A NEW SEMIPROBABILISTIC CONCEPT

CONCERNING THE CODIFICATION OF THE SEISMIC ACTIONS

by

MIHAIL IFRIM [I], and TIBERIU ZORAPAPEL[II]

SYNOPSIS

The purpose of the paper is to propose a more realistic estimate for the ratio "maximum ground acceleration during an earthquake to the RMS of the realization", to be used in code instead of constant values used in present. First passage techniques are used based on the following assumption: the model for ground acceleration is taken as a ergodic, stationary process normally distributed and the half number of crossings a reasonable high threshold within the earthquake duration is Poisson distributed. The normalized maximum acceleration results as a function of the ratio: predominant period to earthquake duration. On this base a simple formula is proposed in order to replace the constant value used within the international standard CEB-CECM-CIB-FIP-IABSE.

The actual seismic zoning of a territory carried out on the base of a single parameter describing the severity of a strong ground motion, without defining this parameter with relation to the different intensities earthquakes succession and without giving some indications about this succession, appears insufficient for defining earthquake loads to be taken into account for both structural design and structural safety estimates.

Starting from this fact, seismic zoning methods based upon the seismic risk concept have been born. Maximum velocity or acceleration realized on a site during a ground motion is usually taken as a severity parameter.

If we consider the ground motion felt on a given site and provided by a same source zone keeping a same earthquake mechanism, as a realization of a ergodic stationary (or even local stationary) stochastic process, normalized by dividing it to its root mean square, then the normalized maximum ordinate of a realization will be a random variable.

I Professor of Structural Engineering, Ph.D., Faculty of Civil Engineering, Bd. Lacul Tei, 124, R-72302 Bucharest, Romania.

II Research Engineer, Building Research Institute, Sos. Pantelimon, 266, R-73559 Bucharest, Romania.

To define the seismic risk of a site on the base of a variable which is random even in the case when all the parameters of the mathematical model taken for the ground motion are constant, is obviously inconsistent from the mathematical point of view. Moreover, such a definition does not allow a rigorous approach to estimate the safety of a structure undergoing earthquakes.

Obviously, a rigorous definition could be based on the velocity or acceleration root mean square (or its maximum in the case of a nonstationary process), but this would require a set of stochastical ground motion models for all source zones and for all possible earthquake mechanisms.

Now, in order to pass over this inconvenient, one considers the normalized maximum ordinate of a realization (the maximum ordinate divided by the root mean square) to be a constant for stationary processes. J.F. Borges and M. Castanheta [1] consider this value to be 3, while the international standard CEB-CECM-CIB-FIP-IABSE [2] takes this value equal to $\sqrt{10}$.

The purpose of this paper is to suggest a more realistic estimate of this value, based upon first passage techniques.

Since the probability distribution function of the normalized maximum ordinate of the realization is not available, one can assimptotically estimate it by means of the no passage probability that is the probability that the ordinate of the processus does not exceed a given threshold within the specified time interval (in the case, the duration of the ground motion).

Let us consider the ground acceleration during an earthquake to be an ergodic, stationary processus normally distributed, and also the half number of the threshold crossings within the time interval to be Poisson distributed. These assumptions simplify the computation of the no passage probability which can be obtained by different approaches [3], [4],[5] as follows:

$$P_o \quad e^{-\frac{t}{2\pi}\sqrt{-\ddot{K}(0)/K(0)}\; e^{-a^2/2K(0)}} \qquad (1)$$

where
P_o = no passage probability
t = the duration of the ground motion
a = the given threshold
$K(\tau)$ = the autocorrelation function of the processus
$\ddot{K}(\tau)$ = the second derivative of $K(\tau)$

Hence:

$\sqrt{K(o)} = \sigma$ will be the root mean square of the processus

$\sqrt{\ddot{K}(o)} = \sigma^*$ will be the root mean square of the derivative of the processus.

