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THE MODEL OF SEISMIC IMPACT AS A SHORT TEMPORARY PROCESS FOR CALCULATION OF SEISMOISOLATED SYSTEMS

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SUMMARY

The short-duration process for seismic calculations is proposed. The process is represented as a velocigram, which is composed of the sum of three damping sinusoids. The frequency of the first sinusoid coincides with the predominant frequency of impact. The frequency of the second sinusoid equals to the frequency of fundamental structure period. And the frequency of the third sinusoid depends on the calculation goal. For example it may be equal to the frequency of the second structure mode. For the base isolated systems with a friction damper the period of the first sine curve equals the predominant period of earthquake. The second period equals the main period of structure oscillation with closed friction damper. The third one equals the main period of structure oscillation with opened friction damper. The parameters of the input are defined by the approximate satisfaction of the system of conditions by the method of the least squares. The main requirements for design accelerograms and the system of conditions have been worked out on the basis of the statistical treatment of 340 strong accelerograms. The main peculiarity of the proposed process is the dependence of process parameters on dynamic characteristics of structure.

INTRODUCTION

In engineering calculations the modelling of seismic impact by the short-time processes gained a wide application. There are different methods to model the earthquake action by the short temporary process. In majority of works the selection of such process was motivated by correspondence of their acceleration spectrum to a standard spectrum, which are used in calculations of the building structures.

In Russia the most well-known are the models described in the papers [Jonson and Epstein, 1976], [Vetoshkin, Kostarev and Schukin, 1984], [Aubakirov, 1989]. These models are securing the proximity of acceleration spectrum of model and real processes. The seismograms corresponding to the synthetic accelerograms of Kostarev and Aubakirov are presented on the figures 1 and 2.

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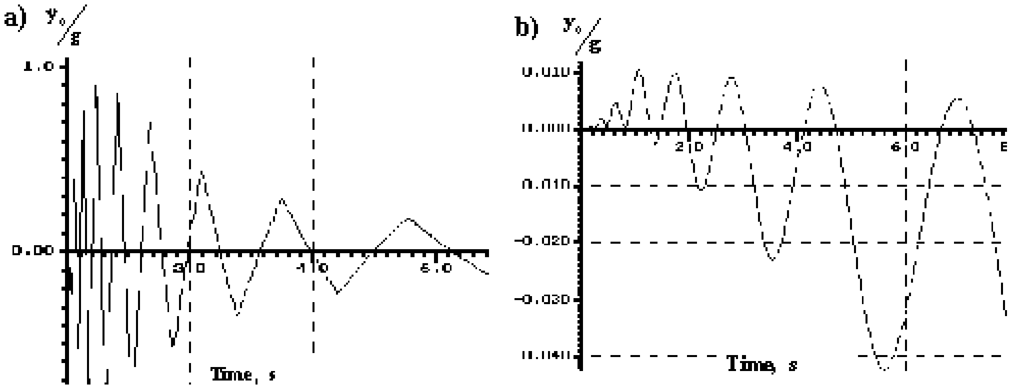

Figure 1: Accelerogram (a) and seismogram (b) of Aubakirov process.

