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DETERMINATION OF AN ARTIFICIAL BASE ACCELEROGRAM COMPATIBLE WITH A NATIONAL BUILDING CODE FOR SEISMIC RESISTANT BUILDINGS

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Abstract. *Although strong seismic events are rare in Brazil, Brazilian structural engineers are frequently involved in such analysis for neighboring Latin American countries. Seismic base excitation data, of random nature, is not, in general, available. Usual National Building Codes for seismic resistant constructions don't provide design base accelerograms for time history type analysis. The standard information is the so called Elastic Design Spectrum that provides the maximum response acceleration for a one degree of freedom linear damped system, slightly different for each National Code. Much research is being developed to generate artificial base motion accelerograms compatible with these Code Spectra. Thus, in this paper, we present a study on a proposal for generating artificial base motion accelerograms compatible with the Brazilian National Code for Seismic Resistant Building NBR: 15421:2006.*

Keywords: *structural dynamics, seismic analysis, Brazilian seismic resistant building code.*

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1 INTRODUCTION

Although strong seismic events are rare in Brazil, Brazilian structural engineers are frequently involved in such analysis for neighboring Latin American countries.

Information on seismic base excitation, of random nature, is not, in general, available. Usual National Building Codes for seismic resistant constructions don't provide design base accelerograms to compute the inertia forces. The standard information is the so called elastic design spectrum, which provides the maximum response acceleration for a one degree of freedom linear damped system for each country. Much research is being developed in order to generate artificial base motion accelerograms compatible with these Code spectra. We presented a proposal for generating artificial base motion accelerograms compatible with the Brazilian National Code for Seismic Resistant Building NBR: 15421:2006.

2 ELASTIC RESPONSE SPECTRUM

Currently, the response spectrum concept is an important seismic tool being adopted in earthquake resistant building codes around the world. According to Newmark and Hall (1982), this type of spectrum can generally be defined as a graphical representation of the approximate maximum response, either in displacements, velocities, acceleration or any other parameter of interest obtained by an excitation on a set of oscillators of one degree of freedom, characterized by different values of the structure's frequency or period and all with the same value of damping ratio.

The motion of such systems is described by Eq. (1):

$$\ddot{x}(t) + 2\nu\omega\,\dot{x}(t) + \omega^2 x(t) = -\ddot{y}(t). \tag{1}$$

Where, x(t) represents the displacement response of the system, ω is the vibration frequency (rad / s), ν is the critical damping rate and $\ddot{y}$ is the ground seismic acceleration.

The solution of Equation (1) is expressed as:

$$x(t) = -\frac{1}{\omega_v}\int_0^t \ddot{y}(\tau)e^{-\nu\omega(t-\tau)} sen[\omega_v(t-\tau)]d\tau\,. \tag{2}$$

Deriving Eq. (2) in time, we obtain response in absolute velocities and accelerations:

$$\dot{x}(t) = -\int_0^t \ddot{y}(\tau)e^{-\nu\omega(t-\tau)} \cos\omega_v(t-\tau)d\tau + \nu\omega x(t)\,. \tag{3}$$

$$\ddot{x}(t) + \ddot{y}(t) = \omega_v\int_0^t \ddot{y}(\tau)e^{-\nu\omega(t-\tau)} sen\omega_v(t-\tau)d\tau - 2\nu\omega\,\dot{x}(t) - (\nu\omega)^2 x(t)\,. \tag{4}$$

The acceleration, velocity and displacement response spectra are defined as the maximum values of the system responses expressed as a function of period or frequency:

$$S_d^t(\omega,\nu) = \left| -\frac{1}{\omega_v}\int_0^t \ddot{y}(\tau) e^{-\nu\omega(t-\tau)} sen[\omega_v(t-\tau)] d\tau \right|_{\max} \quad (5)$$

$$S_v^t(\omega,\nu) = \left| -\int_0^t \ddot{y}(\tau) e^{-\nu\omega(t-\tau)} \cos\omega_v(t-\tau) d\tau + \nu\omega x(t) \right|_{\max} \quad (6)$$

$$S_a^t(\omega,\nu) = \left| \omega_v \int_0^t \ddot{y}(\tau) e^{-\nu\omega(t-\tau)} sen\omega_v(t-\tau) d\tau - 2\nu\omega\dot{x}(t) - (\nu\omega)^2 x(t) \right|_{\max} \quad (7)$$

Equating ω_v and ω and substituting the cosine function for the sine function, these equations can be rewritten as follows:

$$S_d(\omega,\nu) = \left| -\frac{1}{\omega_v}\int_0^t \ddot{y}(\tau) e^{-\nu\omega(t-\tau)} sen\omega\,(t-\tau) d\tau \right|_{\max} \quad (8)$$

$$S_v(\omega,\nu) = \left| -\int_0^t \ddot{y}(\tau) e^{-\nu\omega(t-\tau)} sen\omega(t-\tau) d\tau \right|_{\max} \quad (9)$$

$$S_a(\omega,\nu) = \left| \omega\int_0^t \ddot{y}(\tau) e^{-\nu\omega(t-\tau)} sen\omega(t-\tau) d\tau \right|_{\max} \quad (10)$$

where one can write Eq. (11):

$$S_d(\omega) = \frac{1}{\omega} S_v(\omega) = \frac{1}{\omega^2} S_a(\omega) \quad (11)$$

