THE SP VRANCEA NT DATABASE. EXAMPLE OF USE FOR A COMPARATIVE ANALYSIS OF RECORDS OBTAINED IN RUSSE (BULGARIA) AND GIURGIU (ROMANIA)

Dr. Ioan Sorin Borcia[1]

Assoc. Prof. Dr. Iolanda-Gabriela Craifaleanu[1,2]

Dr. Florenta-Nicoleta Tanase[1]

Eng. Ioan Constantin Praun[1]

Lect. Dr. Claudiu Sorin Dragomir[1,3]

Lect. Dr. Daniela Dobre[1,2]

Dr. Emil-Sever Georgescu[1]

[1] National Institute for Research and Development in Construction, Urban Planning and Sustainable Spatial Development "URBAN-INCERC", INCERC Bucharest Branch, **Romania**, isborcia@yahoo.com, isborcia@incerc2004.ro
[2] Technical University of Civil Engineering Bucharest, **Romania**
[3] University of Agronomic Science and Veterinary Medicine, Bucharest, **Romania**

ABSTRACT

The SP VRANCEA NT database contains results obtained by the processing of Vrancea earthquake ground motions recorded by the seismic networks of Romania, Bulgaria and Republic of Moldova. The records were obtained at ground level, during strong seismic events with moment magnitude $M_w > 5$ and with epicenters situated in the Vrancea seismogenic zone. The primary (corrected) digitizations of seismic records were obtained, in collaboration, within various Romanian and international research projects. For all records, the database provides the computed values of: peak ground acceleration, peak ground velocity and peak ground displacement, as well as their "effective" values, the corner (control) periods, T_C and T_D, response spectra and instrumental intensity spectra. The SP VRANCEA NT database also includes time-histories of the horizontal components of ground acceleration, instrumental intensity spectra, absolute acceleration response spectra, relative velocity and relative displacement response spectra. The SP VRANCEA NT database is freely downloadable from the INCD URBAN-INCERC website. As an example of database use, a comparative analysis of records obtained in the cities of Russe (Bulgaria) and Giurgiu (Romania) during the May 30, 1990 ($M_w = 7$) Vrancea earthquake is presented.

Keywords: seismic records, instrumental intensity, response spectra, database

INTRODUCTION

The SP VRANCEA NT database contains results obtained by the processing of Vrancea earthquake ground motions recorded by the seismic networks of Romania (INCERC, INCDFP and ISPH-GEOTEC), Bulgaria and Republic of Moldova. The records were obtained at ground level, during strong seismic events with moment magnitude $M_w > 5$

and with epicenters situated in the Vrancea seismogenic zone. New numerical processing methodologies were developed and applied to the records of strong Vrancea 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 behavior of buildings during strong Vrancea earthquakes.

ADVANCED PROCESSING OF SEISMIC RECORDS OBTAINED AT GROUND LEVEL

After performing the initial processing of the recorded accelerograms (i.e. after obtaining the time-histories of (corrected) acceleration, velocity and displacement [3]), the calculation of peak acceleration, *pga*, peak velocity, *pgv*, peak displacement, *pgd*, for the records obtained at ground level, secondary processing of accelerographic information was performed. Consequently, response spectra (absolute acceleration response spectrum, S_{aa}, relative velocity response spectrum, S_{vr}, and relative displacement response spectrum, S_{dr}) were computed.

Based on these spectra, the "effective" measures were estimated, i.e. effective peak ground acceleration, *epa*, effective peak ground velocity, *epv*, effective peak ground displacement, *epd* (as defined in [4] and in Appendix A of the Romanian P 100-1/2006 seismic design code), according to the following relations:

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

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

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

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 for the range 0.1 s … 4.0 s. Based on these quantities, the control periods, T_C and T_D were obtained as follows.

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

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

Additionally, intensity measures were computed, as follows.

Instrumental seismic intensities (alternative definitions)

The interest for new definitions of the instrumental seismic intensity, as well as the developments that it generated, have their starting point in INCERC. These were based on the experience acquired following the earthquake of March 4, 1977, when the elementary instrumental criteria specified by the MSK and MMI macroseismic scales led to results that were not consistent with reality [2], [7].

Two main ways of obtaining complex instrumental criteria [7] were used: first, destructivity spectra were defined, which can be extended to tensor characteristics [5], [6], as generalization of the Arias approach [1]; second, the intensity (response)

spectrum was defined, based on absolute acceleration response spectra and absolute velocities [8].

