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THE **DBE** DESIGN RESPONSE SPECTRUM DOES NOT MEAN DOUBLE OF THE **SDE** ONE

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ABSTRACT

In the seismic analysis of the nuclear power plants, dams, military buildingas, etc., the seismic input is generally specified in terms of the design response spectrum. The object of the paper is to compute the design response spectra for SDE and DBE seismic severity levels by using nonlinear filtering anaysis.The question is : If the SDE maximum ground acceleration level is 0.2g and the DBE maximum ground acceleration is double, that is 0.4g, then the DBE design response spectrum is the double of the SDE one?

INTRODUCTION

Design basis ground motions shall be evaluated for each site and two levels of severity are usually specified, SDE and DBE.The SDE level is considered to be the maximum ground motion which reasonably can be expected to be experienced at the site area once during the operating life of the nuclear power plant [1].A purely probabilistic and seismotectonic approach should be use for evaluating the SDE. The DBE level of ground motion has a very low probability of being exceded and represents the maximum level of ground motion to be used for design purposes.Its evaluation may be based on seismotectonic considerations, historic earthquake experience in the region and a knowledge of the characteristics of the site area geology and soil materials. In our case, SDE level is 0.2g and DBE level is 0.4g.

On the other hand , design response spectra are a relatively smooth relation obtained by analysing , evaluating and statistically combining a number of individual response spectra derived from the record of significant past earhquakes from a ground acceleration process generation.

THE DERIVATION OF THE SDE DESIGN RESPONSE SPECTRA

The SDE and DBE are derived on the basis of historical earthquakes that have affected the site area.They can be expressed as the ground motion having a defined probability of not being exceeded and may be derived using a probabilistic approach, or the approach may include seismotectonic considerations (combined probabilistic and seismotectonic approach). Also, the SDE and DBE can be derived by using computation models simulating earthquake from a local ground acceleration process generation [2].In our case, at the Măgurele site we have two records: the Vrancea earthquake on August 30, 1986 (H=21:28:37; $\phi = 45.53°$N ;$\lambda = 26.47° E; h =$ 133Km and magnitude $M_S = 6.7$)which were recorded at a Bucureşti- Măgurele seismic station of the National Institute for Earth Physics. Corrected peak accelerations (a_{max}), velocities(v_{max}), and displacements (d_{max})by using Kinemetrics and CALTECH (in brackets) methodology are given in Table 1.

