AMERICAN JOURNALS
Open Access, Peer Reviewed Journals

American Journal of Technology and Applied Sciences
ISSN (E): 2832-1766| Volume 5, | Oct., 2022

MODELING THE PROBLEM OF FORCED OSCILLATIONS OF A DAM-PLATE WITH CONSTANT AND VARIABLE STIFFNESS, TAKING INTO ACCOUNT THE VISCOELASTIC PROPERTIES OF THE MATERIAL AND HYDRODYNAMIC WATER PRESSURES

A. A.Tukhtabaev
Candidate of Technical Sciences, Associate Professor
Namangan Engineering Construction Institute, Uzbekistan

M. M. Juraboev
Master Student, Namangan Engineering Construction Institute, Uzbekistan

A B S T R A C T	***K E Y W O R D S***
In this article highlights of modeling the problem of forced oscillations of a dam-plate with constant and variable stiffness, taking into account the viscoelastic properties of the material and hydrodynamic water pressures.	modeling, forced oscillations, dam-plate, stiffness, viscoelastic properties, material, hydrodynamic water pressures.

The problem of forced oscillations of a dam-plate with constant and variable stiffness under the action of a seismic load is considered. We consider the dam as a plate of constant and variable thickness, taking into account the transverse seismic load and water pressure. The following forces will act on the dam-plate: - inertial forces arising from the movement of the dam and its deformation; - hydrodynamic water pressure. On the basis of the Kirchhoff - Love hypothesis, the equations of dam-plate vibrations are derived taking into account the viscoelastic properties of the material. The mathematical model of the problem, with respect to the transverse deflection $w_1 = w_1(x, y, t)$, under known assumptions [1], taking into account the viscoelastic properties of the dam-plate material, is reduced to solving equations of the form

$$\frac{1}{h}\left(1-R^*\right)\left[D\nabla^4 w_1 + 2\frac{\partial D}{\partial y}\frac{\partial}{\partial y}\nabla^2 w_1 + 2\frac{\partial D}{\partial z}\frac{\partial}{\partial z}\nabla^2 w_1 + \nabla^2 D \nabla^2 w_1 - \right.$$

$$\left. -(1-\mu)\left(\frac{\partial^2 D}{\partial z^2}\frac{\partial^2 w_1}{\partial y^2} - 2\frac{\partial^2 D}{\partial z \partial y}\frac{\partial^2 w_1}{\partial z \partial y} + \frac{\partial^2 D}{\partial y^2}\frac{\partial^2 w_1}{\partial z^2}\right)\right] +$$

$$+\rho_1 \frac{\partial^2 (w_1 + w_0)}{\partial t^2} - \frac{\rho}{h} \cos\alpha \frac{\partial \varphi_1}{\partial t}\bigg|_{x=ytg\alpha} - (1)$$

$$-\frac{\rho}{h}\left\{\frac{\partial \varphi_0}{\partial t} + \frac{1}{2}\left[\left(\frac{\partial \varphi_0}{\partial x}\right)^2 + \left(\frac{\partial \varphi_0}{\partial y}\right)^2\right]\right\}_{x=ytg\alpha+w_0(t)} \cos\alpha = 0$$

where $w_1(x, y, t)$ is the deflection of the dam-plate; h is the thickness of the dam-plate; ρ_1 - density of the dam material; ρ- density of water; $\varphi_1(x, y, z, t)$ - function of the potential of the fluid motion velocities arising from the deformation of the dam-plate; $\varphi_0(x, y, t)$ - function of the potential of the fluid motion velocities arising from the motion of the dam as a solid body;
$w_0(t)$ - the law of motion of the base during an earthquake:

$$w_0(t) = a_0 e^{-\varepsilon_0 t} \sin \omega_0 t$$

here is the a_0 initial maximum amplitude; ε_0 - soil attenuation coefficient; ω_0 - frequency of ground vibrations; t -time. All these values are determined from the analysis of the seismogram of the corresponding earthquake magnitude.

The system of equations (1) is quite general. From it, in a particular case, one can obtain the equations of oscillations of a dam-plate of constant and variable thickness, taking into account the viscoelastic properties of the material.

The solution of integro-differential equations (1), which satisfies the boundary conditions of the problem, is given in the form

$$w_1(y, z, t) = \sum_{k=1,3,\ldots}^{\infty} C_k(t) w_k(y, z),$$

where $C_k = C_k(t)$ are the desired functions of time; coordinate functions $w_k(y,z)$ satisfy the boundary conditions for fixing the edges of the dam-plate.