Two requirements were considered in the development of the instrumental seismic intensity concepts synthesized in [8]:

- obtaining the best possible compatibility with traditional macroseismic scales,
- achieving a flexible and practical tool for the cases requiring more detailed information than that could be provided by a global measure of seismic intensity.

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.

$$I_S = \log_{7.5}(EPAM \cdot EPVM) + 8.0 \tag{9}$$

1.2. The *Arias-type intensity*:

$$I_A = \log_{7.5} \int [w_g]^2 dt + 7.14 \tag{10}$$

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*, $i_s(\varphi)$:

$$i_s(\varphi) = \log_{7.5}[S_{aa}(\varphi,0.05) \cdot S_{va}(\varphi,0.05)] + 7.79 \tag{11}$$

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,

$$i_d(\varphi) = \log_{7.5}[\int w_a^2(t,\varphi,0.05)\ dt] + 6.45 \tag{12}$$

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, $i_s(\varphi)$:

$$i_s^*(\varphi',\varphi'') = \log_{7.5}\left\{1/\ln(\varphi',\varphi'')\int [S_{aa}(\varphi,0.05)d\varphi \cdot S_{va}(\varphi,0.05)d\varphi/\varphi]\right\} + 7.79 \tag{13}$$

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

$$i_d^*(\varphi',\varphi'') = \log_{7.5}\left\{1/\ln(\varphi',\varphi'')\int[(\int w_a^2(t,\varphi,0.05)\,dt)d\varphi/\varphi]\right\}+6.45 \qquad (14)$$

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

Numerical values for the seismic records of Vrancea earthquakes with moment magnitude, M_w, higher than 5, obtained from seismic networks in Romania (INCERC, INCDFP and ISPH-GEOTEC), Bulgaria and Republic of Moldova, 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 (SP VRANCEA NT.xls) and a MS Access database (SP VRANCEA NT.mdb).

THE STRUCTURE OF THE DATABASE WITH RESULTS FROM THE PROCESSING OF VRANCEA EARTHQUAKE RECORDS

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

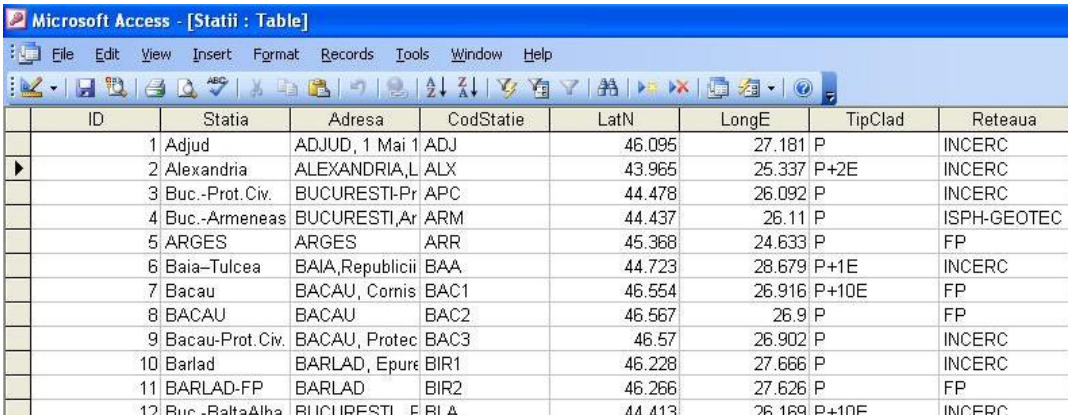
- Seismic events (source parameters) are given in Table SP VRANCEA NT *Earthquakes* (containing information on the eight Vrancea earthquakes with $M_w > 5$ that occurred between 1977 and 2009) (Fig. 1).
- Seismic stations (geographical coordinates, station code) are given in Table SP VRANCEA NT *Stations* (containing information on the 94 stations that provided at least one record in one of the earthquakes listed in the table SP VRANCEA NT *Earthquakes*) (Fig. 2).
- Seismic records are given in Table SP VRANCEA NT *Records* (Fig. 3), containing information on the 205 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, graphic representations 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) are given in Table SP VRANCEA NT *Components* (Fig. 4), containing information on the 615 record components in the table VRANCEA NT SP *Records*.