2.1 Standard elastic response spectrum

The Brazilian standard NBR 15421: 2006 defines the seismic actions that provide the expected maximum response of a linear system of one degree of freedom (SDOF) in terms of pseudo-acceleration response spectrum for a critical damping ratio of 5%. The response spectrum is then defined numerically at three time intervals, by the expressions:

$$S_a(T) = \begin{cases} a_{gs0}(18.75\dfrac{C_a}{C_v}+1), & 0 \le T < 0.08\dfrac{C_a}{C_v} \\ 2.5a_{gs0}, & 0.08\dfrac{C_a}{C_v} \le T < 0.4\dfrac{C_a}{C_v} \\ \dfrac{a_{gs1}}{T}, & T \ge 0.4\dfrac{C_a}{C_v} \end{cases} \quad (12)$$

where:

T = natural period of vibration, associated with each of the modes of vibration of the structure,

$S_a(T)$ = is the response spectrum pseudo-accelerations,

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C_a = is the seismic ground amplification factor, for the period T= 0.0s,

C_v = is the seismic ground amplification factor, for the period T= 1.0s,

a_{gs0} = is spectral acceleration for the period T=0.0s,

a_{gs1} = is spectral acceleration for the period T=1.0s.

The latter quantities are calculated by:

$$a_{gs0} = C_a a_g \tag{13}$$

$$a_{gs1} = C_v a_g \tag{14}$$

where:

a_g = it is the horizontal seismic reference acceleration for a given region, normalized to soil Class B (rock), obtained from the national seismic map.

Figure 1 shows a typical design response spectrum, normalized by the acceleration of zero periods (S_a/a_{gs0}) as function of the period of the structure:

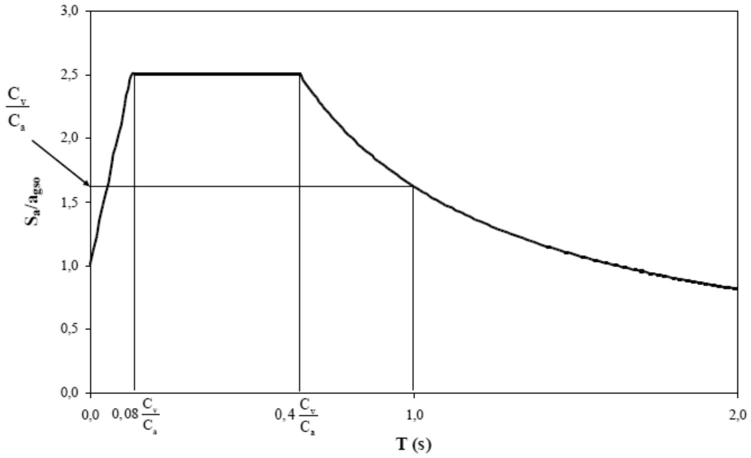


Figure 1. Design response spectrum (ABNT NBR 15421:2006)

The seismic ground amplification factors can be obtained, depending on the terrain, in Table 1, linear interpolation used to obtain intermediate values between 0.10g e 0.15g. The categorization of the site soil class is associated with the propagation velocity of shear waves ($\overline{V_s}$) in the ground 30 meters higher, from Table 2. It is also allowed the classification, in some cases, from the average results of the SPT ($\overline{N}$), the Standard Penetratios Test, the number of strikes necessary to insert a one foot long sampler into the ground.

Table 1. Seismic ground amplification factors (ABNT NBR 15421:2006)

Classe do terreno	Ca		Cv	
	ag ≤ 0.10g	ag ≤ 0.15g	ag ≤ 0.10g	ag ≤ 0.15g
A	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0
C	1.2	1.2	1.7	1.7
D	1.6	1.5	2.4	2.2
E	2.5	2.1	3.5	3.4

Table 2. Ground classification (ABNT NBR 15421:2006)

Classe do terreno	Designação da classe do terreno	Propriedades médias para os 30 m superiores do terreno	
		$\bar{V}_s$	$\bar{N}$
A	Rocha sã	$\bar{V}_s \geq 1.500\ m/s$	(não aplicável)
B	Rocha	$1.500\ m/s \geq \bar{V}_s \geq 760\ m/s$	(não aplicável)
C	Rocha alterada ou solo muito rígido	$760\ m/s \geq \bar{V}_s \geq 370\ m/s$	$\bar{N} \geq 50$
D	Solo rígido	$370\ m/s \geq \bar{V}_s \geq 180\ m/s$	$\bar{N} \geq 15$
E	Solo mole	$\bar{V}_s \leq 180\ m/s$	$\bar{N} \leq 15$
	-	Qualquer perfil, incluindo camada com mais de 3 m de argila mole	
F	-	Solo exigindo avaliação específica, como: 1. Solos vulneráveis à ação sísmica, como solos liquefazíveis, argilas muito sensíveis e solos colapsíveis fracamente cimentados 2. Turfa ou argilas muito orgânicas 3. Argilas muito plásticas; 4. Extratos muito espessos (≥ 35 m) de argila mole ou média	

As stated, NBR15421: 2006 defines the terms of pseudo-acceleration response spectrum for a critical damping ratio of 5%. It is common practice in normative codes to adopt this value. However, for isolated base structures, structures with damping devices, and structures that do not behave linearly, spectral values often require distinct levels of damping. In these cases, the damping ratio must be adjusted by damping correction factors. NBR15421: 2006 indicates the need to apply a correction factor for a critical damping ratio different from 5%, but does not present any methodology for such correction. The European design spectrum EC8 also indicates the need to use correction factors for damping values other than 5%. This correction is based on the model proposed by Bommer et. al.(2000) through Eq. (15).

$$\eta = \sqrt{\frac{10}{(5+\xi)} \geq 0.55} \tag{15}$$

The correction factor is shown in Figure 2.

