Faculty of Civil and Environmental Engineering
Institute of Structural Engineering

Dynamics

Project exercise No. 2

Name and surname ....
Group ....
Academic year ....
Final grade ....

Date	Remarks	Signature

Machine foundation II

Conduct the dynamic analysis of machine foundation show on figure. It is the foundation under the frame sawing machine. The foundation is a rigid concrete block settled on vibroisolators. In particular you are asked to do the following:

1. calculate the mass matrix of the analyzed system;
2. calculate the stiffness matrix and the damping matrix of system under consideration;
3. calculate the natural frequencies and modes of vibration; show modes of vibration on figures;
4. calculate the amplitudes of the steady state vibration; consider two cases: with and without damping;
5. using code PN-80/B-03040 determines the admissible amplitude of vibration and checks the code requirements.

Calculation data

Description of foundation

Foundation is made of concrete B25. Exemplary shape of foundation is shown on enclose picture. The foundation consists of 4 parts: the upper block and the lower block, the block for machine and the counterweights to engine. The track and engine are mounted on foundation. Dimensions of block for the machine and dimensions of the counterweights to engine are shown on figure. The possible combinations of other dimensions of foundation are given in Table 1.

Table 1

Upper block			Lower block			Number of springs	Numbers of vibroisolators
a [cm]	b [cm]	e [cm]	c [cm]	d [cm]	h [cm]		
1000	600	80	800	400	120	4	12
1200	670	80	1030	500	170	4	20
1500	800	100	1300	600	200	8	16
1800	1200	100	1600	1000	230	8	24
1800	1000	100	1600	700	230	8	24
2500	800	150	2300	600	235	8	36

It is assumed that all mentioned below coordinates of points are given in coordinate system x, y, z. Axes x and y set a plane which became covered with the lower plane of the lower block. The origin of coordinate system is located at the point where the symmetry axes of the lower plane of lower block are crossing. The axis z is oriented vertically.

Description of machines located on foundation

On foundation the frame sawing machine and the engine are located. The mass of the frame sawing machine is M_t =12, 0 Mg. The mass moments of inertia of this machine with respect to the coordinate system settled at the mass centre of machine are:

$$J_{xx} = 5{,}83\ Mgm^2, \qquad J_{yy} = 4{,}45\ Mgm^2, \qquad J_{zz} = 3{,}35\ Mgm^2 .$$

Assume that the remaining mass moments of inertia are equal to zero.

A distance between the upper level of block for machine and the centre of mass of the frame sawing machine is equal 106.0 cm. The frame sawing machine is a machine which execute the pushing – returning motions. Rotations of machine are n=280 rotations per minute.

The engine is mounted on the foundation. The mass of engine M_S=1400 kg. The mass center of engine has coordinates x=+395 cm, y=+80 cm. Calculate the z-th coordinate of the mass center using information that the distance between the upper level of upper block and the engine mass centre is 41 cm. Dynamic forces excited by the engine are negligible in comparison with forces excited by the frame sawing machine. Moreover, the mass of inertia of the engine with respect to the engine own system of coordinates is neglected.

Description of excitation forces

The vertical excitation force is acting on the system. The force is acting in the mass centre of frame sawing machine. The in time behavior of the excitation force is given by the formula:

$$P(t) = P_{1V} \cos \lambda t + P_{2V} \cos 2\lambda t \quad ,$$

where λ is the excitation frequency and,

$$P_{1V} = 348,6 \;\; kN \, , \qquad\qquad P_{2V} = 88,6 \;\; kN \quad .$$

Moreover, the horizontal excitation force is acting in the mass center of the frame sawing machine. The horizontal force is parallel to the x-axis. The force changes with time according to the following formula:

$$P_H(t) = P_{1H} \cos \lambda t \quad .$$

where $P_{1H} = 88,6 \;\; kN$.