Microsoft Access - [Seisme : Table]

File Edit View Insert Format Records Tools Window Help

ID	Seism	LatN	LongE	CodSeism	h(km)	Data	Mw
1	Vrancea M (G-F	45.34	26.30	19771	109	1977.03.04	7.5
2	Vrancea M (G-F	45.53	26.47	19861	133	1986.08.30	7.3
3	Vrancea M (G-F	45.82	26.90	19901	91	1990.05.30	7
4	Vrancea M (G-F	45.83	26.89	19902	79	1990.05.31	6.4
5	Vrancea M (G-F	45.49	26.27	19991	151	1999.04.28	5.3
6	Vrancea M (G-F	45.79	26.71	20041	99	2004.10.27	6
7	Vrancea M (G-F	45.64	26.53	20051	148	2005.05.14	5.1
8	Vrancea M (G-F	45.76	26.59	20091	100	2009.04.25	5.3

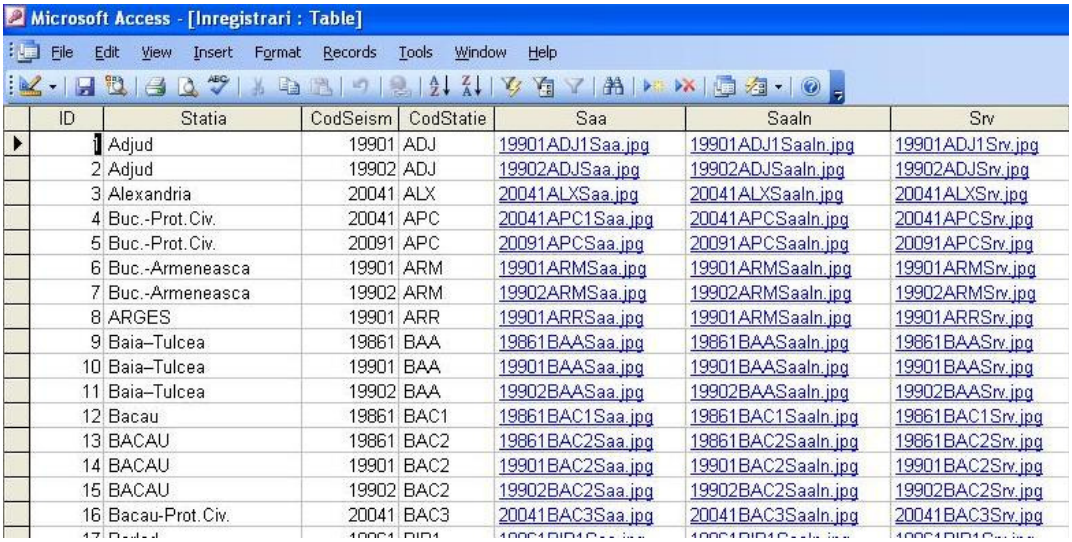
Fig. 1. Screenshot of Table SP VRANCEA NT *Earthquakes*


Microsoft Access - [Statii : Table]

File Edit View Insert Format Records Tools Window Help

ID	Statia	Adresa	CodStatie	LatN	LongE	TipClad	Reteaua
1	Adjud	ADJUD, 1 Mai 1	ADJ	46.095	27.181	P	INCERC
2	Alexandria	ALEXANDRIA,L	ALX	43.965	25.337	P+2E	INCERC
3	Buc.-Prot.Civ.	BUCURESTI-Pr	APC	44.478	26.092	P	INCERC
4	Buc.-Armeneas	BUCURESTI,Ar	ARM	44.437	26.11	P	ISPH-GEOTEC
5	ARGES	ARGES	ARR	45.368	24.633	P	FP
6	Baia–Tulcea	BAIA,Republicii	BAA	44.723	28.679	P+1E	INCERC
7	Bacau	BACAU, Cornis	BAC1	46.554	26.916	P+10E	FP
8	BACAU	BACAU	BAC2	46.567	26.9	P	FP
9	Bacau-Prot.Civ.	BACAU, Protec	BAC3	46.57	26.902	P	INCERC
10	Barlad	BARLAD, Epure	BIR1	46.228	27.666	P	INCERC
11	BARLAD-FP	BARLAD	BIR2	46.266	27.626	P	FP
12	Buc.-BaltaAlba	BUCURESTI, F	BLA	44.413	26.169	P+10E	INCERC

