
RECORDED ACCELEROGRAMS AS AN ALTERNATIVE DESCRIPTION OF THE SEISMIC ACTION IN THE P 100-1 / 2006 ROMANIAN SEISMIC DESIGN CODE

Ioan Sorin Borcia*

ABSTRACT

A combined method of scaling the recorded accelerograms (in the range of the dominant spectral amplification periods, followed by a scaling in the field of accelerations amplitude) was developed in order to obtain: accelerograms requiring the structure to be designed, 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; all the accelerograms thus scaled should have an instrumental Arias type intensity of the controlled values.

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

REZUMAT

S-a dezvoltat o metodă combinată de scalare a accelerogramelor înregistrate (în domeniul perioadelor de amplificare spectrală dominantă, urmată de o scalare în domeniul amplitudinilor accelerațiilor) pentru a se obține: accelerograme care să solicite structura de calculat, un set de accelerograme de calcul pentru aplicarea prevederilor articolului “3.1.3. *Accelerograme înregistrate*.” din codul de proiectare seismică **P 100-1 / 2006**, toate accelerogramele astfel scalate să aibă o intensitate instrumentală tip Arias controlată.

Cuvinte cheie: intensitate seismică, criterii instrumentale, compoziție spectrală, selecția înregistrărilor, aproximare a spectrului

1. INTRODUCTION

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

The efforts made by the INCERC (National Building research Institute) and IGAR (Institute of Geodynamics of the Romanian Academy) research groups managed by dr. Horea Sandi provided remarkable results [Sandi et al, 2004] in defining the seismic action based on the utilization of the entire data base on the seismic records obtained during the strong Vrancea earthquakes of 1977, 1986 and 1990 [Sandi&Borcia, 2007], [Borcia&Sandi, 2009]. 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 integral) [Sandi&Florice, 1998] which proved

compatible with the macro-seismic intensities [Aptikaev et al, 2008], [Sandi et al, 2009].

In order to sustain the choice of the Arias intensity [Arias, 1970], [Sandi&Florice, 1998] in scaling the recorded accelerograms, [Aptikaev et al, 2008] and [Sandi et al, 2009] present the proper matching between the macro-seismic intensities and the instrumental intensities in the case of 23 records of strong earthquakes in the north of the American continent and of 31 records of strong Vrancea earthquakes. It was thus concluded that the instrumental seismic intensity is an assessment perfectly compatible with the macro-seismic intensity.

The Arias type intensity [Arias, 1970] I_A is provided by the following expression [Sandi&Florice, 1998]:

$$I_A = \log_4 \int [w_g(t)]^2 dt + 6.75 \quad (1)$$

where $w_g(t)$ is the ground acceleration (expressed in m/s^2), or, more recently [Sandi et al, 2010]:

*INCUB URBAN-INCERC, INCERC Bucharest Branch, Romania; e-mail: isborcia@incerc2004.ro

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

(expression (2) is used starting with the works presented in chapter 4).

2. RECORDED ACCELEROGRAMS – SEISMIC MOTION ALTERNATIVE DESCRIPTION

The technical regulation “Seismic design code – Part I – Buildings design provisions”, index P 100-1 / 2006 [MTCT, 2006] is specified as

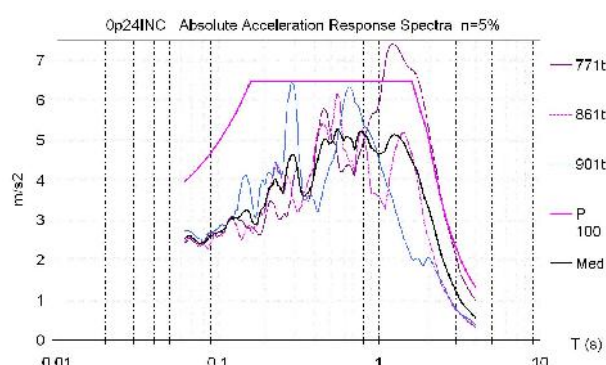


Fig. 1. Absolute acceleration response spectra for the main horizontal components of the INCERC Bucharest records scaled at $pga = 0.24g$, average of the spectra of the 3 accelerograms (Med) and the spectrum of code P 100-1 / 2006 for Bucharest (P100)

Table 1.

General data on the strong Vrancea earthquakes of 1977, 1986 and 1990

Date of occurrence	earthquake code	Instrumental epicenter		depth h (km)	M_{GR}	M_w
		Lat. N	Long. E			
1977.03.04	771	45.34	26.30	109	7.2	7.5
1986.08.30	861	45.53	26.47	133	7.0	7.3
1990.05.30	901	45.82	26.90	91	6.7	7.0
1990.05.31	902	45.83	26.89	79	6.1	6.4

Table 2.

