ANALYSIS OF INFLUENCE OF SEISMIC OSCILLATIONS ON PRECISION LASER PLANTS’ WORK

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Abstract. The seismic situation in a number of rooms of the NRNU MEPhI, including the Laboratory Building, where the construction of the multifunctional laser complex ELF is planned, is studied. Estimations of seismic and vibrational noise at the main and isolated parts of the basement of the room that hosts the laser complex are obtained.

Introduction

In the modern world, which is saturated with technological equipment, we are constantly confronted with an increased level of vibration effects on the measuring systems. Examples of the spectral density of typical seismic noise in the territory of a large city (Warsaw) and in a deserted area (Hanover region) are shown in Figure 1. The black dotted lines in these graphs represent the averaged values of the minimum and maximum seismic noise typical for our planet [1, 2].

The integrated level of vibrational noise in a seismically and technologically quiet region of the Earth can be roughly estimated as 1 mkm/s. Moreover, because of the dependence of the spectral density of the background noise on the frequency, the integral estimation for displacement and
acceleration will also be 1 mkm and 1 mkm/c². Due to the high variability of seismic noise, specific measurements should be made exactly in the place where the multifunctional laser complex is planned to be located.

The study of the level of vibration interference

The research presented in this paper were carried out using a digital three-component seismic recorder ZET 048 with a working frequency band (0.3-400) Hz and a sensitivity of 0.5 V/(m/s²) [3]. Daily diurnal variations of the levels of vibrational acceleration in three buildings of the National Research Nuclear University MEPhI were measured. The main long-term measurements were taken in the Building “K” on the 10th floor in the K1010 audience. Short-term observations were carried out in the basements of the building K and the Main Building. In the Laboratory building, in addition to vibration control in the ELF placement hall, the mapping of the noise level over the working area was carried out and the degree of mutual isolation of the independent part of the foundation, intended for placement of the main ELF elements, and the rest of the working surface of the room was estimated.

The most complete picture of seismic noise was obtained for the 10th floor of the Building K. Measurements were carried out in different weather, day and night, during classes and on weekends. Examples of seismograms and spectra of the signals registered in the Building K are shown in Fig. 2. A characteristic feature of the recorded signals is the presence of low-frequency picks in the region of 1 Hz, related to the fact that high-rise buildings are swinging at their resonant frequencies under the influence of wind and seismic loads. The second feature of the noise spectrum is related to the operation of various types of electric motors, the rotational speed, which are subharmonics of the power frequency. The wide peak in the region (60-120) Hz is due to traffic on the Kashirskoye highway. The characteristic fractional frequency components caused by the movement of the railway transport and the subway were not found.

![Seismograms](image1)

**Figure 2.** Seismograms in windy weather (a), and variants of seismic noise spectra in three axes in windless weather in the K1010 case (b, c), blue denotes instantaneous noise spectrum, green averaged over the last 10 samples
The amplitude of low-frequency oscillations of the case K at frequencies of 0.98 Hz and 1.05 Hz with the force of the wind in gusts up to 20 m/s was (2-4) mm/s², which, in terms of the displacement, gives 0.1 mm. This value is three orders of magnitude higher than the typical value of the seismic noise in this frequency band on the ground in the MEPhI region. This circumstance in a compartment with a huge number of narrow-band vibrations caused by technological equipment (each with an individual level of ~ 1 mm /s²) excludes the possibility of placing large laser systems on the upper floors of multi-storey buildings. The root-mean-square level of the seismic noise in the frame K did not exceed 2 mm/s². In this case, the peak values of vibrations associated with the movement of people, the fall of chairs and the slamming of the door were 2 orders of magnitude higher than the average level and reached 0.5 m/s². Such a level of seismic noise is unacceptable for the normal functioning of precision laser installations.

Measurements of the background level of the seismic noise in the Laboratory building demonstrated the absence of low-frequency components in the noise spectrum, the weak effect of vehicles and (20-40) dB a lower level of noise power spectral density in Fig. 4a. An important feature of the noise spectrum was the absence of powerful discrete components in the spectrum. Such behavior for the background level of seismic activity in the absence of industrial interference [4, 5].

To study the degree of vibration isolation of the foundation ELF from the bearing structures of the building, a pulsed broadband source of seismic noise was used. It was a solid rubber ball weighing 0.5 kg. When it fell to the floor from a height of 2 m and a jump after an impact of 1 m into the energy of the vibrations of the building's structures, the kinetic energy of the rubber ball passed to 5J. This energy was sufficient to excite the oscillations of the concrete overlap in the housing K with a peak acceleration value of ~ 5m/s², while in the basement location of the Main Building the vibrational acceleration caused by the drop of the rubber ball was of the same order of ~ 5 m/s², which indicates the presence of free space under the slab forming the floor of the basement floor. In the Laboratory building, the impact acceleration dropped to 0.3 m/s², both on a general and isolated foundation, indicating a large floor thickness in the working room and the presence of a sand cushion beneath the entire floor surface.

To control the degree of seismic independence of individual areas of the floor of the working hall, the seismic receiver was installed on an isolated foundation, and the rubber balloon fell onto various parts of the floor - outside and inside the isolated part of the basement. As can be seen from the presented data in Fig.3 b, the impact levels of the impact outside and inside the isolated part differ by a factor of 10, that is, the seismic effect of the drop of the rubber ball on the floor in the working hall is a thousand times less than on the 10th floor of the K building and is only 5mm/s² while it is tenfold greater than the level of background noise in the Laboratory building. These data indicate the significant role of mass and rigidity of the foundation on which precision equipment is installed [6].

Figure 3. Spectrum of seismic noise in the Laboratory building (a) (blue color denotes instantaneous noise spectrum, green averaged over the last 10 counts) and seismograms of the impact of the rubber ball to different points of the floor outside and inside the isolated part of the basement (b)
Conclusion
The measured values of the seismic noise in the Laboratory building indicate the optimal choice of this particular location on the territory of the NNIU MEPhI for the construction of the multi-functional laser complex ELF. The conducted research shows that there is no significant influence of the subway and railway transport on the level of seismic noise and the dominant influence of seismic disturbances caused by vital activity inside the Laboratory Building. Based on the obtained spectral data and design documentation at the ELF, the vibration behavior of the laser complex will be simulated in the future and the question of the necessity and nature of the vibration isolation equipment included in ELF will be solved. We consider it advisable to introduce a seismic monitoring system into the ELF, excluding the carrying out of laser experiments during the increased seismic and vibrational activity on the territory of MEPhI and in the premises of the Laboratory building.

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