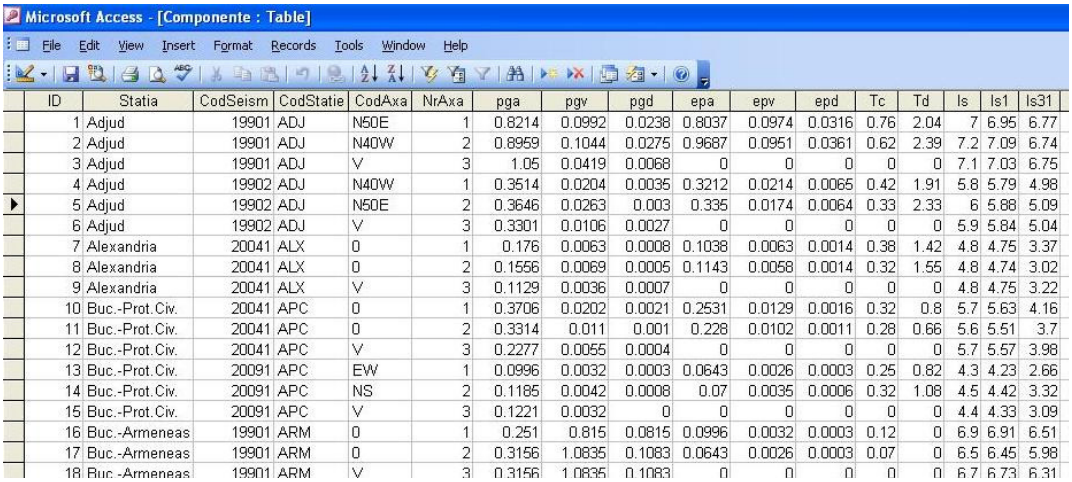
Fig. 2. Screenshot of Table SP VRANCEA NT *Stations*


Microsoft Access - [Inregistrari : Table]

File Edit View Insert Format Records Tools Window Help

ID	Statia	CodSeism	CodStatie	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

Fig. 3. Screenshot of Table SP VRANCEA NT *Records*


Microsoft Access - [Componente : Table]

File Edit View Insert Format Records Tools Window Help

ID	Statia	CodSeism	CodStatie	CodAxa	NrAxa	pga	pgv	pgd	epa	epv	epd	Tc	Td	Is	Is1	Is31
1	Adjud	19901	ADJ	N50E	1	0.8214	0.0992	0.0238	0.8037	0.0974	0.0316	0.76	2.04	7	6.95	6.77
2	Adjud	19901	ADJ	N40W	2	0.8959	0.1044	0.0275	0.9687	0.0951	0.0361	0.62	2.39	7.2	7.09	6.74
3	Adjud	19901	ADJ	V	3	1.05	0.0419	0.0068	0	0	0	0	0	7.1	7.03	6.75
4	Adjud	19902	ADJ	N40W	1	0.3514	0.0204	0.0035	0.3212	0.0214	0.0065	0.42	1.91	5.8	5.79	4.98
5	Adjud	19902	ADJ	N50E	2	0.3646	0.0263	0.003	0.335	0.0174	0.0064	0.33	2.33	6	5.88	5.09
6	Adjud	19902	ADJ	V	3	0.3301	0.0106	0.0027	0	0	0	0	0	5.9	5.84	5.04
7	Alexandria	20041	ALX	0	1	0.176	0.0063	0.0008	0.1038	0.0063	0.0014	0.38	1.42	4.8	4.75	3.37
8	Alexandria	20041	ALX	0	2	0.1556	0.0069	0.0005	0.1143	0.0058	0.0014	0.32	1.55	4.8	4.74	3.02
9	Alexandria	20041	ALX	V	3	0.1129	0.0036	0.0007	0	0	0	0	0	4.8	4.75	3.22
10	Buc.-Prot.Civ.	20041	APC	0	1	0.3706	0.0202	0.0021	0.2531	0.0129	0.0016	0.32	0.8	5.7	5.63	4.16
11	Buc.-Prot.Civ.	20041	APC	0	2	0.3314	0.011	0.001	0.228	0.0102	0.0011	0.28	0.66	5.6	5.51	3.7
12	Buc.-Prot.Civ.	20041	APC	V	3	0.2277	0.0055	0.0004	0	0	0	0	0	5.7	5.57	3.98
13	Buc.-Prot.Civ.	20091	APC	EW	1	0.0996	0.0032	0.0003	0.0643	0.0026	0.0003	0.25	0.82	4.3	4.23	2.66
14	Buc.-Prot.Civ.	20091	APC	NS	2	0.1185	0.0042	0.0008	0.07	0.0035	0.0006	0.32	1.08	4.5	4.42	3.32
15	Buc.-Prot.Civ.	20091	APC	V	3	0.1221	0.0032	0	0	0	0	0	0	4.4	4.33	3.09
16	Buc.-Armeneas	19901	ARM	0	1	0.251	0.815	0.0815	0.0996	0.0032	0.0003	0.12	0	6.9	6.91	6.51
17	Buc.-Armeneas	19901	ARM	0	2	0.3156	1.0835	0.1083	0.0643	0.0026	0.0003	0.07	0	6.5	6.45	5.98
18	Buc.-Armeneas	19901	ARM	V	3	0.3156	1.0835	0.1083	0	0	0	0	0	6.7	6.73	6.31