Pga values and Arias intensity values calculated for the original and scaled accelerograms (INCERC Bucharest records)

PGA = 0.24g	Tc = 1.6s		m/s/s
INCERC BUC	I_A	I_A ini	PGAini
771 t	8.17	7.99	2.0700
861 t	7.96	6.68	0.9696
901 t	7.87	6.62	0.9891

follows: “3.1.1. Alternative descriptions of the seismic action... 3.1.3 Recorded accelerograms. The recorded accelerograms may be used if they are recorded close to the site in discussion, on the condition that the maximum value of the recorded acceleration should be scaled so as to be the same as the a_g value on the site and the frequency contents should be compatible with the local ground conditions. Accelerograms recorded on other sites may also be used, if the following conditions are observed: the maximum acceleration should be scaled, the characteristics of the seismic sources, the source – site distance and the field conditions on the site should be similar. In all the cases, at least three (3) accelerograms should be used. All the values of the medium spectrum of the recorded accelerograms to be used will not be lower than by 10 % at the most than the corresponding value in the response elastic spectrum on site $S_e(T)$ ” and in Comments on chapter 3 of the Code: “The recorded accelerograms (paragraph 3.1.2. of P 100-1: 2006) will be compatible with the seismic conditions specific to the site (seismic source type, breaking mechanism, position in terms of the focus, local ground conditions etc.), first of all the value of the ground acceleration for design, a_g , on site etc.”

The article further presents an analysis on the possibilities of simultaneously meeting these conditions in the case of the records obtained during the strong Vrancea earthquakes in several locations where records of the strong Vrancea earthquakes of 1977, 1986 and 1990 are available.

Figure 1 presents the absolute acceleration response spectra for the main horizontal components of the INCERC Bucharest records (code INC, control (corner) period $T_c = 1.6$ s., peak value of ground acceleration $pga = 0.24g$) [***, 2009]; Table 2 presents the pga values and the Arias intensities values calculated for the original and scaled accelerograms.

Table 1 presents the general data on the strong Vrancea earthquakes of the years 1977, 1986 and 1990.

Similar information on:

- Focșani (code FOC, control (corner) period $T_c = 1.0$ s, peak value of ground acceleration $pga = 0.32g$), in Figure 2 and Table 3;

- Cernavodă (code FOC, control (corner) period $T_c = 1.0$ s, peak value of ground acceleration $pga = 0.16g$), in Figure 3 and Table 4;

- Vaslui (code VLS, control (corner) period $T_c = 0.7$ s, peak value of ground acceleration $pga = 0.24g$), in Figure 4 and Table 5.

It is noticed that the accelerogram of March 4, 1977 thus scaled exceeds by over 10 % the elastic spectrum on the site prescribed by code P 100-2006 in the range of the maximum amplification periods, while the accelerograms of 1986 and 1990

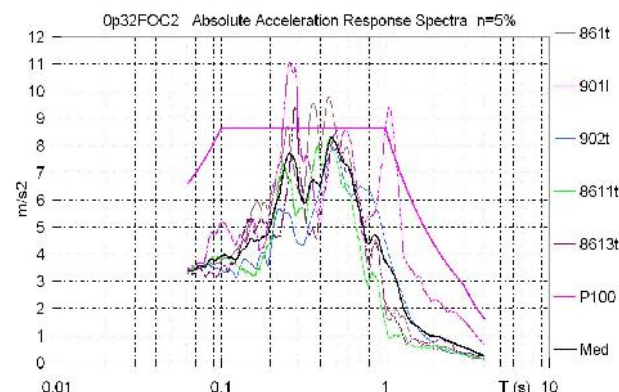


Fig. 2. Absolute acceleration response spectra for the main horizontal components of the Focșani records scaled at $pga = 0.32g$, average of the spectra of the 5 accelerograms (Med) and the P 100-1/2006 code spectrum for Focșani (P100)

Table 3.

Pga values and Arias intensity values calculated for the original and scaled accelerograms (Focșani records)

PGA = 0.32g	Tc= 1.0s		m/s/s
FOCSANI	I_A	I_A ini	PGAini
8611 t	7.75	7.62	2.8785
8611 t	8.06	7.60	2.3760
8613 t	7.85	7.77	2.9714
901 l	8.50	7.10	1.1795
902 t	7.59	6.64	1.6183

Table 4.

Pga values and Arias intensity values calculated for the original and scaled accelerograms (Cernavodă records)

PGA = 0.16g	Tc = 1.0s		m/s/s
CERNAVODA	I_A	I_A ini	PGAini
861 l	8.09	6.56	0.5426
901 l	7.59	6.06	0.6822
902 l	7.04	6.95	1.0091

Table 5.

Pga values and Arias intensity values calculated for the original and scaled accelerograms (Vaslui records)

PGA = 0.24g	Tc = 0.7s		m/s/s
VASLUI	I_A	I_A ini	PGAini
861 t	8.00	7.51	1.6694
901 l	7.82	6.96	1.3004
902 l	7.78	5.52	0.4928

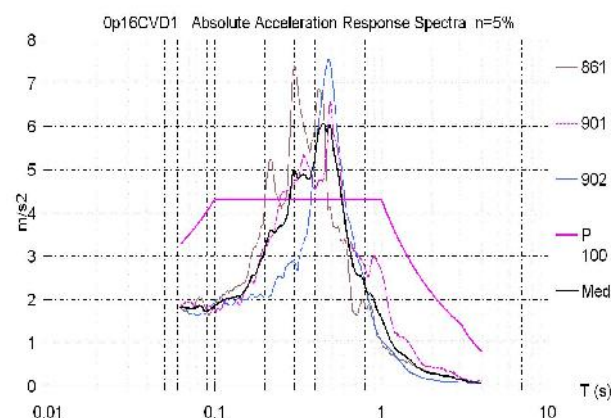


Fig. 3. Absolute acceleration response spectra for the main horizontal components of the Cernavodă records scaled at $pga = 0.16g$, average of the spectra of the 3 accelerograms (Med) and the P 100-1/2006 code spectrum for Cernavodă (P100)

