Influence of vibration impacts from vehicles on the state of the foundation structure of a residential building

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Abstract. In this work, experimental studies were conducted on the effect of vibrational influences from highways on the state of the foundation structures of a five-story residential building in Astrakhan. The studies were combined with an examination of the geo-base, foundations, and foundation of a multi-story brick residential building. Studies have shown that over four years, damaged building structures underwent significant changes due to increased vibration from the highway, and the rate of deformation in the supporting structures prove their emergency state. It is confirmed that the main factors affecting the magnitude of vibration acceleration of the building foundation structure are: structural type of the building; distance from the building to the source of seismic waves; longitudinal wave propagation velocity in the soil layer.

1 Introduction

Over the past 10 - 15 years, as a result of a multiple increase in the level of saturation of cities, the growth of all types of cargo flows, an increase in the speed and intensity of traffic make it necessary to obtain qualitative and quantitative estimates of the impact of transport vibration on the safety of building structures of buildings and structures.

In multi-story buildings, along with a decrease in vibration on high floors, its increase due to resonance phenomena is also observed. Both in domestic and in foreign literature, with frequent periodicity, there are reports of the negative effects of transport vibration [1-5], however, as a rule, it is not taken into account either during new construction, during operation, or during reconstruction of existing buildings and structures. In the direction of action, the vibration is divided into vertical and horizontal. Vibration transmitted through the ground and generated during the passage of the vehicle propagates in the form of seismic longitudinal and transverse waves.

Consideration of local engineering and geological conditions allows us to calculate more earthquake-resistant and safe structures. This fact is taken into account in many building codes and rules, which introduced amendments to seismic effects, taking into account the resonant amplification of vibrations of the upper soil layer. The effects of the geological structure of the site can be studied more thoroughly, taking into account the

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nature of the propagation of waves through a layered medium, which will increase the accuracy and reduce the variance of the parameters of possible estimated ground vibrations.

Longitudinal (see Fig. 1), or P-wave (primary) has a maximum speed. During its passage, each rock particle moves back and forth along the direction of wave motion, while the medium experiences a series of compressions and stretches. There is no particle rotation in these waves. With the passage of a transverse or S-wave, soil particles move perpendicular to the direction in which it propagates. Surface waves, which often leave the most intense part of a seismograph record, are L-waves or long waves since they have a longer oscillation period than P and S-waves. Surface waves are a mixture of two different types of waves - Love waves and Rayleigh waves [4-6]. P and S - waves propagate throughout the volume and therefore attenuate inversely with the cube of the distance, and L - waves propagate along the surface and attenuate inversely with the square of the distance. Therefore, starting from a certain distance, surface waves are the most dangerous for buildings and structures.

In this work, experimental studies were conducted on the effect of vibrational influences from highways on the state of the foundation structures of a 5-story residential building in Astrakhan. The studies were combined with an examination of the geo-base, foundations, and foundation of a multi-story brick residential building with longitudinal load-bearing walls built-in 1975. Project documentation for the construction of the facility in the archives of the city has not been preserved. The building underwent numerous deformations, expressed in through cracks in the foundation, walls and unacceptable sliding of floor slabs. The walls of the building with a thickness of 510 mm are made of white silicate brick, not plastered along the facade. Ceilings are made of reinforced concrete slabs with round voids. Loggias adjoin the ends of the building. The constructive solution of the loggias is made in such a way that two walls 410 mm thick abut perpendicular to the end wall. The height of the floor is 2.5 meters. Figure 1 shows a section of a building with dimensions and in Figure 2 - a general view of the building, the effect of seismic waves from transport on the building under examination and the nature of the growth of cracks in the concrete foundation, in the walls from vibration (with photo fixation).

2 Materials and methods

To determine the constructive type of foundation, pits were developed around the entire perimeter of the building. The PSG-MG4 static action penetrometer, designed for accelerated control of soil compaction quality, as well as the strength characteristics of subgrade soils - the angle of internal friction, specific adhesion, the elastic modulus was carried out in the soil measurement pits. According to the results, the soil lying under the basement to a depth of 2 meters is water-saturated loam with layers of fine sand.

Fig. 1. Effect of longitudinal-transverse seismic waves of vibration from the intensity of road transport near buildings and the propagation of vibration up the building.

According to the results of the development of 7 pits, it was revealed that the grillage under the bearing walls of the building is a concrete foundation of a strip type with a thickness of 500-550 mm and with a step from 2000 mm to 36000 mm the second step in the form of columns spaced from each other, which are made from a width of 400 mm to 600mm. Columns are located on both sides of the foundation tape. This can be clearly seen in Figure 3. As a result of pitting, it was precisely established that in the places of crack formation in the grillage in the aerial part, these columns in the underground part have cracks and “come off” from the main grillage and do not bear the load from the building, but only the load from own weight, passing it to the pile. The length of piles under the columns was determined using an instrument based on spectral-temporal analysis [4]. Established as a result of destructive testing - grillage not reinforced.

