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Seismic Vibration of Nuclear Power Station Building

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SYNOPSIS. Reactor Building is considered as a system with concentrated masses. The movement of the system is described with account of elastic component, shear and rotation of the base relatively foundation. Seismic excitation is described by set of accelerogramms. The equations of movement are solved using complex modal analysis. Natural frequencies are acceleration functions for masses of the system are defined.

INTRODUCTION

The dynamic behaviour of reactor building, interacting with foundation during the earthquake passes over, is examined. The typical east-european layout of the structure is considered(fig.1). In this layout constructions of the building, including containment are rested on the multi-storey basement, which contacts with the foundation via a basement slab. The foundation is considered as a uniform viscoelastic halfspase. The contact between slab and foundation is considered as corresponding to conditions of adhesion, i.e. it provides both compressive and tension connections.

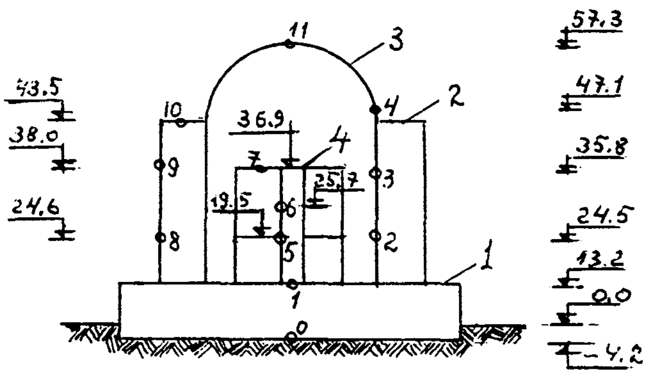

Fig.1. General layout of reactor building

MATHEMATICAL MODEL

In the seismic analysis the reactor building is represented by the dnamically similar model(fig.2) in the form of system of linear shear bars with concentrated masses, fixed in an absolutely rigid basement slab. To decompose the problem the halfspace of foundation is represented with viscoelastic bonds, which model the integral reaction of foundation in directions of degrees of freedom of the slab: shift and roll. These bonds may be characterized by their quasistatic stiffnesses C, C_φ and instant stiffnesses η , η_φ. The values of these stiffnesses were obtained by approximation of solution of dynamic contact problem as described by Sargsian A.E.(1986).

The movement of the system was described with the matrix equation

$$M \cdot \ddot{U} + B \cdot \dot{U} + K \cdot U = s(t) \qquad (I).$$

Here U is vector of displacements with N components, its first N-2 components U_i, i=1,

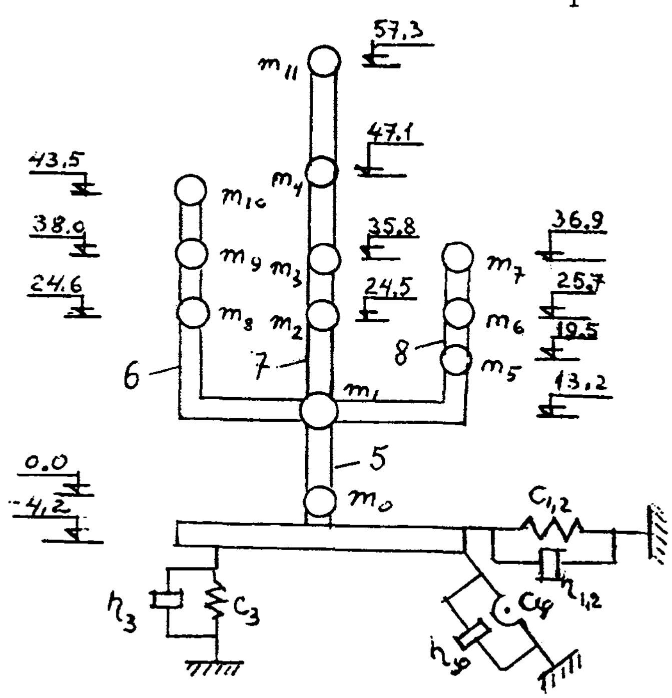

Fig.2. Shear bar model of reactor building

... N-2 are the displacements of the nodes of the bar system: u_{N-1} is shift and $u_N = \varphi$ is roll of the slab.

The stiffness matrix

$$K = D^{-1}$$

where D is matrix of compliancies.

The elements δ_{ij} of the matrix D at i,j=1,2,...,N-1 define displacements of j-mass due to unit force applied to the i-node of the model. Each of them includes three components:

$$\delta_{ij} = \delta'_{ij} + \delta''_{ij} + \delta'''_{ij} . \qquad (2)$$

First component δ'_{ij} represents unit displacements of the masses due to elastic deformation of the bar system; component δ''_{ij}- displacements due to shift of the slab; component δ'''_{ij}- displacements due to roll of the slab about Y-axis.

The component δ' , i,j=1,2,...,N-2 were defined using general methods of structural mechanics. For absolutely rigid slab $\delta'_{ij} = 0$, i,j=N-1,N.

The second components may be defined as a shift of rigid body:

$$\delta''_{ij} = \frac{P}{C} = \frac{I}{C} , \qquad (3)$$

where P=1 is a unit force of i- node.