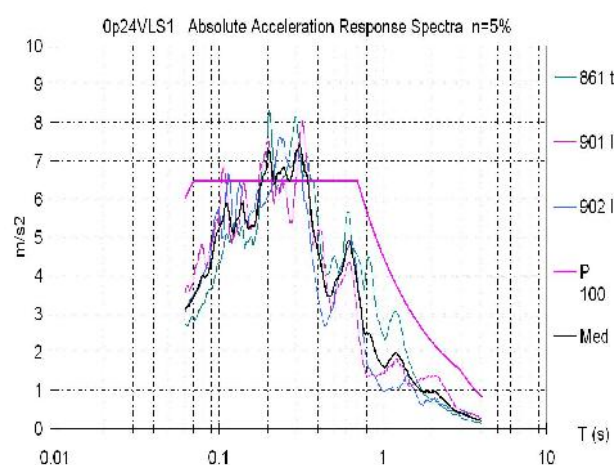


Fig. 4. Absolute acceleration response spectra for the main horizontal components of the Vaslui records scaled at $pga = 0.24g$, average of the spectra of the 3 accelerograms (Med) and the P 100-1/2006 code spectrum for Vaslui (P100)

thus scaled are both under the prescribed elastic spectrum on the site.

In all the 4 cases analyzed, the mean values of the scaled recorded accelerograms spectra are much lower than the corresponding value of the response elastic spectrum on the site in large zones of periods corresponding to the maximum spectral acceleration range. Taking into account this observation as well, we propose, in the next paragraph, a scaling in the time range (as well) (which involves at the same time the modification in terms of periods of the response spectrum) of the recorded accelerograms, using the Arias instrumental intensity to obtain the scaled accelerograms which will have the same Arias intensities as the recorded accelerograms (the originals).

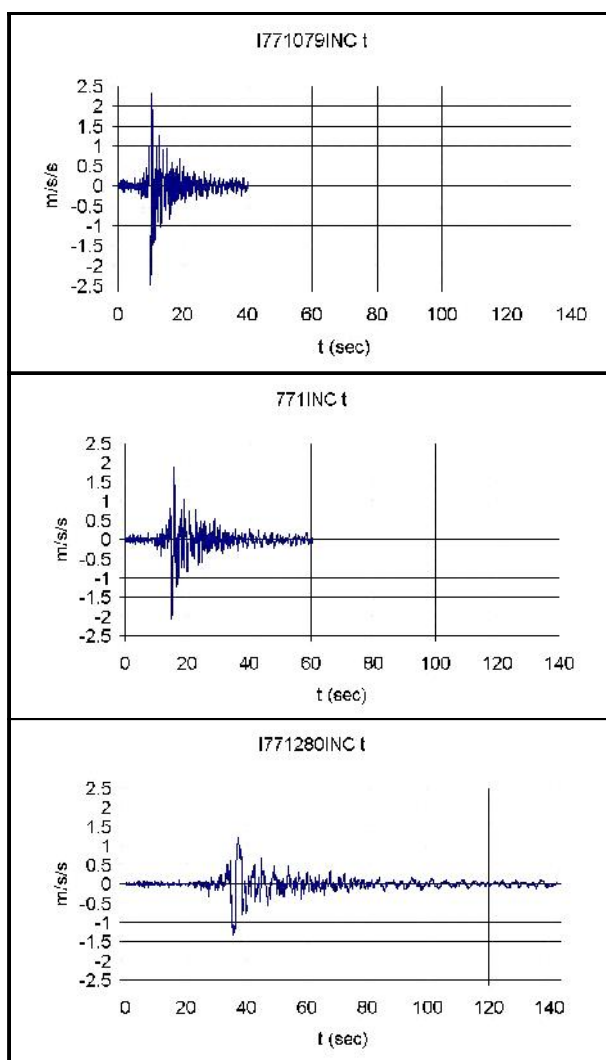


Fig. 5. 771INC t accelerogram scaled in the time range (so that the maximum spectral amplification should be $T = 0.79$ s (top), $T = 1.23$ s (original, middle) and $T = 2.80$ s (bottom) and in the amplitude range, so that the Arias intensity $I_A = 7.986$ should remain constant

3. SCALING IN THE TIME RANGE PRESERVING THE ARIAS INTENSITY INITIAL VALUE

In the time history analyses, the seismic input is formed by accelerograms – ground acceleration time histories. Especially in the cases of selecting the design variant (initial or consolidation) using the base isolation method, the accelerograms should be thoroughly selected, so as to be able to emphasize the dynamic-seismic amplifications both for the base unisolated structure and (or mainly) for the base isolated structure.

If a recording 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 code spectrum of P-100/2006), 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 [***, 2009].

As an example, we selected from [Iordachescu & Iordachescu, 2008] the values specific to a building: $T = 0.79$ sec in the classical consolidation variant and $T = 2.80$ sec in the variant of the consolidation by the base isolation method. The seismic input used in the dynamic analyses was formed of the accelerographic records obtained at INCERC and scaled at 0.24 g to follow the P 100/2006 code in force. Therefore the recorded accelerograms were scaled only in terms of the acceleration amplitudes.