Information on springs and vibroisolators

Springs are made of the 55S2 steel. Spring parameters are: $d = 43 \;\; mm$, $D = 280 \;\; mm$, $H_0 = 530 \;\; mm$, $i_0 = 6,5$, $G = 78500,0 \, MN/m^2$, $R_t = 730 \, MN/m^2$. A number of springs in one vibroisolator and a number of vibroisolators under foundation are given in Table 1. An exemplary distribution of vibroisolators is show on figure.

Damping description

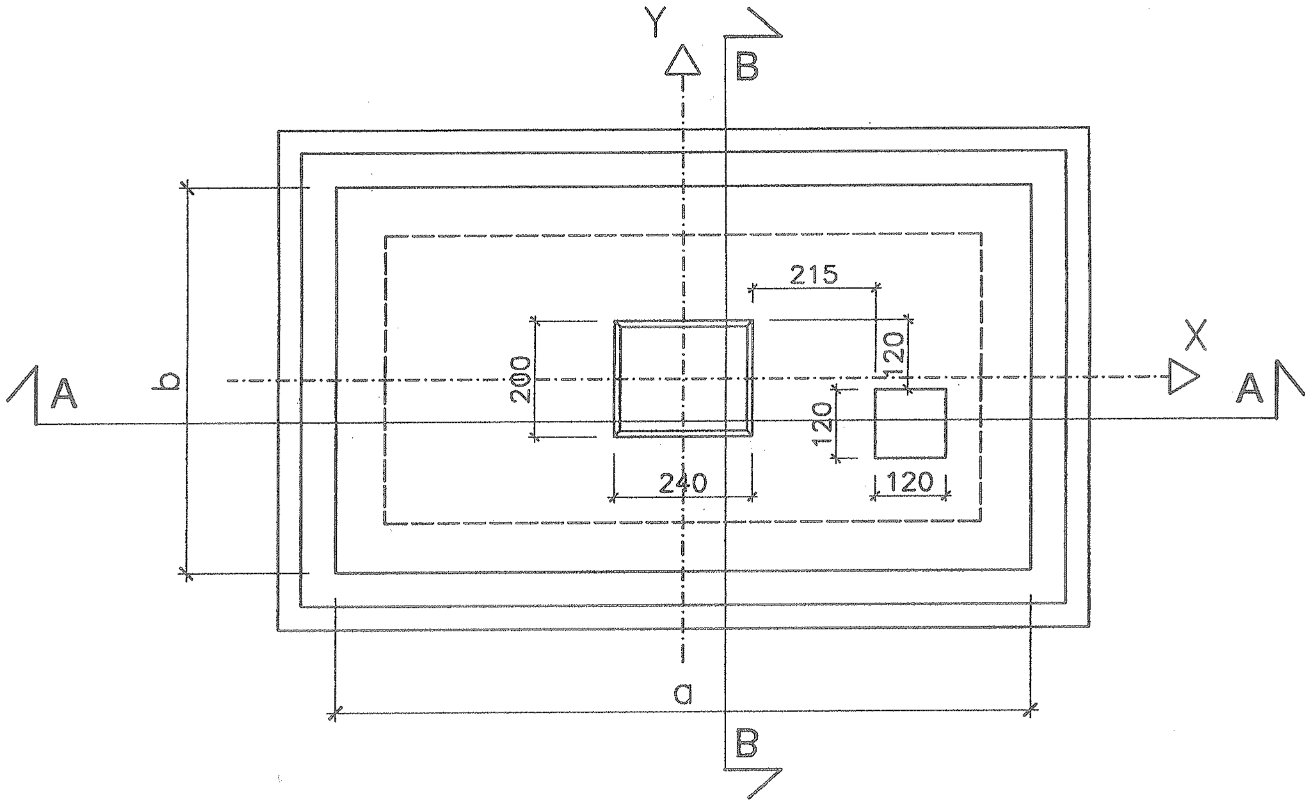
The damping matrix is proportional to the stiffness matrix. The dimensionless damping ratio of the fundamental mode of vibration is $\gamma = 0{,}001$.

