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Stress-Strain State of a Dam-Plate With Variable Stiffness, Taking Into Account The Viscoelastic Properties of The Material

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ABSTRACT: This article describes the stress-strain state of a dam-plate with variable stiffness, taking into account the viscoelastic properties of the material.

KEYWORDS: *Mathematical model, seismic zone, seismic stability in water, seismic load, hydrodynamic water pressure.*

INTRODUCTION

The mountainous regions of Central Asia from the point of view of ecology are a promising area for obtaining clean drinking water and electricity. When solving the energy and water management problems of this region, one of the main tasks is the creation of economical and reliable structures of mining hydraulic structures, taking into account the fact that the construction area is a highly seismic zone.

In connection with hydraulic engineering in seismic regions, the question of developing methods for its design taking into account real factors is relevant.

The peculiarities of calculating hydraulic structures for seismic resistance are associated with the need to take into account the influence of the aquatic environment, the presence of which leads to additional hydrodynamic water pressure on the pressure faces, a change in the frequencies and modes of natural and real vibrations, i.e. the viscoelastic properties of the material of structures, which, as a result, can significantly affect the stress-strain state of structures.

In the construction of hydraulic structures, there are often elements of dams such as a plate of finite length: flat gates, buttress dams with flat pressure ceilings, sluice walls, various enclosing structures, etc.

The use of new materials in engineering practice, the design and creation of strong, lightweight and reliable structures requires further improvement of mechanical models and the development of methods for their calculation, taking into account the real properties of structural materials.

In this direction, it should be noted the works of academician MT Urazbayev, R.Kh. Mukhitdinova [1]. In their works, the main general provisions of the theory of seismic stability of an elastic system in water are given. The article deals with the calculation of flexible dams-plates on the action of seismic load, taking into account the hydrodynamic pressure of water and supported soil.

Analysis and results

We have investigated the stress-strain state of a dam-plate of variable thickness. The dam was considered as a plate of variable thickness, taking into account the transverse seismic load and water pressure. The following forces will act on the dam-plate: - the forces of inertia arising from the movement of the dam and its deformation; -hydrodynamic water pressure. On the basis of the Kirchhoff-Love hypothesis, the equations of vibrations of the dam-plate are derived, taking into account the viscoelastic properties of the material.

Mathematical model of the problem with respect to lateral deflection $w_1 = w_1(x, y, t)$, under known assumptions [2-7], taking into account the viscoelastic properties of the material of the dam-plate, is reduced to solving equations of the form

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

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

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

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

Where $w_1(x, y, t)$— deflection of the dam-plate; h - the thickness of the dam-plate; ρ_1 - the density of the dam material; ρ - density of water; $\varphi_1(x, y, z, t)$ - function of the potential of the velocities of fluid movement arising from the deformation of the dam-plate; $\varphi_0(x, y, t)$- a function of the potential of the velocities of fluid movement arising from the movement of the dam as a solid;

$w_0(t)$- the law of motion of the base during an earthquake:

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

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

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 variable thickness, taking into account the viscoelastic properties of the material.

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

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

Where $C_k = C_k(t)$-sought functions of time; coordinate functions $w_k(y,z)$ satisfy the boundary conditions for securing the edges of the dam-plate.

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

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

The calculations used the three-parameter Koltunov-Rzhanitsyn kernel:

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

The integration of the system of equations (2), obtained on the basis of numerous approximations of the deflections, was carried out using a numerical method based on the use of quadrature formulas [8]. On the basis of this method, an effective computational algorithm has been developed for solving problems of the dynamics of a dam-plate with variable stiffness, taking into account the viscoelastic properties of the material.

The analysis of the influence of the viscoelastic properties of the material, the hydrodynamic pressure of water on the amplitude-frequency characteristics of the viscoelastic dam-plate is carried out. The calculation results are shown in the graphs shown in Fig. 1.2 (a, b).

