Selection of optimal vibration parameters molding reinforced concrete products

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Abstract. The efficiency of reinforced concrete products vibration molding depends largely on the rational modes of vibration on the compacted concrete mix and the selected parameters of the equipment used. The article summarizes the results of experimental studies on the compaction of concrete mixes in molds that are freely installed on the vibration platform through elastic pads. It is shown that the forming concrete products in non-fixed molds provide for effective compaction by selecting the parameters of the oscillating system “vibrating table - elastic element - a mold with concrete mix”. The obtained results open a new prospect in the development and improvement of vibration molding machines with free set molds.

1. Introduction

It is impossible to improve the efficiency of vibration molding of reinforced concrete products, especially of dry mixes, without choosing effective vibration modes and rational parameters of vibrating platforms providing high density and homogeneity of compacted concrete mixes [1-6]. When molding reinforced concrete products on vibration platforms under the production conditions, the mold may collide with the surface of the vibrating table due to it being unreliably attached to the vibrating table, the inconsistency of the static moments of the unbalances and other factors.

It is possible to improve the efficiency of vibration molding significantly when forming reinforced concrete products in molds freely installed (without fastening) on vibration platforms via elastic elements (pads), with an appropriate choice of parameters of the system “vibrating table - elastic element - mold with concrete mix”, as shown in [7-11]. The theoretical prerequisites for taking into account the interaction of the elements of the oscillating system when compacting concrete mixes on vibrating plates are considered in [10–13].

The article summarizes the results of experimental studies on the vibration compaction of concrete mixtures in molds freely installed on the vibrating platforms through elastic pads, while varying the parameters of the system “vibrating table - elastic element - mold with a mixture”.

2. Research methods

Vibration platforms with harmonic oscillations were used in the studies. The selection of the mass ratio of the platform vibrating parts and the shape, elastic parameters and dimensions of the pads [3, 8, 11, 12] plays an important role in implementing the oncoming movement of the vibrating platform surface.
and the shape defining the impact mode. Under certain parameters of the system, a mold with concrete mixture may come off the surface of the vibrating table and collide with it. When forming large-sized products, it is also necessary to take into account the peculiarities of the wave front propagation through the product thickness [14, 15, 16].

The most important parameter of the system “vibrating table - elastic element - a mold with concrete mix” is the coefficient of elasticity (rigidity) of the pad [10, 12, 17]. This coefficient \( C \) is determined by the shape, size and dynamic modulus of elasticity of the pad material. The manufacturers are recommended to use sheets of rubber or plastic as pads [6, 8, 18, 19].

The range of changing stiffness of the pads used for a vibrating platform with a capacity of 1.2 tons was determined by the equation:

\[
C = \frac{(1.7...2.6)M_1M_2}{M_1+M_2}, \text{ N/m , (1)}
\]

where \( M_1 \) and \( M_2 \) are the mold weight with the concrete mixture and the weight of the vibration table, respectively.

In the studies, the ratio \( M_1/M_2 \) changed from 1:2 to 1:5. The required bearing area of the pads \( S \) was determined on the basis of the calculated stiffness \( C \), the magnitude of the dynamic modulus of elasticity \( E \) of the pad material, and the selected thickness by the formula:

\[
C = \frac{E \cdot S}{\delta}, \text{ (2)}
\]

The choice of rubber pads depending on the mold weight and the type of rubber for different frequencies of the driving force was made according to the nomograms given in [12].

The process of the mold interaction with the mixture and the working surface of the vibration platform was studied with using molds of 10x10x10 cm, 20x20x20 cm, and 450x450x900 cm. Oscillation pulses patterns of the mold and vibrating table that occur during collisions were recorded using holographic interferometry [20]. Also, the study involved measuring magnitudes of the mold accelerations for various parameters of the oscillatory system.

The nature and magnitude of the impulses during the collisions of the mold with the surface of the vibrating platform depend primarily on the vibration modes of the table, which are determined by the static moment of the unbalances \( K \), the stiffness of the elastic elements and by the ratio of vibrating masses \( M_1/M_2 \) [11, 12, 17].

Depending on these factors, the impact occurs in each period, every second period, after 3 periods of oscillation of the operated device. In our tests, we studied modes with stable impacts, during which one impact occurred for one period of changed driving force.

