19771, 19861 and 1990(1 and 2)

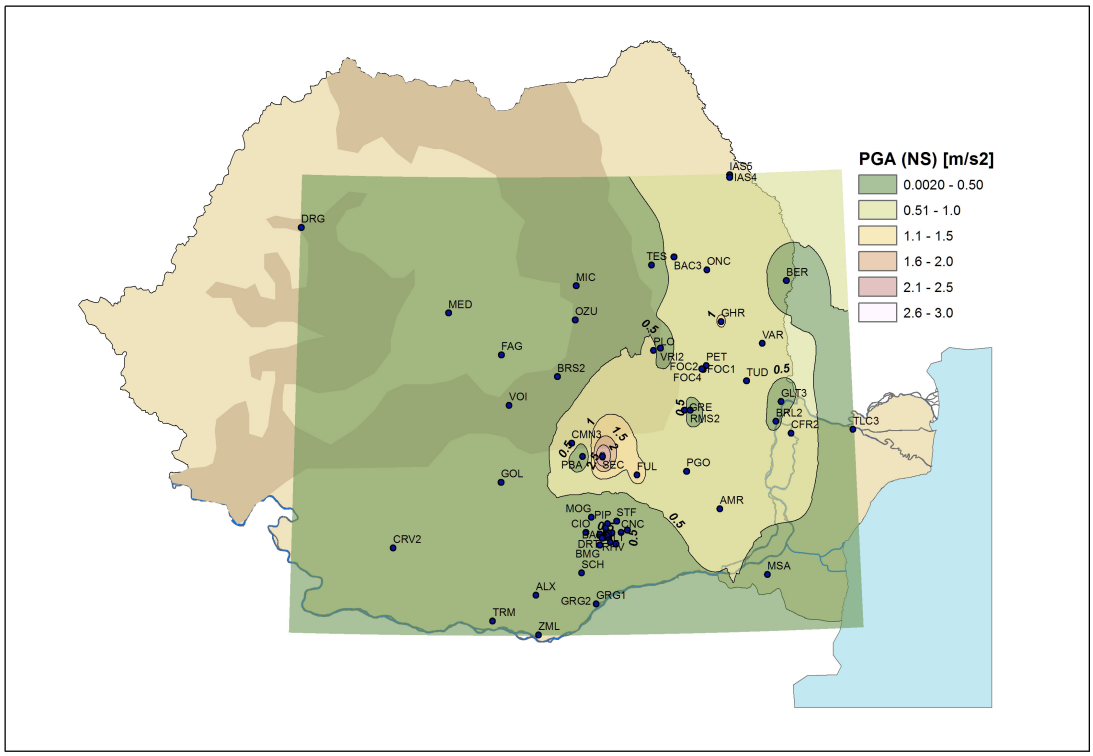

Figure 6. Map of peak ground acceleration values (PGA) for the Vrancea earthquake of October 27, 2004 (NS components)

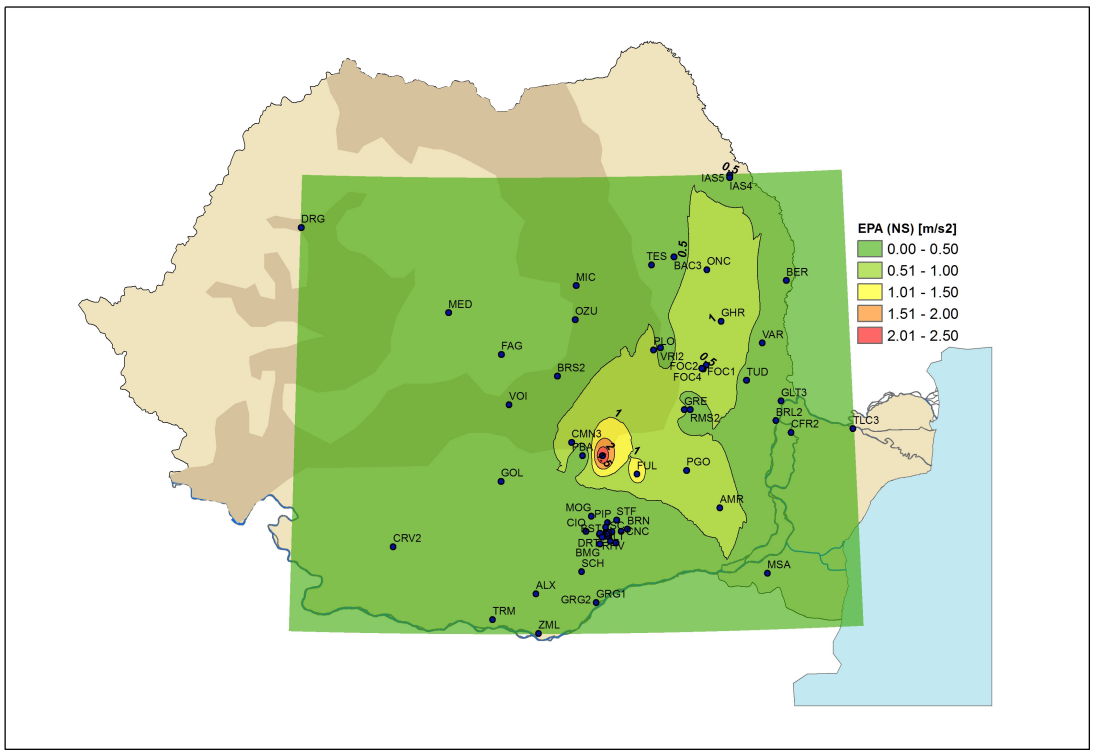

Figure 7. Map of effective peak ground acceleration values (EPA) for the Vrancea earthquake of October 27, 2004 (NS components)