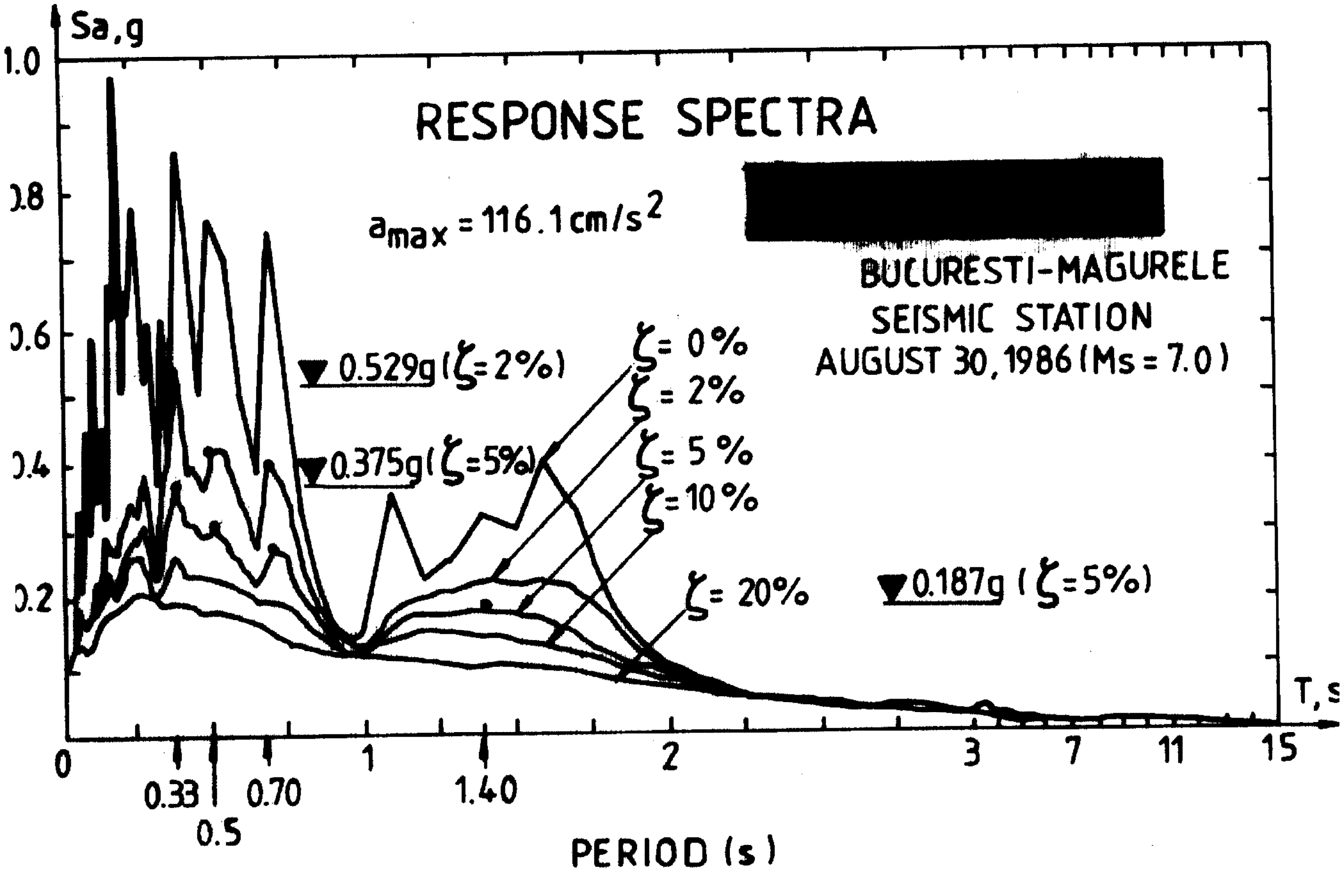
RESPONSE SPECTRA
[redacted]
BUCURESTI-MAGURELE
SEISMIC STATION
AUGUST 30,1986 (Ms = 7.0)
a max = 116.1 cm/s2
0.529g (ζ=2%)
0.375g (ζ=5%)
0.187g (ζ=5%)
ζ= 0%
ζ= 2%
ζ= 5 %
ζ=10 %
ζ= 20%
Sa,g
T,s
PERIOD (s)
0.33
0.5
0.70
1.40