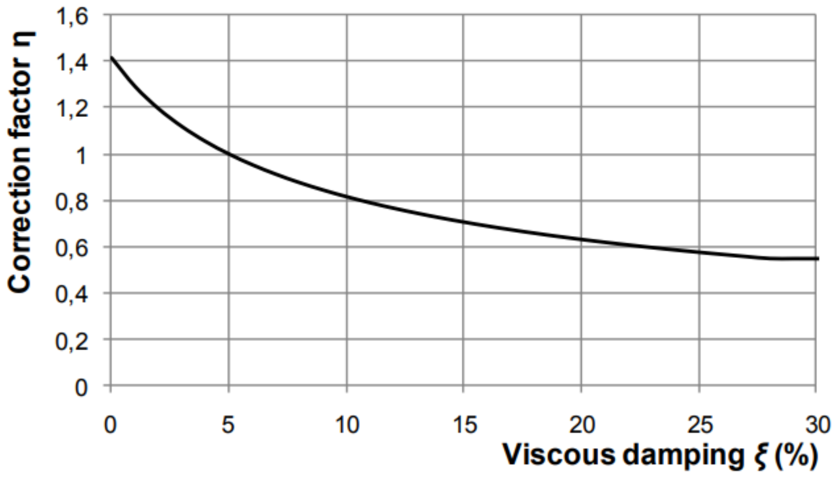


Figure 2. Correction Factor (BISCH et. Al, 2001)

3 DETERMINATION OF AN ARTFICIAL BASE ACCELEROGRAM

The usual national building codes for seismic-resistant constructions allow the engineer to represent the motion of the simian ground by accelerograms, but do not provide methodologies for such general accelerograms. We propose a possible solution in the following.

The method is based on the fact that any periodic function can be expressed as a superposition of sine waves modulated by an envelope function defining the temporal shape of the ground acceleration.

$$a(t) = I(t)\sum_{i=1}^{n} A_i \sin(\omega_i t + \theta_i) \qquad (16)$$

where

a(t) is the artificial accelerogram sought.

n = it is a given number that increasingly improves compatibility of the spectrum to give more "wealth" in the signal frequencies,

I(t) = to simulate the transitory nature of real earthquakes, a function of predefined deterministic intensity envelope I*(t)* is used,

θ_i = the random nature of the signal is modeled by the phase angles θ_i are generated taking random values between 0 y 2π,

ω_i = the frequencies ω_i are chosen at regular intervals within a specified range, so that the record contains the entire desired frequency range,

A_i = the artificial signal *a(t)* is compatible with the response spectrum because the A_i are calculated from the stationary function of power spectral density $G_{\ddot{U}g}(\omega)$ obtained, in turn, from response spectrum $S_a(T)$.

3.1 Signal duration

The definition of duration is a parameter of wide variability, a reliable prediction being difficult to make. To date, there is no universally accepted definition for the apparent duration of a soil motion due to an earthquake (GONZALEZ, 2006).

In this work we adopted the most usual recommendation proposed by Trifunac & Brady (1975), who indicate a significant duration (Ds) with interval corresponding to 5% and 95% of all energy developed. The significant duration (Ds) is associated with the cumulative energy of the accelerogram and has the advantage of considering the entire accelerogram and defining a continuous time window. This definition is related to the intensity of Arias (ARIAS, 1970) and is defined by Eq. (17).

$$I_A = \frac{\pi}{2g}\int_0^{tf} a^2(t)dt \qquad (17)$$

where I_A is defined as Aria Intensity, *a(t)* corresponds to the acceleration register over time, *tf* is the total duration of the accelerogram and *g* is the acceleration due to gravity.

The concept described is presented in Fig. 3 through a Husid chart, which graph represents the intensity of Arias as a function of time.

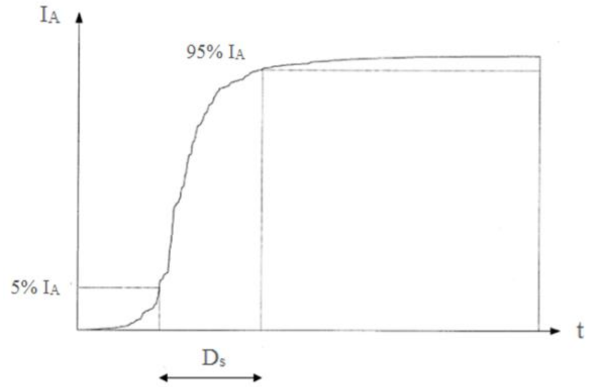


Figure 3. Significant duration –Ds (Trifunac & Brady ,1975)

3.2 Envelope function

To simulate the transient character of real earthquakes, a pre-determined deterministic envelope intensity function I (t) is used (BARBAT et al., 1994). There is a wide range of enveloping functions for each type of earthquake.

