

RESEARCH OF THE EARTHQUAKE RESISTANCE OF FLAME TOWERS COMPLEX

Mamedov Shakir Ahmad- PhD. in tech.sc., ass.prof., Department of Exploitation and Reconstruction of Buildings and Construction, AzUAC, shakir.mamedov@azmiu.edu.az

Aliyev İlqar Qiyas- PhD. in tech.sc., ass.prof., Department of Exploitation and Reconstruction of Buildings and Construction, AzUAC, ilqar.aliyev@azmiu.edu.az

Hasanova Tukezban Jafar- PhD. in tech.sc., Department of Exploitation and Reconstruction of Buildings and Construction, AzUAC, tukezbhan.hasanova@azmiu.edu.az

Abstract. According to construction norms and rules, the territory of the Republic of Azerbaijan is a region prone to moderate and strong earthquakes. Therefore, it is of great importance to obtain information about the nature and main parameters of seismic events that may occur in the territory of the Republic of Azerbaijan and its adjacent zones, as well as to determine the seismic stability of buildings under construction and operation. It is important to conduct dynamic studies to study the stability of buildings. The theoretical calculation of the period of free oscillations of buildings based on the stiffness, mass, geometric dimensions and shape of the load-bearing system is based on an important assumption. Experimental determination of dynamic parameters is of great importance in the investigation of how the building behaves during its construction and use. It is an important issue to determine the dynamic parameters of the 16-22-story monolithic reinforced concrete frame buildings built in Baku and whose construction has become massive. By determining the dynamic parameters of buildings and comparing them with the values of normative parameters, it is possible to have certain knowledge about the earthquake resistance and condition of buildings. The object of investigation of the research work is a complex of buildings built at M. Huseyn Street, 1A, Sabail District, Baku City. In this work, research works on determining the dynamic parameters of the residential building with the mobile diagnostic complex "Struna-3 Expert" were carried out.

Keywords: dynamic tests, seismometric stations, construction complex, free oscillations, dynamic parameters

Introduction. As a result of a large number of random natural phenomena and so on (earthquake, vibration, strong wind, additional loading), the dynamic parameters of the building change. Therefore, repeating the dynamic tests for that building after a certain period of time and comparing the obtained dynamic parameters with the previous parameters can be of great importance. This will allow to reassess the durability of the residential building after a certain period of operation. Taking into account that the area is a landslide zone, it would be appropriate to conduct annual dynamic tests to determine the dynamic parameters of the stiffness characteristics of the building structures and to take strengthening measures if necessary. There is always a possibility of landslides in the area. It is important to install permanently operating engineering seismometric stations in the building and surrounding area. Tests are repeated several times to get reliable results. By using the received seismograms, the period, frequency, and longitudinal wave propagation in the building structures are determined.

Brief information about the investigated building. "BAKI FLAME TOWERS" construction complex is located at 1A, M. Huseyn Street, Sabail District, Baku. This building complex includes a hotel, office and residential buildings. The residential building has 38 floors. Basements are designed on 4 levels in the building. The building's stability and spatial rigidity are ensured by the joint work of reinforced concrete frames and monolithic facing plate. A general plan of the site and a general view of the residential building are shown below (Fig.1,2) [2,3].



Figure 1. General view of the building from different directions [2,3]



Figure 2. General view of the building from different directions [2,3]

Physical-geographical and geomorphological description of the construction site. The area where the office building is built is an area with a slope of 15-200 degrees towards the sea, in the north-east direction. In the immediate vicinity of the studied area, 50-55m. There is a sliding zone in the distance towards the north.

Engineer-geological characteristics of the construction site. Clay, sand, clay and limestone soils are mainly involved in the geological structure of the area. The characteristics of the base soil obtained as a result of literature materials and laboratory studies are given below (Tab. 1).

Table 1.