Fig.1

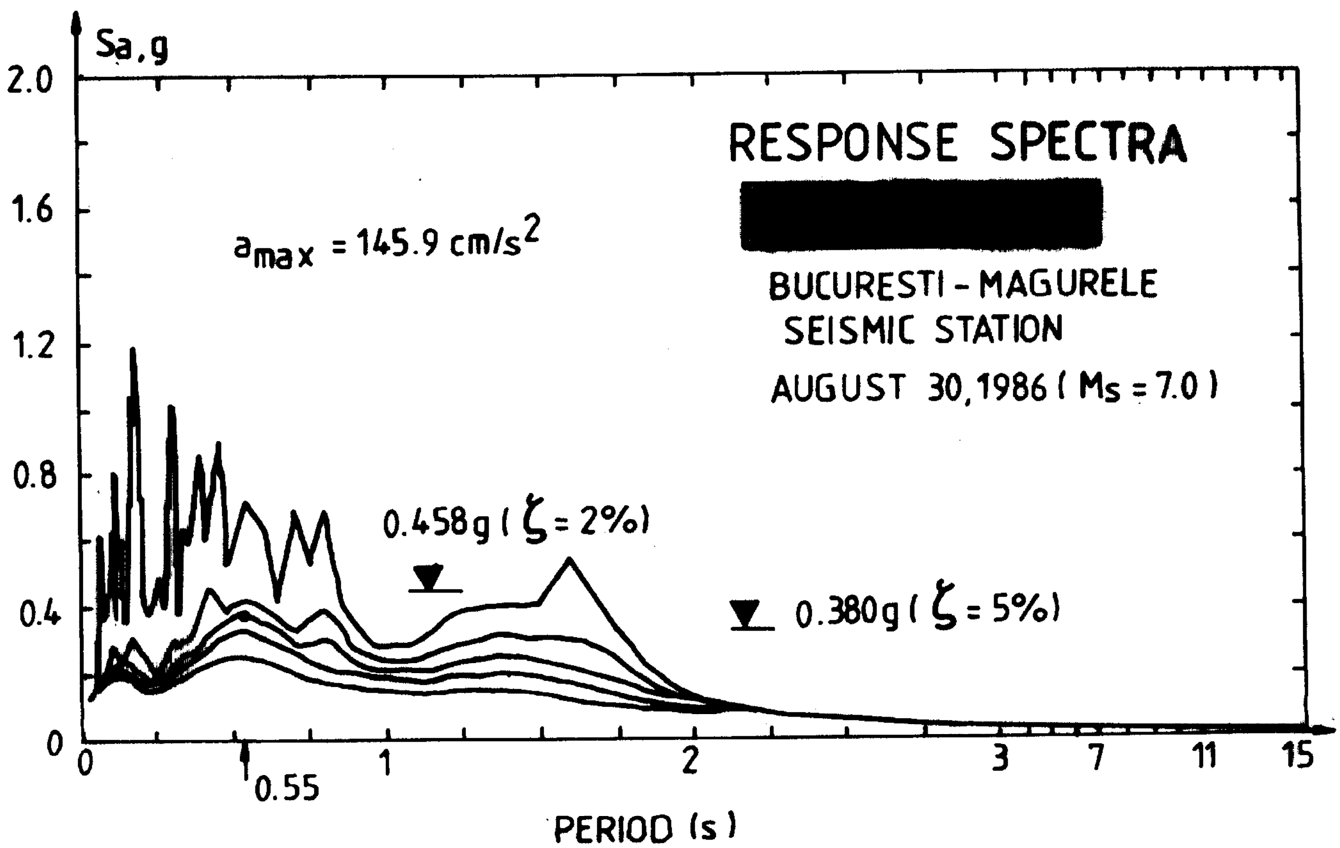
RESPONSE SPECTRA
[redacted]
BUCURESTI - MAGURELE
SEISMIC STATION
AUGUST 30,1986 (Ms = 7.0)
a max = 145.9 cm/s2
0.458g (ζ = 2%)
0.380g (ζ = 5%)
Sa,g
PERIOD (s)
0.55

Fig. 2

Seismic station	Component	August 30,Vrancea earthquake $M_S = 7.0$			May 30,1990,Vrancea earthquake $M_S = 6.7$		
		a_{max} (cm/s^2)	v_{max} (cm/s)	d_{max} (cm)	a_{max} (cm/s^2)	v_{max} (cm/s)	d_{max} (cm)
Bucureşti Măgurele	N-S	135.53 (145.9)	22.35 (20.88)	3.89 (3.70)	90.17	4.83	1.51
	V	50.31 (50.8)	3.60 (4.05)	0.98 (1.20)	60.85	2.35	1.04
	E-W	114.65 (116.10)	16.27 (16.95)	3.72 (2.58)	87.12	15.88	4.14