Fig. 4. Screenshot of Table SP VRANCEA NT *Components*

In the following, the numeric sections (Tables 1 and 2) and the graphic sections of the NT SP VRANCEA database are presented comparatively for two records obtained during the May 30, 1990 earthquake, i.e. the 19901RUS record (obtained in RUSSE, Bulgaria) and for the 19901GRG1 record (obtained in GIURGIU, Romania), as follows: time histories for the horizontal components of the acceleration (Figs. 5 and 6), spectral intensities $i_s\tilde{}(\varphi\ ', \varphi')$ (Is6) and $i_d\tilde{}(\varphi\ ', \varphi')$ (Id6), averaged over 6 intervals of 6 dB for horizontal components (Fig. 7) and response spectra for absolute acceleration, relative velocity and relative displacement, respectively (Figs. 8 ... 10).

Table 1. Stations and earthquake characteristics (English translation)

Station	**StationCode**	**LatN**	**LongE**	**BldgType**	**Network**	
GIURGIU	GRG1	43.893	25.982	P+6E	INCERC	
RUSSE	RUS	43.864	26.014	P	BULGARIA	
Earthq	**LatN**	**LongE**	**EarthqCode**	**h(km)**	**Date**	**M_w**
Vrancea	45.820	26.9	19901	91	1990.05.30	7

Table 2. Numerical values resulting from record processing

Station	**Axis Code**	**pga**	**pgv**	**pgd**	**epa**	**epv**	**epd**	**Tc**	**Td**	**Is1**	**Ia**	**Id1**
GIURGIU	N-S	1.085	0.092	0.011	1.197	0.091	0.0096	0.48	0.67	7.10	7.03	7.04
GIURGIU	E-W	0.501	0.041	0.006	0.695	0.049	0.0086	0.44	1.11	6.53	6.86	6.87
RUSSE	N20E	0.873	0.041	0.029	0.795	0.040	0.0203	0.32	3.19	6.63	6.99	6.96
RUSSE	E20S	1.124	0.066	0.022	1.070	0.061	0.0154	0.36	1.60	6.96	7.29	7.26

