# 423. Excitation of Low-frequency Vibrations and their Propagation

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*(Received: 08 November; accepted: 02 December)*

**Abstract.** In putting into production various new technologies, often for the forced excitation of vibrations special vibration machines, which are used in the product formation technology, are applied.

The paper deals with the vibration excitation source, which is used in the production technology of construction blocks, their mass compaction. The measured parameters of vibrations show that local insulation of vibrations caused by the vibration machine is not sufficient. Theoretical and experimental investigations showed that despite of the application of standard methods, for reducing vibrations, propagated by them, the transversal and longitudinal waves, excited by vibrations are propagating through the constructions of the buildings and the ground with low extinction losses. Those harmful vibrations propagating into the environment reach the living zones and cause considerable problems for human work and recreation.

Having studied the ways of vibration propagation, some were proposed and some implemented in the specific object. The data of the works performed provided in the paper show that in order to protect objects and people from the harmful impact of vibrations, while designing such plants it is necessary to implement the new methods for vibration reduction.

**Keywords:** vibration sources, propagation of vibrations, damping of vibrations.

## Introduction

The work deals with vibrations, which propagate from the vibration machine, intended for the manufacture of keramzit blocks, to the place of observation (the residential zone). For manufacture of construction blocks, i.e. making their mass denser, a special vibromachine is used (see Fig. 1).

**Fig. 1.** Vibromachine

The parameters of vibrations, excited by the vibromachine, transferred through the ground to the residential premises, may affect parts of the human body or the whole organism. Research conducted showed that vibration disturbed the activity of some organs and systems (cardiac and vascular, nervous and motor apparatus) [1, 2, 3 ]. There were complaints about ailments (poor sleep, headaches and anxiety) from the residents of the dwelling house located some 300 metres from the place of action of the vibromachine, even though no sound was heard in the residential premises. During investigation of the propagation of vibration parameters through the ground to the constructions of the residential house (to the foundation, walls), it was established that parameters of low-frequency vibrations (vibration acceleration and speed) excite correspondingly low-frequency noise (infrasound).

The problem, studied in this work, is the reduction of the hazardous impact on the environment, inhabited by the people, of the vibromachine, vibration parameters, propagated through the ground. For performance of technological process, the forced vibration frequency of the operating part of the vibromachine (40-50 Hz) propagates at a big distance from the block manufacture equipment through the ground and reaches the zone of residential houses. The parameters of those vibrations in their turn cause an increase of ground deformation and the settlement of the foundations of buildings, reduce the cyclic strength of structures and constructions to the dangerous limit, interfere with the normal work and rest of the residents of the neighbouring residential houses, since the vibration parameters (speed) excite infrasound.

**The purpose of the work** is to research and evaluate our already previously proposed measures [4, 5], efficiency of reduction of the vibration parameters, propagated by the vibromachine, and to perform analysis.

To achieve that purpose in theory and practice, we shall determine the values of vibration parameters, their propagation principles and ways, by which they reach the foundation and walls of the residential house before and after the implementation of the measures proposed (Fig. 2, 3)

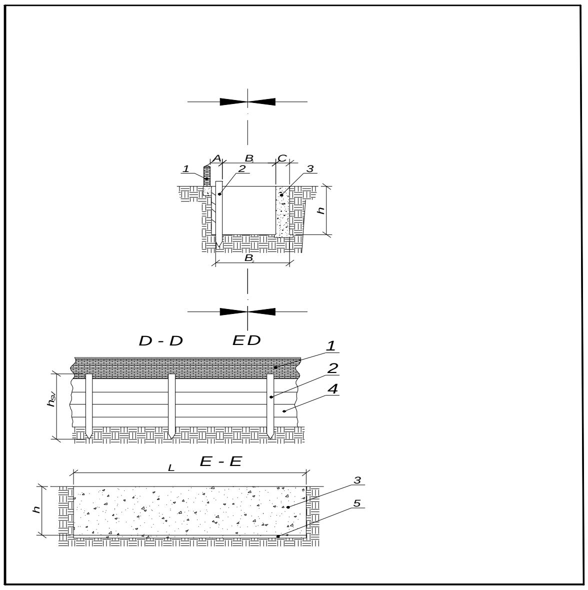



**Fig. 2.** Vibroacoustical seam diagram: 1. Brick wall near the street.2. Poles for supporting of partitions and the future screen support 3. Concrete–reinforced concrete fence 4. Polymer or other plate material for the ground support of corresponding resistance. 5. The bottom of the fence. A, B, C, h and t dimensions are given in calculations

**Fig. 3.** A general view of vibroacoustical seams after implementation

## Excitation of vibrations and their propagation in the ground

The vibrations under study are excited by a vibromachine, intended for concrete compaction and block production. The machine is mounted on the special foundation.