The Regulatory Guide 1.60 of the U.S.Atomic Energy Comission specifies that he numerical values of design displacements, velo cities and accelerations for the horizontal component Design Response Spectra are obtained by multiplyng the corresponding values of the maximum ground displacement and acceleration by the spectral amplification factors [4].The spectral amplification factor for accelerations, for example, is defined as the ratio between maximum spectral absolute acceleration from response spectra for a fraction of critical damping(S_a^{max}) and peak value of acceleration(a_{max}) from corrected accelerations of the record [3,5].In the same way we define as the spectral amplification factor for velocities and displacements, that is:

$$\frac{S_a^{max}}{a_{max}}; \qquad \frac{S_v^{max}}{v_{max}}; \qquad \frac{S_d^{max}}{d_{max}}$$

An example as response spectrum is shown in Fig.1 and Fig.2 for N-S coponent, respectively, E-W component of the records from Bucureşti-Măgurele seismic station 1986 Vrancea earthquake ($M_S = 7.0$) For any general motion of the support $z(t)$ of the simple degree of freedom linear oscilator of mase m, stiffnes k and viscous damping constant C, the relative displacement $x(t)$ can be computed from Duhamel integral. For zero initial conditions we have :

$$x(t) = \frac{-1}{\omega_n\sqrt{1-\xi^2}} \int_0^t \ddot{z}(\tau)e^{-\xi\omega_n(t-\tau)} \sin\omega_n\sqrt{1-\xi^2}(t-\tau)d\tau \tag{1}$$

where the natural frequency ω_n and the function of critical damping ξ may be defined as follows :

$$\omega_n^2 = \frac{k}{m} \qquad and \qquad \xi = \frac{c}{2\sqrt{km}} \tag{2}$$

The exact relative velocity $\dot{x}(t)$ follows from :

$$\begin{aligned}\dot{x}(t) = &-\int_0^t \ddot{z}(\tau)e^{-\xi\omega_n(t-\tau)} \cos\omega_n\sqrt{1-\xi^2}t-\tau)d\tau+ \\ &+ \quad \frac{\xi}{\sqrt{1-\xi^2}} \int_0^t \ddot{z}(\tau)e^{-\xi\omega_n t-\tau)} \sin\omega_n\sqrt{1-\xi^2}(t-\tau)d\tau\end{aligned} \tag{3}$$

and the absolute acceleration $\ddot{y}(t)$ of the mass m of the oscilator is obtained by further differentiation of $\dot{x}(t)$ and nothing that

$$\ddot{y}(t) = \ddot{x}(t) + \ddot{z}(t) \tag{4}$$

we have :

