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FREE FLUCTUATIONS OF THE BOX-SHAPED DESIGN OF THE BUILDING

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Abstract

In article it is solved problems of free fluctuation of a box-shaped design of a building, of structure from of beams and the lamellar elements which deformation has spatial character. The problem dares a method finite difference schemes. Own frequencies of fluctuations are found.

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Introduction.

This article examines the vibrations of the box of large-panel buildings (Figure.1), consisting of transverse and longitudinal walls, under the influence of dynamic action. As an external influence, we set the movement of the base $u_0(t)$ (Figure. 2). Suppose, in butt joints, transverse and longitudinal panels are attached to beam elements as shown in Figure 2. When the panels are deformed, the beam connecting them simultaneously works in bending and torsion. Bending and twisting of the beam is caused by the longitudinal, shear forces and bending moments of the panels.

Note that this work is a continuation and development of the scientific works of the authors [1] on the vibration of the box-shaped structure of buildings. Unlike [1], here it is taken into account: first, the deformation of transverse panels, described by a two-dimensional problem of the theory of elasticity; secondly, the full contact conditions between the elements of the box are considered; thirdly, the beam elements of buildings and the presence of window openings are taken into account. This formulation of the problem makes it possible to determine the stresses on beams and panels, as well as on butt joints.

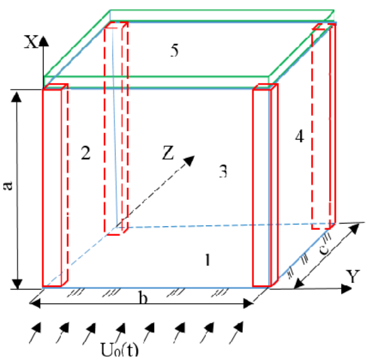

Figure. 1 Spatial box structure of the building

Suppose that the load-bearing walls of the building, panels 1, 3 (Figure. 1), located perpendicular to the direction of seismic influences, work only for transverse dynamic bending.

Panels 2 and 4, located in the direction of the external impact, are subjected to tension and shear in the OXZ plane.

All beam elements located in the contact zone of the panels work simultaneously for bending and torsion. Based on this consideration, we will depict in Figure. 2 all bending and tensile (compressive) force factors in the area of butt joints of panels.

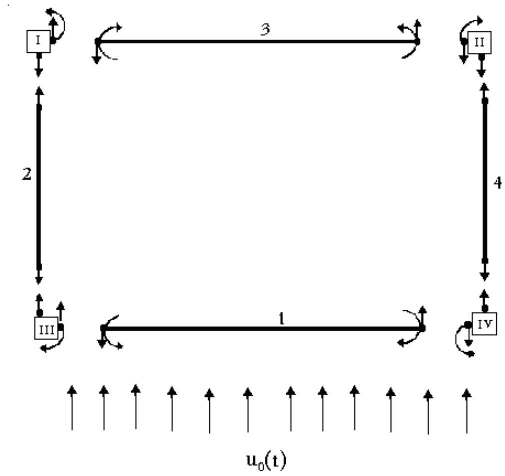

Figure. 2 Calculation model of vibrations of a box-shaped structure of a building

Method.

The equation of motion for bending panels 1 and 3 has the form

$$D\left(\frac{\partial^4 W}{\partial x^4}+2\frac{\partial^4 W}{\partial x^2 \partial y^2}+\frac{\partial^4 W}{\partial y^4}\right)+\rho H_b \ddot{W}=0, \ (1)$$

where D is the cylindrical stiffness of the panels in transverse bending.

