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RESEARCH ON DYNAMICS OF THE CONCRETE VIBRATORY TABLE FOR LABORATORY WORKS

NGHIÊN CỨU ĐỘNG LỰC HỌC THIẾT BỊ BÀN ĐẦM RUNG HỖN HỢP BÊ TÔNG PHỤC VỤ TRONG PHÒNG THÍ NGHIỆM

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Abstract

The article presents the scientific basis for studying the influence of the eccentric shaft rotation speed on the compaction quality of the concrete mixture. In this regard, the dynamic model of the table-type concrete vibrator is first developed and solved by the numerical method. Then, the reasonable eccentric shaft rotation speed is estimated to improve the compaction quality of fresh concrete materials. In addition, the observed results serve as the guideline and suggestions for designing and using such types of construction machines.

Keywords: *Concrete vibratory table, compaction quality, rotation speed of eccentric shaft.*

Tóm tắt

Bài báo trình bày cơ sở khoa học nghiên cứu ảnh hưởng của tốc độ quay trục lệch tâm đến chất lượng đầm chặt của hỗn hợp bê tông. Về vấn đề này, mô hình động lực học của đầm bàn rung bê tông lần đầu tiên được phát triển và giải bằng phương pháp số. Từ đó, thông số tốc độ quay trục lệch tâm được lựa chọn một cách hợp lý để nâng cao chất lượng đầm chặt hỗn hợp bê tông tươi. Ngoài ra, các kết quả đạt được đóng vai trò quan trọng trong quá trình tính toán, thiết kế và khai thác, sử dụng các loại máy đầm rung bê tông tương tự.

Từ khóa: *Đầm bàn rung bê tông, tốc độ quay trục lệch tâm, chất lượng đầm chặt hỗ hợp bê tông.*

1. Introduction

Nowadays, there have been many studies on the influence of concrete mixture's compressive strength and waterproofing ability. The results show that the flexural and tensile strength of the product concrete depends on the percentage of voids of the concrete mixture. One of the most important steps when pouring concrete is the consolidation or vibration of concrete. The quality and durability of normal concrete directly depend on the number and the shape of voids, so, to produce durable concrete, it is necessary to reduce the amount of air that is trapped inside the concrete, which is usually done by vibrating the concrete in the mixing stage or the casting stage. Concrete vibrators, if used properly, will help consolidate concrete and will reduce the number of air pockets inside the concrete mass. The cement-concrete mixture will be of high quality if it is compacted to suitable compaction by compacting machines including a concrete vibrator table. This machine allows changing some of the structural and working parameters to determine the influence of this parameter on the quality of compaction of the concrete mixture. The scope of this paper shows the influence of the eccentric shaft rotation speed parameter on the quality of compaction of the concrete mixture.

2. Determining the effect of eccentric shaft rotation speed on vibration parameters of the concrete vibratory table

2.1. Structure and working principles

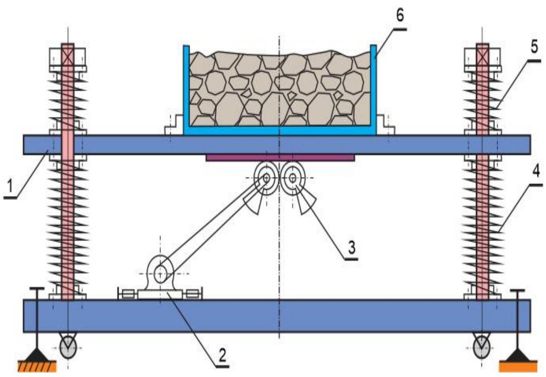

Figure 1. Diagram of the principle and structure of the concrete vibratory table

1 - Body, 2 - Electric motor, 3 - Vibrating cluster, 4 - Main springs, 5 - Extra springs, 6- Concrete mold.

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The torque from the motor is driven through the belt transmission which rotates the eccentric shaft, creating excitation force on the vibrating table thanks to eight springs mounted on the top and bottom, the compactor will vibrate and transmit the vibration force to the concrete block inside molding, making the concrete mix compact. Thus, the compaction force acting on the vibrating table is generated from vibration cluster 3 and depends on the rotation speed of the eccentric shaft.

2.2. Model parameters

*Vibrational mode: For effective tightening, the correct vibration mode should be determined, including the oscillation speed-v (m/s) or the intensity of the oscillation-W (cm^2/s^3). To be able to break the link between the core particles, the value of v and W must be reached a certain number. The Oscillation speed-v associated with amplitude oscillation and frequency of oscillation through the following expression:

v = Aωsinωt (m/s) with A - amplitude of oscillation, m; ω - frequency of oscillation, rad/s; t - oscillation time, s.