In fig. 1 a, b shows the change in the shape of the deflections in the plane and in space (Fig. 2 a, b) at different values α^*. It can be seen from the figures that an increase in the value of the parameter α^* leads to an increase in the oscillation amplitude and a phase shift to the right (in the case $h=h(y)=h_0(1-\alpha^* y))$, and in case $h=h(y)=h_0(1+\alpha^* y)$ leads to a decrease in the amplitude of the oscillation and a phase shift to the left. Note also that the asymmetry of the buckling shape depends on the chosen law of variation in the plate thickness $h(y)$.

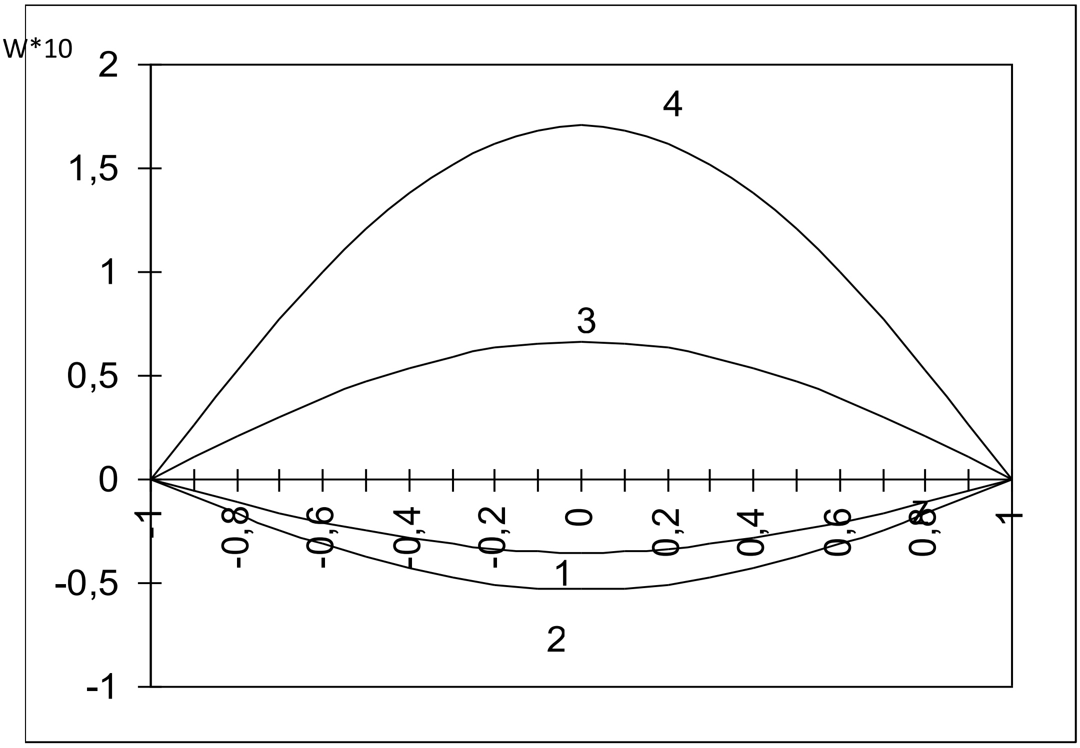

fig. 1 a. A=0,05; α=0,25; β=0,05; λ=2; μ=0,3; ρ/ρ_1=1/2,4; α^*=0;