Serial number	Indicators	Averages
1	Bulk mass, g/sm^3	2,14
2	Uniaxial compressive strength (in natural state) kgf/sm^2	65
3	Uniaxial compressive strength (under water) kgf/sm^2	48
4	Softening factor	0,74

Hydro-geology and seismicity of the construction site. From the point of view of earthquake safety, the construction site has II-level seismic composition according to the table No. 1 of TN and Q II-0.7-81, and it has been evaluated as a 7.0-point area. During the construction of the building itself, groundwater encountered in the field is transferred through the drainage system. The correction added to the score due to soil is $(0.51 \div 0.12)$ points. Thus, the maximum intensity of vibration of the area where the residential building is located from the strongest earthquakes is 7.5 points. This score (8.0) was accepted as a normative document for calculating the building.

Experimental determination of dynamic parameters of the building. Tests were conducted with the help of "Struna-3" type mobile diagnostic complex to detect the dynamic parameters of the building's vibration movement and the location of closed (hidden) damage in the building structures. The dynamic parameters of the building were determined experimentally by impacting the building's X and Y (longitudinal and transverse) directions with the help of a loading device on the soil of the area where the building is located (Fig.3.).



Figure 3. General view of the loading device [3]

Taking into account the large number of floors of the building (38 floors), the tests were performed in 2 variants. In the 1st option, the seismic receivers are placed on the 1st, 4th, 8th, 11th, and 19th floors, and in the 2nd option - on the 1st, 19th, 25th, 32nd, 36th floors. The location levels of seismographs in the building during the test are shown in figure 4.

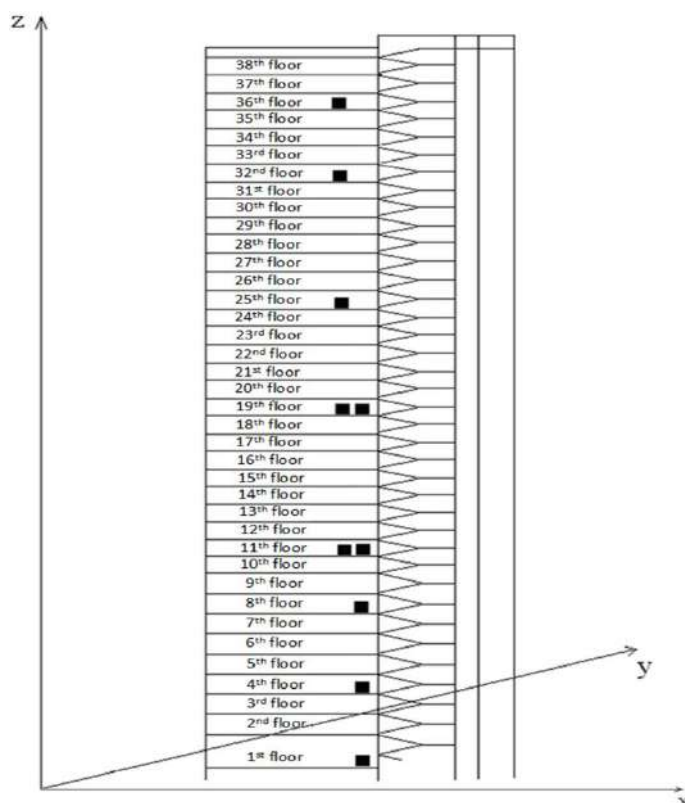


Figure 4. Location levels of seismographs in the building during the test [3,4]

With the help of the loading device, blows are made in the directions of the X and Y axes of the building. The building dance begins to move. The shaking movement of the building is received by seismographs placed on different floors and recorded in a computer connected to the seismographs with the help of wires (Figure 5).



Figure 5. General view of the computer [3,4]

In addition to the impact methods, the recording of the building's oscillation movement due to the wind effect was also carried out (Figures 6-7). The wind speed is determined with the help of a mechanical device of type ARC-48.