For each type of concrete, the effective speed of oscillation to tighten the mixture will vary from v_{min} to v_{max}. According to [4], it could get the best concrete mixture quality, the amplitude range of concrete vibrators usually ranges from 0.4mm to 0.8mm, frequencies range from 22Hz to 66Hz, and acceleration is less than $70m/s^2$.

* Forming vibration time: The vibration time has a direct effect on the tightness of the concrete. If it is too short, the concrete cannot reach the required compactness. On the other hand, too long a vibration time will reduce the concrete intensity. The reasonable vibration time is within from 2 to 4 minutes depending on the properties of the concrete mixture.

* Method and oscillating direction: Oscillating perpendicular to the surface of concrete for higher compaction efficiency in the tangent direction. Besides, in the same fluctuates perpendicular to the concrete surface, the top to bottom direction is more effective from bottom to top.

* Oscillating properties: Harmonic and non-harmonic oscillations affect the compaction of concrete mix differently.

* The mass of concrete mixture: The volume of concrete mix put into the mold directly affects the amplitude of vibration of the mold. As the volume of concrete loaded into the mold increases, the amplitude of vibration decreases.

2.3. Dynamic model

With the above equipment, when building a computational model, the following assumptions need to be made:

- The survey center of the vibrating table does not change during the working process

- Neglecting damping force of support springs and compression springs.

- The stiffness and geometric dimensions of the main and auxiliary springs at the supports are the same.

- Consider the table to be absolutely rigid and the eccentric radius to be unchanged.

* Setting paradigmatic calculation:

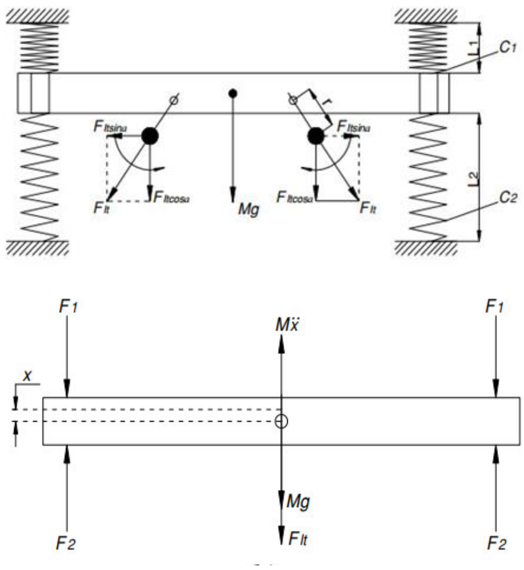

Figure 2. Calculation diagram of vibration table

Symbols used: *M* - Mass of vibrating part (kg); C_1 - Extra spring stiffness (N/m); C_2 - Main spring stiffness (N/m); L_1 - Initial length of extra spring (m); L_2 - Initial length of main spring (m); *Mg*- Weight of vibrating part (N); F_{lt} - The centrifugal force (N): $F_{lt} = m\omega^2 r\cos\omega t$, *m* (kg)- eccentric mass, *r* (m)– eccentric radius, *ω* (rad/s) - the eccentric shaft rotation speed; *M* - Moment of inertia of the vibrating part (N.m); F_1, F_2 - Elastic force of spring (N); x_{01}, x_{02} - Initial compression of the spring (m).

The differential equation of motion of the vibrating table is as follows:

$$M\ddot{x} + 4F_2 - 4F_1 = Mg + F_{lt} \qquad (1)$$

According to [2] and [3]:

$$F_1 = -C_1 x + C_1 x_{01}$$

$$F_2 = C_2 x + C_2 x_{02}$$

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Substituting the values into equation (1):

$$M\ddot{x} + 4x(C_1 + C_2) = Q(t) \qquad (2)$$

With:

$$Q(t) = -\ 4C_2x_{02} + 4C_1x_{01} + Mg + m\omega^2 r\cos\omega t$$

Let $z_1 = x,\ z_2 = \dot{x}$, equation (2) becomes:

$$\begin{cases} \dot{z}_1 = z_2 \\ \dot{z}_1 = \frac{1}{M}\left[Q(t) - 4z_1(C_1 + C_2)\right] \end{cases} \qquad (3)$$

From equation system (3), we can see that all of the parameters (M, r, x_{01}, x_{02}) are constant. Moreover, the extra spring is arranged above to create the initial compression and it affects the oscillation lightly so C_1 is chosen as a constant. Then, equation system (3) depends only on C_2, m ,and ω. Equation system (3) is solved by using Matlab (using function ode45) with initial conditions of: $x(0) = 0$, $\dot{x}(0) = 0$, $\ddot{x}(0) = 0$.

3. Results and discussion

Values of some parameters : C_1 = 10000N/m; C_2 = 160000N/m; m_0 = 0.8kg; r = 0.04m; M = 90kg. We keep the values of C_1, C_2, m_0, r, M and only change ω by the values of: 314rad/s; 261rad/s and 209.3rad/s; we get the following graphs (Figure 3).

