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To cite this article: A Muratov and S Melikuziev 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **883** 012060

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240th ECS Meeting ORLANDO, FL

Orange County Convention Center **Oct 10-14, 2021**

Abstract submission deadline extended: April 23rd

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Technology of formation of combined products of meliorative purpose

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Abstract. In this article new approaches of determining vibration intensity of vibration compactors and molding machines by two examples: for the simplest type of vibros and for vibrating areas with modulated multipara meter vibrations with the purpose assessing the technical and economic efficiency of parameters of new technologies regimes, as well as assessing practical feasibility of optimal values of constructive and technological parameters of proposed technologies in the production of combined constructions of ameliorative objects are described. In the same concrete mix, high-frequency oscillations damp more strongly than low-frequency oscillations. With increasing mobility and the degree of compaction of the mixture, the attenuation becomes lower, and the propagation velocity of the oscillations to the limit corresponding to the maximum for these conditions of compaction. By stabilizing the amplitude, intensity of the oscillations, the speed of their propagation, and the wavelength, one can judge the end of compaction of the mixture.

1. Introduction Nowadays, combined products reinforced concrete structures are the main building material, without which it is almost impossible to build a single structure. The main thing that attention and efforts are directed to for ensuring the high quality of manufactured structures at the lowest energy costs. Saving resources should in no case be detrimental to the quality and durability of structures [1, 2, 3, 4]. Based on these requirements, technological solutions are developed for optimizing the molding processes of concrete mixtures.

2. Methods

The object of research is the process of vibroforming products for hydro ameliorative construction. Based on the results of the analysis of laboratory studies, the boundaries of the region of stable periodic vibrations are established, mathematical models of the process are compiled for determining their intensity and the ratio of system parameters is determined at which these desired characteristics reaches its maximum, i.e., the conditions for optimizing the technological mode of forming combined parts for reclamation construction.

In further description as applied to the features of the device of various machines, ready-made solutions will be given for the determination the optimal ratio of their parameters and, in particular, containing a formula for determining the intensity of vibrations during the molding of a wide range of precast reinforced concrete reclamation structures.



3. Results and discussion

Currently, the types of mechanical effects on the mixture during compaction are quite numerous. Conventionally, they can be classified according to two main parameters: by the form of movement and by the type of movement displayed by the oscillograms.

The quality of compaction depends, on one hand, on the configuration, reinforcement, parametric dimensions of combined parts of land reclamation facilities, and, on the other hand, on the workability of the mixture, method and molding mode. Usually, the parameters of the product are determined by the method of its molding, and the mixture determines the vibration mode [2, 3, 4]. The latter depends on the intensity and duration of the oscillations, the time of their application, as well as the form of motion and oscillograms. When the method, equipment, and composition of the mixture are determined, the efficiency and quality of vibro forming depend on the intensity (U) and duration (t) of the impact of the working body on the mixture being compacted (Fig. 1) [5, 6, 7].

The intensity of vibration exposure is usually estimated by the value of proportional power of vibrations of the working body of molding machine and in the case of non-sinusoidal vibrations is calculated as a function of main parameters of vibration, according to the formula:

$$U = f \cdot (A^2 \cdot \omega^2) \tag{1}$$

Where: A is the amplitude (range) of movements, cm; – angular frequency;

Often, other characteristics of efficiency of vibroforming are used (maximum acceleration of vibrations, relative deformation or its speed, dynamic pressure gradient, stress), but each of them is somehow connected in its most general form with the period of vibrations and the magnitude of the maximum displacement.

In the most general case, for any type of vibration exposure and the selected performance characteristic, with the increase in its value, the viscosity (η) of the concrete mix and density (ρ_{av}) change quite naturally (figure 1). With the increase in the intensity of onset, a sharp dilution of the mixture is observed, and then it practically stops (plot GH, on curve 1). The density (ρ) firstly increases noticeably, and then remains almost unchanged (plot AF, curve 1). The intensity (U_0) at which these characteristics stabilize is optimal

