Direct solution of the dynamic aseismic design problem of multi-story systems, with the use of electronic analog computer

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Direct Solution of the Dynamic Aseismic Design Problem of Multi-Story Systems, with the Use of Electronic Analog Computer

Solution dirècte du comportement dynamique dû au séisme de bâtiments de grand hauteur à l'aide d'une calculatrice analogue

Direkte Lösung des dynamischen Verhaltens bei Erdbeben von Hochhäusern mittels des Analog-Elektronenrechners

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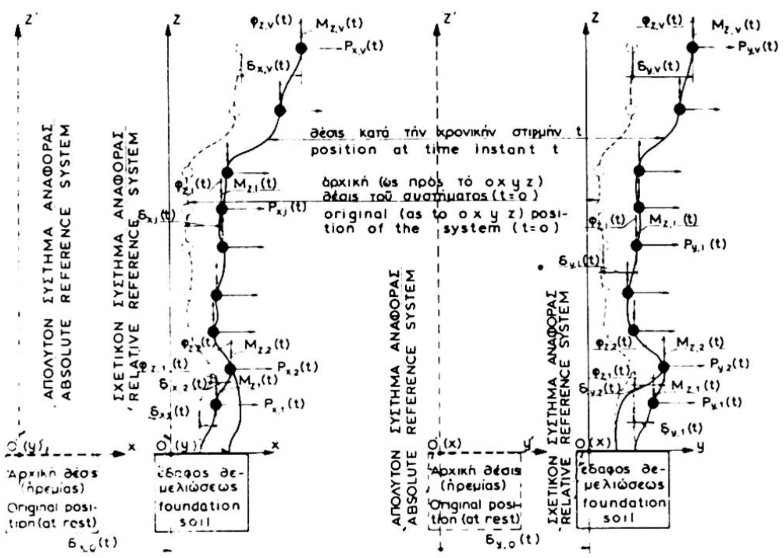
A method is suggested which considers an idealized lumped mass multi-degree of freedom system subjected to forced vibrations caused by earthquake ground motion (see fig.).



These masses are connected to each other by elastic joints with known elastic properties. The vertical components of the mass displacements and the rotations about horizontal axes are neglected. Elastic behavior of the material is assumed. The mass m_i have horizontal displacement δ_i and rotations φ_i about the vertical axis with respect to a three dimentional reference system OXYZ fixed on the ground. At an instant t the forces acting on the mass are linear functions of the above deformations and are given by the matrix equation

$$E = \varepsilon \Pi \qquad \text{(a)}$$

On the other hand the equation of dynamic equilibrium of the system are expressed by the matrix equation

$$m\Pi_o'' + m\Pi_i'' = E = \varepsilon \Pi_i \qquad \text{(b)}$$

In the above equations E=column vector of elastic forces or loading vector Π_i =the column vector of the relative distortions δ_i , φ_i of the system,

$\mathcal{E}$=the known square stiffness matrix, Π_i'' =the column vector of the relative accelerations of the masses, m=the diagonal square matrix of masses and mass moments of inertia(also known) and Π_o'' =the column vector of the ground accelerations with respect to an absolute reference system OX'Y'Z'. The ground motion vertical and rotational components are ignored. The functions $\delta_i(t)$ and $\varphi_i(t)$ due to a given ground motion are obtained by the solution of the system (b) of second degree differential equations.

The proposed method makes use of tables referring to a given "standard" seismic vibration and to a variety of "standard" mass and rigidity distributions in the system. The standard form is reduced to the actual seismic vibration, mass and rigidity distribution in the following manner: Let the indices Σ', Σ symbolize two different n-story systems with the same number of masses and let the corresponding stiffness and mass matrices be related by the expressions $\mathcal{E}_{\Sigma'}=\vartheta_1\mathcal{E}_\Sigma$, $m_{\Sigma'}=\vartheta_2 m_\Sigma$. The two systems being subjected to different ground motions, their absolute acceleration matrices $\Pi_{o\Sigma'}''$, $\Pi_{o\Sigma}''$ will be related by $\Pi_{o\Sigma'}(t)=\vartheta_3\Pi_{o\Sigma}(\vartheta_4 t)=\vartheta_3\Pi_o(\vartheta_4\lambda t)$ in which $\Pi_o(\lambda t)$=seismogram depending on the values of the parameter λ given in the tables ($\vartheta_1,\vartheta_2,\vartheta_3,\vartheta_4$ =constants). The above systemsare regarded under these conditions as "similar" and their dynamic deflections $\Pi_{i\Sigma'}$ and $\Pi_{i\Sigma}$ are obtained from the solution of the equations

$$m_{\Sigma'}\Pi_{o\Sigma'}''+m_{\Sigma'}\Pi_{i\Sigma'}''=\mathcal{E}_{\Sigma'}\Pi_{i\Sigma'} \qquad (c)$$

$$m_\Sigma\Pi_{o\Sigma}''+m_\Sigma\Pi_{i\Sigma}''=\mathcal{E}_\Sigma\Pi_{i\Sigma} \qquad (d)$$

The equation (c) can be transformed into the following:

$$\vartheta_3 m_\Sigma\Pi_o''(\lambda t)+m_\Sigma\Pi_{i\Sigma'}''=\mathcal{E}_\Sigma\Pi_{i\Sigma'} \qquad (e)$$

in which

$$\lambda=\vartheta_4\cdot k\cdot\sqrt{\vartheta_1/\vartheta_2} \qquad (f)$$

It is easily seen from (d) and (e) that the dynamic deformation of Σ' at any t are equal to the corresponding deformations of the "similar" system Σ subjected to a vibration $\vartheta_3\Pi_o(\lambda t)$. If the system Σ is considered as a "model" and is solved by an electronic analog computer for a wide variation of the values of λ then the solution for any other system Σ' with known mass stiffness distributions and subjected to any vibration $\Pi_{o\Sigma'}(t)$ can be obtained by measuring the resulting $\Pi_{i\Sigma}$ at the position of the ordinate λ given by (f) and by multiplying the result by ϑ_3. The theory can also be easily expanded to include the influence of damping in the structure.