RECORDED ACCELEROGRAMS DURING STRONG VRANCEA EARTHQUAKES AND THE P 100-1/2006 ROMANIAN SEISMIC DESIGN CODE

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SUMMARY:
A combined method of scaling the recorded accelerograms (in the range of the dominant spectral amplification periods - scaling in time (with changes in also the periods), followed by a scaling in the field of acceleration's amplitude) was developed: in order to obtain a set of design accelerograms for the application of the provisions of item "3.1.3. Recorded accelerograms." of the P 100-1 / 2006 Romanian seismic design code; and all the accelerograms thus scaled should have an Arias type instrumental intensity of a controlled value. It was obtained a set of 10 accelerograms for Bucharest, scaled by the combined approach, all with Arias type instrumental intensity equal to 8.4, and in period range 0.0625 sec. - 2.71 sec., mean spectrum of all the 10 accelerogram spectra exceed 90% of the Bucharest regulatory spectrum.

Keywords: Seismic intensity, Instrumental criteria, Spectral contents, Record selection, Spectral matching.

1. INTRODUCTION

In the Romanian National Annex of (CEN, 2004) is stated that in Romania the ground classification scheme (A, B, C, D, E, S1 and S2) from (CEN, 2004) is not applicable in present. For design, the local site conditions are classified in 3 zones/sites, A, B, C, based on accelerograms recorded during 1977, 1986 and 1990 Vrancea earthquakes (Sandi&Borcia, 2011a), zones characterized by the values of the control period of the response spectra, Tc, as follow: for A Tc=0.7, for B Tc=1.0 and for C Tc=1.6, and according to the Figure 1. Zonation of the Romanian territory in terms of values of the design ground acceleration ag is presented in Figure 2, while the Normalized elastic response spectra for Romania are presented in Figure 3.
Seismic zoning in Romanian P100-1/2006 Seismic Design Code (MTCT, 2006) is bi-parametric and so, for each distinct area of ag and Tc values it is necessary to be defined a system of accelerograms (all with Arias type instrumental intensity equal to 8.4) to provide an arithmetic mean of their response spectra in acceleration at least 90% of the elastic response spectrum of the area, areas resulting from overlapping maps in Figures 2 and 3 of the Code.
An alternative system of instrumental intensities was drawn up (instrumental intensities based on response spectra, based on Fourier spectra, based on destructivity spectra and instrumental intensities spectra based on Arias type integral) which is proved to be compatible with the macro-seismic intensities (Sandi et al., 2010). The Arias type intensity I_A is provided by the following expression (Sandi et al., 2010), (Sandi&Borcia, 2011b):

$$I_A = \log_{7.5} \int [w_g(t)]^2 dt + 7.14 \quad (1.1)$$

(w_g (t): ground motion acceleration).

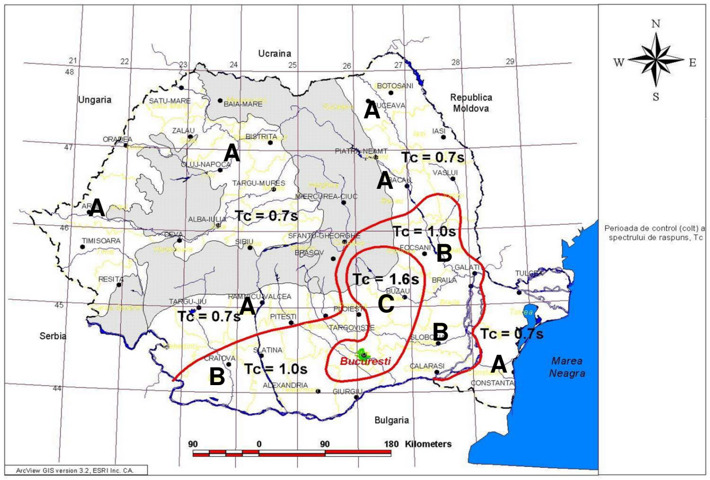


Figure 1 Zonation of the Romanian territory in terms of control period (corner period) Tc