The third components

$$\delta'''_{ij} = \varphi_i \, z_j = \frac{z_j \cdot \mathfrak{M}_i}{C_\varphi} = \frac{z_j \cdot z_i}{C_\varphi} \qquad (4)$$

where $\mathfrak{M} = P_i \, z_i = 1 \, z_i$ (5)

is a moment of the unit force in i- node on the contact surface between the slab and foundation.

The elements δ_{ij} of matrix D at i or j=N, define angle displacements of the slab due to unit force applied to the i- node of the model:

$$\delta_{i,N} = \delta_{N,j} = \frac{\mathfrak{M} \cdot z_i}{C_\varphi} = \frac{z_i}{C_\varphi} . \qquad (6)$$

The element δ_{NN} of the matrix D defines the angle displacement of the slab due to unit moment,applied to its center of gravity:

$$\delta_{N,N} = \frac{\mathfrak{M}}{C_\varphi} = \frac{I}{C_\varphi} . \qquad (7)$$

Generalized mass matrix of the system

$$M = \begin{bmatrix} m_I & 0 & 0 & . & 0 & 0 \\ 0 & m_2 & 0 & . & 0 & 0 \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & & . & 0 & 0 \\ 0 & 0 & 0 & . & m_{N-I} & 0 \\ 0 & 0 & 0 & . & 0 & J_p \end{bmatrix} \qquad (8)$$

where J_p defines the moment of inertia of the slab.

In present work the causes of dissipation of energy are divided in three groups. First group compose the losses of energy due to inner friction in construction materials. To the second group belong the energy losses due to radiation of shear waves into the foundation. This radiation is genereated at the shear deformation on the surface of contact. Third group compose the energy losses due to radiation of compression wave. This radiation is generated on the contact surface at the roll of slab. The expressions of the energy losses were formulated in this work with account of viscpelastic behaviiour of materials.

To describing the energy losses due to inner friction the corrected model of Foight (1979) wos used. In accordance to this model dissipation forces are assumed proportional to velocity:

$$F = B \cdot \dot{U} . \qquad (9)$$

The vector of dissipation forces F form the second member or equation (1).

The elements b_{ij} of dissipation matrix B represent the attenuation cofficients. Each of them define the dissipation force f_i at the i- node due to movement of j- mass with unit velocity $\dot{u}_i = 1$ at zero velocity of remaining masses.

The elements of dissipation matrix may be defained as follows:

$$b_{ij} = \frac{I}{\frac{I}{\alpha \, K_{ij}} + \frac{I}{\eta_I} + \frac{z_i \cdot z_j}{\eta_\varphi}} \quad i,j = I,2,...,N-2$$

$$b_{i,N-I} = b_{N-I,i} = \frac{I}{\frac{I}{\eta_I} + \frac{z_i \cdot z_j}{\eta_\varphi}} \quad i=I,2,...,N-I \qquad (10)$$

$$b_{NN} = \eta_\varphi .$$

In equations (10) $K_{ij} = \frac{m_i}{\omega_j}$, $\alpha = \frac{\pi}{\delta}$,

where ω_j - angle frequency of j- form of vibration, δ - Logarithmic decrement of vibration.

METHOD OF ANALYSIS.

The system of equations (1) - (10), describing the dynamic model of reactor building may by solved in real form only for case of dissipation matrix of special form, namely when B = aM + bK, where a,b some coefficients .

Such case very rear occures in practice. Therefore dynamic analysis in real form does not allow to use experimentally measured attenution coefficients. To make possible to use experimental data in present work modal analysis in complex form was used as given by Inoue Y.(1985) et. el. As a result the components of displacement vector $\bar{u}$, were obtined in form Duhamel integral:

$$u_i(t) = \sum_n \frac{I}{R_n} \phi_n^i \cdot \int_0^t F_n(\tau)\, e^{\alpha_n (t-\tau)} d\tau, \quad (II)$$

where $F_n(t)$ - generalized force of n- form of oscilation, ϕ_n^i - i- component of vector of n- form of oscilation, α_n - complex n- root of frequency equation.

The solution in the form (11) allow to reduce significantly amount of calculations, because in the wide range of practical cases it is enough to take into considaration some first members of the row to obtain the reasonadle accuracy.

RESULTS.

Using described technique seismic vibrations of reactor building were analized at different soil conditions. Seismic excitation S(t) was obtained by standart set of synthesized accelerogramms adopted as given by Salganik A.A. et. el.(1988) for earthquake of magnitude 8. Soil condition were defined by velocity of trasverse wave b. The following cases were analized: b = I50; 600; I200 $\frac{M}{C}$ и ∞.

The value of b = ∞ defines the case of the slab rigidly fixed on the rock foundation. The first natural angle frequencies of system for this case are displayed in table 1

Table 1

# of form	1	2	3	4	5	6
Angle frequency rad/sec	33.3	46.8	68	96.7	131.2	161.2

For the nodes of system time - displacement functions were obtained. Also were obtained their first and second derivatives - the story veloci- and accelerogramms. Using the latter seismic losds S_j for these nodes were defined. The maximum load is presented in table 2. In the same table is presented

Table 2

Node	a_{max}	Siemens
	accelration in m / sec^2	
11	11.47	10.24

the value of seismic load for this node, calculated by Siemens company(Germany). Comperison shows that result, obtained by both techniques are near enough.

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