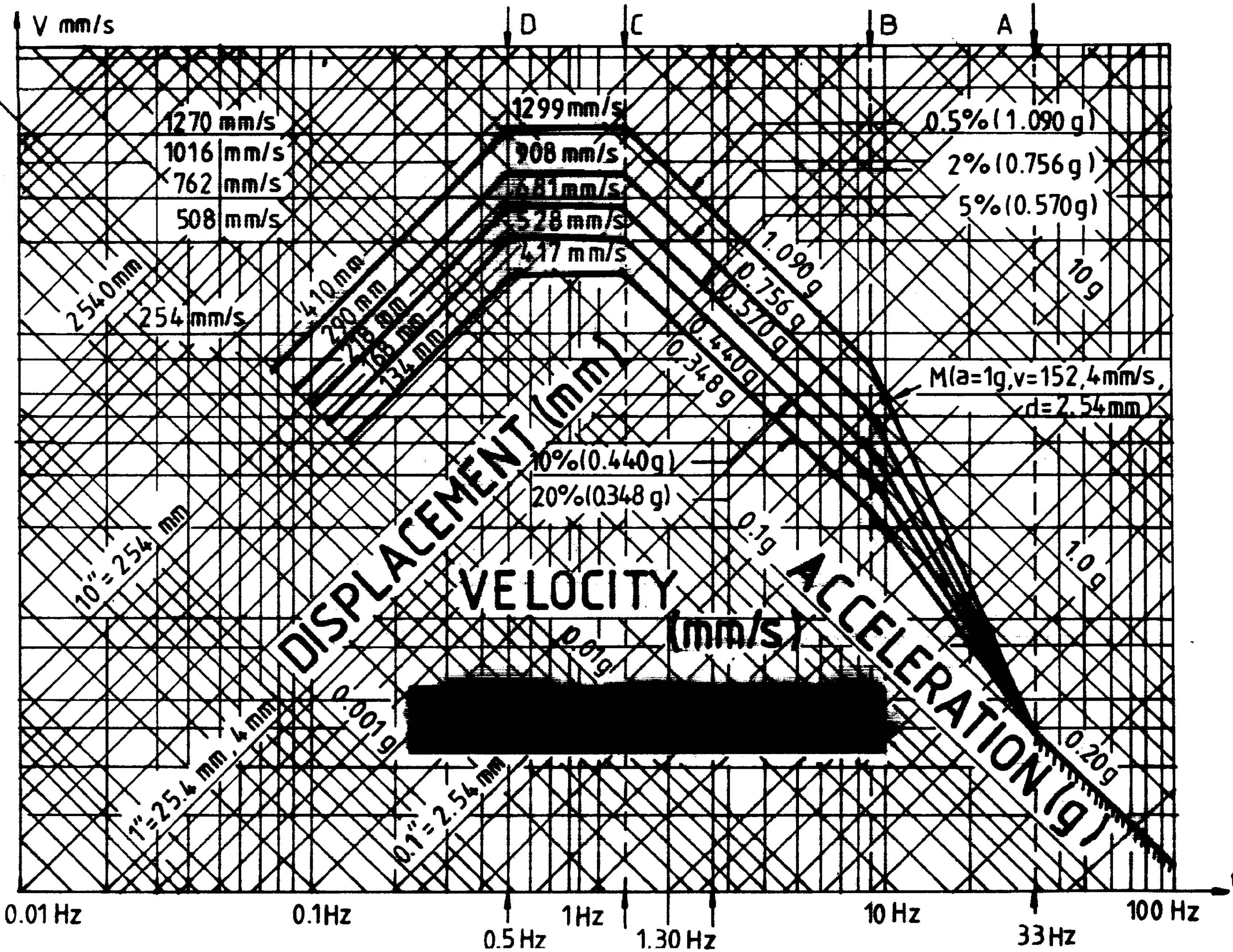
V mm/s
2540 mm/s
D, mm
1270 mm/s
508 mm/s
254 mm/s
152.4mm/s
25.4 mm/s
2.54 mm/s
D
C
B
A
1270 mm/s
1016 mm/s
762 mm/s
508 mm/s
1299 mm/s
908 mm/s
681 mm/s
528 mm/s
417 mm/s
0.5% (1.090 g)
2% (0.756 g)
5% (0.570 g)
10% (0.440 g)
20% (0.348 g)
1.090 g
0.756 g
0.570 g
0.440 g
0.348 g
10g
1.0 g
0.1g
0.01g
0.001g
0.20g
M(a=1g, v=152,4 mm/s, d=2,54 mm)
2540 mm
254 mm/s
410 mm
290 mm
218 mm
168 mm
134 mm
10" = 254 mm
1" = 25.4 mm, 4 mm
0.1" = 2.54 mm
DISPLACEMENT (mm)
VELOCITY (mm/s)
ACCELERATION (g)
[redacted]
0.01 Hz
0.1Hz
0.5 Hz
1Hz
1.30 Hz
10 Hz
33 Hz
100 Hz
f