In this work, we opted for the trapezoidal form function proposed by Hou (1968). Fig. 4 illustrates this function.

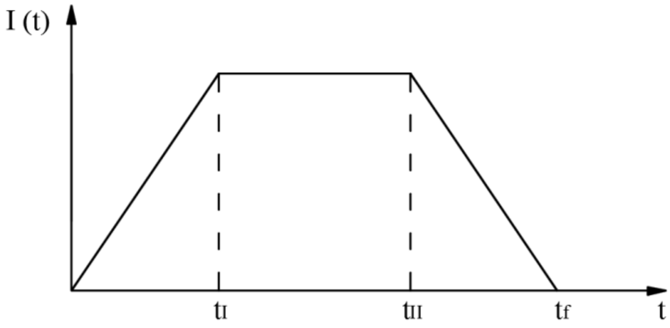


Figure 4. Trapezoidal envelope function (Hou, 1968)

$$I(t) = \begin{cases} \dfrac{t}{t_1}, & 0 \le t < t_I \\ 1, & t_I \le t < t_{II} \\ \dfrac{(t - t_f)}{(t_{II} - t_f)}, & t_{II} \le t \le t_f \end{cases} \tag{18}$$

3.3 Computing amplitudes

It is known that in a given random function with a stationary zero mean process, the variance of the function is equal to the total power spectral density function (Barbat et al.,1994)

$$\sigma^2_{\ddot{U}g} = \int_0^{\infty} G_{\ddot{U}g}(\omega)d\omega \tag{19}$$

Moreover, the variance of a sinusoidal function, given by

$$\ddot{y}(t) = A\sin(t) \tag{20}$$

is equal to

$$\sigma^2_{\ddot{y}} = \frac{1}{2\pi}\int_0^{2\pi} A^2 \sin^2(t)dt = \frac{A^2}{2} \tag{21}$$

Consequently, the total power of the process defined by Eq. (16) according to Eqs. (19) and (21) is:

$$\int_0^{\infty} G_{\ddot{U}g}(\omega)d\omega = \sigma^2_{\ddot{U}g} = \sum_{i=n}^{n} \frac{A_i^2}{2} \tag{22}$$

Approximating the total power as the integral of the area under the curve $G_{\ddot{U}g}(\omega)$,

$$\sum_{i=1}^{n} G_{\ddot{U}g}(\omega_i)\Delta\omega_i = \sum_{i=n}^{n} \frac{A_i^2}{2} \tag{23}$$

This expression is valid only when the number *n* of sinusoids in the function that defines the process *a(t)* is large.

Since the power spectral density represents the relative contribution of each frequency ω_i, one can accept the hypothesis of equal addends in Eq. (23):

$$G_{\ddot{U}g}(\omega_i)\Delta\omega_i \approx \frac{A_i^2}{2} \tag{24}$$

Therefore, the said function can be calculated, amplitudes defined in Eq. (16) as

$$A_i^2 \approx \sqrt{2G_{\ddot{U}g}(\omega_i)\Delta\omega_i} \tag{25}$$

3.4 Generation of a Power Spectral Density function (PSD) compatible with the standard response spectrum

NBR 15421:2006 allows the engineer to represent the seismic ground motion by artificial accelerograms. However, the code does not define how to adopt a PSD, requiring it only to be compatible with the response spectrum specified and providing conditions for this compatibility to be achieved. In particular, a PSD function $G\ddot{U}g(\omega)$, of the ground acceleration is considered compatible with an assigned acceleration RS, *Sa (T),* if a SDOF system with an assigned damping ratio, subjected to accelerogram samples generated from $G\ddot{U}g(\omega)$, experiences an absolute maximum acceleration *Sa (T)* for each value of the natural period T into a time window of the nominal duration of the pseudo-stationary part *Ts* of the earthquake (Baroni *et al*., 2015).

The spectral acceleration can also be expressed as:

$$S_a(\omega,\xi) = \omega^2 \eta_U(\omega,\xi)\sigma_U(\omega,\xi) \tag{26}$$

The pick factor η_U (Vanmarcke, 1972) is defined

$$\eta_U(\omega,\xi) = \sqrt{2\ln\{2N_U(\omega)[1-\exp(-\delta_U^{1,2}(\xi)\sqrt{\pi\ln(2N_U(\omega))})]\}} \tag{27}$$

Despite the system response not being previously known, the parameter $N_U(\omega)$ and the factor of spreading $\delta_U(\xi)$ can be expressed by the following approximate expressions (Kiureghian, 1980):

$$N_U(\omega) = -\frac{T_s}{2\pi}\frac{\omega}{\ln(p)} \tag{28}$$

$$\delta_U(\xi) = \sqrt{1-\frac{1}{1-\xi^2}\left[1-\frac{2}{\pi}\arctan\left(\frac{\xi}{\sqrt{1-\xi^2}}\right)\right]^2} \tag{29}$$