Free oscillations due to the influence of wind ($V_k=3.0-4.0$ m/sec)

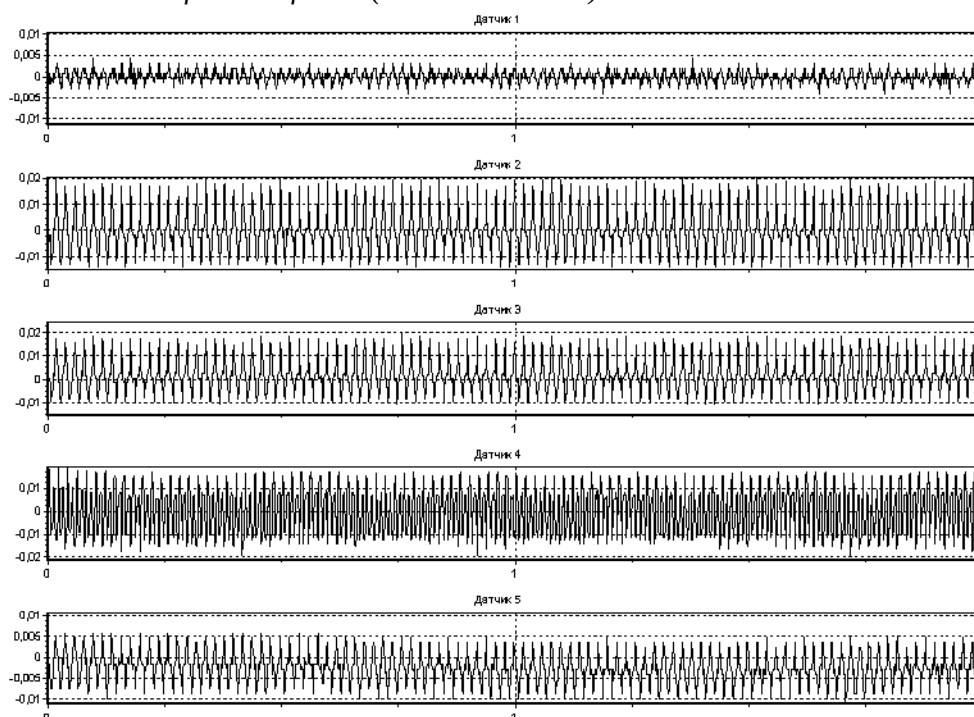


Figure 6. Free oscillations along the floors of the building. X-axis oscillations test1x01x [5]

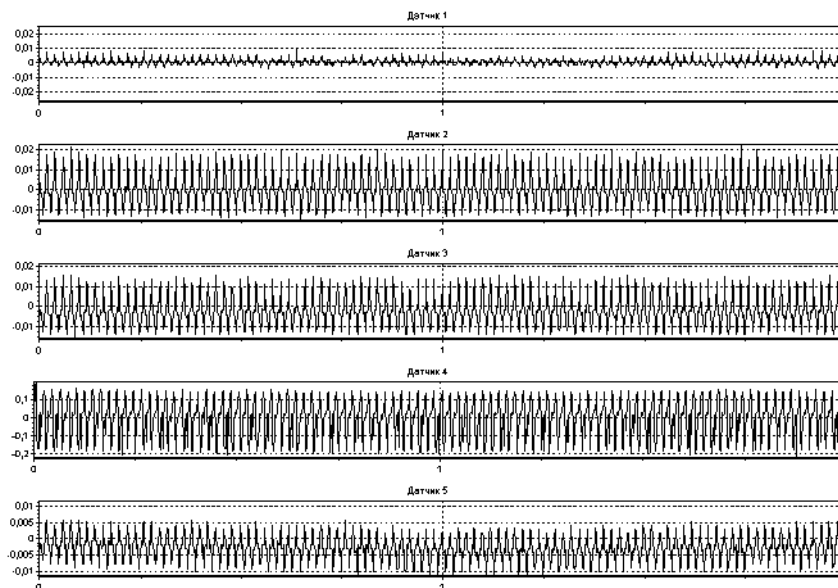


Figure 7. Free oscillations along the floors of the building oscillations on the Y axis. file: test 1x01y [5]

Processing and analysis of seismograms obtained as a result of tests. The seismographs recording the building's vibration are located on the 1st, 4th, 8th, 11th, 19th, 25th, 32nd and 36th floors of the building and are oriented along the X, Y and Z axes of the building.