Let us consider as a model for the ground acceleration a processus whose autocorrelation function is

$$K(\tau) = \sigma^2 e^{-\alpha|\tau|} \left(\cos \beta \tau + \frac{\alpha}{\beta} \sin \beta|\tau|\right) \qquad (2)$$

where:

β = the predominant circular frequency of the processus

α = the autocorrelation rate

The function given by the formula (2) is more suitable than the function given by the often used formula

$$K(\tau) = \sigma^2 e^{-\alpha|\tau|} \cos \beta \tau \qquad (3)$$

which has not the second derivative in the origin, hence the derivative of the processus does not exist.

Using the autocorrelation function as given by the formula (2) we shall obtain:

$$K(o) = \sigma^2 , \qquad \ddot{K}(o) = -(\alpha^2 + \beta^2)\sigma^2 \qquad (4)$$

I.M. Eisenberg [6] fitting a similar autocorrelation function to a great number of recorded ground motions, has found that α and β are rather close correlated, and has estimated the mean and the root mean square of the random variable $\theta = \alpha/\beta$ as follows:

$$M[\theta] = 0.36 , \quad \sigma[\theta] = 0.136 \qquad (5)$$

Therefore, assuming θ to be normally distributed, one can consider with o,84 probability a trust interval for θ

$$\theta \in [0.224;\ 0.496] \qquad (6)$$

Computing the root from the equation (1) for the bounds of the trust interval (6), one get:

$$\sqrt{-\frac{\ddot{K}(o)}{K(o)}} = \beta\sqrt{1+\theta^2} \in [1.025\beta ;\ 1.130\beta] \qquad (7)$$

that will lead to errors less than 3 percent in the estimate of P_o. Therefore, we can consider only the mean value of θ (5) when computing the no passage probability.

Substituting the predominant circular frequency β by the predominant period $T=2\pi/\beta$ and using (4) and (5), one get from (1):

$$\frac{a}{\sigma} = \sqrt{2\ln\left(\frac{t}{T}\cdot\frac{1.065}{\ln 1/P_0}\right)} \qquad (8)$$

If one choose a reasonable high threshold "a" one can consider the right side of the equation (1) as an assimptotical estimate of the probability distribution function of the maximum ordinate (that becomes "a"), therefore one can consider the right side of the equation (8) as a probabilistic definition of the normalized maximum ground acceleration a/σ, as follows:

a/σ is the normalized ground acceleration (for the choosen stochastical model) with the probability P_o; the bigger the probability, the bigger will be the normalized ground acceleration.

In fig. 1, values of a/σ against T/t for several P_o probabilities are plotted; the below abscissa indicates the values of T in seconds for the standard duration t = 3o sec. [2] .

The assimptotical trend of the upper branches of the curves in fig. 1 is due, of course, to the use of an infinite gaussian distribution instead of a more realistic finite distribution, not available up to date. The use of the gaussian distribution for random vibrations is based mainly on the central limit theorem, but, in fact, especially for narrow-band vibrations, the assumptions of the central limit theorem are no more fulfilled.

Distortions could be also provided at the lower branches by the Poisson distribution assumed for the number of threshold crossings. (In fact, the excursions beyond the threshold tend to occur in a clump).

In order to provide a simple estimate for replacing the constant value used in the CEB-CECM-CIB-FIP-IABSE standard [2] , in fig. 2 the probability P_o against T for $a/\sigma = \sqrt{1o}$ is plotted. It could be noticed that 7o percent probability for P_o is to be chosen in order to keep a same overall safety level within the range of predominant periods from o.2 to 2.5 sec. Hence, we obtain in (8) for P_o = o.7o and t = 3o sec. the following formula:

$$\frac{a_{max}}{\sigma} = \sqrt{2\ln\frac{90}{T}} \qquad (9)$$

We propose the above formula instead of the constant value $\sqrt{1o}$ taken in the international standard [2] .

