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STUDY THE OSCILATIONS OF DISCRETE-CONTINUOUS SYSTEM BY IMPULSE IMPACT

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Abstract Today, the main methods for assessing seismic resistance and calculating seismic loads involve calculating a static load, mainly horizontal, which is considered equivalent to the seismic load. Initially, these design static loads were defined as inertial forces equal to the mass of the building multiplied by the seismic acceleration of the ground. This approach is called the static calculation method.

Under impulse action, the displacements of the elastic-plastic system are smaller compared to displacements during elastic vibrations. In the case of an elastoplastic system, oscillation after the end of the pulse is presented, which occurs due to residual plastic displacement. Under impulse action, the same acceleration can be caused by different types of velocities corresponding to the values of displacement and forces. Therefore, in the area adjacent to a tectonic fault, where the impact is of a pulsed nature, it is appropriate to take not acceleration, but speed, as the zone of seismic regions.

In the case of a re-strike, depending on at what point in the swing the re-strike occurs, the result will be different. According to the physical law of material, the force cannot exceed the limit value, and it can be significantly reduced by reducing it. And if movements are not limited, they can increase significantly.

Keywords: buildings, impulse action, seismic regions, seismic codes,discrete-continuous system.

As for the mechanisms of destruction of above-ground structures as a result of tectonic impact, it is believed that they have been well studied and, accordingly, means of protection against them have been developed, ensuring a reduction in both human casualties and material losses.

So why are these losses so significant? The answer may be simple: the measures implemented are insufficient, not implemented everywhere, etc. But we are talking about "earthquake-resistant"

buildings built according to all the rules,

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which must withstand seismic loads, but at the same time practically collapse. According to the now officially accepted theory, the cause of building collapse is the coincidence of the natural frequency of vibration of the building and the frequency of vibration of the ground. Although measures to prevent this phenomenon are well known and applied in many countries around the world, observations show that protected buildings are damaged in the same way as unprotected buildings.

Experts analyzed the results of a 9-magnitude earthquake that occurred in Kyrgyzstan in August 1992, Spitak in 1988, Gazli in 1967, Racha-Imereti in 1991, Imereti, Turkey in 2023 [1,2, 3,4,5,6]. The influence of this earthquake on reinforced concrete load-bearing structures was studied. In particular, the surface areas of wall and column fragments and cracks were calculated as a characteristic of the energy intensity of the impact. The picture obtained from the results of the study contradicts the concept of ground shaking, which Seismologists consider to be the cause of the dizaster. The damaged structures gave the impression that they were not subject to periodic oscillation, but rather a strong impact resulting from exposure to very short pulses of high energy. The amount of calculated energy was at least a thousand times higher than the vibration energy of the building.

Thus, buildings are damaged not by the forces calculated in accordance with the currently valid theory of inertial vibrations, but by the forces generated by the impact. The impulse is transmitted in space according to the laws of shock mechanics. [7,8,9,10,11].

The norms, codes and standards of all countries of the world related to methods for calculating buildings for seismic loads are

based on the same principles. The only

difference is in the details or coefficient values.

In the design of most structures in seismic areas, the applied, predominantly horizontal load, which includes the seismic load, is compared with the load-bearing capacity of the structure. Seismic resistance criteria are considered satisfactory if the bearing capacity is equal to the product of the seismic load and the safety factor. A decrease in seismic intensity by the specified amount corresponds to a decrease of 1-2 earthquakes at each given construction site.

Traditional seismic analysis, as mentioned above, consists of determining the static forces, equivalent to the inertial forces, that will be modeled on the massive elements of the building and on the roof slabs. At the same time, generally accepted criteria of static strength are accepted as criteria for the indestructibility and strength of building elements, which leads to serious contradictions. [12,13,14].

Thus, buildings are damaged not by forces calculated according to the modern theory of inertial vibrations, but by the forces generated by the impact.

CHAPTERS

Let us consider a discrete-continuous system consisting of discrete masses m_i and their cross-section s_i. connecting rods. We mean that the driving forces $Q_i = Q_i(t)$

It is installed at the centers of inertia of the masses so that the masses perform only longitudinal vibrations.