The constructed spectra of the building's swaying motion caused by wind are given below (Figure 8). In the spectrum graph, the horizontal axis represents period (T) or frequency (F), and the vertical axis represents displacement (U, microns).

Spectra of free oscillations formed in the building due to the influence of wind

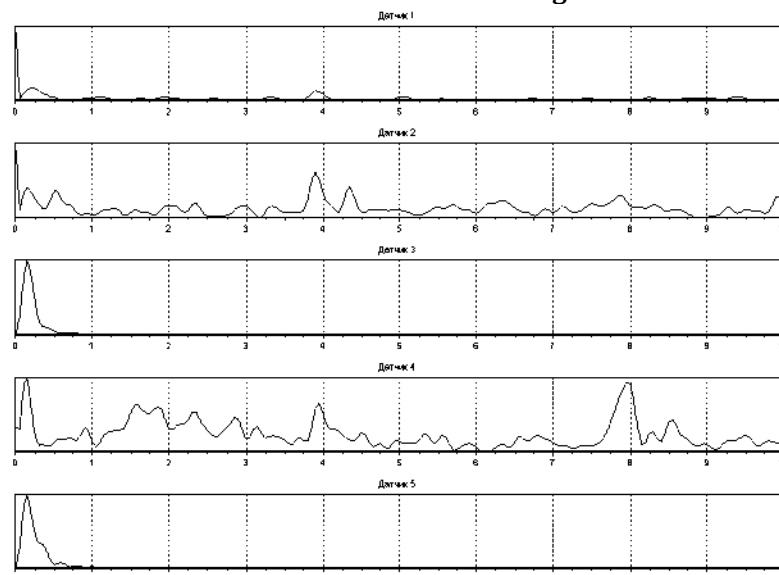


Figure 8. X-axis spectrum of the free oscillation of the building. file: test1x01x [5]

The constructed spectra of the building's oscillating motion caused by the impact in the X and Y direction are given below (Figure 9-12).

Forced oscillations due to transmission of seismic impulse along the X-axis

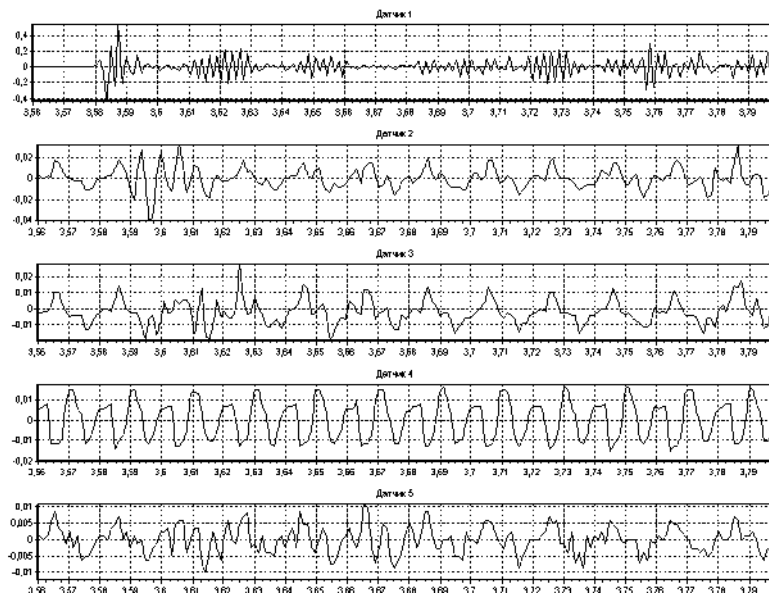


Figure 9. Free oscillations along the floors of the building. X-axis oscillations. file: test 1x1x [5]