For comparison, the accelerogram recorded at INCERC in 1977 (coded 771, NS: $I_A = 7.986$, $\text{pga} = 2.069 \text{ m/s}^2$) was scaled as follows:

- component NS scaled at $T_{\text{princip.}} = 0.79 \text{ sec}$ ($I_A = 7.691$); then component NS scaled at $I_A = 7.986$ ($\text{pga} = 2.540 \text{ m/s}^2$);
- component NS scaled at $T_{\text{princip.}} = 2.80 \text{ sec}$ ($I_A = 8.604$); then component NS scaled at $I_A = 7.986$ ($\text{pga} = 1.349 \text{ m/s}^2$).

The following aspects are noticed:

- for the INCERC 1977 recording, scaled at $T_{\text{princip.}} = 0.79$ sec. and $I_A = 7.986$ the spectral amplification at the period $T = 0.79$ sec is actually twice higher than that for the initial recording;
- for the INCERC 1977 recording, scaled at $T_{\text{princip.}} = 2.80$ sec. and $I_A = 7.986$ the spectral amplification at period $T = 2.80$ sec is actually twice higher than that for the initial recording.

It is considered that the aspects previously presented 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).

4. ATTEMPT TO DEFINE A SET OF DESIGN ACCELEROGRAMS FOR APPLYING THE PROVISIONS OF ITEM "3.1.3. RECORDED ACCELEROGRAMS" OF THE P 100-1/2006 SEISMIC DESIGN CODE

The set of design accelerograms for applying the provisions of item "3.1.1. Recorded accelerograms" of the P 100-1 / 2006 seismic design code concerning the North-Eastern half of Bucharest is presented. The start-up records were those provided by the INCERC network from the INCERC stations (INC – 1977), EREN (EXP – 1986), Brănești (BRN – 1986) and Titulescu (TIT – 1986). The selected standard Arias intensity (common to all the 11 resulted accelerograms) was $I_A = 8.40$.

The scaling only in the range of the amplitudes provided the accelerograms coded 77INCt, 86EXPI, 86BRNt and 86TITt. By scaling first in the time range (periods) and then in the amplitude range, the accelerograms coded 77INC1p6t (with maximum spectral amplification at $T = 1.6$ sec), and 77INC1pt (with maximum spectral amplification at $T = 1.0$ sec), 861pBRNt (with maximum spectral amplification at $T = 1.0$ sec.), 86p67BRNt (with maximum spectral amplification at $T = 0.67$ sec),

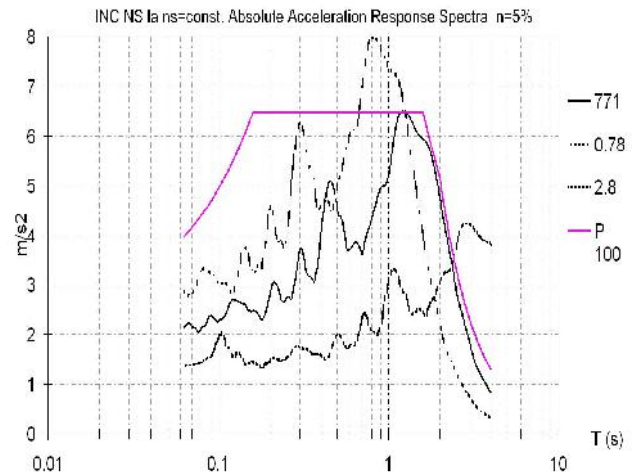


Fig. 6. Absolute acceleration response spectra for the accelerograms presented in Fig. 5

Table 6.

Correspondence accelerogram (Fig.5) – response spectrum in absolute accelerations (Fig.6), Pga acceleration peak values and Δt time pace

Accelerogram Fig. 5	Spectrum Fig. 6	Pga (m / s ²)	Δt (s)
I7712p80INC t	2.8	1.35	0.0118
771INC t	771	2.07	0.0050
I7710p79INC t	0.78	2.54	0.0033

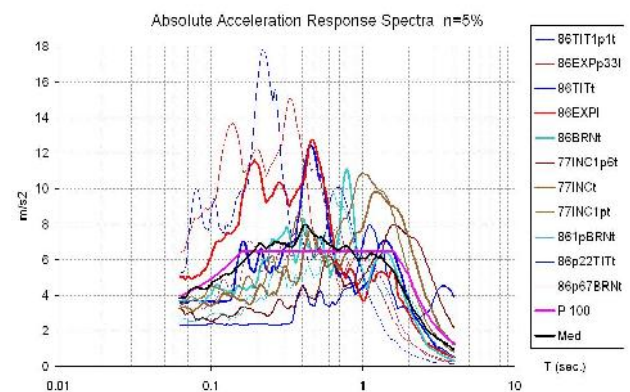


Fig. 7. Absolute acceleration response spectra for the 11 accelerograms scaled at $I_A = 8.40$ which, together, fairly approximate the code spectrum for the North-Eastern half of Bucharest

86TIT1p1t (with maximum spectral amplification at $T = 1.1$ sec), 86p22TITt (with maximum spectral amplification at $T = 0.22$ sec) and 86EXPP331 (with maximum spectral amplification at $T = 0.33$ sec) were obtained. The absolute acceleration response spectra were thus obtained for the 11 accelerograms scaled at $I_A = 8.40$ which, together, significantly match the code spectrum for the Northern half of Bucharest presented in Figure 7.