The study of such equations using the Bubnov -Galerkin method, based on the polynomial approximation of the deflection, is reduced to solving systems of integro-differential equations in the usual derived Volterra type :

$$\sum_{k=1,3,\ldots}^{\infty} \left[L_{mk} \ddot{C}_k(t) + \omega^2 (1 - R^*) M_{mk} C_k(t)\right] + a_0 \omega^2 N_m(t) = 0(2)$$

parameter Koltunov-Rzhanitsyn kernel was used in the calculations :

$$R(t) = At^{\alpha-1} \exp(-\beta t), A, \beta > 0, 0 < \alpha < 1.$$

The integration of the system of equations (2), obtained on the basis of numerous approximations of deflections, was performed using a numerical method based on the use of quadrature formulas [3]. On the basis of this method, an efficient computational algorithm for solving problems of the dynamics of a dam-plate with constant and variable stiffness c has been developed. taking into account the viscoelastic properties of the material. Figures 1 and 2 show the graphs of the curves for different values of the rheological parameter A. These results show the influence of the viscoelastic properties of the dam-plate material. The solutions of the elastic and viscoelastic problems in the initial period of time differ little from each other. With time, the viscoelastic properties have a significant effect, which leads to a noticeable difference in the solutions. We also note that with an increase in the parameter A, the oscillation amplitude decreases. Observations show that with an increase in the coefficient A, the oscillation frequency also decreases.

In addition, the work studied the effects of other properties and parameters of the dam and water under seismic loads. The influence of these parameters on the stress-strain state of the dam-plate has been studied in detail.

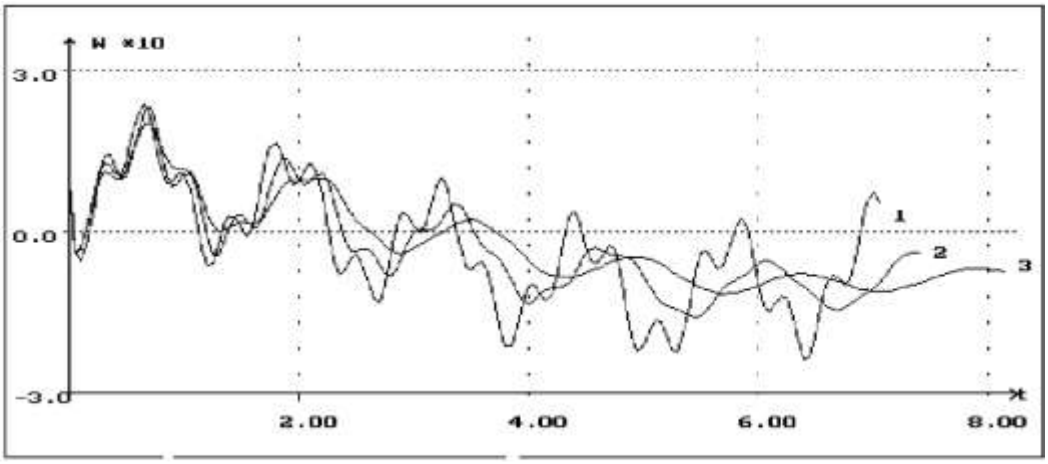

Fig.1. Influence of the viscoelastic property of the material of the dam-plate of constant thickness

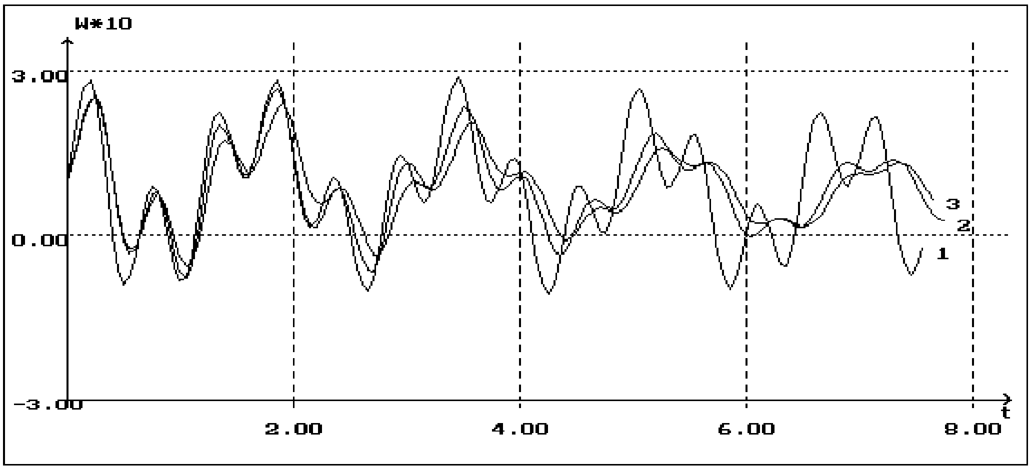

Fig.2. Dam-plates of variable thickness at different values of the rheological parameter A : 0(1); 0.05(2); 0.1(3).

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