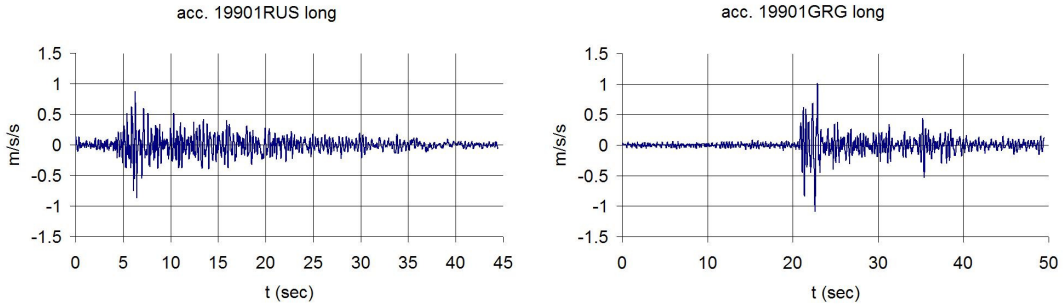


Fig. 5. Accelerograms (longitudinal components) recorded in RUSSE and GIURGIU

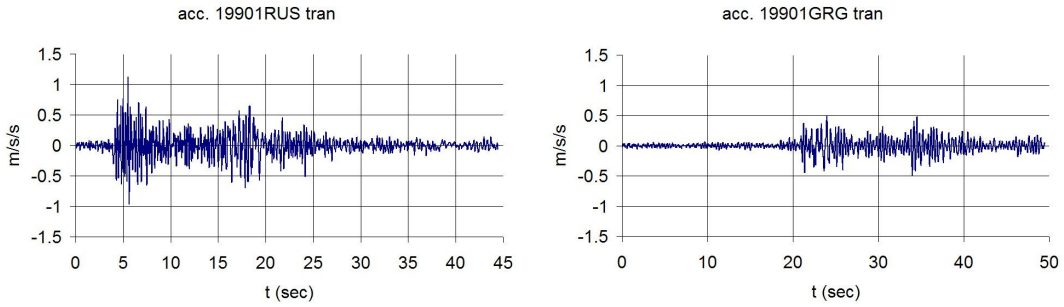


Fig. 6. Accelerograms (transversal components) recorded in RUSSE and GIURGIU

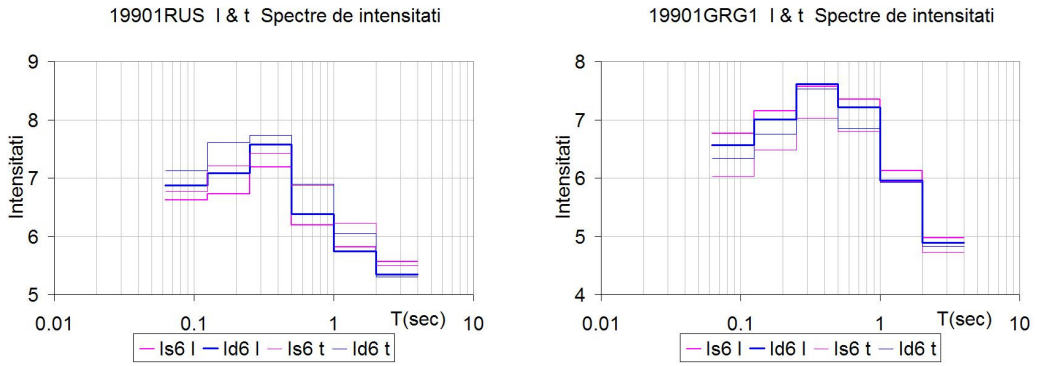


Fig. 7. Spectra of $i_s\tilde{}(\varphi', \varphi'')$ (Is6) and $i_d\tilde{}(\varphi', \varphi'')$ (Id6) intensities, averaged over 6 frequency intervals, for the two horizontal components (longitudinal *l* and transversal *t*) of the 19901RUS and 19901GRG1 seismic records

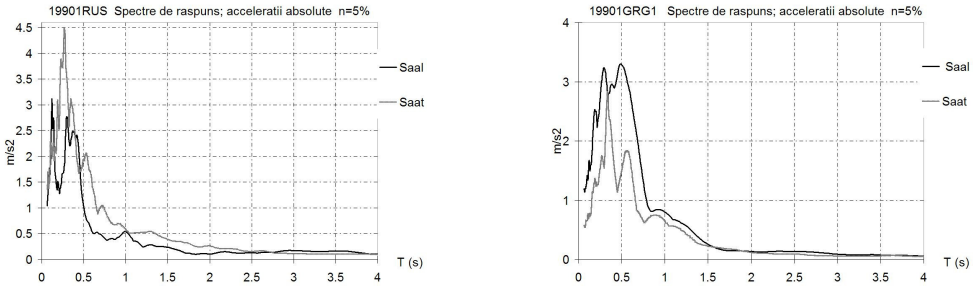


Fig. 8. Absolute acceleration response spectra: 19901RUS and 19901GRG1 seismic records

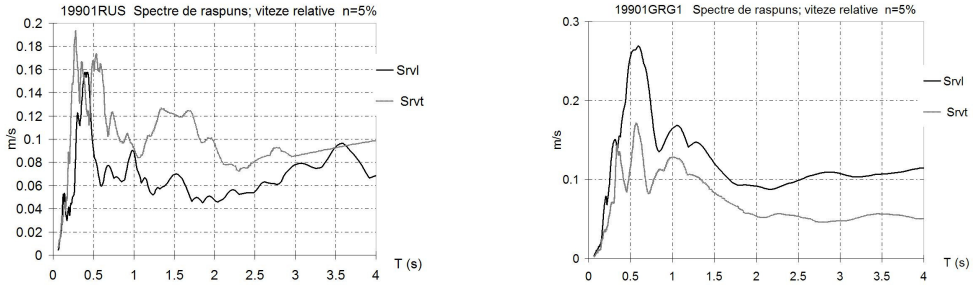


Fig. 9. Relative velocity response spectra: 19901RUS and 19901GRG1 seismic records