The following elements are noticed:

- in the range of periods 0.0625 sec – 1.44 sec all the spectra mean values of the 11 accelerograms (MED) exceed 90 % of the P 100-1 / 2006 spectrum value,
- in the range of periods 1.44 sec – 1.68 sec all the spectra mean values of the 11 accelerograms (MED) exceed 80 % of the P100-1/2006 spectrum value and
- in the range of periods 1.68 sec – 4.0 sec all the spectra mean values of the 11 accelerograms (MED) exceed 73 % of the P100-1/2006 spectrum value.

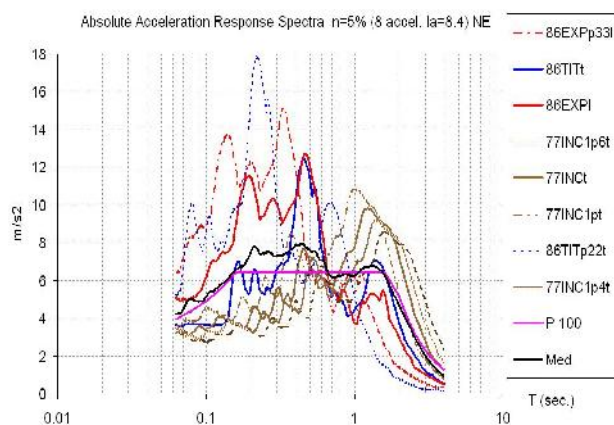


Fig. 8. Absolute acceleration response spectra for the 8 accelerograms scaled at $I_A = 8.40$ which, together fairly match the code spectrum for the North-Eastern half of Bucharest

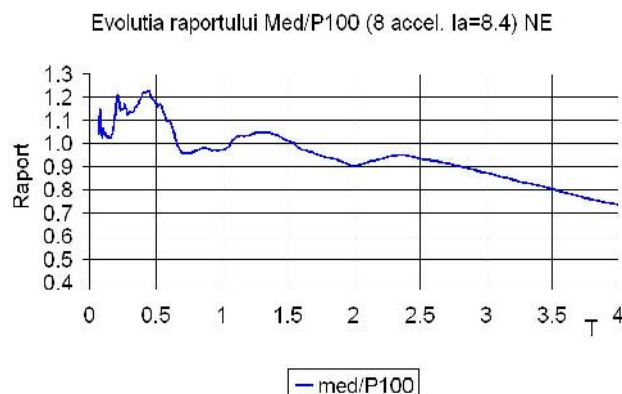


Fig. 9. Evolution of the mean value of the spectra of the 8 accelerograms scaled at $I_A = 8.40$ / P 100-1/2006 spectrum value, for the North-Eastern half of Bucharest

5. DEFINITION OF A SET OF DESIGN ACCELEROGRAMS FOR THE NORTH-EASTERN HALF OF BUCHAREST, IN VIEW OF THE APPLICATION OF THE PROVISIONS OF ITEM “3.1.3. RECORDED ACCELEROGRAMS” OF P100-1/ 2006 SEISMIC DESIGN CODE

The design accelerograms set for the application of the provisions of item “3.1.3. Recorded accelerograms” of the P 100-1/2006 seismic design code for the North-Eastern half of Bucharest is presented. The start-up recordings were those provided by the INCERC network in the INCERC stations (INC – 1977), EREN (EXP – 1986) and Titulescu (TIT – 1986). $I_A = 8.40$ was chosen as Arias standard intensity (for all the 8 resulted accelerograms). By scaling only in the amplitude range, the accelerograms coded 77INCt, 86EXPI and 86TITt were obtained. By scaling first in the time range (periods) and then in the amplitude range, the accelerograms coded 77INC1p6t (with maximum spectral amplification at $T = 1.6$ sec), 77INC1p4t (with maximum spectral amplification at $T = 1.4$ sec), and 77INC1pt (with maximum spectral amplification at $T = 1.0$ sec), 86p22TITt (with maximum spectral amplification at $T = 0.22$ sec) and 86EXPp33l (with maximum spectral amplification $T = 0.33$ sec) were obtained.

The absolute acceleration response spectra for the 8 accelerograms scaled at $I_A = 8.40$ were obtained which, together, fairly match the code spectrum for the North-Eastern half of Bucharest, presented in Figure 8.

The following aspects are noticed (Figure 9):

- in the range of periods 0.0625 sec – 2.84 sec all the spectra mean values of the 8 accelerograms (MED) exceed 90 % of the P 100-1 / 2006 spectrum value,
- in the range of periods 2.84 sec – 3.52 sec all the spectra mean values of the 8 accelerograms (MED) exceed 80 % of the P 100-1 / 2006 spectrum value and
- in the range of periods 3.52 sec – 4.0 sec all the spectra mean values of the 8 accelerograms (MED) exceed 73 % of the P 100-1 / 2006 spectrum value.