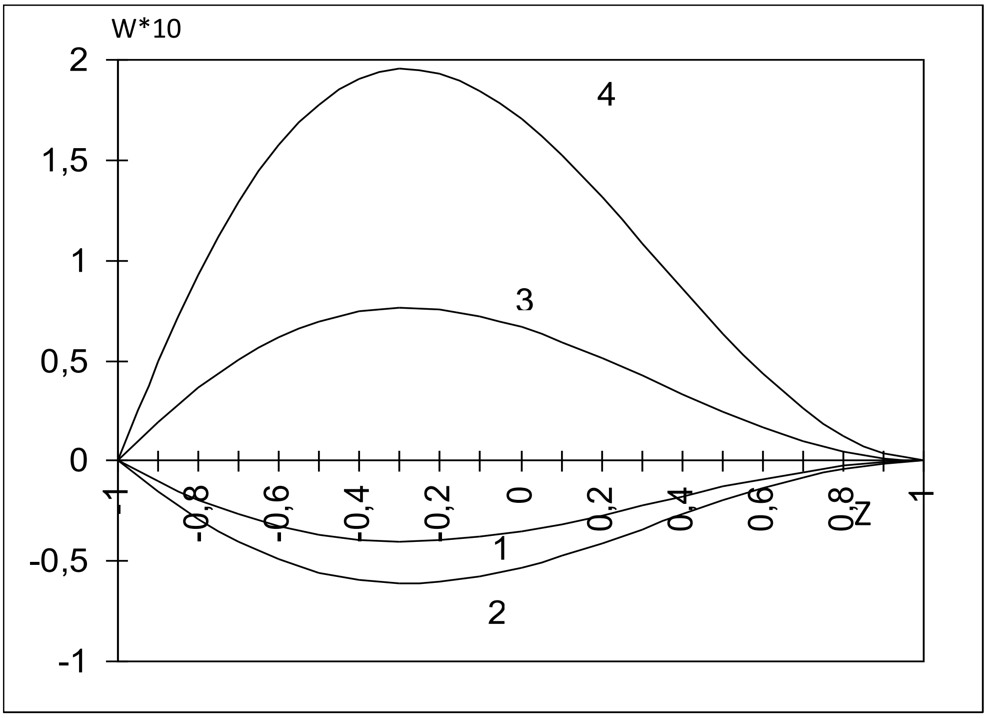

fig. 1 a. A=0,05; α=0,25; β=0,05; λ=2; μ=0,3; ρ/ρ_1=1/2,4; α^*=0,95;

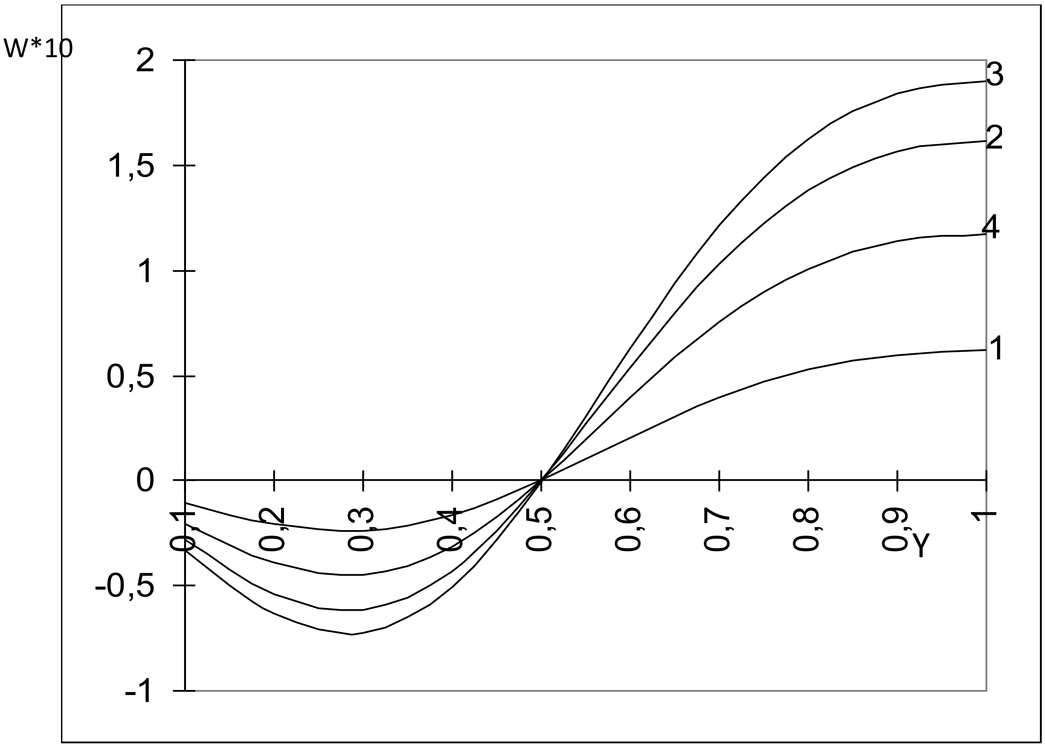

fig. 1 b. A=0,05; α=0,25; β=0,05; λ=2; μ=0,3; ρ/ρ_1=1/2,4; α^*=0;