The parameter ξ assumes the value 0.5 when the average value of peak values can be approximated by half the maximum distribution. For ξ=0.05, $\delta_U(\xi)$=0.24561. Once the PSD is known, the response spectrum can easily be found. However, the inverse problem is not easy because of the high nonlinearity of equation $S_a(\omega,\xi)$. To overcome this problem, an approximate expression for the response variance can be used (Vanmarcke, 1977) to determine the PSD:

$$G_{\ddot{U}g}(\omega) = \frac{\gamma}{\omega_C}\left[\left(\frac{S_a(\omega,\xi)}{\eta_U(\omega,\xi)}\right)^2 - \int_0^{\omega} G_{\ddot{U}g}(\omega)d\omega\right] \tag{30}$$

$$\gamma = \frac{4\xi}{(\pi - 4\xi)} \tag{31}$$

Determining the power spectral density function from a response spectrum is a considerable effort. The objective is to calculate a function for an unknown signal *a(t)* from the horizontal seismic acceleration. In this paper it is used an approximate analytical method proposed by Barone et al.(2015). This method is compatible with fairly generic forms of response spectrum and can be used for spectral response of various international standards of earthquake resistant buildings.

In order to define an analytical PSD function, extensive numerical campaign was carried out varying the intensity and shape of designated RS and evaluating the corresponding PSD. It was observed that the method always returned PSD's with the format in Fig. 5 (Barone et al.,2015:

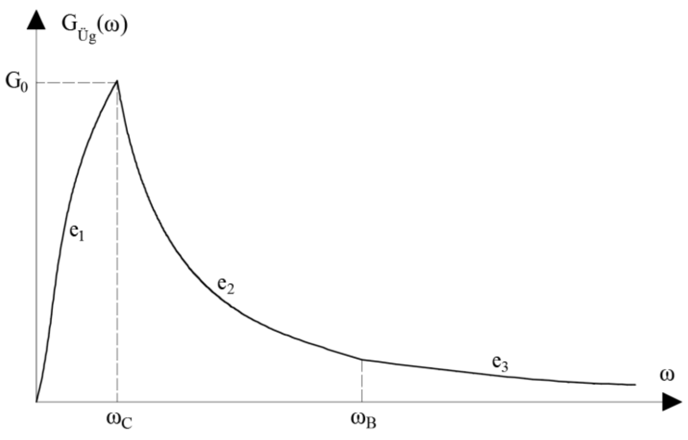


Figure 5. PSD compatible with response spectrum

Therefore, one may describe the PSD as a function with three intervals and a simple mathematical structure and completely defined by only a few parameters determined from the exact equation $G_{\ddot{U}g}(\omega)$, where G_0 pick value of the PSD to $\omega = \omega_C$:

$$G_{\ddot{U}g}(\omega)=\begin{cases} G_0\left(\dfrac{\omega}{\omega_C}\right)^{e1} & 0\le\omega\le\omega_C \\ G_0\left(\dfrac{\omega}{\omega_C}\right)^{e2} & \omega_C<\omega\le\omega_B \\ G_0\left(\dfrac{\omega_B}{\omega_C}\right)^{e2}\left(\dfrac{\omega}{\omega_B}\right)^{e3} & \omega>\omega_B \end{cases} \tag{32}$$

To determine the exponent e_1, the Eq. (30) is, at first, rewritten for the frequency $\omega=\omega_C$

$$G_0\frac{\omega_C^{e1+1}}{\omega_B^{e1}}=\frac{\gamma}{\omega_C}\left[\left(\frac{2.5a_{gs0}\left(\dfrac{\omega_C}{\omega_B}\right)}{\eta_U(\omega_C)}\right)^2-\int_0^{\omega_C}G_{\ddot{U}g}(\omega)d\omega\right] \tag{33}$$

and substituting the Eq. (32) into the integral term:

$$G_0\omega_C\left(\frac{\omega_C}{\omega_B}\right)^{e_1+1}\frac{\gamma+1}{\gamma}=\left(\frac{2.5a_{gs0}\left(\dfrac{\omega_C}{\omega_B}\right)}{\eta_U(\omega_C)}\right)^2 \tag{34}$$

Then, following the same reasoning, but considering a new frequency $\omega=\omega_C/\rho(\rho>1)$, the following expression is obtained:

$$G_0\omega_C\left(\frac{\omega_C}{\omega_B}\right)^{e_1+1}\frac{\gamma+1}{\gamma}=\left(\frac{2.5a_{gs0}\left(\dfrac{\omega_C}{\omega_B}\right)}{\eta_U\left(\dfrac{\omega_C}{\rho}\right)}\right)^2\rho^{-1} \tag{35}$$

Comparing Eqs. (34) and (35) and considering the limit $\rho=1$, it can be demonstrated that the exponent e_1 can be expressed in closed-form as:

$$e_1=2-L(\omega_D) \tag{36}$$

where the function $L(\omega)$ is defined as:

$$L(\omega)=2\omega\frac{d(\log(\eta_U(\omega)))}{d\omega} \tag{37}$$

The evaluation of the closed-form expressions for the other parameters is based on the same concepts, but considering points on the other three branches of the PSD. After some algebra, the following set of parameters is obtained.