Final remarks. The normalized maximum ground acceleration, that is the maximum ground acceleration divided by its root mean equare is a function of the ratio "predominant period to the duration of the ground motion". Of course, the analysis could be carried out on more sophisticated stochastical models for the ground motion, and/or by various first passage techniques [7] . The target of this paper is to let know the nature of the phenomena, and to provide a very simple formula to be used in codes.

REFERENCES

1. J. Ferry Borges and M. Castanheta, Structural Safety, 2nd Edition, Lisbon 1971.
2. CEB-CECM-CIB-FIP-IABSE, Note L-o3, Basic data for loads. Seismic Vibrations in Bedrock and Superficial Layer, June 1973.
3. T. Zorapapel, A Stochastical Approach to the Safety of Structures undergoing Earthquakes, SCI no. 2, 1975, Building Research Institute, Bucharest.
4. S. Larionescu, Damage Effects of Mechanical Systems submitted to Random Vibrations, Euromech Colloquium, Dynamics of Machine Foundations, Bucharest, 1973.
5. A.A. Sveshnikov, The Applied Theory of Random Functions, Fizmatgiz, Moscow, 1968.
6. I.M. Eisenberg, A. Random Spectral-time model for Seismic Actions, TZNIISK papers, vol. 33, 1974.
7. Jann-Nan-Yang, Approximation to first Passage Probability, Journal of the Eng. Mrch. Div., ASCE, August 1975.
8. Mihail Ifrim, Dynamic Analysis of Structures and Earthquake Engineering, Bucharest 1973.

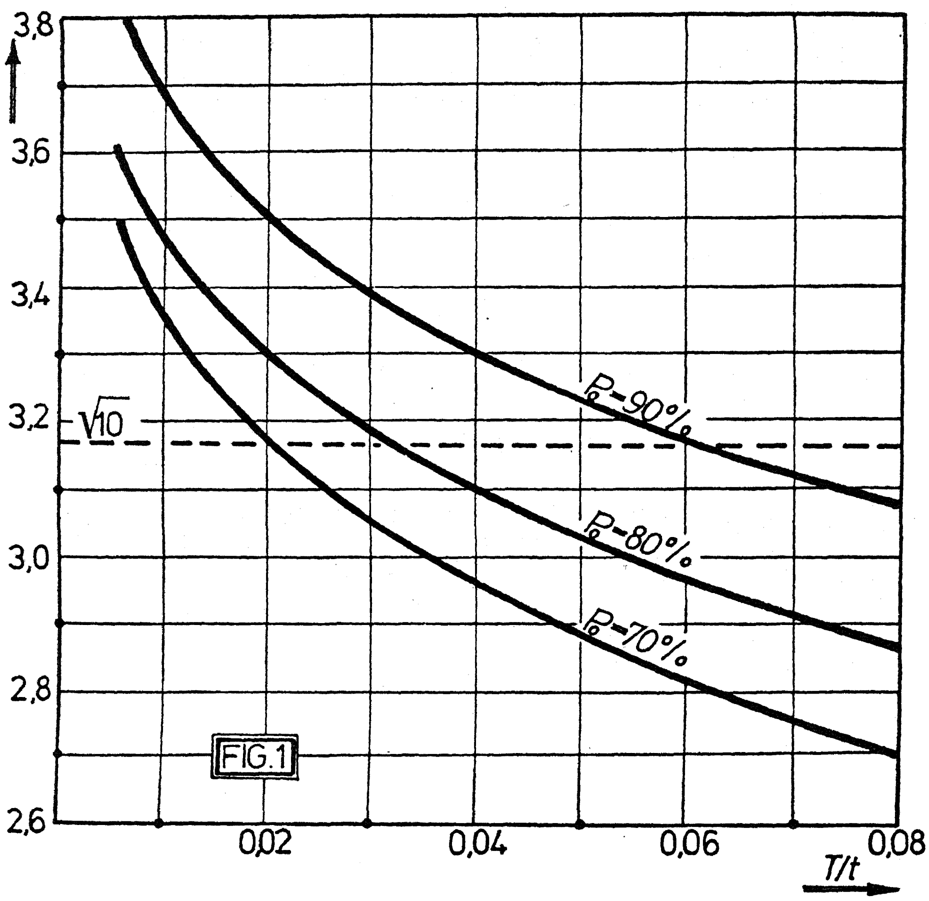
a/σ
3,8
3,6
3,4
3,2
3,0
2,8
2,6
√10
P₀-90%
P₀-80%
P₀-70%
0,02
0,04
0,06
0,08
T/t