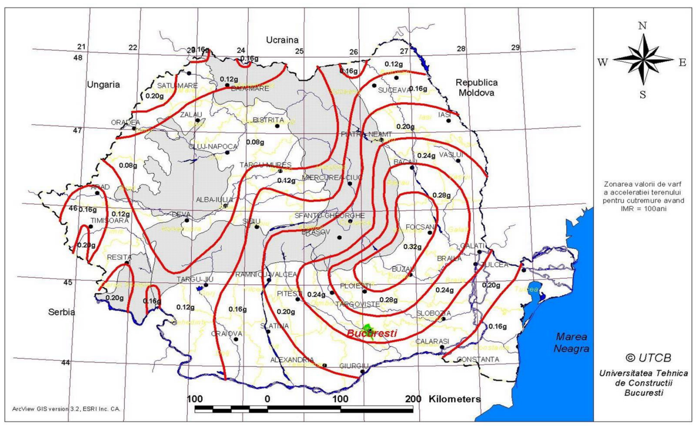


Figure 2 Zonation of the Romanian territory in terms of values of the design ground acceleration ag

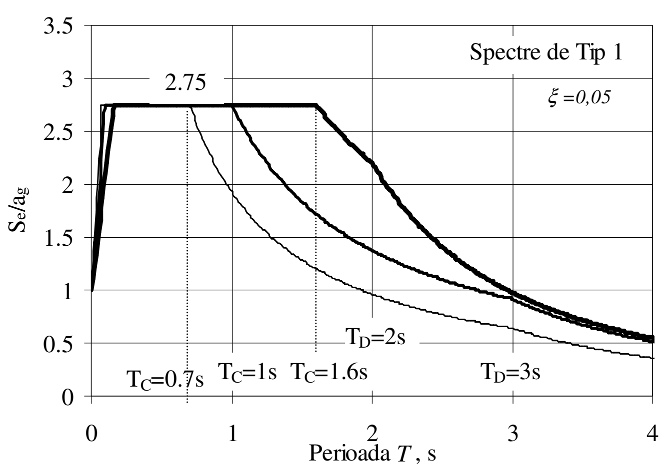


Figure 3 Normalized elastic response spectra for Romania

2. SCALING IN TIME DOMAIN WITH PRESERVING THE INITIAL ARIAS TYPE INTENSITY

It is showed in (Borcia, 2011) that, for Bucharest, Focsani, Vaslui and Cernavoda sites, the mean spectrum of the spectra of the recorded accelerograms, accelerogram scaled in amplitude so that pga arrive at ag of the site, is much smaller than the elastic response spectrum corresponding to the site in large domains.

If a record of a strong earthquake is available, for instance the accelerogram recorded at INCERC on 1977.03.04 (which in fact was the main support in the calibration of the Romanian code spectrum), this may/should be scaled in the time range (which also represents a scaling in the periods range), so as to provide an accelerogram with the maximum amplification at the desired period, but which should be then scaled in the acceleration amplitude range (which in general represents the usual pga scaling) so that the accelerograms preserves the initial value of the Arias intensity. It is obvious that the scaling in time domain (time step changes) alters the frequency content of the initial accelerogram and the accelerogram thus obtained can be considered as an artificial accelerograms.

It is considered that the aspects presented in (Borcia, 2011) certify the validity of scaling the recorded accelerograms by the method presented (first scaling in the range of the periods (in the time range) and then scaling in terms of the accelerations amplitudes in order to reach the initial Arias intensity).

3. DEFINITION OF A SET OF DESIGN ACCELEROGRAMS FOR BUCHAREST

Were chosen, after a careful analysis of response spectra of accelerogram recorded during the Vrancea earthquake of August 30, 1986, the records obtained at sites Magurele (codified 86MAG) and EREN (86EXP), and, of course, the record of 4 March 1977 in Bucharest INCERC (77INC).

Horizontal components of the three records were scaled, each in the amplitudes field so that the intensity of each instrumental type Arias intensity, Ia, is equal to 8.4 and the corresponding pga is at least 0.24 g (ag prescribed in the code P 100-1/2006), resulting 77incl, 77inct, 86magl, 86magt, 86expl, 86expt components.