$$e_1 = 1 - L(\omega_C) \tag{38}$$

$$e_2 = -1 - \gamma - \beta_2 L(\omega_C) \tag{39}$$

$$e_3 = -1 - \gamma - \beta_3 (L(\omega_B) + 1.2) \tag{40}$$

$$G_0 = \frac{\gamma}{\beta_2 \omega_C} \left(\frac{2.5 a_{gs0}}{\eta_U^2 (\omega_C)} \right)^2 \tag{41}$$

with the following positions:

$$\beta_2 = \frac{\gamma + e_1 + 1}{e_1 + 1} \tag{42}$$

$$\beta_3 = \left(\frac{\omega_C}{\omega_B} \right)^{e_2+1} \beta_2 + \left(1 - \left(\frac{\omega_C}{\omega_B} \right)^{e_2+1} \right) \frac{\gamma + e_2 + 1}{e_2 + 1} \tag{43}$$

3.5 Adjustment of the generated artificial accelerogram

It should be noted that the maximum acceleration resulting from the described algorithm is a random variable and although the response spectrum was suitably scaled at a maximum acceleration, the procedure described does not guarantee that the end result will provide this acceleration. However, it is to be expected that the difference between the obtained and the expected will be relatively small. Therefore, one can directly impose the desired value of the maximum acceleration taking into account two possible alternatives, as follows.

• If the absolute value of the maximum acceleration found is less than the specified value, simply change its absolute value to the desired value.

• If this absolute value is higher, all those accelerations whose absolute value exceeds the specified are scaled.

The procedure described will ensure that there is only a maximum acceleration of absolute value equal to that specified. Finally, it should be noted that this artificial modification only affects the response at the very high frequencies level (BARBAT et al., 1994).

4 SIMULATION RESULTS AND DISCUSSION

For the definition of the seismic action, the response spectra are calculated according to the prescriptions in the Brazilian Code NBR 15421: 2006. The horizontal seismic acceleration of the ground ag = 0.15 g was considered for soil classified as "C", having as dynamic soil amplification factors, Ca = 1,2 and Cv = 1,7 and damping ratio ξ = 5%. The resulting response spectrum is shown in Figure 6.

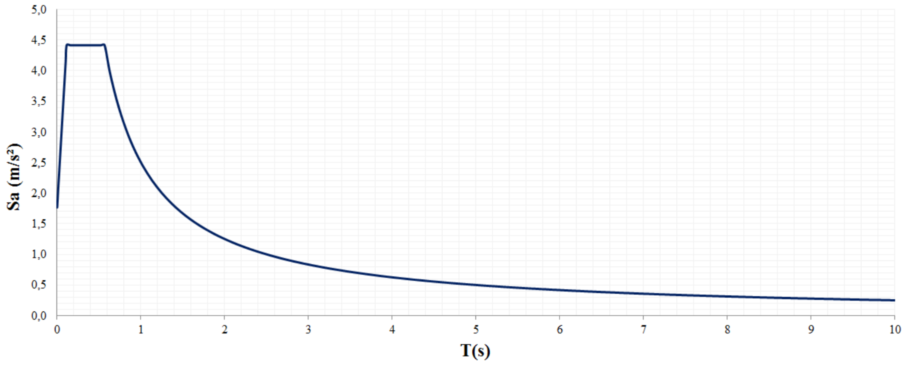


Figure 6. Response Spectrum

The Power Spectral Density Function compatible with the response spectrum shown is displayed in Figure 7.

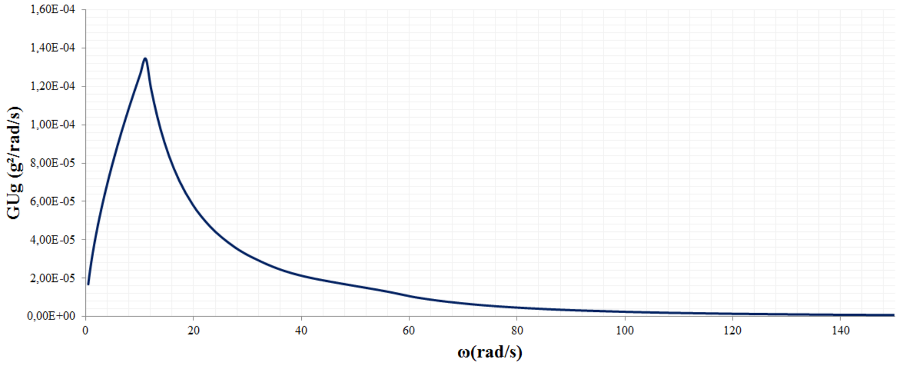


Figure 7. Power Spectral Density Function

To simulate the transient character of a real earthquake, the trapezoidal envelope function was used. Following the recommendation of Trifunac & Brady (1975), the significant duration (Ds) comprises the range of 5% to 95% of all energy developed.

After all parameters definition, the artificial accelerogram is generated. Figure 8 shows the obtained signal.