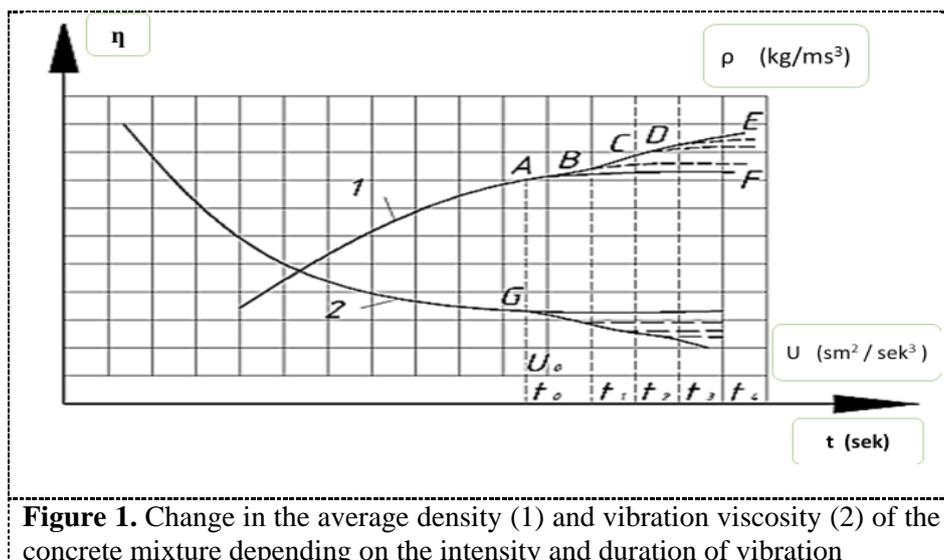


Figure 1. Change in the average density (1) and vibration viscosity (2) of the concrete mixture depending on the intensity and duration of vibration

At its lower values, the density decreases, and thus, due to under compression of the mixture, the strength capabilities that materials constituting its possess are not used to the maximum extent. Intensity exceeding optimal is useless and even harmful, as it can cause the mixture to stratify. At the same time, the power consumed by the vibration exciters increases with increasing intensity, the

working conditions of mechanisms, and maintenance personnel deteriorate. The time (t) after which the density practically does not increase corresponds to the optimal compaction time at the selected intensity and molding method. A longer duration has the same negative effects as an exceeded optimum intensity.

The density level in AF area is not guaranteed to be maximum but is the maximum possible with this method of vibration.

It was noted that if at time t , at a constant intensity of vibration, the vertically directed vibration is replaced by horizontal vibration, then there will be a certain increase in density, therefore, in the material strength, in the aircraft section (figure 1). When, at the same intensity, at the time of t_2 , for example, circular or torsional vibration is carried out, further compaction along the CD curve is observed. The increase in the density of concrete mixture depending on change in the method of vibration (when $U = const$) can be explained by the ability of the concrete mixture to compact to the maximum possible density, only with a combination of different directions and frequencies, sequentially or simultaneously applied vibrations. That even if the molding method and its intensity remain unchanged when t_3 is subjected to a different frequency (at the corresponding amplitude, realizing $U = const$), one can also observe a density increase (section DI), if the density maximum has not been reached yet. This phenomenon was verified by numerous experiments on a specially designed experimental multi-frequency vibration platform [9, 10]. It ensured a continuous cyclic change in the period of oscillations ($T = 1/h$) from 1/75 to 1/25 s with an amplitude of $2.5 \cdot 10^{-4} \dots 13 \cdot 10^{-4}$ m, respectively, and maintaining a constant intensity of vibration at any frequency ($U = 300 \text{ cm}^2/\text{s}^3$). The cycle of frequency change was about 70 seconds.

Comparative experiments with a 435A laboratory vibratory platform tuned to the same intensity showed a significant advantage of different-frequency vibrations, especially for high (over 30 cm) and massive products molded with mixtures of reduced workability. The increase in the efficiency of different-frequency vibrations (at $U = const$) occurs due to a change in the structure, which helps to improve the transmission of vibration from the source to the mixture (coefficient K_1 , with vertical vibration $K = 1.0$) and the transmission of vibration in the mixture (coefficient K_2) and, as a result, creating a cumulative effect – several separately applied vibrations, which we call modulated multi-parameter exposure. A sequential transition from vertically directed vibration to horizontal, circular, torsional, or multicomponent creates additional excitations of the side walls, the bottom of the form, and complex wave processes in the concrete mixture, which in terms of total intensity efficiency are close to the effectiveness of modulated multi-parameter vibration (Table 1.).

In addition to the intensity of vibrational influences, the process of compaction of a mixture is largely determined by the form of vibration, and the degree of its influence largely depends on the composition of the mixture. The shape of the oscillations also determines the development of the processes of the delamination of the mixture. The question of the rational form of vibrations was usually resolved from the standpoint of maximum energy absorption by the concrete mixture during compaction. Attempts have been made to relate the wavelength formed in the mixture to the size of the product in the direction of wave distribution. However, the analysis of the influence of vibration form on compaction mode has shown that technically and economically (taking into account all indicators, including labor protection), the creation of a mixture of vertical or horizontal vibrations in the mixture is most effective [11, 12]. It is rather difficult to justify the advantage of one or another form of oscillation since a large number of different indicators have to be taken into account. The movement of fine aggregate particles (sand), as well as coarse aggregate particles in mixtures with the "floating" position of the coarse aggregate occurs mainly along sliding planes that coincide in direction with horizontally directed vibrations. At the same time, the effect on coarse aggregate particles in contact with each other in the direction of oscillation should be vertical, i.e. coincide with the direction of gravity.

Table 1.