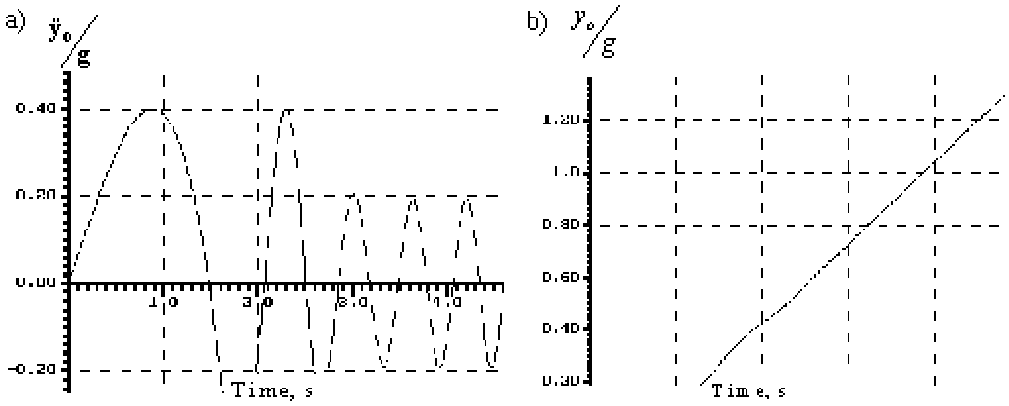

Figure 2: Accelerogram (a) and seismogram (b) of the process of Kostarev and Vetoshkin.

These accelerograms are immaterial for calculating the traditional hard constructors. At the same time the seismogram defects because the errors in the low-frequency area of earthquake input are very important for cinematic calculating, for example for the calculating of base isolation systems. Professor O. Savinov [Savinov, Uzdin, Sandovich and Dolgaya, 1995] considered this question in detail. It is also important for the energy capacity calculating. The short-time duration process for earthquake modelling to calculating of base isolation and other flexible constructions is presented in this report.

THE SHORT-TIME DURATION PROCESS FOR EARTHQUAKE MODELLING.

Three damping sinusoids are presented for modelling the earthquake velocity V

$$\dot{y}_o = \sum_{i=1}^{n} A_i e^{-\varepsilon_i t} \sin(\omega_i t) \tag{1}$$

In this case the base acceleration and displacement can be represented as follows:

$$\ddot{y}_o = \sum_{i=1}^{n} A_i e^{-\varepsilon_i t} \left[\omega_i \cos(\omega_i t) - \varepsilon_i \sin(\omega_i t)\right] \tag{2}$$

$$y_o = \sum_{i=1}^{n} \frac{\frac{A_i}{\omega_i}\left[1 - e^{-\varepsilon_i t}\left(\cos(\omega_i t) + \frac{\varepsilon_i}{\omega_i}\sin(\omega_i t)\right)\right]}{1 + \frac{\varepsilon_i^2}{\omega_i^2}} \tag{3}$$

The frequency ω_1 is taken as equal to the predominant frequency of earthquake and ω_2 is equal to the first natural fundamental frequency of the structure. The third one depends on the type of structure and on the calculation goal. For the base isolated structure it is equal the main period of structure oscillation with closed friction damper. The duration of the process is about 20 seconds. Parameters (amplitudes A_i and dampings ε_i) of input are determined proceeding from the proximity of acceleration spectrum, displacement spectrum and Areas intensity of the model and the real process.

To ensure such proximity seven conditions were formulated. They include two types of conditions including conditions-equalities and conditions-inequalities.

The first condition is the equation to zero the earthquake acceleration in the beginning of the process is:

$$\sum_{i=1}^{n} A_i \omega_i = 0 \tag{4}$$

The second and the third of them are limitation of velocity, residual displacement and acceleration to the end of the process.

$$V\big|_{t>T} < \delta , \tag{5}$$

$$\frac{y_{res}}{\ddot{y}_{max}\tau_{eq}^2} < \delta_1 , \tag{6}$$

where $\ddot{y}_{max}$ and y_{max} are the greatest volumes of the earthquake acceleration and displacement accordingly; y_{res} is the residual displacement; τ_{eq} -earthquake duration. To estimate the kinematics of base isolating foundations it is necessary for residual displacement of expected seismograms to correspond to real ones. At least the calculating residual displacement has been limited in accordance with (6). The value of δ_1 was taken [Savinov and Sakharova, 1985] as 0.005. In accordance with our investigations [Uzdin and Dolgaya, 1997]it is to be decreased and can be taken as 0.001. It makes possible to sort out the acceleration records with non-real residual displacement. The condition (6) provides the equilibrium of acceleration records (the absence of movement after the earthquake is over).