From the results on the graphs, the maximum values of amplitude, velocity, and acceleration of the compactor can be shown in the Table 1:

Table 1. Working parameters-influenced angular velocity

ω (rad/s)	Amplitude (mm)	Speed v (m/s)	Acceleration (m/s^2)	Frequency (Hz)
209.3	0.60	0.16	38.4	33
261.7	0.58	0.17	39.58	41
314	0.55	0.19	41.03	49

***Comment:** When ω is changed, the survey system has i = ω/ω_0 = 4÷5, that is, the survey system oscillates stably after the resonance region.

*** About the rule:** When changing the angular speed of the eccentric shaft and fixing other parameters, the amplitude, velocity, and acceleration parameters oscillate periodically. This is consistent with the structural characteristics of the vibrating table placed on the spring bearings and the dynamic calculation model of the device.

*** About the value:** When increasing the eccentric shaft angular speed ω, the value of amplitude decreases but the speed and acceleration both increase. Specifically, with m_0 = 0.8kg when increasing ω = 209.3rad/s to ω = 314rad/s, the amplitude value decreases from A = 0.60mm to A = 0.5 mm; speed increases from v = 0.16m/s to v = 0.19m/s; acceleration increases from a = 38.4m/s^2 to a = 41.03m/s^2.

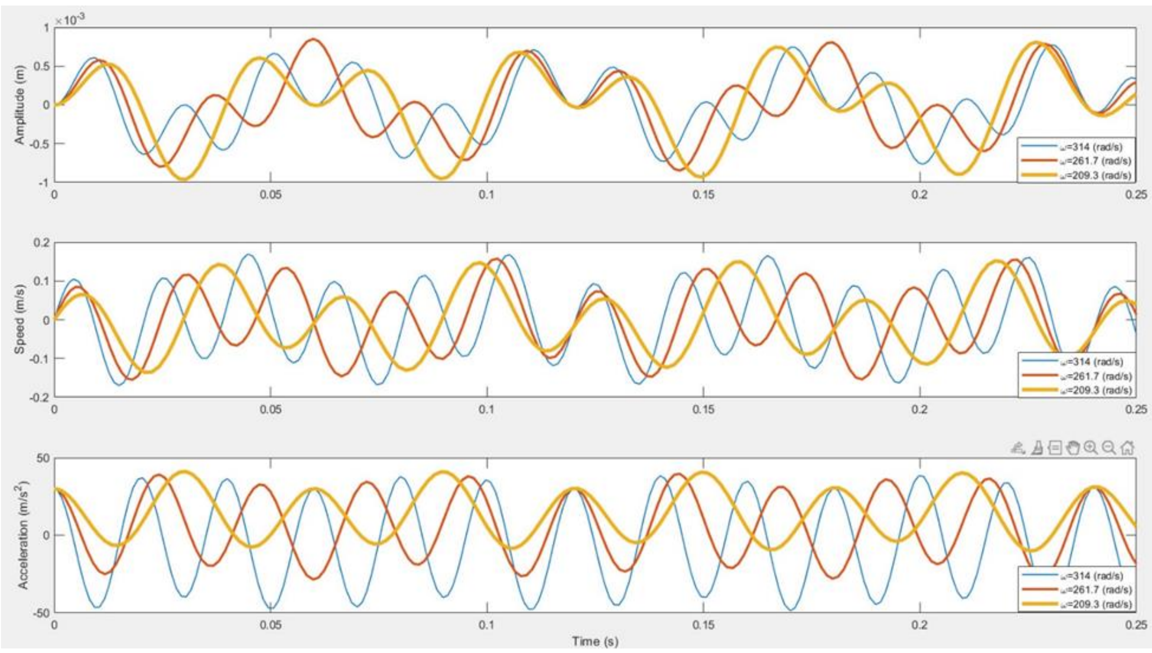

Figure 3. Variation of the amplitude, velocity, and acceleration with the changing of the angular velocity ω

We found that the values of that survey are suitable and ensure reasonable values of amplitude, speed, acceleration, and frequency of reasonable oscillations. These are the basic parameters affecting the compaction quality of the concrete mix.

4. Conclusion

The structural parameters of the compactor equipment directly affect the vibration parameters when the equipment is working, and indirectly affect the quality of compaction of the concrete mix. In this article, we focus on studying the influence of the eccentric shaft rotation speed on the compaction quality of the concrete mix through a number of parameters such as amplitude, velocity, and acceleration of the vibrating table device in working progress. In order to have the vibration parameters on the vibrating table equipment in accordance with the theoretical optimal values, it is essential to choose a reasonable set of structural parameters of the device. At the same time, in the process of exploiting, using, and operating the equipment, it is needed to comply with the procedures and instructions for use. The results contribute to improving the efficiency and quality of the exploitable and using process of the directional vibrating table equipment.

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