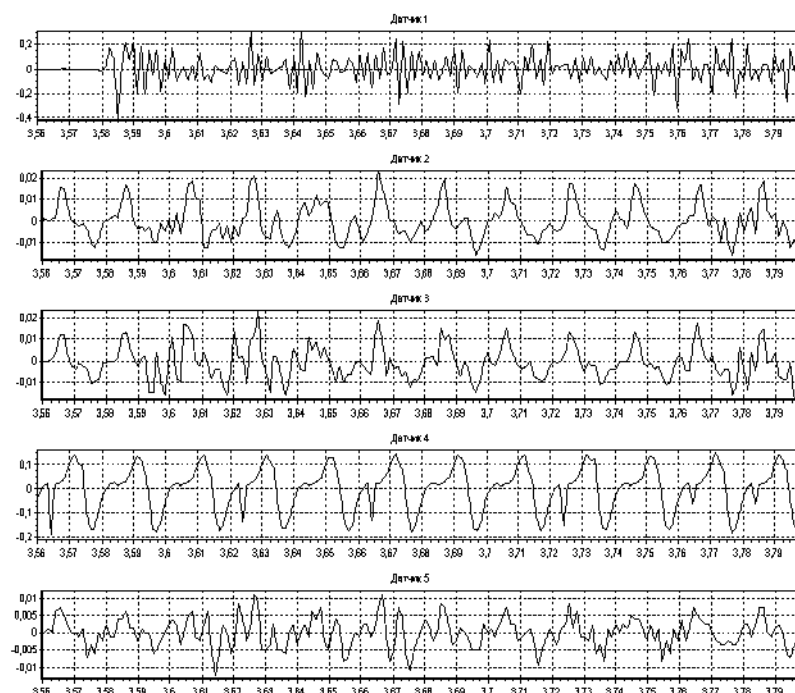


Figure 10. Free oscillations along the floors of the building oscillations along the Y axis. file: test1x1y [5]

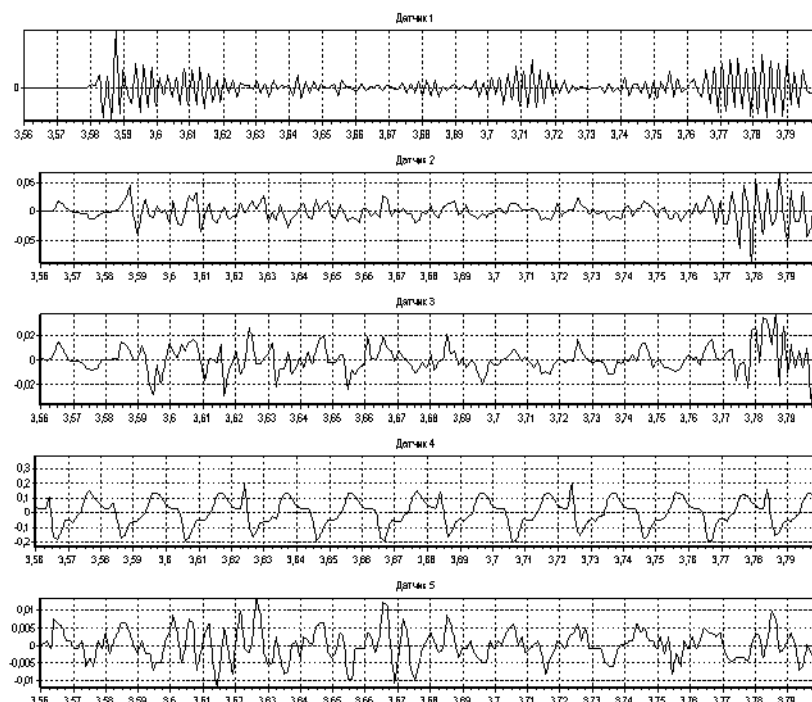


Figure 11. Free oscillations along the floors of the building Z-axis oscillations. file: test 1x1z [5]