The two-dimensional equation of motion for panels 2 and 4 is derived under the assumption that the panels stretch, contract, and shear only in the plane. Due to this equation, the motion of panels 2 and 4 will have the form

$$B\left(\frac{\partial^2 U}{\partial z^2}+\frac{1+\nu}{2}\frac{\partial^2 V}{\partial x \partial z}+\frac{1-\nu}{2}\frac{\partial^2 U}{\partial x^2}\right)=\rho H_c \ddot{U}, \ (2)$$

$$B\left(\frac{\partial^2 V}{\partial z^2}+\frac{1+\nu}{2}\frac{\partial^2 U}{\partial x \partial z}+\frac{1-\nu}{2}\frac{\partial^2 V}{\partial x^2}\right)=\rho H_c \ddot{V}, \ (3)$$

where B is the cylindrical stiffness of the panels in tension and compression.

Now, let's write down the boundary conditions for the edge of the panels. The rectangular panel is connected to the beam supporting it, the deflection at this edge will be equal to the deflection of the beam. The edge rotation angle will be equal to the beam twist angle:

$$W=W_0, \ \alpha=-\left(\frac{\partial^2 W}{\partial x \partial y}\right)_{x=0}. \qquad (4)$$

As noted in the monograph [4], the equations of bending and torsional vibrations of beams [4] are taken as the contact conditions between the transverse and longitudinal panels.

Equation of bending and torsional vibrations of a beam ($y = const, z = const$)

$$EJ\frac{\partial^4 W_0}{\partial x^4} + \rho F\ddot{W}_0 = \pm R_y \mp P \text{ . (5a)}$$

$$\frac{\partial}{\partial x}M_{\kappa p} = \rho I_{\kappa p}\ddot{\alpha} \pm M^I{}_y + \frac{\delta}{2}\cdot R^I{}_y \text{. (5б)}$$

In equations (4) and (5) the sign depends on which beam to consider; and P - the shear force of the bending panel 1.3 and the longitudinal force of the panel 2.4 in the area of the butt joint of panels and beams.

$W_0(x,t)$ - Deflection, $\alpha = -\left(\frac{\partial W}{\partial y}\right)_{x=a}$ - the angle of twisting of the beam and $\frac{d\alpha}{dx} = -\frac{\partial^2 W}{\partial x \partial y}$ - its changes in the vertical direction (along the OX axis); $M_{\kappa p} = EI_{\kappa p}\frac{\partial \alpha}{\partial x}$ - torque,

EJ and $EI_{\kappa p}$ are the bending and torsional stiffness of the beam, respectively.

At the junction of the beam and panels 1, 2 ($y = 0, z = c$), have contact kinematic conditions

$W(x,0,t) = U(x,c,t) = W_0(x,t)$. (6)

Similar kinematic conditions are recorded for other joints of beams with panels.

We write the boundary conditions for the base of the building ($x = 0$) as for rigid pinching. The lower part of the building moves with the base

$U = W = u_0(t)$ (7)

and the angle of rotation does not exist

$\frac{\partial W}{\partial x} = 0$. (8)

In the case of free oscillation $u_0(t) = 0$.

The edges of the contour of the window opening are considered free (Figure.3):

$M_{xx} = 0$, $Q_x = 0$, at $x = const$, (on the contour AB and CD), (9)

$M_{yy} = 0$, $Q_y = 0$, at $y = const$, (on the contour AC and BD). (10)

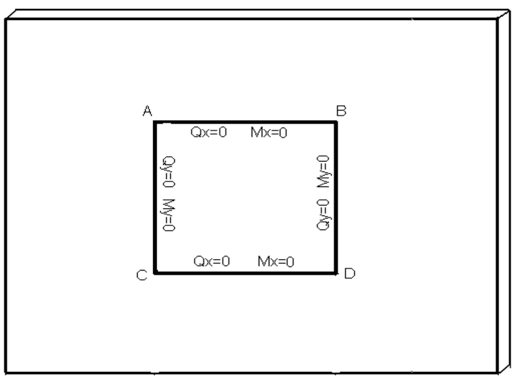

Fig. 3 Bending panel with cutout

We are looking for the solution of the problem by the method of finite-difference schemes, we will use the equations given in [2,3].

