METHOD OF DYNAMIC MODELING AND DYNAMIC ANALYSIS OF BUILDINGS AND STRUCTURES

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The design of buildings and structures with resistance to seismic effects is complicated in the absence of detailed information about the earthquake. When entering correct information about the nature of an earthquake, its magnitude and frequency into modern computer calculation programs, design engineers should not forget to include earthquake intensity in these programs. The idea of an earthquake, its epicenter, hypocenter, magnitude and strength is easy to understand from the figures and formulas below.

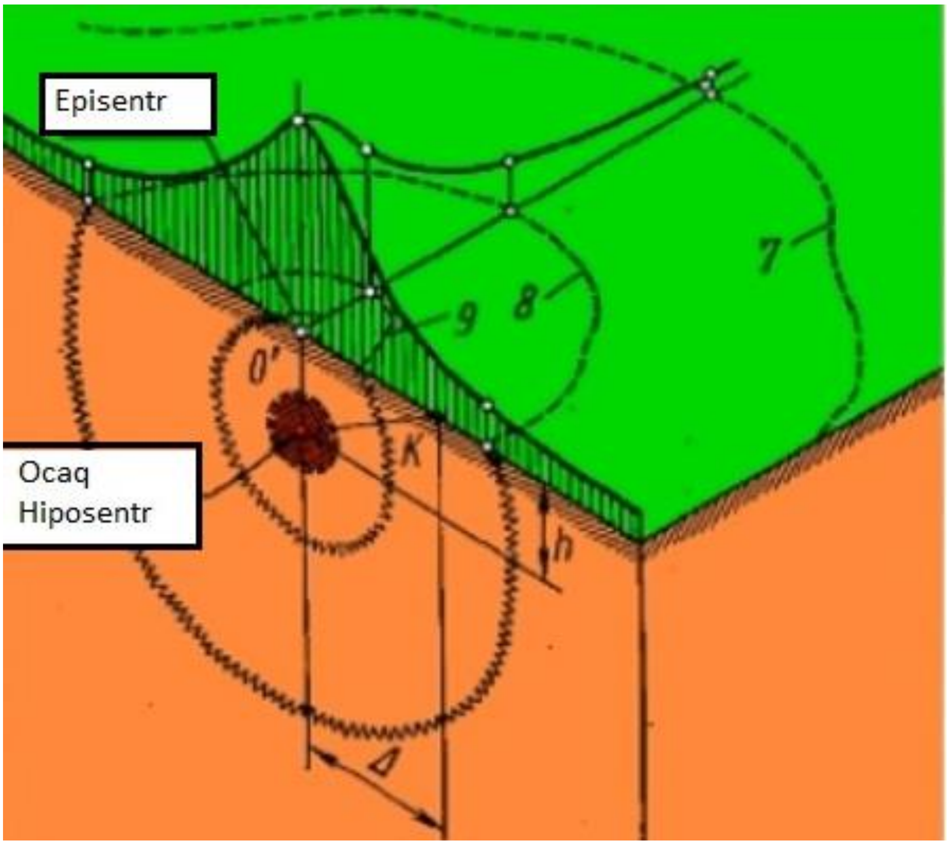

Figure 1. Seismic impact

The relationship between magnitude and intensity of an earthquake can be roughly expressed as follows.

$$I=1.5M-3.5Lg(h2+l2)1/2+3$$

Here, *M* is the magnitude of the earthquake at the earthquake source on the Richter scale.

I - earthquake intensity on the earth's surface (points)

h - the depth of the earthquake source, km

d - distance to the epicenter, km

It is on the basis of these parameters that the issues of the dynamics of various structures modeled using the finite element method should be solved in accordance with the requirements of the current building codes and regulations and the following provisions of the science of structural mechanics.

$$Mx(t)+Cx(t)+Kx(t)=F(t)$$

The problem is solved in two ways by solving the equation below. The first and most applicable is the method that is more convenient to perform during the initial design, based on the linear spectral method and performed in the interval where the frequencies of the corresponding vibrations are calculated. At the same time, nodal loads and moments are applied to the nodal points in the design scheme in accordance with the regulatory documents (AzDTN 2.3-1. SP 20.13330.2016). Based on these loads and moments, a finite element model of buildings and structures with applied quasi-static loads is modeled.

$$Si=mi*ai*Ksn$$

where, *mi* denotes the mass at node *i*, *ai* denotes the seismic wave of node *i*, and *Kn* denotes the appropriate coefficients intended to be applied in the building code.
In the second method, dynamic reports are performed during an appropriate time interval while checking the effectiveness and quality of the implemented design solutions.

