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The influence of the lever fixturing of the vibration exciter on the overall efficiency of concrete-mix vibration

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The article presents the design of the compaction table with the option of fixing the vibration exciter on the lever, providing that there is free space under it (when fixing the compaction table on the supporting structure above the floor line). The authors have conducted research on a specially created research model, aimed at determining the dependence of the amplitude of vibration on the lever length, on which the vibration exciter is fixed, and on the load on the moving member of the compaction table. A research model of the compaction table with lever fixturing of the vibration exciter was created in order to conduct research and obtain measurement results. The results of the conducted research have shown that with increasing the length of the lever, on which the vibration exciter is fixed, the values of the shock pulses acting on the vibratory plate increase accordingly, and the increase in the load leads to the decrease in the magnitude of the shock pulses. The obtained results provide an opportunity to reduce energy consumption in production and to continue further research in this study area.

Keywords: concrete mixture, resilient support, spatial vibrations, vibration exciter, vibration amplitude, vibration compaction, vibration platform

Вплив важільного закріплення вібробуджувача на загальну ефективність віброущільнення

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У статті розглянута конструкція вібростолу, у якого за наявності вільного простору під ним (при закріпленні вібростолу на каркасі вище площини підлоги) виникає можливість закріплення вібробуджувача на важелі. Важіль з вібробуджувачем закріплюється вертикально під віброплитою по центру знизу. Приводиться опис роботи вібростолу при дії на нього важільного закріплення вібробуджувача. Надані кінематична схема вібростолу з важільним закріпленням вібробуджувача та розрахункова схема визначення віброколивань на віброплиті. Дана конструкція вібростолу була створена у вигляді дослідної моделі. На ній за допомогою вимірювального обладнання проведені дослідження, метою яких було виявлення впливу важільного закріплення вібробуджувача на віброущільнення, а саме існування залежності амплітуди віброколивань від довжини важеля, на якому закріплений вібробуджувач, та від навантаження на рухому частину вібростолу Довжина важіля під час експерименту змінювалася поступово від 0 до 150 мм, а навантаження також збільшувалось поступово від 0 до 0,36 кг при постійній довжині важіля 150 мм. На базі результатів дослідів та отриманих показників побудовані графіки залежності величини ударних імпульсів від довжини важеля та від навантаження на вібростіл. Результати проведених досліджень показують, що при збільшенні довжини важіля, на якому закріплюється вібробуджувач, відповідно збільшуються значення ударних імпульсів, що діють на віброплиту, а збільшення навантаження на віброплиту приводить до зменшення величини ударних імпульсів. Отримані результати вказують на те, що за рахунок покращення віброущільнення від зміни амплітуди є можливість заощадити енерговитрати при виробництві. Дані результати також дають перспективу для проведення подальших досліджень у напрямку покращення енергоефективності та загальної ефективності віброущільнення.

Ключові слова: амплітуда віброколивань, бетонна суміш, вібробуджувач, вібростіл, віброущільнення, просторові коливання, пружня опора

Introduction

Concrete mix compaction is one of the most responsible operations in the manufacture of concrete and reinforced concrete products. As far as concrete-mix vibration is widely used in the construction industry, the process of its application has been considered by a number of authors [1-5]. In other words, it can be said that the manufacture of construction products without vibration compaction is not carried out at all [6,7]. Therefore, the manufacturing application of the design of the vibratory compactor, which, at limited metal intensity has the appropriate characteristics of vibration compaction, is an urgent challenge [8]. The ability of the vibratory compactor to transmit the appropriate level of vibration compaction to the concrete product without significantly complicating its design is closely related to the reduction in the time of vibration compaction. With the increase in electricity prices, reducing the operating time of the electrical part of the device leads to electricity savings. Therefore, the creation of an energy-saving vibratory compactor is the task that must be solved, first of all in order to reduce the cost of concrete products.

Review of the research sources and publications

The manufacture of concrete and concrete products is regulated by standard specifications and engineering standards [9-13]. Compaction tables for paving flags are widely used in the production of small-scale concrete products [14]. The structure consists of movable and immovable frames. The immovable frame serves as the basis of the vibration exciter. The movable frame is installed on an immovable frame through vibration-damping springs. A mechanical vibration exciter, the axis of rotation of which is located parallel to the plane surface of the frame, is rigidly mounted directly to the lower plane of the movable frame. Plastic molds, preliminarily filled with concrete, are installed on the upper plane of the movable frame. Plastic molds are made with a profile, which is provided to future products. When the vibration exciter is brought into action, the vibrational oscillations from it are transmitted directly to the plastic molds, in which concrete-mix vibration takes place. The movable frame is held due to vibration-damping springs, which transmit gravitational forces to the immovable frame.