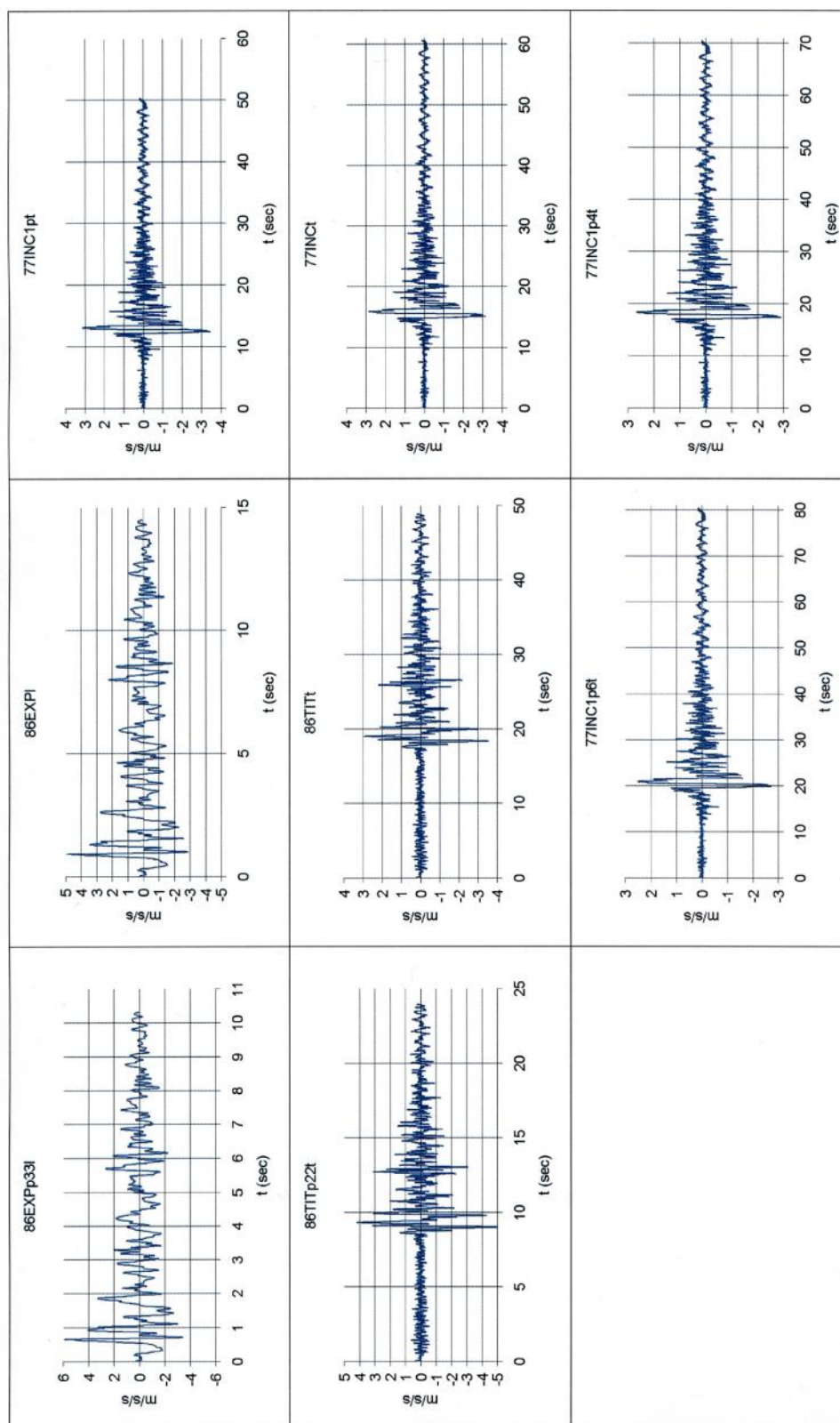


Fig. 10 Accelerograms scaled in the ranges: - amplitude (86TITt, 86EXPI, 77INCt); - amplitude and time (86EXPp33i, 77INC1p6t, 77INC1pt, 86TITp22t, 77INC1p4t), so that all the scaled accelerograms meet condition $I_A = 8.40$.

Table 7.

Correspondence accelerogram (Fig. 10) – absolute acceleration response spectrum (Fig. 8),
Pga acceleration peak values and time *pace* Δt

	86EXPp33i	86TITt	86EXPI	77INC1p6t	77INCt	77INC1pt	86TITp22t	77INC1p4t
Δt (s)	0.0071	0.0050	0.0100	0.0066	0.0050	0.0041	0.0025	0.0058
Pga (m / s^2)	5.8944	3.5432	4.9736	2.7249	3.1266	3.4467	5.0600	2.9130

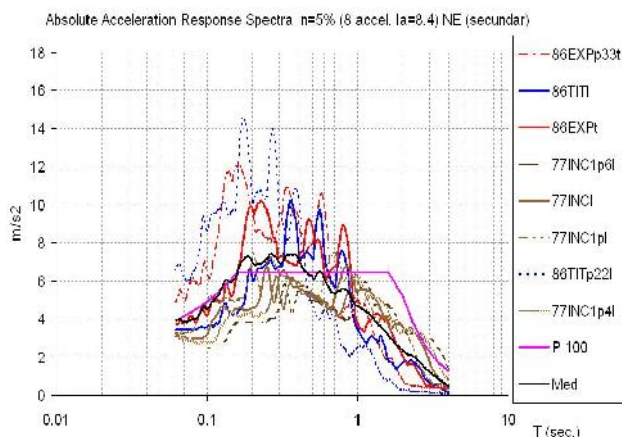


Fig. 11. Absolute acceleration response spectra for the 8 (secondary) accelerograms for the North-Eastern half of Bucharest