Vibrations of the foundations of a vibromachine excite the vibrations of the ground massive on which it is erected. Since the ground has the properties of the elastic medium, the vibrations in the form of waves propagate to all sides from the foundations to considerable distances, reaching 500–1000 m. Buildings and structures, located in the zone of propagation of those waves, are subject to vibrations. Vibrations may be dangerous, having an effect on the durability of buildings and structures, or harmfully affecting people and equipment. In these cases it is necessary to take special measures for prevention of impermissible vibrations and for elimination of vibrations of the already existing objects. For correct selection of such measures it is necessary to have an understanding about the character of impact of those waves on the objects, and the forms and parameters of vibrations of buildings and structures.

As a calculation model of the phenomenon of elastic waves in the ground, the elastic isotropic half-space, into which the vibrating mechanism with the flat foundation of rectangular form was impressed, was taken.

Two types of waves propagate from the vibrating mechanism independently of one another: waves, in the presence of which the ground experiences only a relative change in the volume, or waves of compression and extension, and waves, in the presence of which the ground particles just experience the relative displacement, or shear waves. The former are called longitudinal, since the ground particles during the propagation of such waves are displaced in parallel to the direction of wave propagation (along the radial straight line from the source). The latter are called transversal, since the displacement of the ground occurs perpendicularly to the propagation of a wave.

Relationship between velocities $c_1$ and $c_2$ of the propagation of the former and latter waves is determined by an expression:

$$\frac{c_1}{c_2} = \sqrt{\frac{2(1-\mu)}{1-2\mu}},$$

here $\mu$ – Poisson coefficient

In all cases the relation $c_1 / c_2 > 1$, consequently, the longitudinal waves are propagated with the higher velocity than the transversal waves. Numerical values of the velocities of longitudinal and transversal waves in different grounds [6] are given in the table 1.

**Table 1.**

| Ground | Wave propagation velocity, m/sec | |
|---|---|---|
| | $c_1$ | $c_2$ |
| Humid clay | 1500 | 150 |
| Loess of natural humidity | 800 | 260 |
| Solid gravel-sandy ground | 480 | 250 |
| Sand: | | |
| -Finely granulated | 300 | 110 |
| -Medium granulated | 550 | 160 |
| Medium-sized gravel | 760 | 180 |

In addition to longitudinal and transversal waves, one more type of waves appears on the surface of the ground – surface waves, penetrating the ground not deeply. The foundations of the vibrating mechanism under study are the sources of wave excitation in the ground, and the foundations of buildings and structures, the receivers of waves, are situated close to the surface of the ground. Therefore surface waves are of special interest for us. Longitudinal and transversal waves are propagating in three dimensions, whereas surface waves only in two dimensions, and already at a comparatively small distance from the source they prevail over longitudinal and transversal waves, since the relative energy of surface waves diminishes in proportion to the distance from the source, and that of longitudinal and transversal waves in proportion to the square of the distance.

Velocity $c_3$ of surface wave propagation is somewhat lower than the velocity of propagation of transversal waves $c_2$. Thus, at $\mu = 0.25 \div 0.5$; $c_3 = (0.92 \div 0.95)\ c_2$. The frequency of the vibrations of the ground, propagating from the foundations of the operating machine by surface waves is equal to the frequency of the vibrations of the foundations.

Length of the propagating wave $\lambda = c_3 / f$. Length of surface waves, propagating from the foundations, at the process of operation in the different media of the ground is within the range of 15 to 30 m.

Amplitudes of vertical and horizontal constituents of the ground vibrations decrease with the increase of the depth, but at small depths (within the limits 0.2–0.5 of the wave length) they change comparatively insignificantly. This circumstance is of practical importance. Since the amplitudes of the ground vibrations from the surface waves propagating from the foundations at a depth of 4–10 m do not change practically, there is no sense for the purpose of decreasing the amplitudes of vibrations to increase the depth of laying of the foundations of buildings and structures – receivers of waves. Nor there is necessity to lay the foundations at the depth lower than the foundations of the closest structures (walls, columns).