There is also a vibration machine for the formation of small-scale concrete and reinforced concrete products [15]. In design, it coincides with the previous model [14], but the axis of rotation of the vibration exciter is located at an angle of 30 degrees to the plane of the movable frame. Such location of the axis of the vibration exciter allows changing the direction vector of vibration oscillations pertaining to the plane of reinforced concrete products, which improves the conditions of their vibration compaction. However, direction change of vibration does not allow to reduce the energy consumption of the vibration compaction process.

Definition of unsolved aspects of the problem

One of the main problems in mechanical engineering, which constantly needs to be solved or improved, is the problem of energy conservation [16].

Vibration-damping springs reduce the amplitude of vibration oscillations, especially in the area of their location. This requires increasing the power of the vibration exciter to achieve the required values of vibration oscillations [17].

Problem statement

The main task is to create conditions for increasing the amplitude of vibration vibrations without significantly complicating the design of the compaction table in order to improve the compaction of construction mixes and reduce energy consumption.

For this purpose, the authors offer the effective model of a compaction table with lever fixturing of the vibrating exciter in free space under a vibrating plate. It is necessary to conduct research on a specially created bench tester and then to estimate the efficiency of the offered installation (model) based on the obtained research results.

The purpose of this study is to identify the dependence of the amplitude of vibration on the length of the lever, on which the vibration exciter is installed.

It is assumed that with increasing the lever length, the amplitude of vibration will increase.

It is also necessary to confirm the effectiveness of the proposed design of the compaction table depending on the load level. It is planned to conduct the study of the load capacity of the structure, which would determine the dependence of the amplitude of vibration oscillations on the load on the moving part of the compaction table.

Basic material and results

The formulated problem is solved due to the lever fixturing of the vibration exciter 3 relative to the vibroplate 1 (see Fig. 1).

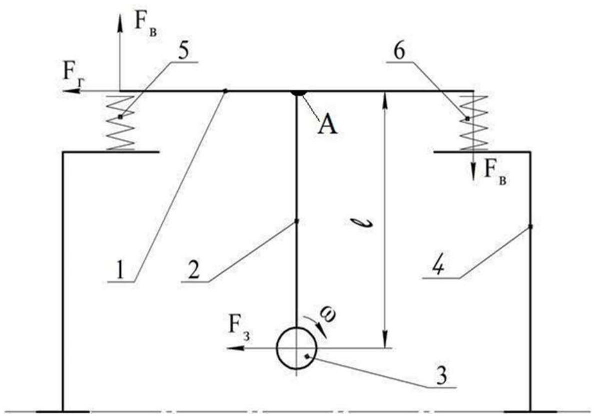

Figure 1 – Kinematic scheme of the compaction table with lever fixturing of the vibration exciter

Vibroplate 1 is fixed on the elastic supports 5 and 6. Under the bottom of the compaction table, in its middle (point A), lever 2 is rigidly fixed at the angle of 90 degrees. The lever length ℓ is determined by the height of frame 4 of the compaction table, and the increase in its length ℓ may affect the change of the amplitude of vibration. The operation of the compaction table with the lever fixturing of the vibration exciter is as follows. The vibration exciter is an electric motor with an eccentrically fixed load. When the electric motor shaft of the vibration exciter rotates, the vibrating exciting force is directed in the radial direction and changes it circlewise within 360 degrees. For example, let us consider the instantaneous horizontal direction which is shown in Fig.1. We present the compaction table with the lever as a braced structure. The vibration direction on the vibroplate 1 at the anchorage point of the fixturing of the elastic support 5 is as follows. The horizontal component $F_{г}$ is transmitted from the horizontal force of the vibration exciter F3. But, in addition to the horizontal component $F_{г}$, there is a vertical component $F_{в}$, whose operation is conditioned by the lever fixturing of the vibration exciter. When considering the rotation of the vibroplatform with the lever with respect to the point "A", the horizontal force of the vibration exciter $F_{з}$ tries to rotate the vibroplate with respect to the point "A" and causes the occurrence of the specified vertical force component $F_{в}$, the value of which increases with increasing the length ℓ of the lever 2. The joint action of forces $F_{в}$ and $F_{г}$ in general, through the single-sided support of the vibration exciter, significantly increases the value of vibration not only for the horizontal direction of the $F_{з}$ force but also for all 360 degrees of direction.

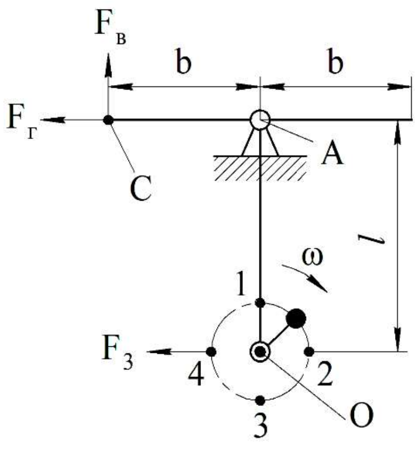

Figure 2 – Calculation scheme for determining vibration oscillations on the vibroplate

The compaction table with the lever fixturing of the vibration exciter, which contains the vibroplate (1), elastic supports (5,6), the frame of the compaction table (4), the vibration exciter (3), is characterized by the availability of the lever (2), which is rigidly fixed to the vibroplate (1). The vibration exciter (3) is fixed on the lever (2), the lever fixturing of the vibration exciter (3) causes an increase in the component values of vibration oscillations on the entire plane of the vibroplate (1).