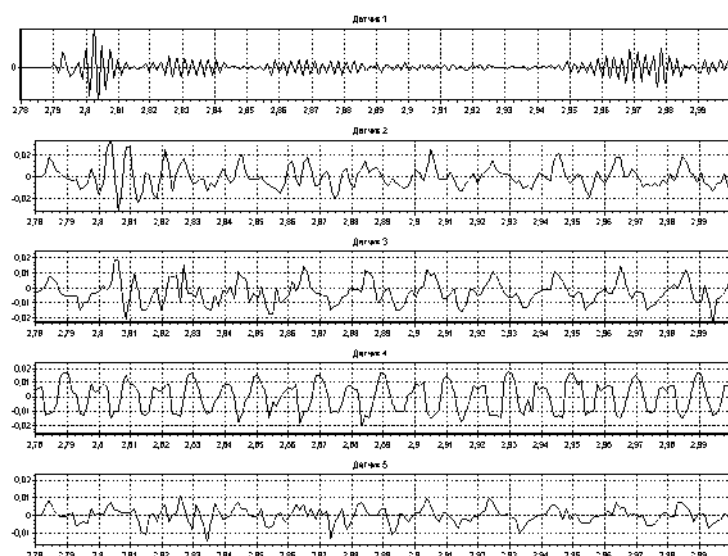


Figure 12. Free oscillations along the floors of the building X-axis oscillations. file: test 1x2x [5]

The degree of damage to the building was determined by comparing the value of the normative period of the building's vibration with the value of the period determined as a result of the tests. The empirical formula given below is used to determine the normative value of the period of the building:

$$T = \alpha \cdot n \quad (1)$$

Here: n - the number of floors of the building; α - is a coefficient that depends on the construction of the building and the type of its foundation.

The value of the coefficient for the most common types of buildings in medium-density soils is determined according to the following table (Table 3).

Table 3.

Serial number	Type of building	α - coefficient
1	Large panel residential building	0,045
2	A residential building with load-bearing walls of brick, stone and large blocks	0,056
3	A large hollowed-out school and other buildings with walls similar to those in P 2	0,065
4	Monolithic reinforced concrete frame buildings with walls filled with brick or light concrete	0,064
5	Infilled steel frame buildings as in P 4	0,08

An increase in the period of the building is characterized by a decrease in the rigidity of the building. These quantities are inversely proportional to each other. When calculating the value of the normative period of the residential building under test, the value of α should be taken $\alpha \pm 0,011$, in the direction of the X axis of the building and in the direction of the Y axis the value of α should be taken $\alpha \pm 0,0125$, . Using these coefficients, let's calculate the normative values of the period along the X and Y axes of the building:

in the direction of the X axis

$$T_x^{norm} = (\alpha \pm 0,011) \cdot n$$

$$T_x^{norm} = 0,075 \cdot 38 = 2,85 \text{ san.}$$

$$T_x^{norm} = 0,053 \cdot 38 = 2,01 \text{ san.}$$

In the direction of the Y axis

$$T_y^{norm} = (\alpha \pm 0,0125) \cdot n$$

$$T_y^{norm} = 0,0765 \cdot 38 = 2,91 \text{ san.}$$

$$T_y^{norm} = 0,0515 \cdot 38 = 1,96 \text{ san.}$$

Thus, the normative values of the period in the direction of the X-axis of the building contain:

$$T_x^{norm} = 2,01 - 2,85 \text{ san.}$$

And in the direction of the Y axis

$$T_y^{norm} = 1,96 - 2,91 \text{ san.}$$

According to the results of the conducted test, the period (T) of the free oscillation of the building on the X, Y, Z axes is given in the table below.

Ground period: 0.22 - 0.24 sec.

According to the results of the test, the values of the amplitudes of oscillations on the floors in the direction of the X, Y, Z axes of the building are given below (Table 5).

The speed of seismic wave propagation on floors along the height of the building is given in the table below (Table 6).