The equations of motion of discrete masses have the form:

$$m_i \frac{d^2 x_i}{dt^2} - P_{+i} + P_{-i} = Q_i \qquad \text{i=1,2,....,N} \qquad (1)$$

Where, $x_i = x_i(t)$ m_i IS current mass

coordinate, P_{+i} and P_{-i} There are reactions of bonds acting from the right and left on the mass.

Establish an attitude P_{+i} and P_{-i} between reactions and kinematic quantities (displacement, speed, acceleration). When building such relationships, they usually either exclude the inertia of connections or allow it $P_i = P_{-(I+1)}$ [1] Or they will see systems of one-dimensional wave equations [14], the implementation of which is associated with serious mathematical difficulties even with a limited number of discrete masses. In our case, we will consider the connection between m_1 and m_2 the masses and write the condition for the equilibrium of forces acting on isolated distributed dm elementary masses [2].

$$\frac{\partial P}{\partial x}dx = \frac{d^2x}{dt^2}d\overline{m} = \frac{d^2x}{dt^2}\rho s dx \qquad (2)$$

Where P is the magnitude of the tensile (compressive) force acting in any section The current X-coordinate is $X=X(X_0, T)$, and X_0 is the initial value of X. Let's write the same attitude:

$$\frac{\partial}{\partial x}(PX) = P + x\frac{\partial P}{\partial x} \qquad (3)$$

and let's enter the image of PP in it according to Fokht's elastic-viscous model:

$$P = Es\frac{\partial u}{\partial x} + \mu s\frac{\partial \dot{u}}{\partial x} \qquad (4)$$

where E is the modulus of elasticity.,μ - dynamic viscosity

$u = x - x_0$ displacmnets, $\dot{u} = \dot{x} = \frac{du}{dt}$ - displacmnet's speed.

If we write $\frac{\partial P}{\partial x}$ We will have such an image according to (2).

$$\frac{\partial}{\partial x}(Px) = Es\frac{\partial u}{\partial x} + \mu s\frac{\partial \dot{u}}{\partial x} + \rho s x\frac{d^2x}{dt^2} \qquad (5)$$

If we take into account the same equality:

$$x\frac{d^2x}{dt^2} = \frac{1}{2}\frac{d^2}{dt^2}(x^2) - (\frac{dx}{dt})^2 \qquad (6)$$

and integrating (5) we get:

$$P_{-2}x_2 - P_{+1}x_1 = Es(u_2 - u_{1)}) + \mu s(\dot{u}_2 - \dot{u}_1) + \frac{1}{2}\rho s\frac{d^2}{dt^2}\int_{\overline{m}} x^2 d\overline{m} - \rho s\int_{\overline{m}} \dot{x}^2 d\overline{m} \qquad (7)$$

If we take into account that

$$J_x = \rho s\int_{x_1}^{x_1} x^2 dx = \frac{\rho s}{3}(x_2^3 - x_1^3) = \frac{\overline{m}}{3}(x_2^2 + x_1x_2 + x_1^2) \qquad (8)$$

And we will connect the ends of the stem of the origin of the coordinates in sequence, provided that $u_1 = x_1 - x_{10}$, $u_2 = x_2 - x_{20}$, $\dot{u}_1 = \dot{x}_1$, $\dot{u}_2 = \dot{x}_2$, We will have

$$P_{+1} = \frac{Es}{l}(u_2 - u_1) + \frac{\mu s}{l}(\dot{u}_2 - \dot{u}_1) - \frac{\overline{m}}{6}\ddot{u}_2 - \frac{\overline{m}}{3}\ddot{u}_1 + \frac{\overline{m}}{3l}(\dot{u}^2{}_1 + \dot{u}_1\dot{u}_2 + \dot{u}_2^2) - 2\frac{W}{l} \qquad (9)$$

$$P_{-2} = \frac{Es}{l}(u_2 - u_1) + \frac{\mu s}{l}(\dot{u}_2 - \dot{u}_1) + \frac{\overline{m}}{6}\ddot{u}_2 + \frac{\overline{m}}{3}\ddot{u}_1 + \frac{\overline{m}}{3l}(\dot{u}^2{}_1 + \dot{u}_1\dot{u}_2 + \dot{u}_2^2) - 2\frac{W}{l}$$

where 2W represents the doubled value of the kinetic energy of the rod and is equal to the last term of (7). To evaluate it, let us assume that, as in the relay method, the velocities along the rod are distributed according to a linear law:

$$\dot{x} = \dot{x}_1 + (\dot{x}_2 + \dot{x}_1)\frac{x}{l} \qquad (10)$$

Let's enter it into the kinetic energy expression

$$W = \frac{1}{2}\int_{\overline{m}} \dot{x}^2 d\overline{m} = \frac{\overline{m}}{6}(\dot{u}_1^2 + \dot{u}_1\dot{u}_2 + \dot{u}_2^2) \qquad (11)$$