The forth condition is the equation of acceleration spectra to the defined values when the period equals the predominant period of earthquake.

$$\beta(T_c) = \beta_o , \tag{7}$$

where

$$T_c = \frac{2\pi}{\omega_2} .$$

The fifth condition is the equation of acceleration maximum to its mean value according to statistical data:

$$\ddot{y}_{max} = \overline{A}(T_{eq}) . \tag{8}$$

Correctly defined amplitude of long-period motions is the most important for estimating earthquake stability of flexible constructions as isolation systems. The less the amplitude, the more the predominant actions period. Statistical analysis of more than 340 records of earthquake accelerations was carried out to estimate the correlation between the amplitude of acceleration and predominant period of earthquakes with intensity I from 6 to 9 on MSK-scale. On the basis of this analysis the dependencies of the average acceleration amplitudes A on the predominant earthquake periods T_{eq} have been obtained [Uzdin and Dolgaya, 1997] as follows:

$$\overline{A}(T_{eq}) = \left[a\left(e^{-\alpha_1 T_3} + ce^{-\alpha_2 T_3}\right) + b\right]2^{I-8} , \tag{9}$$

where the ratios a, b, α_1, α_2 are determined depend on earthquake risk [Dolgaya, Uzdin and Indeykin, 1996].

The sixth condition is connected with proportion of the maximums of accelerations, velocities and displacements of process. In accordance with the USA recommendations for nuclear power plants the following condition is:

$$\upsilon = \frac{y_{max}\ddot{y}_{max}}{\dot{y}^2_{max}} \approx 6 \tag{10}$$

where y_{max} , y_{max} and y_{max} are the greatest volumes of the earthquake acceleration, velocity and displacement accordingly. The equal (10) was obtained for the USA. Our investigation shows that the value of υ depends on the predominant period of earthquake. It is possible to present the following dependencies of υ on T_{eq}.

$$\upsilon = Ae^{-\nu T_{eq}} \tag{11}$$

where A=4.1; υ=0.54.

The seventh condition is the equation of Areas intensity $I_A = \int_0^\infty \ddot{u}_0^2(t)dt$ to its mean value $\bar{I}_A$ according to statistical data. Our investigation shows that the value of Areas intensity for the similar earthquakes in accordance with MSC-scale is a constant value and does not depends on earthquake spectra. Analyses data of about 200 earthquakes with intensity 8 on MSK-scale a shown in fig. 3.

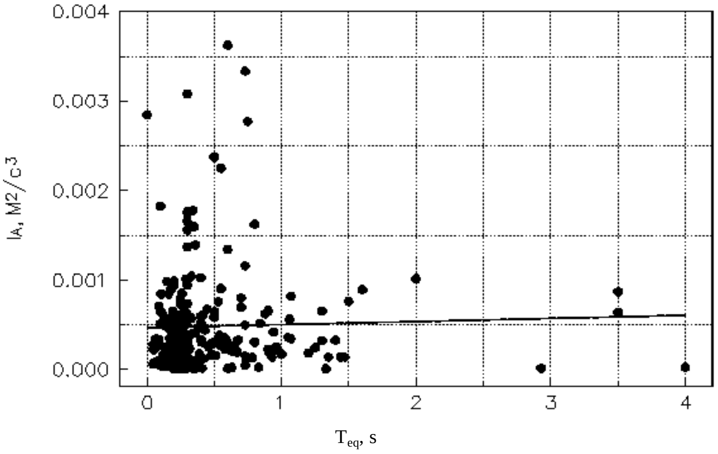

Figure 3: Dependence I_A (T_{eq}).

The parameters of the input are defined by the approximate satisfaction of the conditions (4-10) by the method of the least squares. Fore values of mistakes are calculated.

$$m_1 = \left[\frac{y_{max}\ddot{y}_{max}}{\dot{y}^2_{max}} - \upsilon\right]^2 ; \tag{12}$$

$$m_2 = \left[\ddot{y}_{max} - \bar{A}(T_{eq})\right]^2 ; \tag{13}$$

$$m_3 = \left[\beta(T_c) - \beta_o\right]^2 . \tag{14}$$

$$m_4 = \left[I_A - \bar{I}_A\right]^2 \tag{15}$$

The weighted mean mistake are estimated as follows

$$m = m_1 P_1 + m_2 P_2 + m_3 P_3 + m_4 P_4 \, , \tag{14}$$

where P_i are the weight coefficients.