Fig. 3

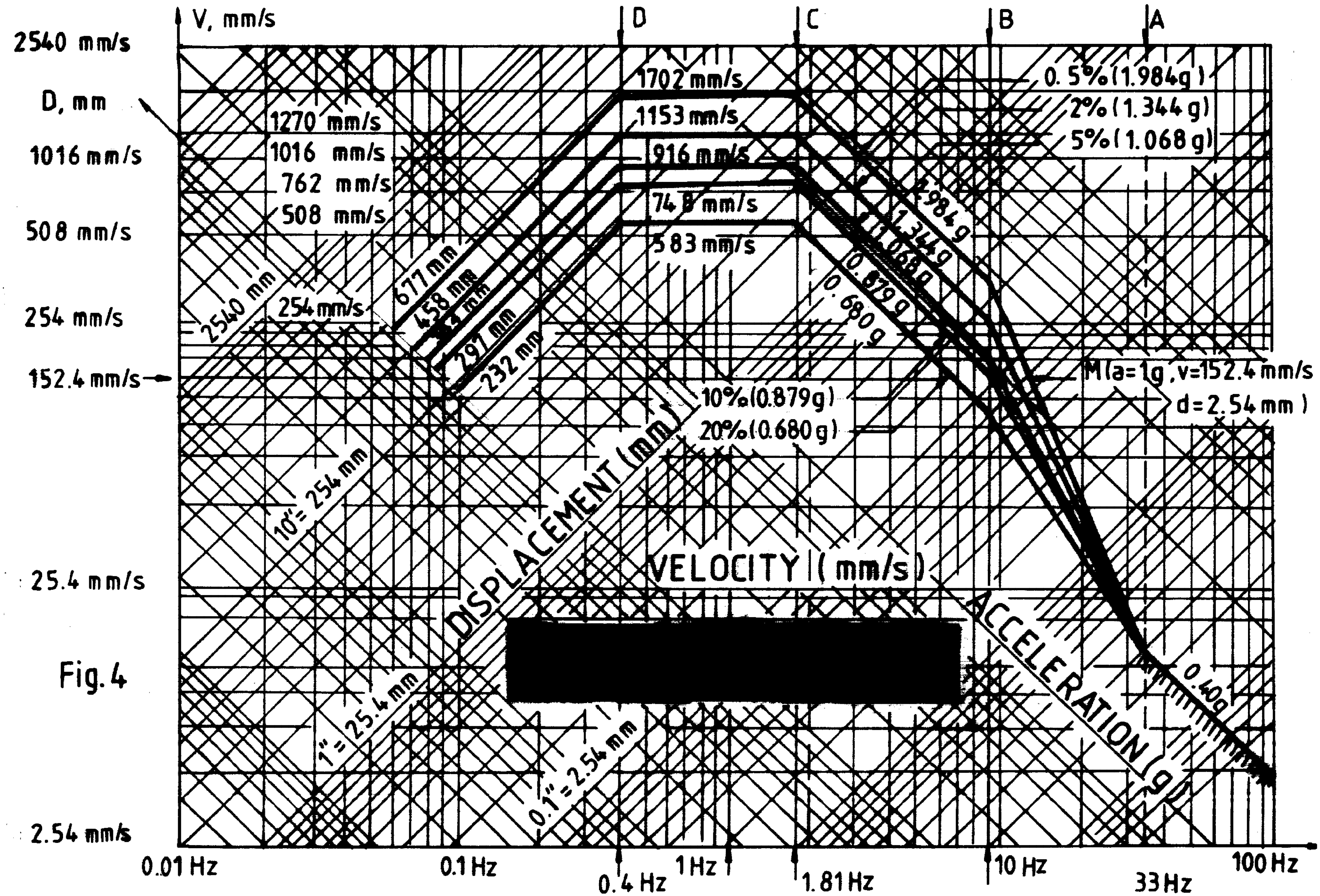
V, mm/s
D
C
B
A
2540 mm/s
D, mm
1016 mm/s
508 mm/s
254 mm/s
152.4 mm/s
25.4 mm/s
2.54 mm/s
1270 mm/s
1016 mm/s
762 mm/s
508 mm/s
254 mm/s
2540 mm
1702 mm/s
1153 mm/s
916 mm/s
748 mm/s
583 mm/s
0.5% (1.984g)
2% (1.344 g)
5% (1.068 g)
1.984g
1.344g
1.068g
0.879g
0.680g
677 mm
458 mm
297 mm
232 mm
M (a=1g, v=152.4 mm/s
d=2.54 mm)
10% (0.879g)
20% (0.680g)
10" = 254 mm
DISPLACEMENT (mm)
VELOCITY (mm/s)
ACCELERATION (g)
[redacted]
1" = 25.4 mm
0.1" = 2.54 mm
0.40g
0.01 Hz
0.1 Hz
0.4 Hz
1 Hz
1.81 Hz
10 Hz
33 Hz
100 Hz