Thus, the last two terms of (9) cancel each

other out for P_1 and P_2, we get:

$$P_{+1} = \frac{Es}{l}(u_2 - u_1) + \frac{\mu s}{l}(\dot{u}_2 - \dot{u}_1) - \frac{\overline{m}}{6}\ddot{u}_2 - \frac{\overline{m}}{3}\ddot{u}_1 \qquad (12)$$

$$P_{-2}=\frac{Es}{l}(u_2-u_1)+\frac{\mu s}{l}(\dot{u}_2-\dot{u}_1)+\frac{\overline{m}}{3}\ddot{u}_2+\frac{\overline{m}}{6}\ddot{u}_1$$

If we write down the expressions (12) for the i-th rod and insert it into the equation (1), we get:

$$(m_i+\frac{\overline{m}_i+\overline{m}_{i-1}}{3})\ddot{u}_i+\frac{\overline{m}_i}{6}\ddot{u}_{i+1}+\frac{\overline{m}_{i-1}}{6}\ddot{u}_{i-1}+\frac{E_{i-1}s_{i-1}}{l_{i-1}}(u_i-u_{i-1})-\frac{E_is_i}{l_i}(u_{i+1}-u_i)+\frac{\mu_{i-1}s_{i-1}}{l_{i-1}}(\dot{u}_i-\dot{u}_{i-1})$$

$$-\frac{\mu_is_i}{l_i}(\dot{u}_{i+1}-\dot{u}_i)=Q_i$$

(13)

Let's consider the same discrete-continuous system with the only difference that this time M twisting moments act on the suspended masses. $M_i=M_i(t)$

The equations of motion of discrete masses during torsional oscillation are written as follows:

$$J_i\frac{d^2\varphi_i}{dt^2}-M_{+i}+M_{\_i}=M_i$$

$i=1,\ 2,.......N$ (14)

Where J_i is the moment of inertia of a discrete mass.

Similarly to the case of longitudinal oscillation, we separate the relationship between the discrete masses m1 and m2 and write the same equation:

$$\frac{\partial}{\partial x}(MX)=M+X\ \frac{\partial M}{\partial x} \qquad (15)$$

Where M is a twisting moment acting in any section of the rod.

Let's write down the corresponding dependence of Fokht's elastic-viscous model in the case of twisting:

$$M=GI\frac{\partial\varphi}{\partial x}+\overline{\mu}I\frac{\partial\dot{\varphi}}{\partial x} \qquad (16)$$

where G is the shear modulus, $\overline{\mu}$ - is dynamic viscosity during shear, I is the polar moment of the cross section of the rod, and φ the angular velocity.

The equilibrium condition of the moments acting on the elementary volume is written as follows

$$\frac{dM}{dx}dx=\frac{d^2\varphi}{dt^2}d\overline{J} \qquad (17)$$

where $d\overline{J}$ is the moment of inertia of the $d\overline{m}$ mass of the elementary volume, which, R for example, for a circular section with a radius, is calculated by the well-known formula:

$$d\overline{J}=\frac{R^2}{2}d\overline{m}=\frac{R^2}{2}\rho s dx \qquad (18)$$

Inserting (16), (17) and (18) into (15) and integrating, we get:

$$M_{-2}x_2-M_{+1}x_1=GJ(\varphi_2-\varphi_1)+\overline{\mu}J(\dot{\varphi}_2-\dot{\varphi}_1)+\int_J x\frac{d^2\varphi}{dt^2}d\overline{J}$$

(19)

From the deformed Sin diagram it follows that

$$dx=\frac{R}{\psi}d\varphi\Rightarrow x=x_1+\int_{\varphi_1}^{\varphi_2}\frac{R}{\psi}d\varphi \qquad (20)$$

Where ψ is the angle of inclination of the cylinder head, which generally depends on x