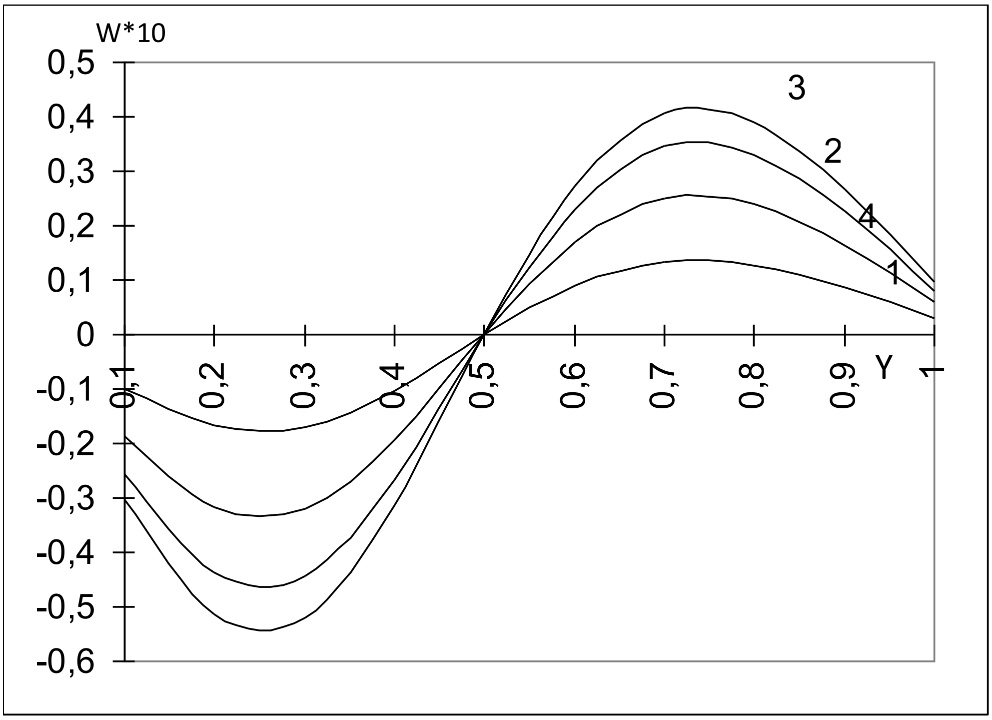

fig. 1 b. A=0,05; α=0,25; β=0,05; λ=2; μ=0,3; ρ/ρ_1=1/2,4; α^*=0,95;