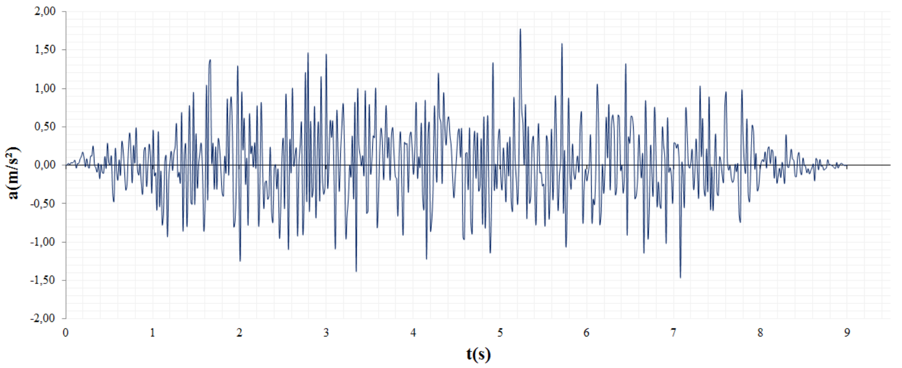
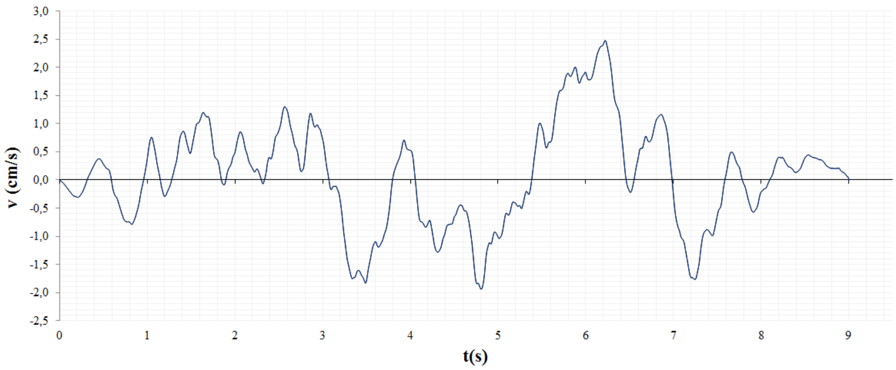


Figure 8. Artificial Accelerogram

In the generated accelerogram, it is possible to perceive that the adjustment criteria produced the expected results. The accelerogram is set on the zero axis, and the maximum acceleration obtained was the expected ag = 1.8 m / s².

In Figure 9, the history of velocities and displacements are shown.

(a)



(b)

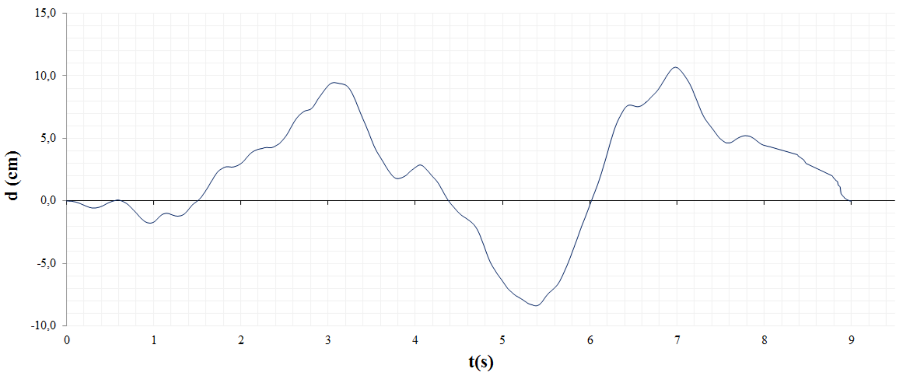


Figure 9. (a) History of Velocities. (b) History of Displacements

In order to verify the significant duration (Ds) between 5% and 95% of all the energy developed, the Arias intensity was calculated as a function of time and represented graphically in Figure 10, known as the Husid chart. In it, it can be seen that the significant duration is between 1.5 and 7 seconds. In Fig. 11 the resulting enveloping intensity function is plotted.

