MODEL OF NONSTATIONARY SEISMIC PROCESS

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ABSTRACTS

The seismic acceleration is regarded as a nonstationary multiplicative random process. A special expression for deterministic amplitude function is proposed which deviates from unit less than 10% in the interval 2 - 10 sec. The formulas for autocorrelation functions and dispersions are given, which show that the response of an undampted system becomes stabilized in a comparativly short interval of time.

Earthquakes can be devided into three groups: great distance deep focus earthquakes; mean distance earthquakes with mean depths of focuses; epicentral earthquakes. The following investigation relates to the mean distance earthquakes.

Seismic ground acceleration, as given by accelerograms, is presumed to have constant, stationary frequency characteristic during all the earthquake /1/. Nonstationary properties results from amplitude variations and short duration of process.

Any accelerogram id assumed to have three phases /2/: initial one lasting from zero to two seconds, when amplitudes of acceleration increase to their mean maxima; the second phase from two to ten seconds, characterized by approximately stationary amplitudes, and final phase of process attenuation to comparativly small values.

According to this assumption the seismic acceleration is regarded as a multiplicative random function, given by the following expression

$$a(t) = A(t)W_0(t) \qquad (1)$$

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$w_0(t)$ - the accelerogram of any real earthquake regarded as a stationary process;
$A(t)$ - amplitude function

$$A(t) = 0{,}75\, t^{0{,}637} e^{-0{,}128 t} \qquad (2)$$

Amplitude function (2) is plotted on the fig 1. It provides initial and final phases as deseribed above and in the middle phase deviates from unit less than by 10%. The reduction of initial and final phases of accelerogram is of no significance since in all the following considerations the accelerogram is represented by its autocorrelation function, which is determined as for a stationary process independently of the amplitude functuon.

Autocorrelation function of the nonstationary multiplicative process (1) may be expressed as

$$K_{aa}(t_1, t_2) = A(t_1) A(t_2) K_{ww}(\tau), \qquad (3)$$
$$\tau = t_2 - t_1$$

Autocorrelation function of accelerogram is taken as

$$K_{ww}(\tau) = K_{ww}(0)\, e^{-\alpha |\tau|} \cos \beta\tau \qquad (4)$$

The parametres of this expression are defined by numerical analysis of accelerogram.
According to (2), (3) and (4)

$$K_{aa}(t_1, t_2) = 0{,}5625\, K_{ww}(0) (t_1, t_2)^{0{,}637} \times$$
$$\times\, e^{-[0{,}128(t_1+t_2) + \alpha |t_2 - t_1|]} \cos \beta\tau \qquad (5)$$

Autocorrelation function of El Centro 1940 accelerogram is represented in fig.2.

The dispersion of the acceleration is obtained by putting $t_1 = t_2 = t$

$$\mathcal{D}_{aa}(t) = 0{,}5625\, K_{ww}(0)\, t^{1,274}\, e^{-0,256t}$$

It tends to zero at $t \to \infty$.

The main interest consists in defining theseiismic response of a structure, which can be expressed in terms of the dispersions in the outputs of a multi - degree - - of - freedom system. The dispersion in the k-th output in the normalized form that is devided by $K_{ww}(0)$, is given by

$$\mathcal{D}_K(t) = 2\int_0^t h_{kj}(t,\xi)\,d\xi \int_\xi^t h_{kj}(t,\zeta)\,K_{aa}(\zeta,\xi)\,d\zeta \qquad (6)$$

$K_{aa}(\zeta, \xi)$ - correlation function (5);
$h_{k_j}(t, \xi)$ - unit impulse response function in k-th output effected by the impulse applied to j-th input.

I If the system has only one input or many inputs effected by the ground acceleration simultaneonsly, it may by used the impulse function with one index, $h_k(t, \xi)$.

For a sindle - degree - of - freedom system with the angular frequency ω_0 it may be taken /3/

$$h(t) = \omega_0 \sin \omega_0 t, \qquad (7)$$

where $h(t)$ - output acceleration corresponding to $\delta(t)$-input acceleration.