Amplitudes of the ground vibrations decrease depending on the distance of the source of vibrations. Vibrations are less intensive in the direct approximation to the source of attenuation of vibrations than at large distances from the source. Therefore in practical computations, the amplitudes of the ground vibrations close to the foundation in the circle of radius $r_o$, equalling the greatest value of the base of the foundation, are taken as constant and equal amplitudes of vibrations of the foundation, and at great distances are determined by a formula (1) :

$$A_r = A_0 \sqrt{\frac{r_0}{r}} \cdot e^{-\alpha(r - r_0)}, \qquad (1)$$

here $A_r$; $A_0$ are amplitudes of the ground vibrations at a distance from the source; $\alpha$ is the rate of attenuation, the value of which fluctuates for different grounds from 0.03 to 0.1 $m^{-1}$. [6 ]

Under other similar conditions the frozen grounds have lower values of the rate of attenuation $\alpha$. Consequently, the waves of the vibrating mechanism in the winter propagate at higher distances than in the summer.

## Amplitudes of excited vibrations and their dependence

Formula (1) gives an opportunity to identify quite precisely the amplitude of the vertical component of the ground vibrations in the cases when the foundations of a vibromachine exercise certain vibrations and when the foundation fluctuates in the horizontal plane. The horizontal component of the ground vibrations at vertical vibrations of the foundation and the vertical component of the ground vibrations at its horizontal vibrations change in dependence on the distance according to the rather complicated law, not corresponding to the expression (1).

Amplitudes of vibrations in the ground augment with an increase of the area of the base of the foundation – the source of vibrations – and become reduced with an increase of the depth of its laying. However, the dimensions of the base and the depth of laying of the foundation have a considerable impact on the amplitudes of surface waves only in the cases when those dimensions may be compared with the length of surface waves. For the foundations of the vibromachine, the depth of laying of which fluctuates from 1 to 3 m, the biggest dimension of the base may be from 3 to 8 m, and the length of the radiated waves 4 – 10 m, the dimensions of the foundation practically do not affect the amplitudes of the surface waves. The size of reduction of the amplitude of vibrations of the ground at the deepening of the foundation may be determined according to the empirical formula [4] :

$$A_n = A_{n0} e^{-\frac{2\pi H}{\lambda}}, \qquad (2)$$

where H - is the depth of the laid foundation;
$A_n$ ir $A_{n0}$ - are amplitudes of the vibrations of the ground at the depth of the foundation laying $H$ and $H_o$;
$\lambda$ - length of the wave.

Thus, at increasing the depth of laying of the foundation from 1 to 3 m at the length of wave of 20 m with other equal conditions, the amplitudes of vibrations of the ground decrease to the value $A_n = 0{,}6 A_0$.

Investigations of vibrations of the ground at different frequency of the exciting force of the machine show that the amplitude curve, except for a maximum, corresponding to the resonant vibrations of the foundation, may be of one more or several maximums. Some researchers explain the presence of additional maximums by the coincidence of the frequency of natural vibrations of the layer of the ground with the frequency of the propagating waves.

Two points of the ground, located one from each other at a distance $r$ along the radial straight line from the source of vibrations, fluctuate with the phase displacement, determined according to a formula:

$$\psi = 2\pi \frac{r}{\lambda}. \quad (3)$$

The surface waves, propagating to all sides from the vibrating foundations of the vibromachine, excite the vibrations of the foundations of the buildings and structures, located at a significant distance from the source of vibrations. Vibrations from the foundations are transmitted to the walls and through them to the floors and all the elements of the buildings. In the case under study those vibrations are transmitted to the foundations of the dwelling house.

A problem of the impact of the vibrations of the ground on vibrations of the foundations of buildings has not been studied sufficiently so far. It is possible to presume that the foundations of buildings, located below the earth level, travel together with the ground without significant natural vibrations. Investigations of the vibrations of buildings and the foundation of the dwelling house that are located within 300-500 metres from the source show that frequency of all vibrations is equal to the vibrations of the foundation of the vibromachine. Otherwise, the frequency of the vibrations of the foundations of buildings equals the frequency of the vibrations of the ground (see Diagrams in Fig. 5 a, b).

Amplitudes of the vibrations of the foundations of buildings differ significantly from the amplitudes of vibrations of the ground and depend in the first case from the ratio of the frequency of the vibrations of the ground and the frequency of the natural vibrations of the foundation. The form and amplitudes of the vibrations of buildings in total or their separate elements also depend considerably on the ratio of the frequency of the vibrations of the ground and the frequency of the natural vibrations of the buildings and structures or their elements.

**Research methods for vibration propagation from the source through the ground to the vibroacoustical seam and outside its limits**

A vibration measurement device is shown in Fig. 4a.