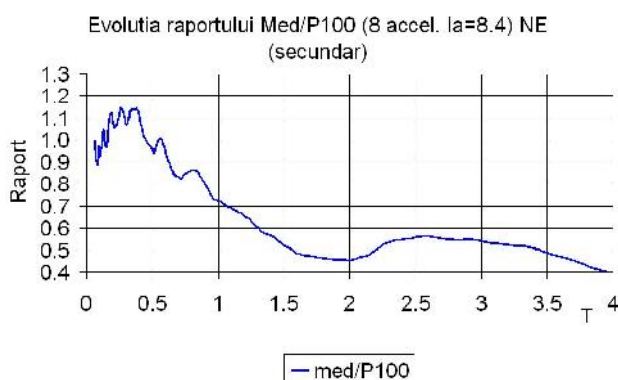


Fig. 12. Evolution of the ratio mean value of the spectra of the 8 (secondary) accelerograms / value of P 100-1 / 2006 spectrum, for the North-Eastern half of Bucharest

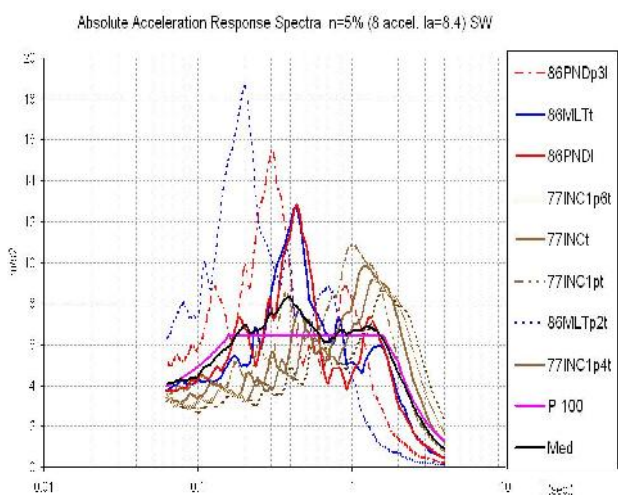


Fig. 13. Absolute acceleration response spectra for the 8 accelerograms scaled at $I_A = 8.40$ which, together, fairly match the code spectrum for the South-Western half of Bucharest

The design accelerograms set is presented (in figures 11 and 12): the “pair” accelerograms (secondary) of the previous ones for the North-Eastern half of Bucharest, namely 77INC1, 86EXPt, 86TITt, 77INC1p6t, 77INC1p4t, 77INC1pt, 86p22TITt and 86EXPp33t.

The absolute acceleration response spectra were thus obtained for the 8 secondary accelerograms which, together with the main scaled accelerograms (77INCt, 86EXPt, 86TITt, 77INC1p6t, 77INC1p4t, 77INC1pt, 86p22TITt and 86EXPp33t) form pairs of design accelerograms for the North-Eastern half of Bucharest.

6. DEFINITION OF A SET OF DESIGN ACCELEROGRAMS FOR THE SOUTH-WESTERN HALF OF BUCHAREST IN VIEW OF APPLYING THE PROVISIONS OF ITEM “3.1.3. RECORDED ACCELEROGRAMS” OF THE P 100-1 / 2006 SEISMIC DESIGN CODE

The design accelerograms set for applying the provisions of item “3.1.3. Recorded accelerograms” of the P100-1/2006 seismic design code to the *South-Western half of Bucharest* is presented. The records provided by the INCERC network: INCERC (INC – 1977), Panduri (PND – 1986) and Militari (MLT – 1986) were used as starts-up. $I_A = 8.40$ was selected as Arias standard intensity (for all the 8 resulted accelerograms). By scaling only in the range of the amplitudes, the accelerograms coded 77INCt, 86PNDt and 86MLTt were obtained.

By scaling first in the range of time (periods) and then in the range of the amplitudes, the accelerograms coded 77INC1p6t (with maximum spectral amplification at $T = 1.6$ sec), 77INC1p4t (with maximum spectral amplification at $T = 1.4$ sec) and 77INC1pt (with maximum spectral amplification at $T = 1.0$ sec), 86PNDp3l (with maximum spectral amplification at $T = 0.3$ sec) and 86MLTp2t (with maximum spectral amplification at $T = 0.2$ sec) were obtained. The absolute acceleration response spectra were thus obtained for the 8 accelerograms scaled at $I_A = 8.40$, which, together, fairly match the code spectrum for the South-Western half of Bucharest, presented in Figure 13.

The following aspects are noticed (Figure 14):

- in the range of periods 0.0625 sec – 2.71 sec all the mean values of the spectra of the 8 accelerograms (MED) exceed 90 % of the P 100-1 / 2006 spectrum value,
- in the range of periods 2.71 sec – 3.37 sec all the mean values of the spectra of the 8 accelerograms (MED) exceed 80 % of the P 100-1 / 2006 spectrum value and
- in the range of periods 3.37 sec – 4.0 sec all the mean values of the spectra of the 8 accelerograms (MED) exceed 71 % of the P 100-1 / 2006 spectrum value.