Description of the metod of calculation of vibroisolator stiffness factors

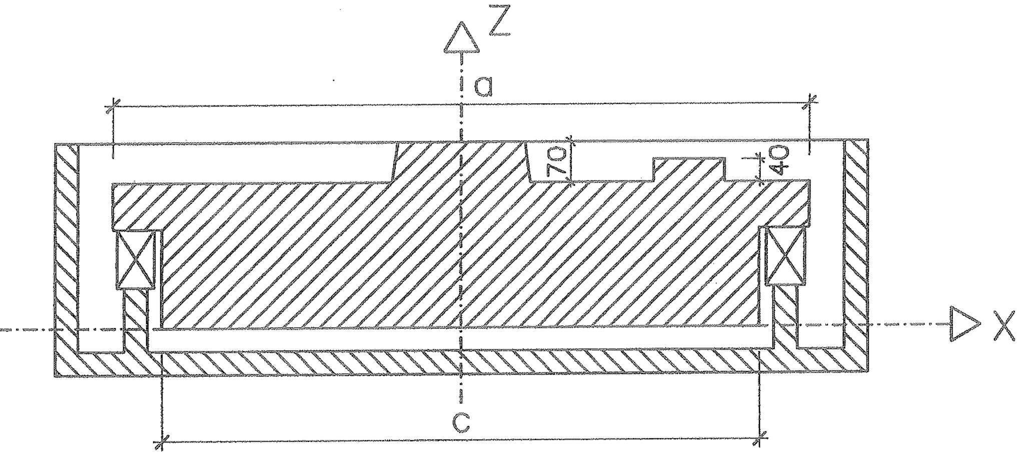
Please calculate the following quantities:

- the spring indicator $w = D/d$, which must be in a range $4 < w < 10$,
- the spring slender $\lambda = H_0/D$, which must be In a range $\lambda \leq 2$;
- a number of working roll $i = i_0 - 1{,}5$;
- the correction factor $k = 1 + \frac{5}{4w} + \frac{7}{8w^2} + \frac{1}{w^3}$,
- the spring stiffness in the longitudinal direction $k_z = \frac{dG}{8iw^3}$,
- the spring stiffness in the perpendicular direction $k_x = k_y = 0{,}75k_z$,
- the admissible load of spring $P_{dop} = \frac{\pi d^2 R_t}{8kw}$,
- the static deflection of spring $f_{st} = \frac{P_{char}}{k_z l_s}$,
- the height of fully pressed spring $H_d = (i_0 - 0{,}5)d$,
- the height of statically loaded spring $H_{st} = H_0 - f_{st}$, where ($H_{st} > H_d$).

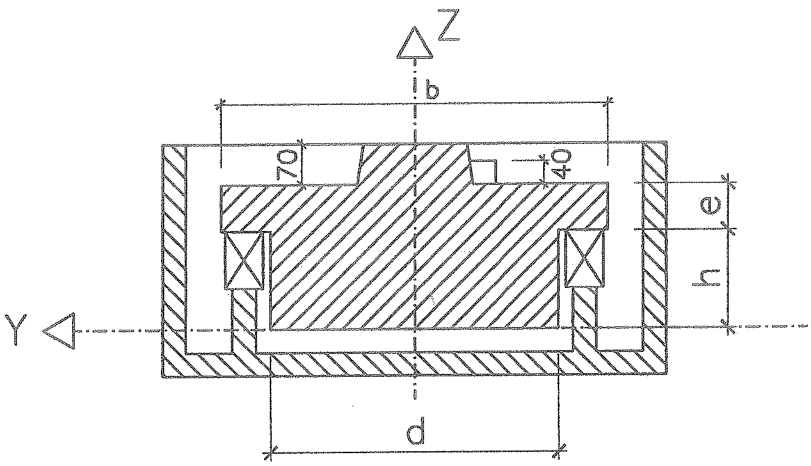
Meanings of symbols appearing in the above formulas are:
d - the diameter of spring wire, D - the diameter of spring, H_0 - the height of unloaded spring, i_0 - a number of spring wires, G - the Kirchhoff's modulus of the spring material; R_t - the resistance of steel under cutting; P_{char} - the characteristic static load of acting on foundation; l_s - a number of spring in all vibroisolators.

