CALCULATION OF BUILDING RESPONSE TO REAL EARTHQUAKE ACCELEROGRAMS

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SYNOPSIS

To obtain reliable results in calculating of structure response to real accelerograms two kinds of random factors must be eliminated. The errors due to the random disposition of a building eigenvalue spectrum relative to the spectrum of a given accelerogram can be avoided by using weight functions technique. The random nature of an accelerogram is the source of another kind of errors which can be eliminated by the proper averaging of the results obtained with a set of accelerograms.

The investigation of structures response to the effect of real accelerograms gives a useful information of their behaviour during earthquakes. To obtain reliable results two kinds of random factors must be excluded. The response spectra of seismic accelerations have a clearly defined oscillatory character because of which the result of a calculation depends to a great extent on the random relation of structure eigenvalue spectrum with a given accelerogram response spectrum. In many cases the slight variation of the first natural frequency of the structure's model leads to a great change of an accelerogram's effect.

Elimination of this kind of errors can be reached by constructing a variable spectrum model of the structure. Let the column of acceleration weight functions $\{h_K(t)\}$ be taken as a mathematical model of a structure, where $h_K(t)$ can be expressed as follows:

$$h_K(t)=\sum_{i=1}^{n} \omega_i \hat{\delta}_i z_{Ki}\, e^{-\frac{\gamma\omega_i}{2}t} \sin(\omega_i t+\alpha) \quad (1)$$

ω_i - circular frequency; z_{Ki} - natural vibration mode value at point K ; γ - energy dissipation coefficient; $\alpha = arctg\,\gamma$; $\hat{\delta}_i=\sum_{K=1}^{n} m_K z_{Ki}$; m_K - mass in point K .

Let $h_{K\nu}(t)$ designate another system's weight function

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having eigenvalues $\nu\omega_1$, $\nu\omega_2$, ..., $\nu\omega_n$. The following relation can be easily derived from (1):

$$h_{k\nu}(t) = \nu h_k(\nu t) \tag{2}$$

The response of ν-system can be determinated as follows:

$$x_k(\nu, t) = \int_0^t W_0(\tau) h_{k\nu}(t-\tau)\, d\tau, \tag{3}$$

where W_0 - the seismic acceleration of the ground.

By varying of parameter ν values from $\nu_1 < 1$ to $\nu_2 > 1$ an average response can be found:

$$x_{k\ av}(t) = \frac{1}{\nu_2 - \nu_1} \int_{\nu_1}^{\nu_2} \nu\, d\nu \int_0^t W_0(\tau) h[\nu(t-\tau)]\, d\tau, \tag{4}$$

The expression (4) can be considered from another point of view. It is known that the structure rigidity varies in the process of seismic motion depending on vibration amplitude and other dynamic factors. The coincidence of any of natural frequencies with a peak or a dip of accelerogram spectrum would be equal to the precise tuning of the structure to one of accelerogram frequencies what is impossible in reality and might lead to essential errors both in the sense of overestimation or underestimation of the calculated seismic effect. Thus the proposed variable spectrum method corresponds to the real properties of structures.

Another random factor - stochastic character of a given accelerogram - can be excluded by using a set of accelerograms, but two necessary conditions must be observed.

The first one is the representativeness of the accelerogram sample. The abscissa of the spectral density curve maximum of an accelerogram being taken as its frequency characteristic. Then the above requirement can be fulfilled by using a sample with a sufficiently wide range of frequencies, for example from 5 to 0,5 cps.

The second condition, the comparability of the sample members can be complied by means of introducing a quantitative measure of earthquake intensity proportional to the standard deviation of the accelerogram, which enables to reduce all accelerograms to unit intensity. If n accelerograms constitute a given sample the designing formula can be written as follows:

$$\bar{x}_{k\ av} = \sigma_d \sum_{r=1}^{n} \frac{f_r}{\sigma_r}\, {}^{r}x_{k\ av} \tag{5}$$

σ_d - the value of standard deviation, taken for designing of structures; σ_r - standard deviation of the r-th accelerogram of the sample; f_r - the local probability of the earthquake with r-th spectral characteristic, $\sum f_r = 1$. If the value of f_r is unknown, the following formula can be recommended:

$$\bar{x}_{k\ av} = \max_r \frac{\sigma_d}{\sigma_r}\, {}^{r}x_{k\ av} \tag{6}$$

The following relation between the intensity of earthquake expressed in degrees of the scale accepted in USSR (J) and the standard deviation of accelerogram (σ_d) can be used

J	6	7	8	9
σ_d	I0	20	40	80

The procedure described provides stable results of calculation suitable for practical use and leading to essential refinement of aseismic design in comparison with building code recommendations.