When solving these dynamic tasks, you must perform the following tasks in the following order.
1. First of all, it is necessary to determine the intensity of the seismic impact A. In this case, it is necessary to accurately determine and apply the velocity of the seismic wave along the selected soil base according to the relevant maps of seismic microzoning, the results of engineering geological and geophysical research. This information must be included in the reports.
2. Dynamic factor β(t) should be selected from the appropriate response spectrum curves for the selected ground conditions.
3. You should correctly select the appropriate coefficients from building codes and regulations.
4. The spatial work of buildings and structures (torsion, asynchronous movements of the soil base and orthogonal movements along special vibration modes) should be taken into account.
5. Modes of seismic loads summation according to CQC or SRSS should be precisely defined.
6. Design and dangerous directions of seismic actions should be determined and selected.
7. Calculation results should be combined in different directions (seismic components).

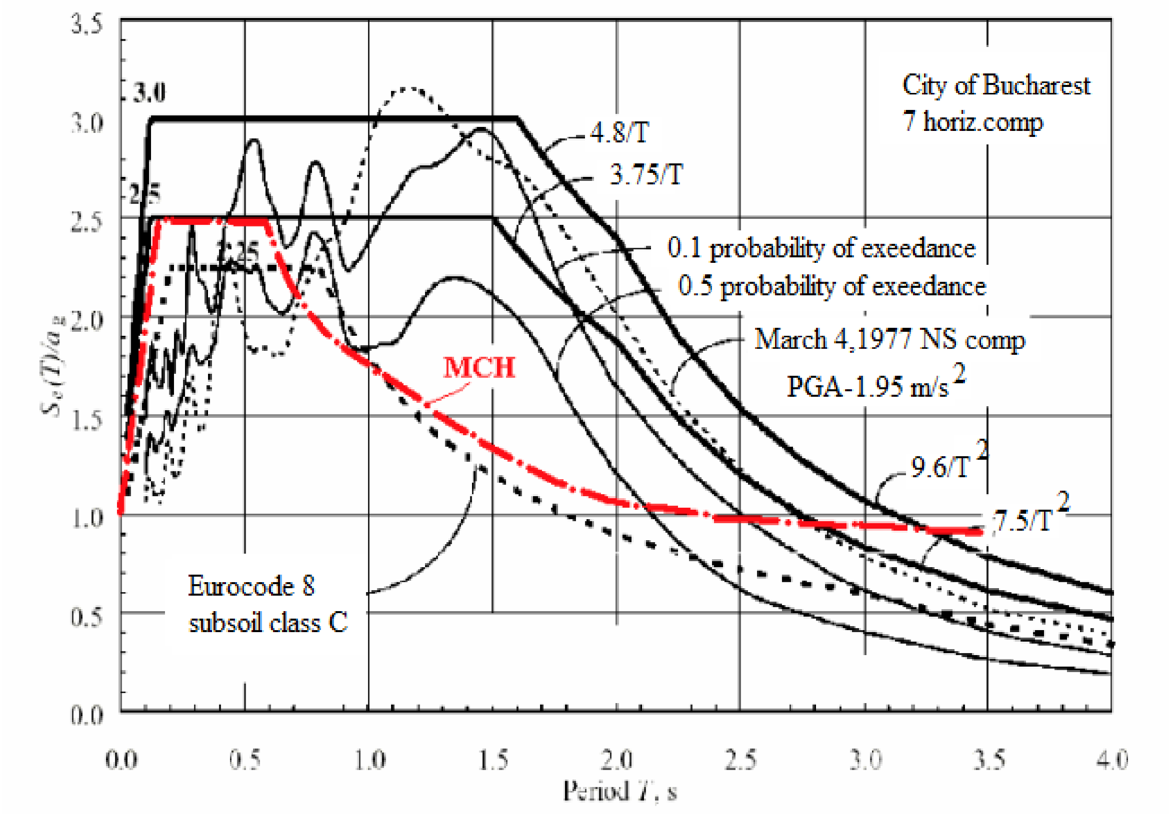

Figure 2. Response spectra for dynamic analysis

The determination of the maximum seismic loads by the linear spectral method (calculation in the frequency interval) is carried out according to the following formula.

$$Sik=QkA\ \beta i\eta ik*Ksn$$

Here, *Qk* is the mass of the structure, *A* is the intensity of the seismic action. *βi* is the coefficient of dynamism. *ηik* and *Ksn* are the corresponding coefficients intended for use in building codes.

The following shows the execution and sequence of applying the calculations performed by the dynamic analysis method when searching for the right options for a constructive solution.