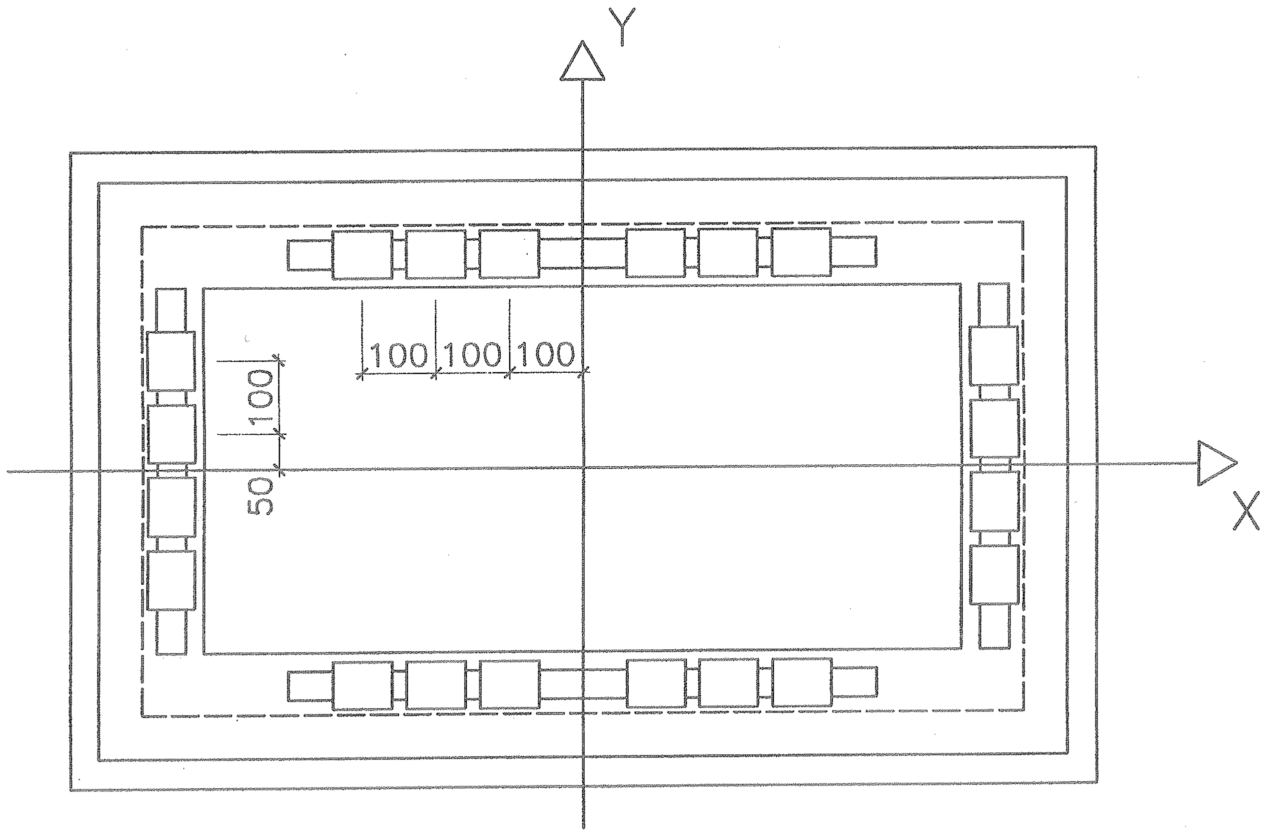


A-A



B-B





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50