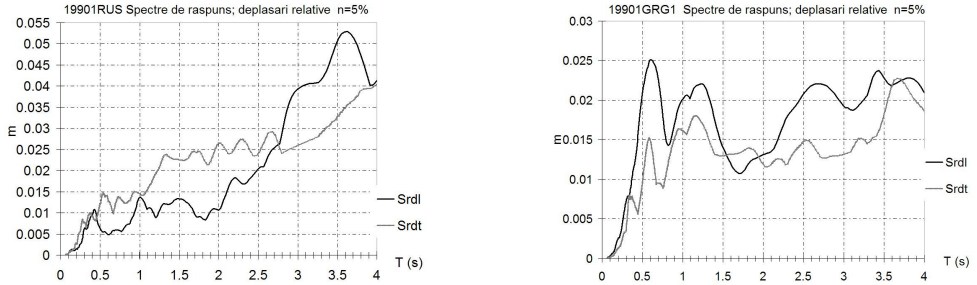


Fig. 10. Relative displacement response spectra: 19901RUS and 19901GRG1 seismic records

The values of the response spectra, as well as those of instrumental intensity spectra are, generally, quite similar for the two records considered. The maximum values of instrumental intensity spectra (Fig. 7) occur, for both records, in the period range 0.25...0.50 s. However, for the Giurgiu record, the values of the instrumental intensity spectra in the range 0.5...1.0 s are greater by almost 0.5 degrees. For the acceleration response spectra, the maximum spectral amplification occurs at $T = 0.3$ s for Russe and at $T = 0.5$ s for Giurgiu. The differences between the spectral acceleration values for the two analyzed records (Figures 5...10) appear due to the different filtering parameters, as well as to the different locations of the stations which provided the records. Thus, the accelerometer in RUSSE is located in free-field conditions, while the accelerometer in GIURGIU is located at the first floor of a three-story building.

FINAL CONSIDERATIONS

Primary (corrected) digitizations of seismic records obtained from the networks that are monitoring Vrancea seismic activity were obtained, in collaboration, within various Romanian and international research projects. Thus, the INCDFP records were obtained during the "MENER" project, within Contract 090/2001 (2001-2004); the ISPH-GEOTEC records were obtained during the "MENER" project, contract 092/2001 (2001-2003); the records from the Republic of Moldova were obtained during the NATO SfP 981619 project (2005-2008) (Institute of Geology and Seismology of the Academy of Sciences, Chisinau); the records from Bulgaria have been obtained during the NATO SfP 980468 project (2005-2008) from the Central Laboratory for Seismic Mechanics and Earthquake Engineering, Sofia.

The ***SP VRANCEA NT*** database is available for download at the address http://www.incerc.ro/date/isb/spvrant.zip.

REFERENCES

[1] Arias A. A measure of earthquake intensity, Seismic Design for nuclear power plants, R. J. Hansen, Ed., Cambridge, Massachussets, The MIT Press, 1970.
[2] Aptikaev F. Instrumental seismic intensity scale, Proc. Symposium on the 40th anniversary of IZIIS, Skopje, FYROM, 2005.
[3] Borcia I. S. Data processing of strong motion records obtained during Vrancea earthquakes (in Romanian), Matei-Teiu Botez Publishing House, Iasi, Romania, 2008.
[4] Dubina D., Lungu D. (coord.). Buildings located in areas with strong earthquakes (in Romanian), Orizonturi Universitare Editions, Timisoara, Romania, 2003.
[5] Sandi H. Measures of ground motion. Proc. 2nd US Nat. Conf. on Earthquake Engineering, Stanford Univ., U.S.A., 1979.
[6] Sandi H. Refinements in characterizing ground motion, Proc. 7th WCEE, Istanbul, Turkey, 1980.
[7] Sandi H., Aptikaev F., Borcia I. S., Erteleva O. & Alcaz V. Quantification of seismic action on structures, AGIR Publishing House, Bucharest, Romania, 2010.
[8] Sandi H. & Borcia, I. S. Intensity spectra versus response spectra: Basic concepts and applications, Pure and Applied Geophysics, Springer, Netherlands, Volume 168, No. 1-2, pp. 261-287, 2011.