If we substitute (20) into (19) and place the origin (x=0) at the end of the stem, we get:

$$\int_{\overline{J}} x\frac{d^2\varphi}{dt^2}d\overline{J}=\int_{\overline{J}_1}(\int_{\varphi_{11}}^{\varphi_2}\frac{R}{\psi}d\varphi)\frac{d^2\varphi}{dt^2}d\overline{J} \qquad (21)$$

The image ψ can be written as follows:

$$\psi=\frac{R(\varphi_2-\varphi_1)}{l} \qquad (22)$$

The image can be written as follows: where

ψ 1 and ψ 2are the angular coordinates of the ends of the rod. Let us substitute (22) into (21), take into account (18) and the following identical equation

$$\varphi \frac{d^2\varphi}{dt^2} = \frac{1}{2}\frac{d^2}{dt^2}(\varphi^2) - (\frac{d\varphi}{dt})^2 \qquad (23)$$

As a result of simple transformations from (21) we get:

$$\int_{\bar{J}} x \frac{d^2\varphi}{dt^2} d\bar{J} = \frac{l}{\varphi_2 - \varphi_1}(\frac{1}{2}\frac{d^2}{dt^2}\int_{\bar{J}} \varphi^2 d\bar{J} - \int_{\bar{J}} \dot{\varphi}^2 d\bar{J} - \varphi_1 \frac{d^2}{dt^2}\int_{\bar{J}} \varphi d\bar{J}) \qquad (24)$$

As a result of the joint transformation of (19), (20), (.22) and (23), taking into account that x1=0, we get:

$$M_{-2} = \frac{GI}{l}(\varphi_2 - \varphi_1) + \frac{\bar{\mu} I}{l}(\dot{\varphi}_2 - \dot{\varphi}_1) + \frac{\bar{J}}{3}\ddot{\varphi}_2 + \frac{\bar{J}}{6}\ddot{\varphi}_1 + + \frac{\bar{J}(\dot{\varphi}_1^2 + \dot{\varphi}_1\dot{\varphi}_2 + \dot{\varphi}_2^2) - 6W}{3(\varphi_2 - \varphi_1)} \qquad (25)$$

Now, if we combine the origin with the other end of the rod ( ) and do similar transformations, we get:

$$M_{+1} = \frac{GI}{l}(\varphi_2 - \varphi_1) + \frac{\bar{\mu} I}{l}(\dot{\varphi}_2 - \dot{\varphi}_1) - \frac{\bar{J}}{3}\ddot{\varphi}_2 - \frac{\bar{J}}{6}\ddot{\varphi}_1 + + \frac{\bar{J}(\dot{\varphi}_1^2 + \dot{\varphi}_1\dot{\varphi}_2 + \dot{\varphi}_2^2) - 6W}{3(\varphi_2 - \varphi_1)} \qquad (26)$$

Where $W = \frac{1}{2}\int_{\bar{J}} \dot{\varphi}^2 d\bar{J}$ – kinetic energy of the rotational motion of the axis.

Now, similar to longitudinal vibration, let's

imagine the angular velocity as follows:

$$\dot{\varphi} = \dot{\varphi}_i + (\dot{\varphi}_2 - \dot{\varphi}_1)\frac{x}{l} \qquad (27)$$

If we include (18) and (27) in expression, we get:

$$W = \frac{\bar{J}}{6}(\dot{\varphi}_1{}^2 + \dot{\varphi}_1\dot{\varphi}_2 + \dot{\varphi}_2{}^2),$$

This indicates that the last two terms in (25) and (26) cancel each other, leading to:

$$M_{-2} = \frac{GI}{l}(\varphi_2 - \varphi_1) + \frac{\bar{\mu} S}{l}(\dot{\varphi}_2 - \dot{\varphi}_1) + \frac{\bar{J}}{3}\ddot{\varphi}_2 + \frac{\bar{J}}{6}\ddot{\varphi}_1 \qquad (28)$$