FIG. 1

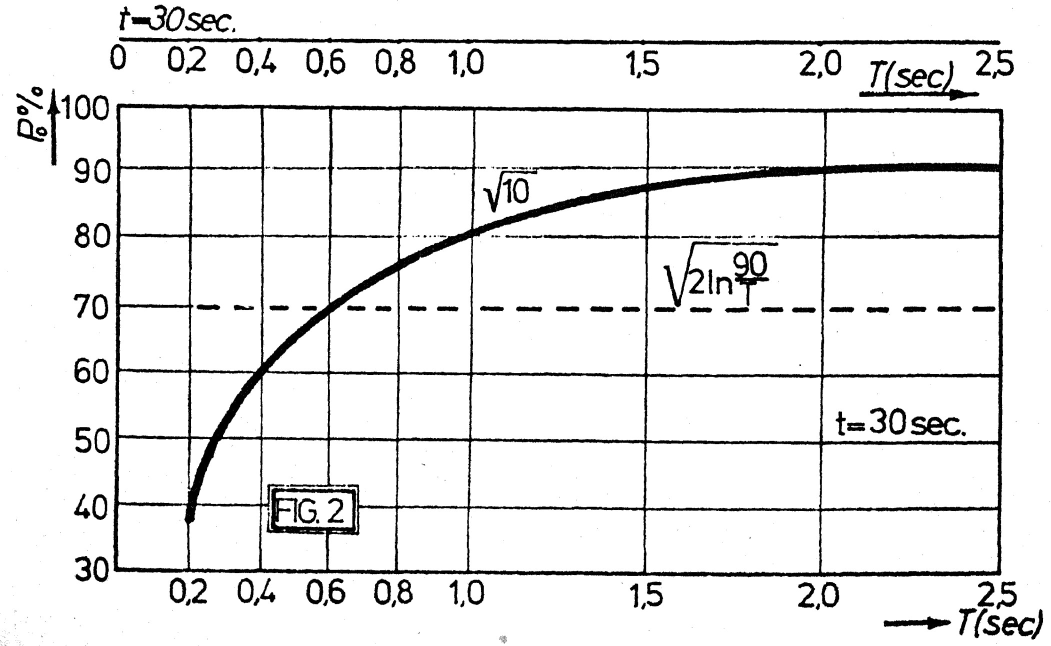
t=30sec.
0 0,2 0,4 0,6 0,8 1,0 1,5 2,0 T(sec) 2,5
P₀%
100
90
80
70
60
50
40
30
√10
t=30 sec.
0,2 0,4 0,6 0,8 1,0 1,5 2,0 2,5
T(sec)

FIG. 2

DISCUSSION

R. Duarte (Portugal)

The predominant period of a ground motion is, in most cases, a slippery (1) and subjective (2) quantity (e.g. : (1) the misinterpretation in a influential work on rock motions of date presented by two well-known seismologists; (2) the definition, in this conference of a predominant frequenty that is approximately two times the frequency at which maximum power spectral density occurs). In the discussor's opinion there is clearly a need to quantify the frequency content of ground motion, but not by predominant periods. There is also plenty of different measures of earthquake durations.

It is the discussor's opinion that, without stating clearly what are "predominant periods" and "durations", and how they relate to source properties distance and local site conditions, there is nothing to be gained from the introduction of this new concept in what is intended to be a very simplified international standard (ref. 2).

Author's Closure

Not received.