The values of vibration parameters are measured using the vibration measurement devices (Fig. 4b), which consists of a sensor, an amplifier, filters and indication device. The frequency range of the used device is not 1-100 Hz and higher. In measuring the vibration parameters in the territory of the enterprise, the sensor was fixed on the metal pivot, set deep for 1 m in the ground.

a)


b)

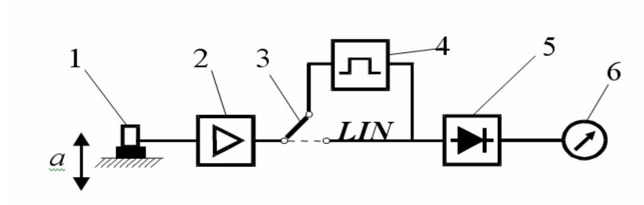
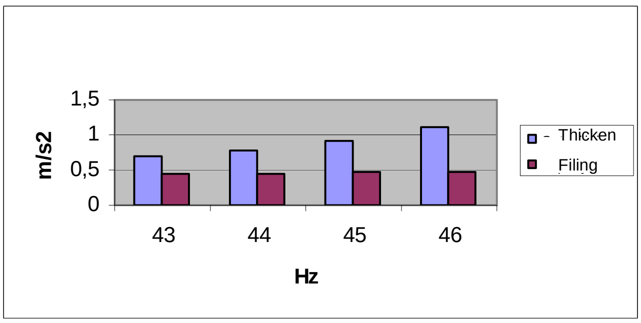



**Fig. 4.** The vibration measuring instrument and its connection diagram: 1) speed transformer; 2) amplifier; 3) set of filters for measurement frequency range; 4) signal rectifier of average square value; 5) indicator.

According to the described investigation methods, measurements of vibration parameters were carried out in front of the implemented vibroacoustical seam from the side of the territory of the plant and behind it, i.e. behind the seam, in the residential zone (see Fig. 3).

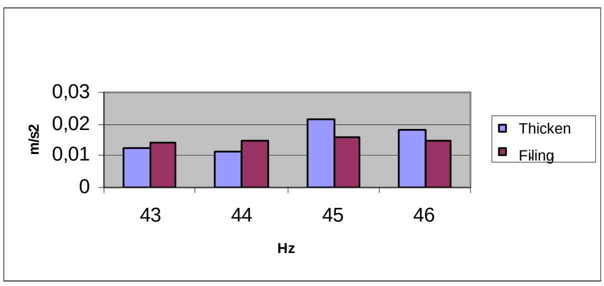
The results obtained are given in diagrams (see Fig. 5. a, b, c, d).

a)



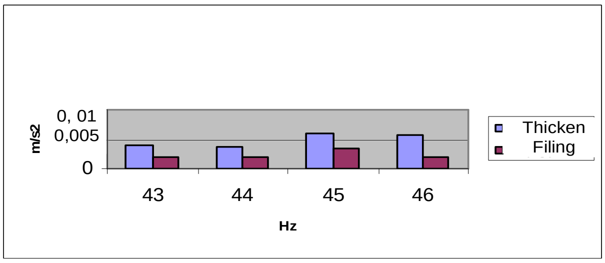

On the equipment foundation

b)



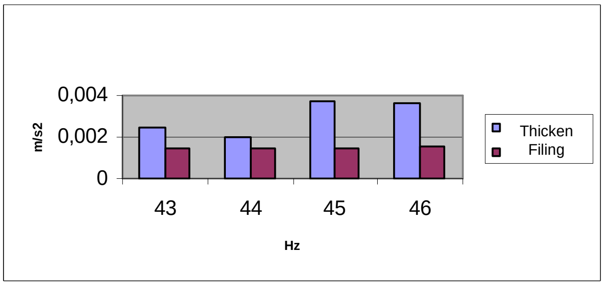

In the enterprice's territory

c)




Outside the limits of the territory near the residential house

d)




On the wall of the residential house

**Fig. 5.** Values of the measured vibration acceleration parameters at points a, b, c, and d

It is seen from the results obtained that after the implementation of the vibroacoustical seam the transmission of vibrations to the foundation of the residential house reduced by 10 and more times. The device during measuring did not show the values of the vibration parameters, and the residents did not complain of the impact of vibrations any more.

## Conclusions

1. The purpose of the work is to study the impact of vibrations propagated by the vibromachine on the environment.
2. During the examination, it was established that the vibromachine, in spite of the foreseen and existing measures for reduction of vibration propagation into the environment, propagates vibrations through the ground, reaches the residential houses and interferes with the rest and work of the people.
3. Theoretical and experimental investigations showed that vibrations from the vibromachine through the ground are transmitted by means of transversal, longitudinal and surface waves.
4. After study of the composition of the ground, a decision is adopted to install a vibroacoustical seam for insulation of vibration propagation.
5. After the implementation of the proposed measure, an impact of vibrations reduced and the residents did not feel their impact.

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