If we include these images in (14), we get:

$$M_{+1} = \frac{GI}{l}(\varphi_2 - \varphi_1) + \frac{\bar{\mu} S}{l}(\dot{\varphi}_2 - \dot{\varphi}_1) - \frac{\bar{J}}{3}\ddot{\varphi}_1 - \frac{\bar{J}}{6}\ddot{\varphi}_2$$

$$(J_i + \frac{\bar{J}_i + \bar{J}_{i-1}}{3})\ddot{\varphi}_i + \frac{\bar{J}_i}{6}\ddot{\varphi}_{i+1} + \frac{\bar{J}_{i-1}}{6}\ddot{\varphi}_{i-1} + \frac{G_{i-i}I_{i-1}}{l_{i-1}}(\varphi_i - \varphi_{i-1}) - - \frac{G_i I_i}{l_i}(\varphi_{i+1} - \varphi_i) + \frac{\bar{\mu}_{i-1} I_{i-1}}{l_{i-1}}(\varphi_i - \varphi_{i-1}) - \frac{\bar{\mu}_i I_i}{l_i}(\varphi_{i+1} - \varphi_i) = M_i \qquad (29)$$

From a comparison of the resulting systems of differential equations (13) and (29) for longitudinal and torsional vibrations, it follows that they coincide in form. They differ only in the given and required quantities: instead of displacements - angles of rotation, instead of masses - moments of inertia, instead of an acting external force - torque.

Therefore, the algorithm for solving the system will be the same for both cases. Therefore, it is necessary to build a system of solved equations, any equation of which

contains the magnitude, speed and acceleration of displacements of the mass and its neighboring masses.

Only the first and last equations are different, the first one contains only the first and second masses, and the last equation contains the displacements, velocities and accelerations of the last and last masses.

Both longitudinal and torsional vibrations are considered. The influence of changes in the masses of the rods and other characteristic parameters on the stress-strain state of the structure as a whole was studied.

The displacements obtained without taking into account the influence of the rods during longitudinal vibrations in the initial period of the impact are maximum for the first and last masses. When moving to the second and subsequent masses, the displacement decreases and for the second mass is 76% of the displacement of the first mass, for the third - 66%, for the fourth - 62%, for the fifth - 95%. (Fig 1)

As for speeds, the speed of the second mass increases from 0 to 29% of the speed assigned to the first mass, to 20% of the third, to 17% of the fourth. fifth to 22%. In this case, the first speed increases to 55% of the initially set speed. In the future, the absolute value obviously decreases even more. The values are acting on the rod are the same at the head and bottom of the rod. This force will pass through all the heads of the rod with a slight change in the maximum value.

When taking rods into account, the picture of the distribution of displacements over time is similar.

Only the magnitude of the displacements increases especially for the fifth mass and reaches 10%. The distribution of speeds is similar, here the speeds are also higher, but not significantly.

Regarding the distribution of forces, the influence of the rods is greater even because the values of the forces at the head and end of each rod are different, and for the first mass this difference reaches 8%. Otherwise less. If we compare these values with the result obtained without taking into account the influence of the rods, we will see that for the first mass this value is located in the middle of the values obtained at the head and below, and for the remaining masses both values are lower by about 9%.It is worth noting that these differences were obtained in the first period of swinging from the impact; subsequently, they gradually decrease both in comparison with the values obtained in the head and below, and in comparison with the value obtained without taking into account the impact. Stem the effect of changing the initial velocity on the forces and deformations occurring in the system was also studied. As expected, forces and deformations change in proportion to the initial velocity (Fig.2).