Table 1 Correspondence accelerogram (Table 2) – absolute acceleration response spectrum (Figure 4), Pga acceleration peak values and time step Δt

	86expl	**86expt**	**77incl**	**77inct**	**771pincl**
Δt (s)	0.01000	0.01000	0.00500	0.00500	0.00411
Pga (m/s2)	4.97	3.82	3.53	3.13	3.90
Pga initial	1.61	1.06	1.88	2.07	
Ia initial	7.28	7.13	7.77	7.99	
Ia (pga=0.24g)	7.66	7.92	8.00	8.12	
	771pinct	**771p6incl**	**771p6inct**	**86magl**	**86magt**
Δt (s)	0.00411	0.00658	0.00658	0.01000	0.01000
Pga (m/s2)	3.45	3.08	2.72	3.80	3.62
Pga initial				1.35	1.15
Ia initial				7.38	7.20
Ia (pga=0.24g)				7.93	8.01

To obtain a set of accelerograms to approximate (arithmetic mean of the response spectra) the code spectrum, scaling first in time field and then scaling in amplitudes field for record 77INC, where used. Thus were obtained new accelerogram components 771p6inc (with maximum spectral amplification at T = 1.6 sec.) and 771pinc (with maximum spectral amplification at T = 1.0 sec.).

The absolute acceleration response spectra for the 10 accelerograms scaled at Ia= 8.40 were obtained which, together, fairly match the code spectrum for Bucharest, are presented in Figures 4 and 5.

The following aspects are to be noticed (Figure 5):

- in the range of periods 0.0625 sec. – 2.72ec. all the spectra mean values of the 10 accelerograms (MED) exceed 90% of the P100-1/2006 spectrum value,
- in the range of periods 2.73c. – 3.32 sec. all the spectra mean values of the 10 accelerograms

(MED) exceed 80% of the P100-1/2006 spectrum value and

- in the range of periods 3.33 sec. – 4.0 sec. all the spectra mean values of the 10 accelerograms (MED) exceed 71% of the P100-1/2006 spectrum value.

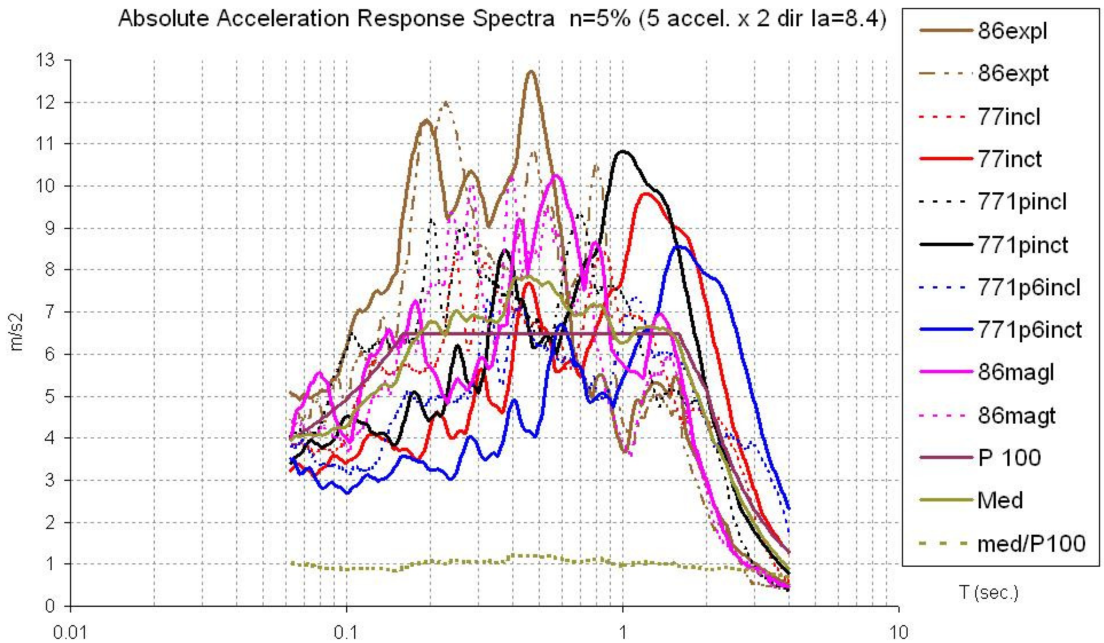


Figure 4 Absolute acceleration response spectra for the 10 accelerograms scaled at Ia = 8.40 which, together, fairly approximate the code spectrum for Bucharest (logarithmic scale in abscissa).