3. Results

Studies of the influence of the pad stiffness on the oscillation frequency, at which the shock-vibration mode of oscillations was implemented, were carried out with a fixed weight of the mold with a concrete mix \( M_1 = 900 \text{ kg} \). Pads with a modulus of elasticity of 6.3 MPa were used in the tests. With different values of the pads bearing area \( S \), their rigidity \( C \) was:

\[
\begin{align*}
S_1 &= 0.20 \text{ m}^2; C_1 = 3.5 \cdot 10^6 \text{ N/m}; \\
S_2 &= 0.48 \text{ m}^2; C_2 = 8.6 \cdot 10^6 \text{ N/m}; \\
S_3 &= 0.75 \text{ m}^2; C_3 = 13.6 \cdot 10^6 \text{ N/m}.
\end{align*}
\]

Obtained results are given in Figure 1.
Figure 1. The influence of the pad stiffness $C$ on the oscillation frequency $f$, at which the mold collides with the table. Static moments $K$ of the unbalance weight:

1 – $3.52 \times 10^3$ N·m; 2 – $6.18 \times 10^3$ N·m; 3 – $13.4 \times 10^3$ N·m.

As it can be seen from Figure 1, the frequency of stable collisions of the mold on the vibrating table increases significantly with an increase in the pad stiffness, which indicates the high dependence of a mode of the oscillating system “vibrating table - elastic element - mold with a mixture” on the stiffness of the elastic element. Thus, an increase in the pad stiffness from $3.52 \times 10^6$ to $13.4 \times 10^6$ N/m leads to an increase in the frequency of vibrations, at which the impact of the table with the mold occurs, by 1.75 times on average. It is also necessary to take into account that depending on the stiffness of the contact of the mold with the vibrating table, the amplitude-frequency spectrum of oscillations propagating in the concrete mix, which determines the intensity of the vibration compaction process, changes significantly [12, 17].

Consequently, by changing the stiffness of the pads and the static moment of the unbalance, it is possible to change the frequency of the mold impact with the vibrating platform table significantly, to form a spectrum of frequencies transmitted to the concrete mix, thus creating an optimal mode of forming concrete products.

As shown in [3, 4, 6, 9], one of the main criteria for the technical evaluation of the efficiency of a vibration machine is the maximum acceleration of the oscillation of a mold with a concrete mix at the time of the impact with the table of the vibrating platform.

Studies to determine the effect of $M_1/M_2$ ratio and the static moment $K$ of the vibrating platform unbalances on the mold acceleration $A_g$, which it receives when interacting with the operated device through an elastic pad, were carried out with a fixed stiffness of the pad being $1.7 \times 10^6$ N/m. The parameters of the static moment of the weight unbalances took the following values: $K = 3.52; 6.18; 9.1; 13.4 \times 10^3$ N·m. The ratios $M_1/M_2$ were chosen as 0.4; 1.0; 1.5; 2.0 (by changing the weight of the mold with a concrete mix). The test results are presented in Figure 2.
Figure 2. The dependence of the acceleration $A_g$ of the mold with a concrete mixture when colliding with the vibrating table on the weight ratio $M_1/M_2$. Static moments $K$ of the unbalance weight: 1 - $3.52 \times 10^3$ N·m; 2 - $6.18 \times 10^3$ N·m; 3 - $9.1 \times 10^3$ N·m; 4 - $13.4 \times 10^3$ N·m.

As can be seen from Figure 2, the mold acceleration at the time of contact with the vibrating platform when changing the parameters of the system “vibrating table — elastic element — mold” varies over a wide range. With an increase in the weight of the mold with a concrete mixture, the mold acceleration regularly decreases at the moment of contact with the vibrating table. When the weight of the mold with the mixture is 2 times more than the weight of the vibrating table ($M_1/M_2 = 2$), the mold acceleration is within 4.5g ... 9g depending on the static moments of the unbalance weight.

If the weight of the mold with a concrete mixture and the weight of the vibrating table are equal ($M_1/M_2 = 1$), and make 900 kg, the mold acceleration at the moment of impact varies from 7g to 11g. In the case of lighter molds ($M_1/M_2 = 0.4$), the peak acceleration reaches 11g or more.

It should be noted that with an increase in the static moment of the weights of unbalances at any values of the weight ratio of the mold and the vibrating table, the mold acceleration increases. The study results show that if lighter molds are used, it is possible to obtain large accelerations of their movement in the process of forming concrete products.

4. Summary
Forming products from concrete and reinforced concrete in molds freely installed via elastic pads on vibrating platforms and creating conditions for the impact of the mold with the table surface through an elastic element allow changing the parameters of the oscillating system “vibrating table - elastic element - a mold with concrete mixture” to implement the optimal modes to consolidate concrete mixes.

The obtained results open a new prospect in the development and improvement of vibration molding machines with free set molds, since this eliminates the need for fasteners, which often do not work reliably. It also simplifies the design and reduces the metal capacity of the machine.

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