Table 6

File	t_{1-4} , s	V_{1-4} m/s 1st - 4th floors	t_{4-8} , s	V_{4-8} m/s 4-8 floors	t_{8-11} s	V_{8-11} m/s 8-11 floor s	t_{11-19} s	V_{11-19} m/s 11-9 floor s	t_{19-25} s	V_{19-25} m/s 19-25 floors	t_{25-32} s	V_{25-32} m/s 25-32 floors	t_{25-36} s	V_{25-36} m/s 25-36 floor s
Test 1x1 (according to x)	9	1480	0,0081	1460	0,0112	1450	0,0244	1440	0,0185	1430	0,0218	1410	0,0128	1380
Test 1x1														
Test 1x2	0,0045	1460	0,0082	1440	0,0113	1440	0,0246	1430	0,0186	1320	0,0220	1400	0,0127	1390
Test 1y1														
Test 1y2	0,0045	1470	0,0082	1450	0,0113	1430	0,0248	1420	0,0187	1410	0,0223	1380	0,0129	1370
Test 1y3														

The comparison of the price of the period obtained as a result of tests of the building with the price of the normative period allows us to come to the conclusion that they differ from each other by an average of 8.7% on the X-axis and 7.1% on the Y-axis. Based on the comparison of the value of the period of actual free oscillations obtained as a result of the tests of buildings and facilities with the normative values, their damage rates are determined according to Table 7.

Table 7.

Degree of injury	Increase in the period of free oscillations, %
1-undamaged, light	0-10
2-medium	11-30
3-strong	31-60
4-heavy	61-90
5-catastrophic	91-100

From the table and comparison, it can be seen that the degree of damage to the building can be attributed to category 1, light, undamaged. The results of the seismic wave propagation velocity in the structures by floors suggest that the velocity variation is small. The strength of concrete varies less in the upper floors than in the lower floors. As a result of the inspection, it was found that the strength of concrete is B 30.

It is possible to determine the seismic coefficient A and the dynamics coefficient β by knowing the experimental dynamics parameters of the building's vibration movement:

$$A = \frac{Y''}{g}; \quad \beta = \frac{1}{1 - \frac{T_{qr}^2}{T_{bn}^2}};$$

Here: Y'' - ground vibration acceleration; g - acceleration of gravity;

T_{qr} - dominant period of the soil; T_{bn} - the period of free oscillation of the building .

The value of A will be lower for our case. This is due to the fact that it is impossible to create an effect corresponding to points 8 and 9 with the load on the ground. The value of β does not depend so much on the strength of the effect. Therefore, we determine the value of β according to the formula given above:

a) for transverse oscillations $\beta_{en} = 1,016$

b) for longitudinal oscillations $\beta_{uz} = 1,017$

Conclusion.

1. It was determined that the height of the residential building is 12.40 m above the ground. installed on the foundation layer at the level of the bottom of the pit to be dug in depth, the foundation poles of the buildings are 20-31m.
2. Taking into account the analysis and analysis of geological-geophysical, tectonic, seismological materials, the engineering-geological and hydro-geological conditions of the construction site, the change in the intensity of the earthquake impact, if the foundation is designed on clay soil through piles, the site is evaluated with 8.0 points.
3. As a result of the tests, the spectra of oscillations in the direction of the X, Y and Z axes of the building were obtained and analyzed. By impacting the soil of the area where the building is located with the help of a loading device and conducting tests under the influence of wind, the period of the building's oscillation movement is $T_y=1.83$ sec. in the width of the building, in the Y direction, $T_x=1.85$ sec. in the longitudinal X direction, and $T_z=1$ in the Z direction. ,81 sec. and the dominant period of the soil is 0.22-0.24 sec. received.
4. The comparison of the period of the experimental free oscillations obtained according to the analysis and analysis of the spectra of the building oscillation with the period of the normative oscillations calculated according to the given methodology showed that these periods differ from each other by an average of 8.7% on the X-axis and 7.1% on the Y-axis. Therefore, according to Table 7, the degree of damage to the building can be classified as undamaged, light, 1st category.
5. As a result of the conducted tests, there is little change in the speed of propagation of the seismic wave on the floors of the building from the bottom to the top. This suggests that the change in strength of concrete from the bottom to the top is negligible. In other words, the brand of concrete hardly changes along the height of the building.
6. According to the obtained experimental results, the coefficients used to calculate of seismic forces are $\beta = 1,016$ in the longitudinal direction of the building and in the transverse direction $\beta = 1,017$.

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