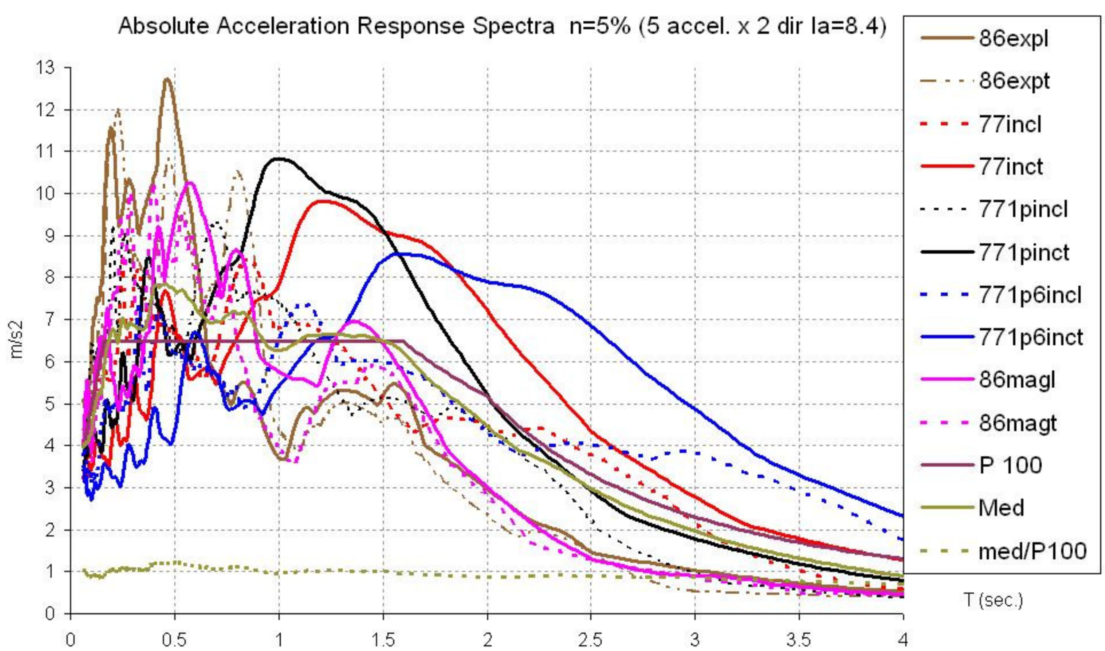
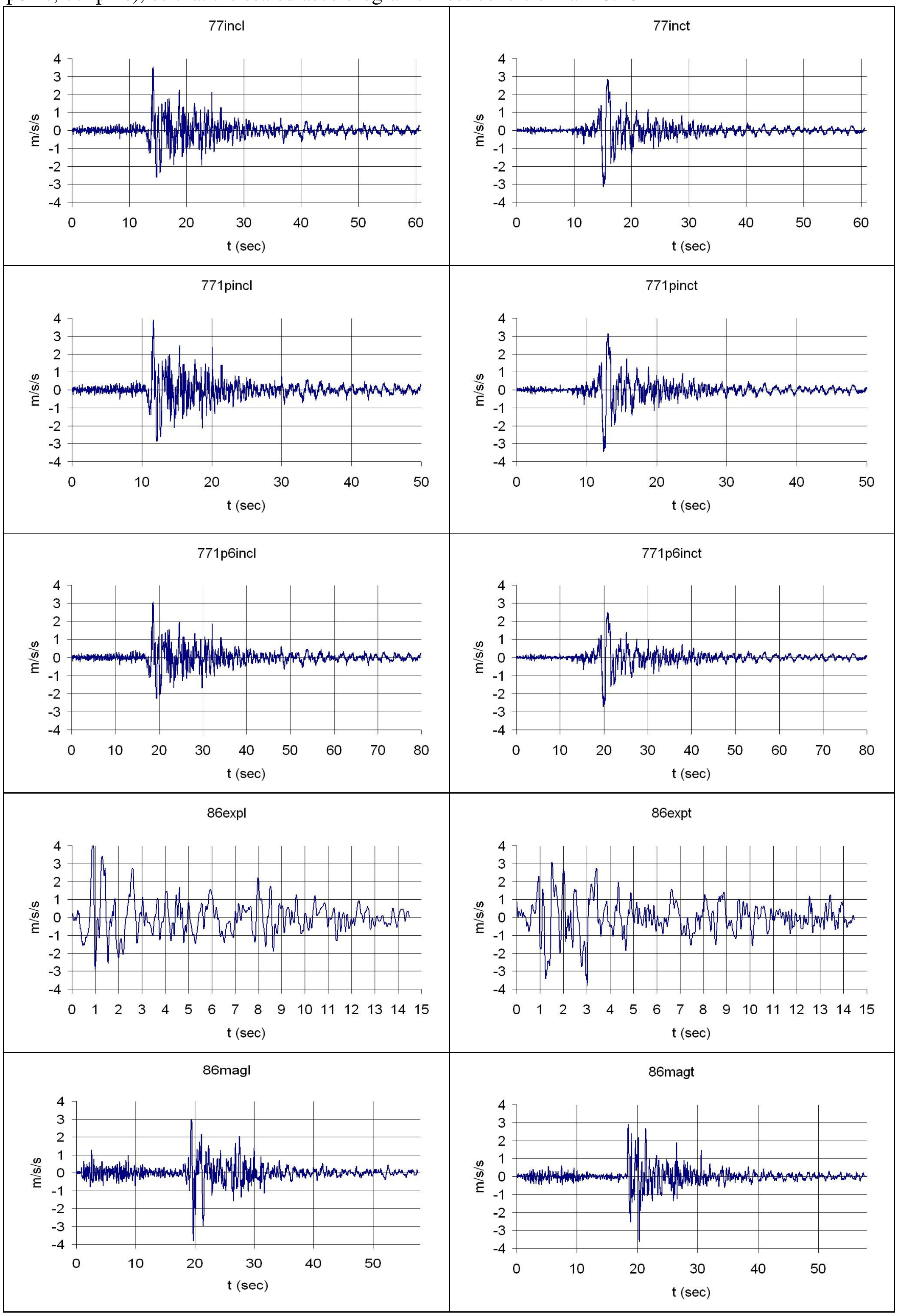