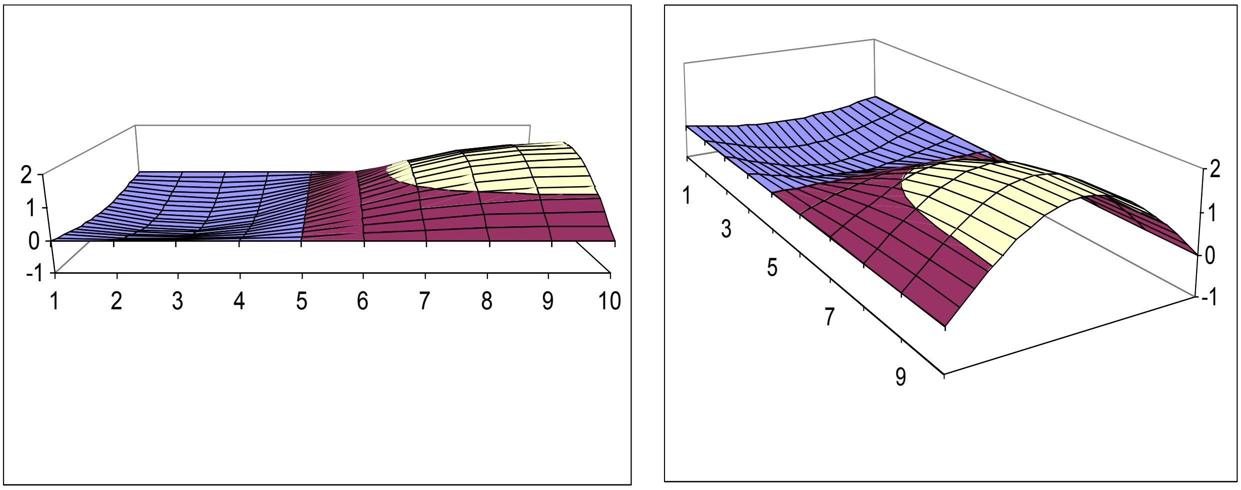

fig. 2 a. A=0,05; α=0,25; β=0,05; λ=2; μ=0,3; ρ/ρ_1=1/2,4; α^*=0;

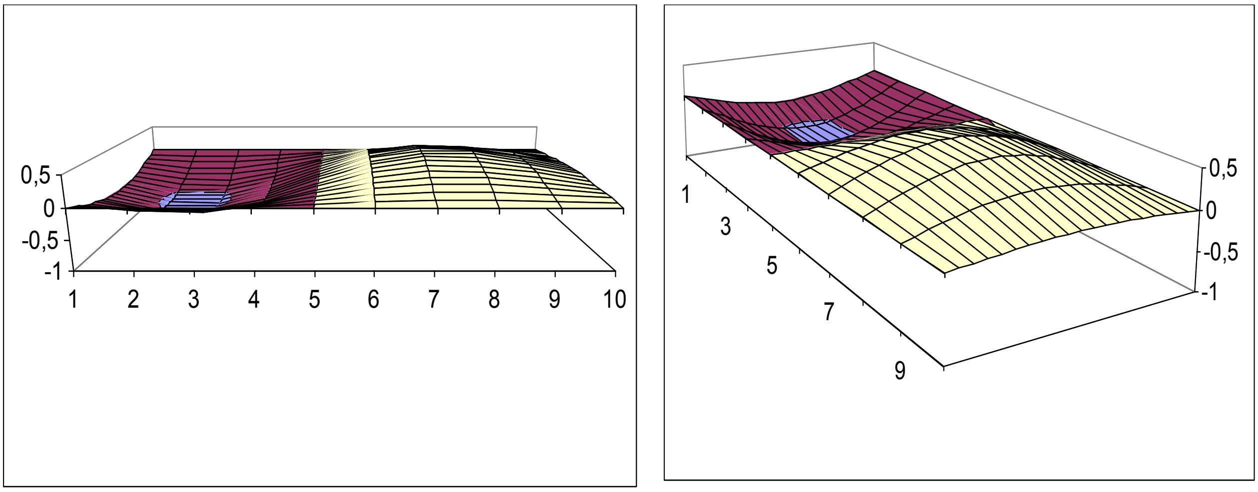

fig. 1 b.A=0,05; α=0,25; β=0,05; λ=2; μ=0,3; ρ/ρ_1=1/2,4; α^*=0,95;

CONCLUSION/RECOMMENDATIONS

In conclusion, we note that the problem of forced vibrations of a dam-plate of variable thickness was investigated taking into account the viscoelastic properties of the material, hydrodynamic water pressure, seismic load, and other parameters of the plate. The influence of a change in the thickness of the plate with a linear increasing (decreasing) law on its behavior is revealed. It was also found that a change in the plate thickness leads to an asymmetric buckling shape.

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