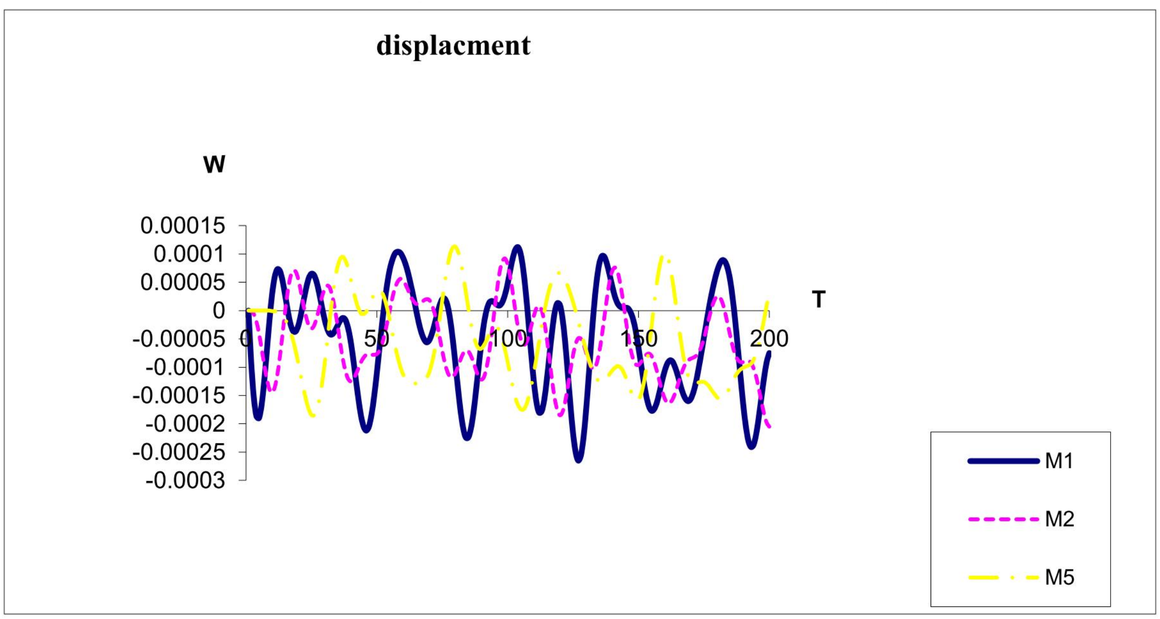
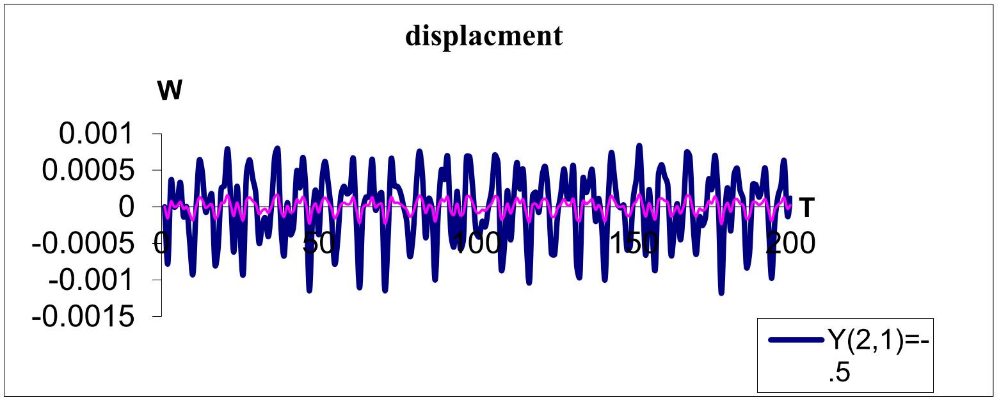


fig. 1. Displacements and Reactions



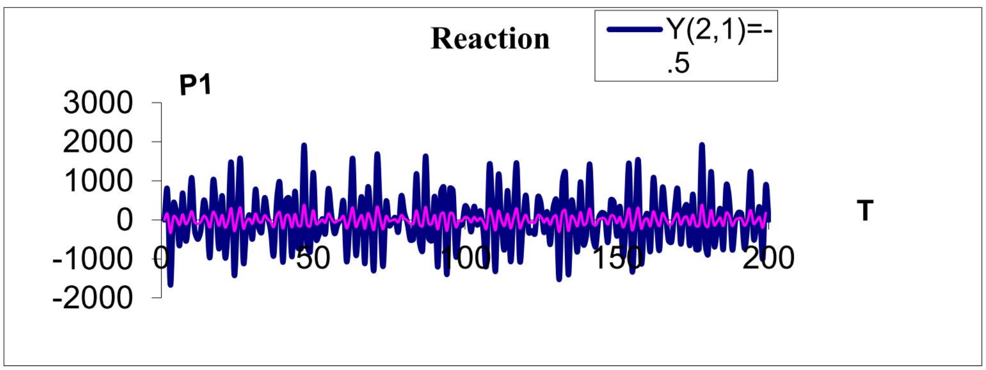


fig. 2. Displacements and forces of initial speed for different meanings

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Taking into account the inertia of the masses of the rod gives qualitatively the same result as without taking into account viscosity. The displacements again decrease somewhat and reach about 14% for the fifth mass.

As for the forces, in the initial period of exposure under the influence of viscosity they decrease slightly, and over time, one might say, several times. The relationship between these values and the values obtained without taking into account the influence of the rods is approximately the same as ours without taking creep into account.