Let us consider the relationship between the exciting force of the vibration exciter $F_{з}$ (see Fig. 2) and the values of vibrations on the vibratory plate in the place of fixing the spring-controlled vibration-damping spring – the point "C".

Let's say that the vibroplate with a lever is a braced structure. The vibroplate on the perimeter is in resting contact upon flexible supports and has the possibility of free motion in any direction. Put the case that the specified braced structure conditionally rotates with respect to the point of attachment of the lever to the vibroplate (point "A"). Therefore, we have indicated the point "A" as an instantaneous fulcrum point (Fig. 2). The axis of the vibration exciter is located parallel to the plane of the vibroplate and is defined by the point "O". When it rotates with an angular velocity ω, the centrifugal exciting force $F_{з}$ arises. In Figure 2, some points of the gravitational center of the unbalanced load of the vibration exciter are marked as 1-4. The instantaneous exciting force $F_{з}$ is applied at these points. For example, let us consider the instantaneous position of the gravitational center of the vibration exciter at point "4". In this position, the action of the exciting force $F_{з}$ causes a burst of the vertical component of the force $F_{в}$ over the flexible support at the point "C". Its value can be determined by the formula through the ratio of the length of the fastening levers:

$$F_{в} = F_{z} \cdot l/b \;; \tag{1}$$

From the analysis of formula (1) it is apparent that with increasing lever l length, the vertical component of the force $F_{в}$ increases in direct proportion. Assuming the actual size of the experimental vibration exciter, namely: l = 0; 0.025; 0.05; 0.075; 0.1; 0.125; 0.15 m (seven variable sizes); b = 0.2 m; F_z = 0.64 H, we have constructed a theoretical graph of the change in the values of shock pulses depending on the lever length of the vibration exciter (see Figure 6). In this graph, we have presented not the values of the vertical component of $F_в$ force, but the values of shock pulses in the dimension of decibels (dB) caused by the $F_{в}$ force. The change of the values of the dimension of the force "H" into the dimension of the shock pulses "dB" was carried out based on table 6 [18]. We need a dependency graph in the specified dimension to further compare the theoretical values of vibration pulses with their practical measurements.

An experimental model of a compaction table with a lever fixturing of a vibration exciter was created in order to conduct research and obtain measurement results (see Fig. 3, 4).

The experimental model is a compaction table with a reduced scale of 1:10. The vibroplate is placed on the metal frame with four frame legs by means of elastic supports. Below it, in the center, we have rigidly fixed the vertical lever, to which we have connected a vibration exciter, which is an electric motor with an eccentrically fixed load. The lever length can vary within 0; 50; 100; 150mm. The vibration exciter is actuated by an electric power supply.

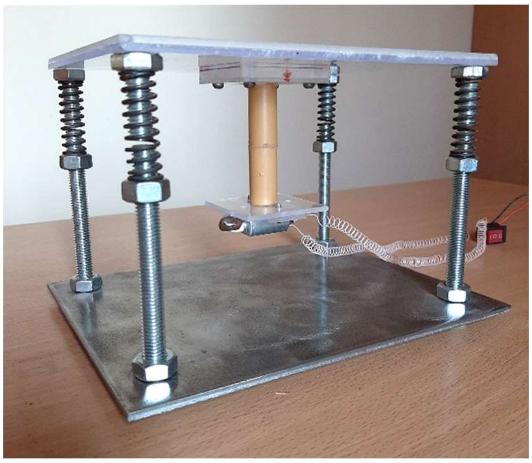

Figure 3 – An experimental model of a compaction table with a lever fixturing of a vibration exciter

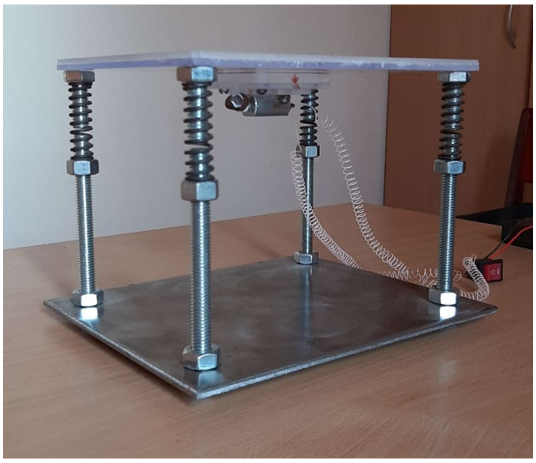

Figure 4 – An experimental model of a compaction table with leverless fixturing of the vibration exciter

The ISP-1 vibrometer (see Fig. 5) was used for measurements, with the help of which we obtained the values of shock pulses (dB) at the test points of the experimental model of the compaction table.