Figure 5 Absolute acceleration response spectra for the 10 accelerograms scaled at IA = 8.40 which, together, fairly approximate the code spectrum for Bucharest

Table 2 Accelerograms scaled in the ranges: - amplitude (86mag, 86exp, 77inc); - amplitude and time (771p6inc, 771pinc), so that the scaled accelerograms meet condition Ia = 8.40



The accelerograms scaled in the ranges: - amplitude (86mag, 86exp, 77inc); - amplitude and time (771p6inc, 771pinc), so that the scaled accelerograms meet condition Ia = 8.40 are presented in Table 2. Time histories of the components accelerograms whose spectra are represented in Figure 4 are shown in Table 2.

In Table 1 the following parameters: Δt (s), the time step of each component - to note that that the smallest is 0.00411 sec. and the largest is 0.01 sec., PGA (m/s/s), the peak acceleration - to note that the minimum and maximum are 72 m/s2 4.79 m/s2, are specified.

For the three scaled accelerograms only in amplitude field, 86mag, 86exp, 77inc, the initial and final pga, the initial and final Arias type intensity are specified also in Table 1.

4. CONCLUSIONS

In the dynamic calculation of structures, the seismic movement is described by means of the variation in time of the ground acceleration (accelerogram).

A combined method of scaling the recorded accelerograms was developed (in the range of the periods of dominant spectral amplification, followed by a scaling in the acceleration amplitudes range).

It was obtained a set of 10 accelerograms for Bucharest, scaled by the combined approach, all with Arias type instrumental intensity equal to 8.4, and in period range 0.0625 sec. - 2.72 sec., mean spectrum of all the 10 accelerogram spectra exceed 90% of the Bucharest regulatory spectrum.

This set of 10 accelerograms can be used in Linear and Nonlinear dynamic calculation following the rules imposed in (MTCT, 2006).

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