The influence of changes in the dimensions of the first mass on the displacements of the upper masses and the magnitude of the forces arising in the rods has been studied. A change in the first mass causes proportional changes in the magnitude of the impact force, but, as calculations show, does not cause proportional changes in the forces and displacements induced in the structure, which is the reason for the influence of the initial speed. .Changing the initial speed, as we have seen, leads to a proportional change in the search variables. As for changing the dimensions of the first mass, its effect is as follows: without taking into account the influence of the inertia of the rod masses, reducing the first mass by half leads to a decrease in the displacement of the masses from 20% to 50%, respectively, from the first to the fifth masses

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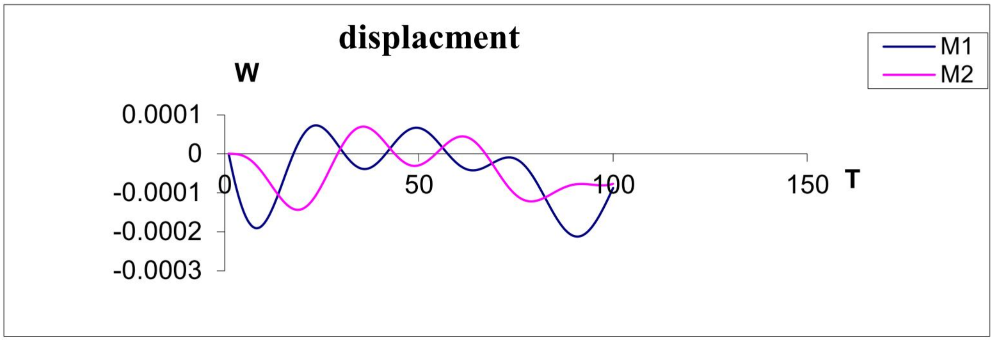

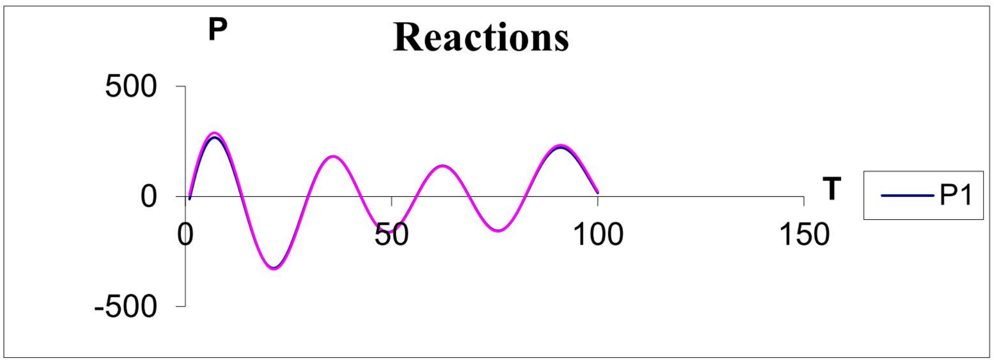

Fig. 3. First and second mass displacements

Taking into account the stem mass, the pattern of influence remains the same, only quantitatively reduced from 10% to 43%. The influence on the forces is approximately the same both without rods and with them taken into account. The effect of mass reduction is much stronger in the case of the Vocht model.

As for the picture of the distribution of forces, it is approximately the same without taking into account the influence of the masses of the rods.In this case, the forces acting on the head and end of the rod differ slightly from each other. So the influence of the rod masses in this case is even less than in the case of rotation angles.The influence of he initial speed on the torques and rotation angles occurring in the system was also studied. As expected, these values change proportionally to the magnitude of the initial velocity.

Similar calculations are carried out in the case when the building material obeys the Vocht model.

DISCUSSION

- The forces and displacements occurring in a structure are proportional to the initial velocity, but they are not proportional to the impact force when we also have an initial velocity. - Displacements and forces do not change in proportion to the viscosity coefficient. Its growth initially leads to a more intense reduction in forces and displacements than the process of its subsequent growth. In the specific case of the considered longitudinal vibrations, taking into account viscosity led to a decrease in masses from the first to the fifth by 13–36% and a decrease in forces by 19–41%. - During orsional vibrations, we have a maximum angle of rotation of the fifth mass and a maximum torque in the first rod, both ith and without rod masses.

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