Figure 5 – The ISP-1 vibrometer for measuring the values of shock pulses (dB) at the test points of the experimental model of the compaction table

In the first study, the measurements were performed as follows.

The place for measurements was chosen on the upper plane of the compaction table, at the point above the vibration-damping spring. At the beginning of the study, the vibration exciter was fixed leverless ($l = 0$), it was actuated and the obtained indicators of shock pulses in dB were taken. Then the lever length varied in the above-mentioned ranges from 0 to 150 mm and the appropriate experimental parameters were received as well.

Based on the results of the carried experiment and the obtained indicators, we constructed a graph of the dependence of the magnitude of shock pulses on the length of the lever, on which the vibration exciter is fixed (Fig. 6).

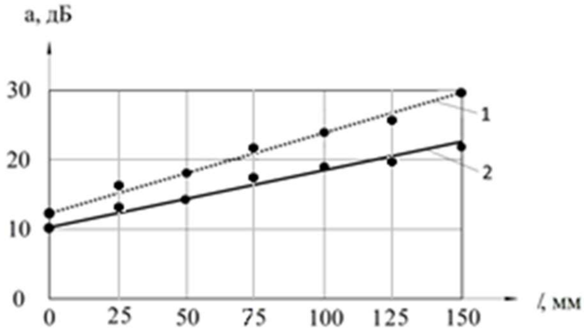

Figure 6 – Value change graph of shock pulses *a* (dB) depending on the lever length, fixturing the vibration exciter l (mm), relationships ratio:
1 - theoretical, 2 - experimental

From the analysis of the ratio, presented in Figure 6, the following conclusions can be drawn. The lever location of the vibration exciter confidently increases pulse amplitude, which is confirmed both theoretically and practically. The discrepancy between theoretical and practical results, in our opinion, is due to the fact that the theoretical curve has been obtained without reference to the weight of the vibroplate and has higher values than the experimental one. This encourages us to develop a theoretical model that would take into account the weight of the vibroplate.

In the second study, we considered the dependence of the vibration oscillations amplitude on the load on the moving part of the compaction table at the optimal lever length $l = 150$ mm. The load was gradually increased, changing the weight of the moving part of the compaction table. The weight of the moving part of the compaction table was increased by placing additional loading weighing 0.12; 0.24 and 0.36 kg. Values indicators of shock pulses were measured, as in the first study, on the upper plane of the compaction table at the point above the vibration-damping spring (Fig. 7).

Based on the obtained results, we constructed the graph of values' variance of shock pulses depending on the load on the moving part of the compaction table (Fig. 8).

Figure 7 – Experimental model of a compaction table with lever fixturing of the vibration exciter under load

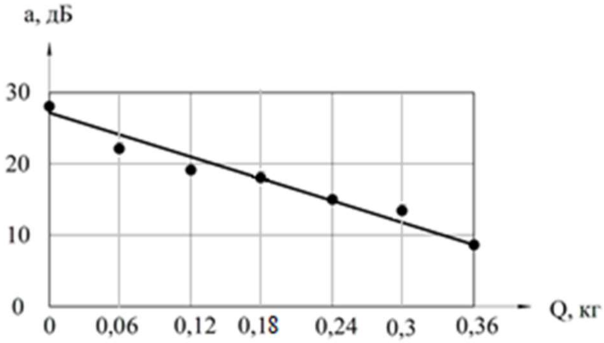

Figure 8 – Value change graph of shock pulses *a* (dB) depending on the load on the compaction table weighing Q (kg)

Conclusions

The results of the research show that with increasing the length of the lever on which the vibration exciter is attached, the values of the shock pulses acting on the vibro plate increase accordingly. That is, without changing the electric driving power, it is possible to increase the amplitude of vibration with the length of the lever for fixturing the vibration exciter.

It has been confirmed that increasing the load on the moving part of the compaction table leads to a decrease in the current amplitude of vibration oscillations. This factor must be taken into account in the production of concrete products, assigning operational and technological parameters of the proposed design of the compaction table.

Having considered the advantages of the proposed compaction table design, we found out the vibration exciter can be fixed on the lever when there is free space under it (when fixing the compaction table on the frame above the floor plane). The lever fixturing of the vibration exciter allows increasing the amplitude of vibration oscillations on the compaction table with a slight increase in steel intensity. This has got a positive effect on improving the quality of vibration compaction of concrete products with an overall reduction in energy consumption.

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