The values of A_i and ε_i are to minimise the value of m.

The experience of using the presented short-time duration processes has shown that all structure forces were somewhat stronger than the similar forces which had been taken while using natural earthquakes records.

THE PROBLEM OF DESIGN ACCELEROGRAMS SETTING FOR BASE ISOLATED STRUCTURES.

The most dangerous for the base isolation structures is the displacement between its isolated parts. It is necessary to have rather correct design action to estimate this displacement. It has been shown that design accelerograms setting determines the optimum parameters of base isolated systems [Eliseev and Uzdin, 1997], [Skinner, Robinson and McVerry , 1993].
The data given above shows that the seismoisolated structure is not responsive to the spectral composition of impact. They react to the long-period component of the earthquake, which exists in seismic oscillations of all strong earthquakes and is clearly seen on the displacement spectrum of the earthquake. The most difficult to build the design input for non-linear isolated structures, for example, for structures with dry friction dampers or with switch-controlled members.

From this point of view, the use of a short time process proposed by authors is the most effective for analysis of the seismoisolated systems. For the seismoisolated structure the frequency of the first sinusoid coincides with the predominant frequency of input, the frequency of the second sinusoid equals to the frequency of seismoisolation. And the frequency of the third sinusoid equals to the frequency of the seismoisolated system at the closed DFD.

For example, synthetic accelerogram with T_1=0.6 s, T_2=0.15 s T_3=0.4 s is presented on figure 4.. Its acceleration and displacement spectrum are shown on figure 5. This accelerogram was generated to calculate the structure with switch-controlled members.

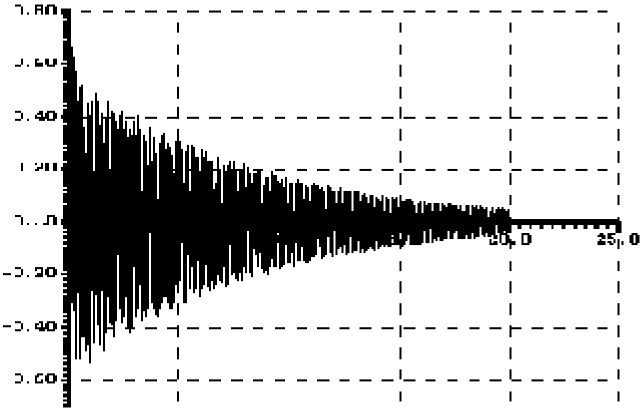

Figure 4: Accelerogram for synthetic process.

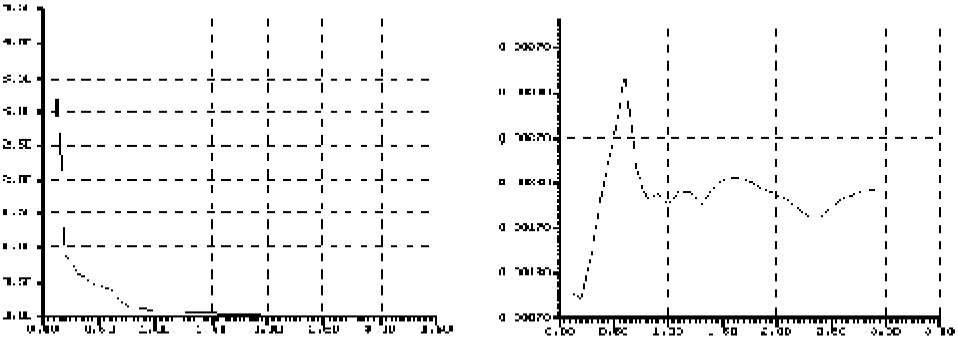

Figure 5: Acceleration and displacement spectrum of synthetic process.

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