Consider the problem of natural vibrations of a building box. Based on the box (at $x = 0$), the boundary conditions are as follows:

$$\frac{\partial W}{\partial x} = 0, \ \mathrm{u} = 0 \ , \mathrm{W} = 0.$$

On the zone of butt joints of floors and side panels of the box (at), we will accept the following boundary conditions.

$W = U = u_l(t)$, (11)

$M_{xx} = 0$, (12)

$H_c \int_0^c \tau_{xz} dz + \int_0^b Q_{zx} dy = M_0 \frac{\partial^2 W}{\partial t^2}$, (13)

where M_0 is the mass, $u_l(t)$ are the displacements of the floor.

Result and discussion.

In this article, we will analyze the numerical results obtained in the case of free vibration of a box-shaped structure, with and without window openings.

The natural frequency is determined by the formula $\varpi_k = P_k \frac{H_1}{a^2} c_p$,

where H_1 is the thickness of the bent panel; P_κ is the frequency parameter, $Cp = \sqrt{\frac{E}{12\rho}}$ is the flexural wave velocity.

Panels working in bending (Figure. 1, panels 1 and 3) have the same elastic characteristics: modulus of elasticity $E = 75000$ kg /cm^2, density ρ = 1.2 t/m^3, Poisson's ratio ν = 0.25. Shear panels (Fig. 1, panels 2 and 4) have: modulus of elasticity $E = 200000$ kg/cm^2, density ρ = 2.5 t/m^3, Poisson's ratio ν = 0.25.

1) Oscillation of the box without taking into account the opening.

Let for panels 1 and 3 thickness $H_b = 0.5 м$, height $a = 3{,}5 м$ and length $b = 8 м$, and for panels 2 and 4 thickness $H_c = 0{,}2 м$; height $a = 3{,}5 м$; length c= 6m (figure. 1).

The first three values of the natural frequency parameter P_k, the circular natural frequencies ω_k and the period T_k of the natural frequency of vibration of the box-shaped structure of the building, excluding window openings, are determined.

Table. 1 Values of natural frequency and period of oscillation

Frequency parameter	$\overline{P}_1$ =18.659	$\overline{P}_2$ =45.719	$\overline{P}_3$ =109.192
Natural frequency	ϖ_1 = 549.632 s^{-1}	ϖ_2 =1347.031 s^{-1}	ϖ_3 = 3216.102s^{-1}
Period	T_1 =0.0114 s	T_2 =0.00466 s	T_3 =0.00195 s

The period of natural oscillations is determined by the formula: $T_k = \frac{2\pi}{\omega_k}$

2) We present the numerical results obtained for the problem of free vibrations of a box-shaped structure, taking into account the window openings located in the middle of the panel. Opening dimensions 1.75m x 1.5m.

Select the above-mentioned initial data as mechanical parameters. The geometric parameters of the box were taken:

for panels 1 and 3 thickness $H_b = 0.5м$, height $a = 3{,}5м$ and length $b = 8м$; for panels 2 and 4 thickness $H_c = 0{,}2м$, height $a = 3{,}5м$, length $c = 6м$.

Table 2 shows the first three values of the natural frequency parameter $P_к$, the circular natural frequency ω_k and the oscillation period T_k of the building. Analysis of the numerical results given in Tables 1 and 2 shows that the presence of window openings significantly reduces the values of natural frequencies.

Table 2 Values of natural frequency and oscillation period

Frequency parameter	$\overline{P}_1$ =10.383	$\overline{P}_2$ =43.729	$\overline{P}_3$ =115.473
Natural frequency	ϖ_1= 305,848 s^{-1}	ϖ_2 =1288,00s^{-1}	ϖ_3 =3401,00 s^{-1}
Period	T_1 =0.0205 s	T_2 =0.00487 s	T_3 =0.00185 s

Conclusion

The equations of motion of points of plate and beam elements of the box of buildings, boundary, contact and initial conditions of the problem of free vibrations are given. Within the framework of finite difference methods, the frequency and period of natural oscillations are determined and numerical results are obtained.

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