Type of vibration	Total efficiency	Effective Values Intensities
Vertical	$U = \sum U_z$	$U = A_z^2 \cdot \omega^3 \cdot K_1 \cdot K_2$
Horizontally longitudinal	$U = \sum U_y$	$U = A_y^2 \cdot \omega^3 \cdot K_1 \cdot K_2$
Horizontally transverse	$U = \sum U_x$	$U = A_x^2 \cdot \omega^3 \cdot K_1 \cdot K_2$
Horizontally Torsional	$U = \sum U_y + \sum U_x$	$U = (A_y^2 \cdot \omega^3 + A_x^2 \cdot \omega^3) K_1 \cdot K_2$
Circular	$U = \sum U_x + \sum U_z$	$U = (A_x^2 \cdot \omega^3 + A_z^2 \cdot \omega^3) K_1 \cdot K_2$

The values of K_1 and K_2 for each type and component of the oscillations are determined separately. At the interface between two media with different densities, especially the concrete mixture - air, reflection, and, accordingly, distortion of the direct wave occur and, depending on the boundary conditions, the wave field can be significantly distorted. The reflected and incident waves along the height of the mixture column have a certain phase difference and overlapping each other, are amplified in some places, and are suppressed in others, which leads to uneven compaction in the size of the product, which coincides with the direction of the wave. In this regard, it can be divided the process of propagation of oscillations into 2 stages. The first stage is the transfer of vibrations from the vibrating organ to the medium, the second is the transfer of vibrations through the medium. At the first stage, it is advisable to determine the efficiency of forming installation by the coefficient of transmission of vibrations to the mixture [13, 14]. It is the ratio of the intensity of oscillations of the mixture near the working body (U_c) to the intensity of vibrations of the organ itself:

$$K = \frac{U_c}{U_b} \quad (2)$$

With the increase in K_1 , the efficiency of the installation increases. From the point of view of the balance of energy supplied to the site, energy is spent on the resistance inside the system and transferred to the concrete mix.

$$E_p = E_B + E_c \quad (3)$$

where: E_p is the supplied energy;

E_B is the dissipation energy due to the internal resistance of the system; E_c is the energy is transferred to the mixture. Taking into account losses in the transition zone, this value is determined as $K_1 \cdot E_c$.

The flow of energy entering the mixture is estimated by the instantaneous power N_v determined by the dependence:

$$N_v = \sum_{i=1}^n P_i(t) \cdot v_i(t) \quad (4)$$

Where: $P_i(t)$ is the disturbing force;

$v_i(t)$ is the speed of the point of application of the motion, the energy going to the vibration itself will be characterized by the average power N_{vc} for the period, determined by the dependence (5):

$$N_{vc} = \frac{1}{T} \int_c^t \sum_{i=1}^n P_i(t) \cdot v_i(t) dt \quad (5)$$

Where: T is the period of oscillation. It can be assumed that the disturbing force:

$$P_1(t) = P_2(t) = \dots = P_n(t) = P_{\sin \alpha} \omega \cdot t \quad (6)$$

where: ω is the angular frequency of oscillations.

Thus, to estimate the energy of concrete mixture going to compaction, it is necessary to know the law of motion of points of application of disturbing forces. In the operating mode, the oscillations of points of application of disturbing force can be considered as the sum of two oscillations - the oscillations of the point of the exciting force as an absolutely rigid body and the fluctuations of the points of application of force due to deformations of the site and shape. The theoretical determination of displacements of site and form points, which are rather complicated systems from the point of view of structural mechanics, it is difficult; it is more convenient to use experimental methods for determining displacements in studies in the calculation of vibration devices [15].

4. Conclusions

Analyzing the results of studies on the vibro forming of products for hydro ameliorative construction, the following conclusions are made:

1. At the vibration frequencies currently used in the practice of vibro forming, a concrete mixture can be considered as a medium in which energy propagation is a wave process.

2. When molding concrete mixtures in products with a height of more than 30 cm on vibratory platforms, the intensity of vertically directed vibrations is variable in height, the regularity is determined by the frequency of vibration, the layer height, its composition and the distribution of the mixture density over the height of the product.

3. The period of oscillation during their distribution in the concrete mixture remains constant. The amplitudes in all areas of molded product increase and stabilize over time by the time the compaction ends.

4. Oscillations in the concrete mixture at various distances from the source have a phase displacement, the magnitude of which for a given mixture, and vibration frequency is determined by the distance between the measurement points.

5. During easel vibration of concrete mixtures of prefabricated structures of land reclamation facilities as a result of interference phenomena inside the mixture, amplitudes exceeding vibrations of the vibrating table can be observed, which leads to uneven compaction in the volume of the product, i.e., product quality non-uniformity.

6. Any change in the frequency of vibration without reducing the intensity contributes to further compaction of the mixture. In this regard, we can assume that the best mode for molding reclamation products is obtained with modulated multi-parameter oscillations, with a variable frequency (at least two, see table 1), when the amplitude and frequency change so that the total vibration intensity is optimal for compaction of the product from a mixture of selected consistency and composition. Therefore, they are most effective in forming prefabricated parts for land reclamation construction of a vibratory site with a variable frequency and with the possibility of oscillations in the (6DoF) directions of six degrees of freedom.

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