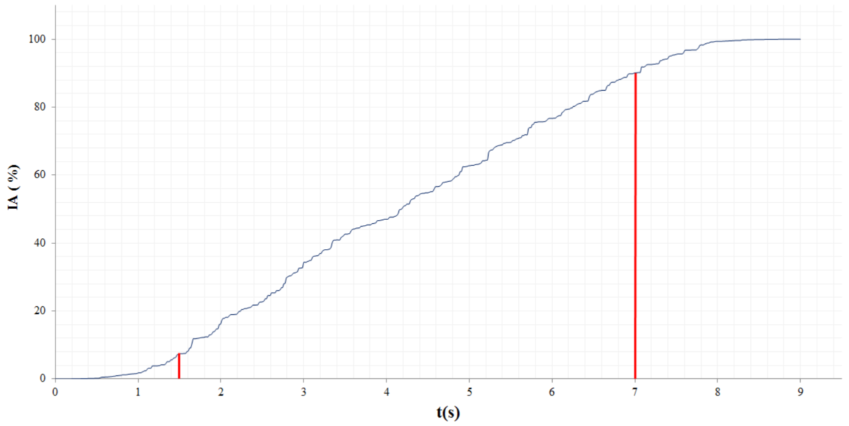


Figure 10. Husid

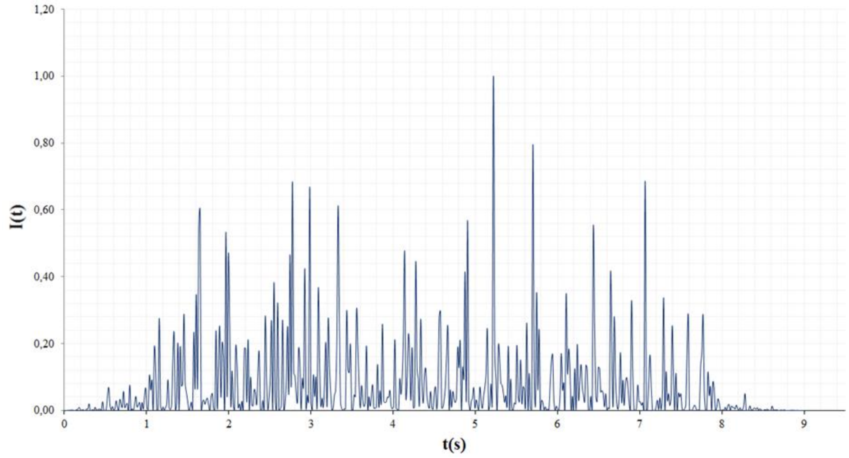
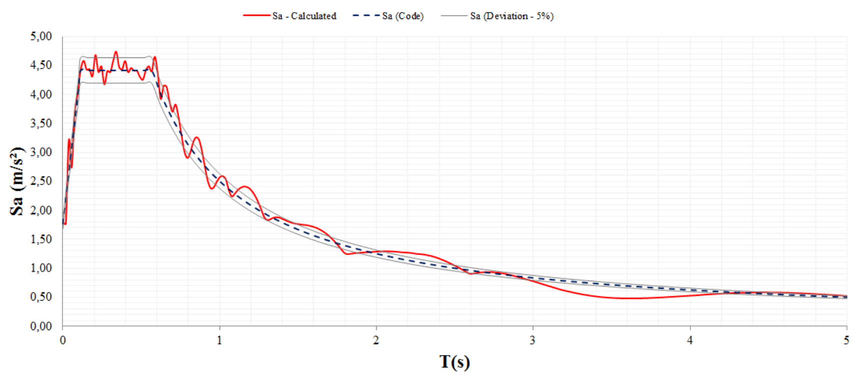


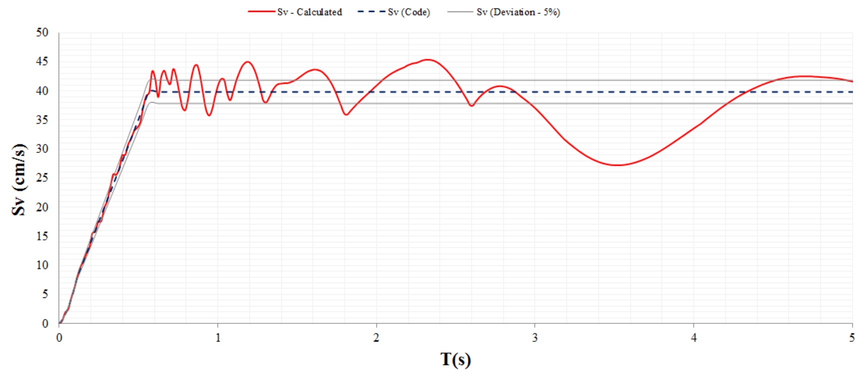
Figure 11. Intensity Envelope Function

After defining all the parameters presented, it remains to verify the compatibility of the artificial accelerogram with the normative response spectrum. For this, spectra of responses were calculated from the generated artificial accelerogram and compared with the Code response spectra. The calculated acceleration spectrum showed a 5% deviation to the Code spectrum. The results are shown in Figure 12.

(a)



(b)



(c)

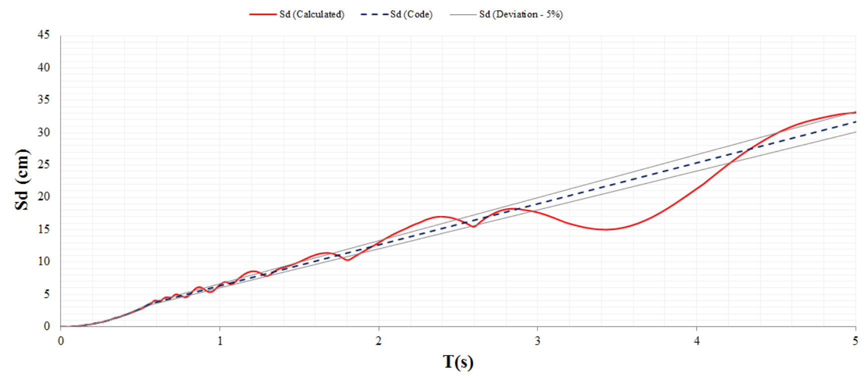


Figure 12. History of Acceleration (a), Velocities (b) and Displacements (c)

5 CONCLUSIONS

This paper aimed to develop a methodology for the generation of artificial seismic accelerograms compatible with standard elastic response spectrum indicated by the codes of construction of earthquake resistant structures. An artificial seismic accelerogram was generated compatible with an elastic response spectrum indicated by the Brazilian norm NBR 15421 (2006). The generated artificial accelerogram presented acceptable results and did not require correction needs for the baseline. Though, the historical speeds and displacements presented such a need.

Results indicate that the proposed methodology is satisfactory and that the generated artificial accelerograms are compatible with the Brazilian standard, since these are based on other norms, making the proposed methodology compatible with several international standards.

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