Fig. 4

$$\ddot{y}(t) = \omega_n \frac{1-2\xi^2}{\sqrt{1-\xi^2}} \int_0^t \ddot{z}(\tau) e^{-\xi\omega_n(t-\tau)} \sin \omega_n \sqrt{1-\xi^2}(t-\tau) d\tau +$$
$$+2\omega_n \xi \int_0^t \ddot{z}(\tau) e^{-\xi\omega_n(t-\tau)} \cos \omega_n \sqrt{1-\xi^2}(t-\tau) d(\tau) \quad (5)$$

For engineering applications of the quantities $x(t), \dot{x}(t)$ and $\ddot{y}(t)$ during of earthquake and these quantities are commonly defined as follows :

$$\begin{aligned} S_d &= |x(t)|_{max} \\ S_v &= |\dot{x}(t)|_{max} \\ S_a &= |\ddot{y}(t)|_{max} \end{aligned} \quad (6)$$

and plots of S_d, S_v, S_a versus the undamped natural period T for various fractions of critical damping ξ , are called earthquake response spectra (Fig1 and Fig2). The rations between S_a^{max} and peak values of a_{max}, v_{max} and d_max are so called spectral amplification factors , that is

$$\frac{S_a^{max}}{a_{max}}; \quad \frac{S_v^{max}}{v_{max}}; \quad \frac{S_d^{max}}{d_{max}}$$

and in Table are giving the median (50%) values of them for horizontal components at Bucureşti - Măgurele seismic station for august 30, 1986 Vrancea earthquake ($M_S = 6.7$)

RESULTS

The design response spectra for **SDE** ($a_{max} = 0.2g$) and **DBE** ($a_{max} = 0.4g$) levels are given in Figure 3 , respectively , Figure 4 by uniq Regulatory Guide 1.60 methodology and the spectral amplification factor from Table 2 for Bucureşti-Măgurele site.

These spectral amplification factor are different of that given by Regulatory Guide 1.60 of the U.S.Atomic Commission and more are function of earthquake magnitude.The phenomenon was printed out in paper [5] for Vrancea earthquake and finally there is a nonlinear dependence between spectral amplification factor and earthquake magnitude.

Soils exhibit a strong-nonlinear behaviour under cyclic (seismic) loading conditions and this basic material characteristic shall, therefore , be taken into account when evaluating seismic response of soil deposits . In our case, under Bucureşti Măgurele seismic station there is about 1400m of sedimentary rocks(clay, sand , loess , sand and gravell , sandy clay etc.) and them exhibit a strong nonlinear dependence between thear modules (G) and damping ration (D) and thear strains (γ) induced by strong earthquakes.

CONCLUSIONS

The numerical values of design displacements , velocities and accelerations for the horizontal component Design Response Spectra can be obtained by multiplying the corresponding values of the maximum ground recorded displacement and acceleration by the spectral amplification factors.

The spectral amplification factors are functions of earthquake magnitude and site conditions and consequently , the Design Response Spectra for **SDE** level and **DBE** level are functions of them .Regulatory Guide 1.60 of the U.S.Atomic Commission don't take into consideration this influence of magnitude and consequently the **DBE** Design Response Spectrum ($a_{max} = 0.4g$) does not mean double of **SDE** one ($a_{max} = 0.2g$). The explanation is that soils exhibit a strong nonlinear behavior under seismic loading conditions and this basic material characteristic shall , therefore , be taken into consideration when evaluating seismic response of soil deposits especially sedimentary one.