As a result of the inspection of the building, it was found that when on the roof, vibration is constantly felt from vehicles passing along the highway, especially trucks. According to the manual to MGSN 2.04-97 “Designing protection against traffic noise and vibrations of residential and public buildings”, vibrations caused by the movement of motor vehicles can be amplified when they propagate up the building structure.

Fig. 2. General view of the effect of seismic waves from transport on the building under study and the nature of the growth of cracks in the concrete foundation and walls from vibration (with photo fixation)

Fig. 3. Photofixing a concrete column with its own separate from the main foundation of the building.

Therefore, additional measurements were carried out for buildings above 12 meters on the upper floor of the building, using a vibrometer mounted vertically in a row every 12 m to allow observation of the nature of the vibration change. Vibration is measured on structural elements that determine the rigidity of a structure, usually near its corners.

The vibration transmitted to the human body should be measured in the accepted directions of the orthogonal coordinate system, which has the origin of the human heart:

- Z-axis - the vertical axis, from the legs to the head;
- X-axis – the horizontal axis, from back to chest;
- Y-axis – the horizontal axis, from right shoulder to left.

The determination of frequencies, vibration velocities and vibration accelerations on the building was carried out using a specialized device VIBROTEST-MG4.01 with which they were compared with standard values in accordance with clause 6.2. SanPiN 2.1.2.2645-10 "Sanitary and epidemiological requirements for living conditions in residential buildings and premises" with maximum permissible vibration levels in residential premises.

The roadway was located both along with the building and perpendicularly. However, from the side of the longitudinally located highway, which is only 5 meters away from the facade, the values of vibration velocities and vibration accelerations were recorded by 50-60% more than from the end facade located perpendicular to the roadway. The most critical is the frequency range within the octave bands from 16 to 63 Hz. The levels of vertical vibration velocity of the inter-floor overlap and coverage measured in the afternoon in octave frequency bands are shown in Table 1.

Table 1. The levels of vertical vibration velocity of the inter-floor overlap and coverage measured in the afternoon in octave frequency bands.

Geometrical average frequencies of octave bands, Hz	2	4	8	16	31,5	63
Measured vibration velocity levels, dB	75	78	79	88	90	94

The vibration of the horizontal direction (along the X and Y axis) did not exceed the background values (without source).

In accordance with Table 2 of the "Sanitary Norms for Acceptable Vibrations in Residential Buildings" No. 1304-75, the following amendments should be made to the standard values of vibration velocity:

- a) vibration pattern - intermittent - 10 dB
- b) the vibration occurs in the daytime + 5 dB
- c) total duration of vibration - 240 s or 13% + 10 dB
- Total: + 5 dB

Table 2. The standard levels of vibration velocity, permissible levels of vibration velocity, as amended, and their comparison with measurements.

Geometrical average frequencies of octave bands, Hz	2	4	8	16	31,5	63
Standard levels of vibration velocity, dB	79	73	67	67	67	67
Correction to standard levels of vibration velocity, dB	+5	+5	+5	+5	+5	+5
Allowable levels, (dB) from 7 to 23 hours	84	78	72	72	72	72
Measured levels, vibration speeds, dB	75	78	79	88	90	94
Exceeding acceptable levels, dB	-	-	7	16	18	22

Table 2 shows the standard levels of vibration velocity, permissible levels of vibration velocity, as amended, and their comparison with measurements.

From the data in the table, it follows that in the daytime in octave bands with geometric mean frequencies of 8, 16, 31.5 and 63 Hz there is an excess of permissible vibration values by 7, 16, 18 and 22 dB.

3 Conclusions

It is worth noting that vibration had a serious impact on the condition of the supporting and enclosing structures of a residential building, affected the wear resistance and reduced the service life of the building. Studies have shown that over four years, damaged building structures underwent significant changes. Crack opening kinematics shows the following crack opening rates for installed beacons: minimum value - 2.5 mm/year, maximum - 11.5 mm/year. Deformation development rates in supporting structures prove their emergency state.

When conducting full-scale studies, the research data of scientists [5-6] were confirmed that the main factors affecting the magnitude of vibration acceleration of the building foundation structure are: structural type of the building; distance from the building to the source of seismic waves; longitudinal wave propagation velocity in the soil layer.

It was confirmed, as in [5-6], that when the building is parallel to the transport highway, the magnitude of vibration accelerations and vibration velocities is greater than when the building is perpendicular to the highway.

Frequency-time analysis allowed with high accuracy and in the shortest possible time to determine the continuity of the material of the construction of foundation piles and analyze the state of the underground structure at a considerable depth without the need to drill near its special wells (pits) and carry out measures to hold its walls, which increases the complexity and cost of work, and also violates the continuity of the structure with the soil.

Application of modern methods of investigation of soil bases, use of effective devices of destructive and non-destructive control in complex researches of examination of a geological basis, bases and foundations will allow to carry out the most complete assessment of operating facility and to define economic efficiency of its reconstruction or liquidation.

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