1. To determine the modes of natural vibrations, a preliminary dynamic analysis should be carried out by limiting six degrees of freedom on the basis of the soil using the coefficient of dynamic stiffness of the base.
2. Analysis of the dynamic model should be carried out in the frequency range found by finding the maximum inertia forces (quasi-static loads) by the linear spectral method.
3. Internal forces should be determined by calculation using static and quasi-static combinations of loads at the nodal points of structural elements.
4. Design calculations (including determination of rebars, determination of cross sections, determination of material characteristics, unfavorable load combinations, combinations of static and quasi-static loads) must be performed.
5. Calculations should be checked, if necessary, the effectiveness of the adopted design solutions should be studied, a temporary nonlinear dynamic analysis should be performed, corresponding acceleration graphs should be entered into the program, and seismic displacements of the soil base should be assessed.

While performing, these calculations should be performed periodically (cyclically) until the specified accuracy is obtained by iteration.

When calculating by the spectral method (clause 2.2 "a") according to

*CSM→CDM→CSIM→CIM**

Calculations must be performed in a loop. Here, CSM is the calculated static model, CDM is the calculated dynamic model, CSIM is the calculated static impact model, and CIM- is the calculated impact model.

When performing a dynamic calculation in the time domain (according to clause 2.2 "b")

→ CSM→CDM→CSIM→CIM* →checks→↓
↑ ←←←←←←←←←←←←←←←←←

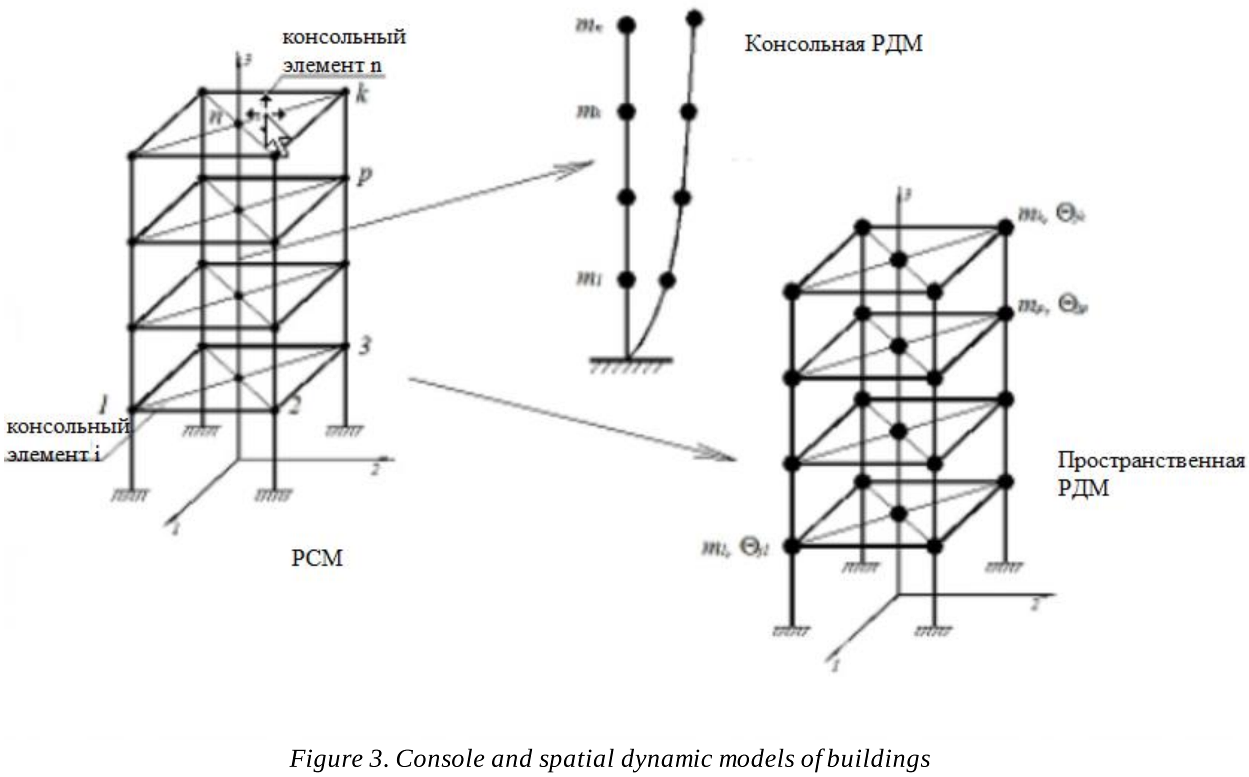

Figure 3. Console and spatial dynamic models of buildings

According to paragraph (2.2 "a"), the loop is executed 1 time.

According to paragraph (2.2 "b"), the cycle is performed each time during the control until plastic deformation occurs in the structure and until the final assessment of this plastic deformation.