Substitution of (5) and (7) and $z= \zeta - \xi$ into (6) gives the dispersion of an undampted oscillator acceleration as

$$\mathcal{D}(t) = 1{,}125\,\omega_0^2\, e^{-0{,}256t} \int_0^t e^{-(\alpha-0{,}128)z} \cos\beta z\, dz \times$$

$$\times \int_0^{t-z} e^{0{,}256\eta} \left[(t-\eta)(t-\eta-z)\right]^{0{,}637} \sin\omega_0\eta\, \sin\omega_0(\eta+z)\, d\eta \qquad (8)$$

In fig.3 in solid lines are shown the time - histories of the simple oscillator output acceleration standards -

$\sigma(t) = \sqrt{\mathcal{D}(t)}$ - for several free vibration periods. For comparison the graphs obtained with stationary input process are given in dotted lines.

With nonstationary input the standard of the acceleration becomes stabilized in comparativly short time interval so it can be taken as a steady characteristic of seismic response, independant of time interval of accelerogram handling.

By means of analysing a set of accelerograms necessary characteristics of seismic response may be obtained with more accuracy than if using the stationary input process formulas.

References.

I. Я.М.Айзенберг. Сооружения с выключающимися связями для сейсмических районов. М.Стройиздат 1976 г.

2. R.N. Claugh, J. Penzien. Dynamics of Structures. McGRAW-HILL Book Company, 1975.

3. В.Т.Рассказовский. Основы физических методов определения сейсмических воздействий. Ташкент,Изд-во"ФАН", 1973 г.

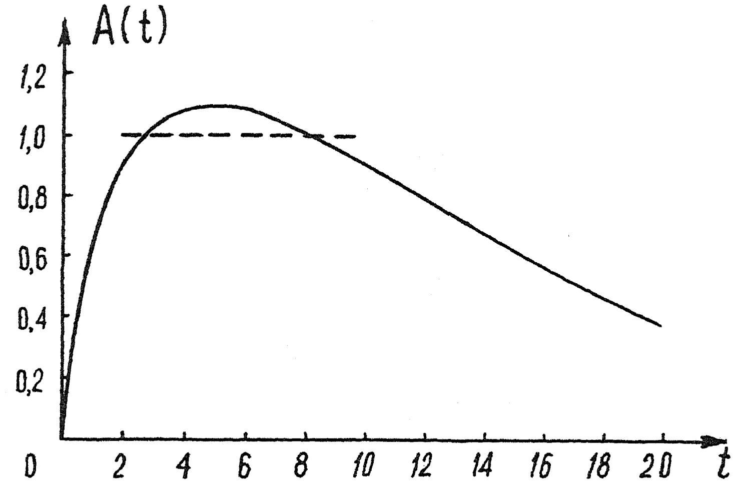

Fig.1. Amplitude function.