The design accelerograms set is presented (figures 15 and 16): the “pair” accelerograms (secondary) of the previous for the South-Western half of Bucharest, namely 77INC1, 86EXPt, 86TIT1, 77INC1p6l, 77INC1p4l, 77INC1pl, 86p22TIT1 and 86EXPp33t. The absolute acceleration response spectra for the 8 secondary accelerograms are thus obtained, which, together with the main scaled accelerograms (77INCt, 86EXP1, 86TITt, 77INC1p6t, 77INC1p4t, 77INC1pt, 86p22TITt and 86EXPp33l) form pairs of design accelerograms for the South-Western half of Bucharest.

7. CONCLUSIONS

After having demonstrated that the instrumental seismic intensity represents an assessment compatible with the macro-seismic intensity, 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) in order to obtain accelerograms requiring the calculation / design structure and in conditions of the base seismic isolation. The exemplifications were performed on the accelerographic records obtained at INCERC during the strong Vrancea earthquakes of 1977, 1986 and 1990. 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) in order to obtain:

- accelerograms requiring the calculation / design structure,
- a set of design accelerograms for applying the provisions of item “3.1.3. Recorded

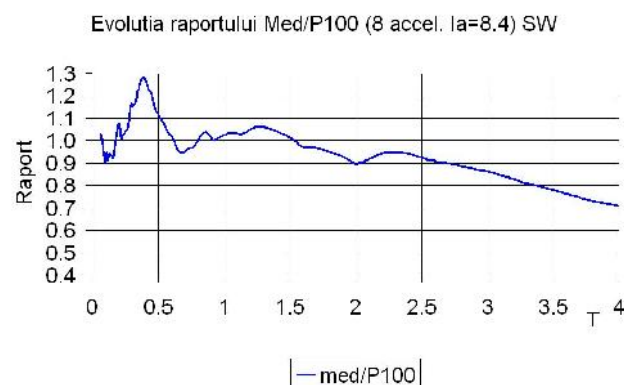


Fig. 14. Evolution of the ratio mean value of the spectra of the 8 accelerograms scaled at $I_A = 8.40 / P 100-1 / 2006$ spectrum value, for the South-Western half of Bucharest

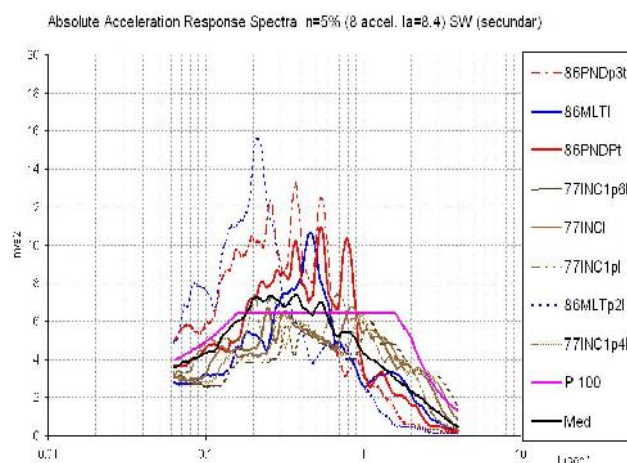


Fig. 15. Absolute acceleration response spectra for the 8 secondary accelerograms for the South-Western half of Bucharest

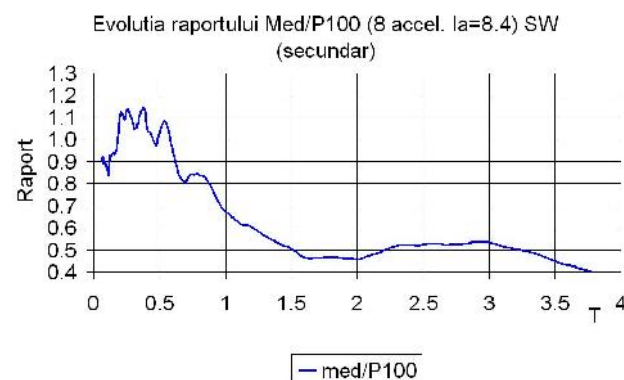


Fig. 16. Evolution of the ratio mean value of the spectra of the 8 (secondary) accelerograms / P 100-1 / 2006 spectrum value, for the South-Western half of Bucharest

accelerograms” of the **P100-1 / 2006** seismic design code,

- all the accelerograms thus scaled will have an Arias controlled instrumental intensity.

Advantages:

- for the original recorded accelerograms, scaled only in the amplitude range, 3 accelerograms are in fact available (2 horizontal orthogonal and 1 vertical) scaled by the same value in the amplitude range;

- for the accelerograms scaled both in the range of time and in that of the acceleration amplitudes, 2 accelerograms are in fact available (2 horizontal orthogonal) scaled by the same value in the amplitude range;

- this method may also be used in the case of adopting, in the future, for item 3.1.3. in the future revised edition of code P 100-1 / 2006, the current provisions of Eurocode 8. EN-1998-1 [CEN, 2004] „*in the range of periods between $0,2T_1$ and $2T_1$, where T_1 is the fundamental period of the structure in the direction where the accelerogram will be applied; no value of the mean 5% damping elastic spectrum, calculated from all time histories, should be less than 90% of the corresponding value of the 5% damping elastic response spectrum*”.

This type of accelerograms scaled in the range of time as well are useful in the “time history” type dynamic calculation of building structures, mainly of seismically isolated structures.

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