CSIM is a mathematical description of the seismic effect. The CSIM must be installed in the same spatial area as the CDM.

In dynamic analysis (analysis of the equivalent seismic load or the so-called cantilever model), it is assumed that the linear displacement and acceleration of the CDM soil base acts at the support nodes, and the linear displacement and acceleration of the elements at the nodes of mass application in the CSIM model.

In the spatial CDM, the CDM is considered as the field of seismic displacements of the subgrade layer surrounding the foundation, while the subgrade modeling using spatial finite elements provides more accurate results.

The CSIM is modeled in two ways. Integral CSIM and differential CSIM. In the integral model, it is assumed that the soil foundation moves in space in the form of a whole soil massif. In this case, it is assumed that the seismic impulse action vector is directed along the horizontal (X, Y) axes or along the vertical axis (Z) in the direction of torsion.

The differential CSIM takes into account the seismic action vectors (displacement and velocity vectors) of each point of the soil base, the ratio of which is normalized by comparing the parameters of the seismic wave and the parameters of the seismic movements of the soil. In both methods, the seismic action vectors change direction in space and time variably.

All six components of the seismic motion of the subgrade are easily determined by the program by applying the finite element method based on the following formula.

$$\chi j(t)=\varphi j\rightarrow TM(AQx\rightarrow(t) + BQa\rightarrow(t))$$

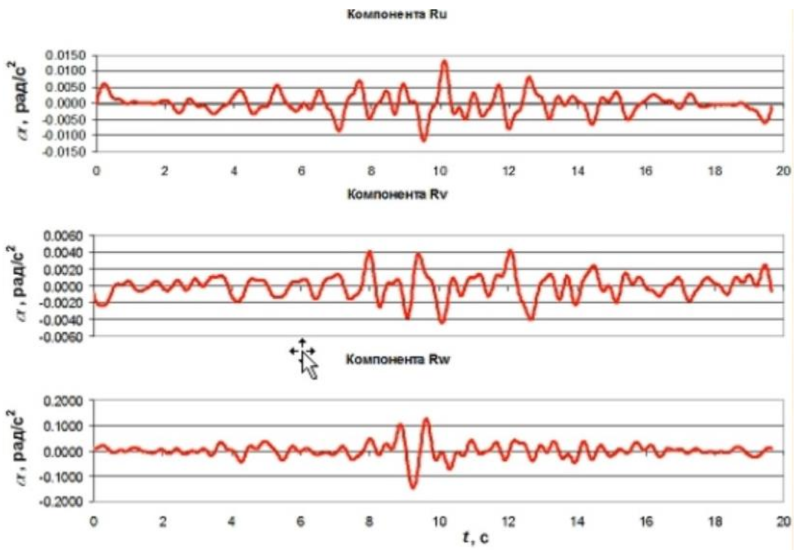

Figure 4. Rotational seismic components of dynamic analysis

Figure 5. Strength factors of dynamic analysis

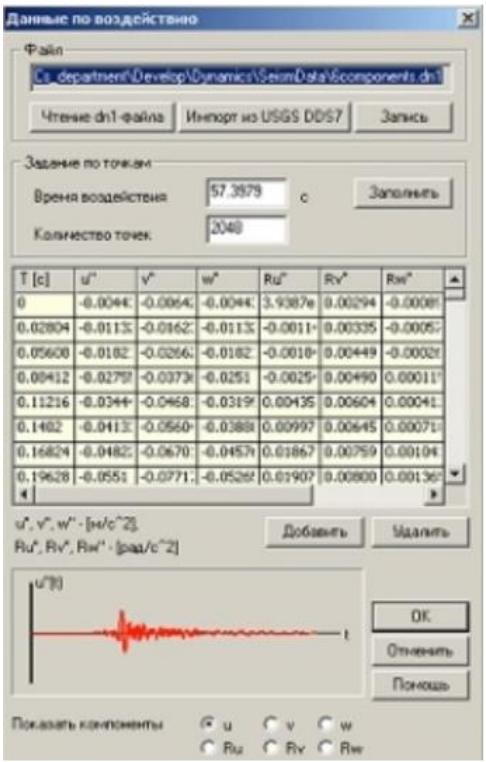

Figure 6. Nodal calculated seismic displacements of dynamic analysis

There are advantages and disadvantages of the spectral method.

Advantages:
1. Simplicity
2. Availability at the design stage.

Disadvantages:
1. The impossibility of a full-fledged application in solving problems of linear elasticity.
2. Determination of vibration modes by approximation.
3. The impossibility of taking into account the change in the direction of the seismic action vector during an earthquake.

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