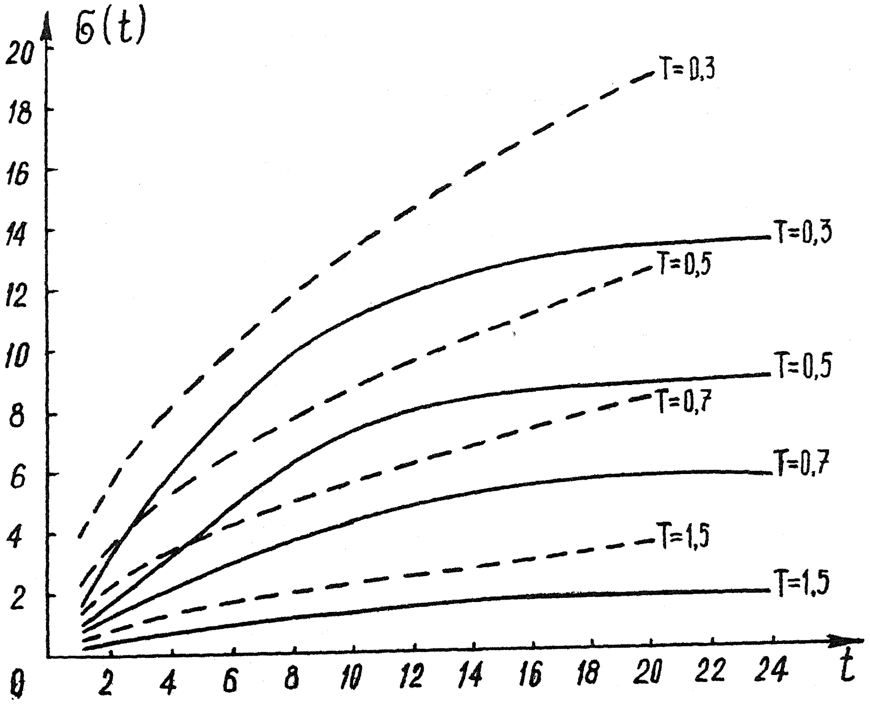

Fig.3. Standard time-history graphs.

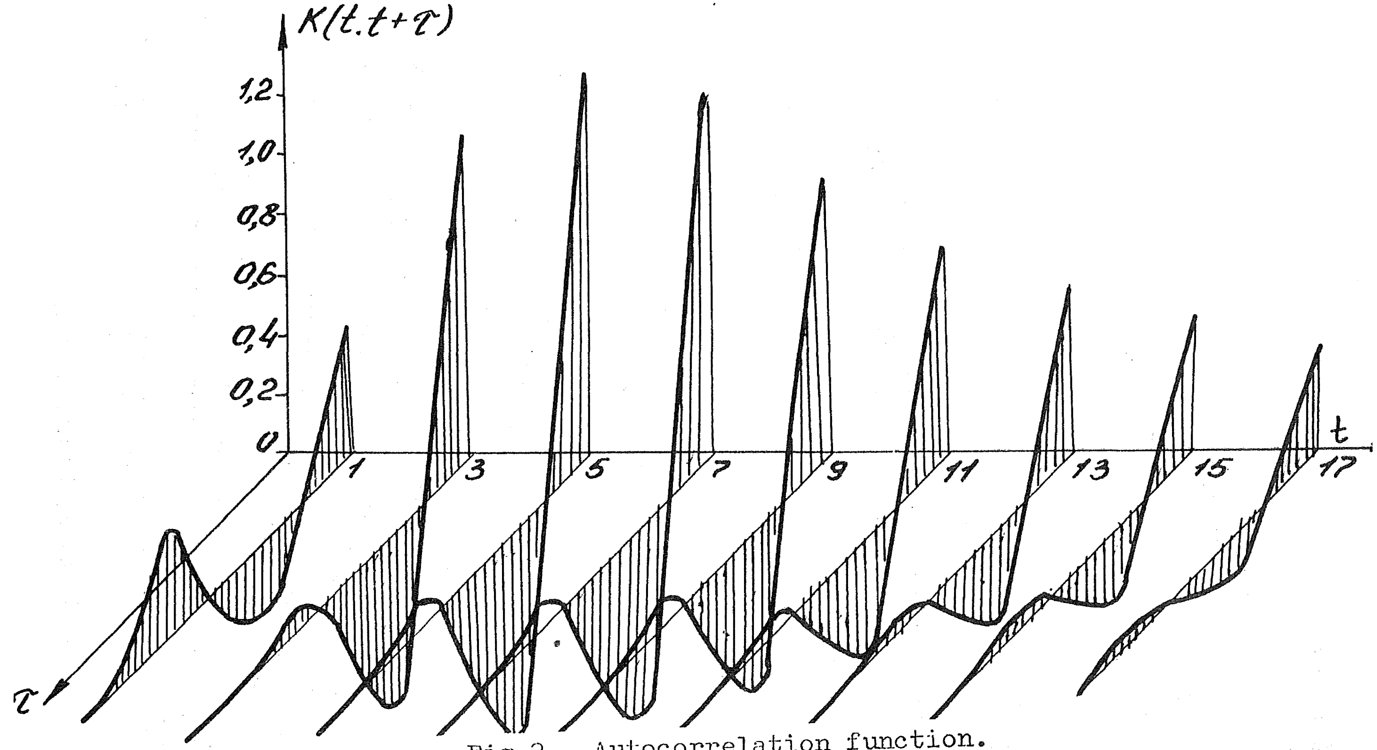

Fig.2. Autocorrelation function.