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Properties of Fine-Grained Concrete Mixtures during the Construction of Monolithic Structures

L B Aruova^{1*}, Z N Ospanova², B S Gordienko³, N T Alibekova⁴, Zh E Kalieva⁵, Zh I Urkinbaeva⁶, M N Nurbaeva⁷

¹Doctor of Technical Sciences, Professor, Eurasian National University named after L.N. Gumilev, Republic of Kazakhstan

^{2,3,4,5}Candidate of Technical Sciences, Associate professor, Eurasian National University named after L.N. Gumilev, Republic of Kazakhstan

⁶Senior Lecturer, Eurasian National University named after L.N. Gumilev, Republic of Kazakhstan

⁷Master of Engineering, Eurasian National University named after L.N. Gumilev, Republic of Kazakhstan

* ecoeducation@mail.ru

Abstract. The article presents the results and methods of studying the rheological properties of fine-grained concrete mixtures with various additives, as well as the regression equation obtained by calculations using the apparatus of mathematical analysis, which shows the significance of the parameters included in the process of compaction of the ICZB. These data are necessary for the correct design and selection of sealing mechanisms in order to obtain the design physical and mechanical properties of ICZB. In many regions of the world there is an acute shortage of high-quality raw materials for large aggregate in conventional concrete, which necessitates its transportation over distances from 400 to 1000 km. In this regard, the cost of one cubic meter of coarse aggregate in many regions is 2-3 or more times higher than the cost of sand, the deposits of which are more common. In addition, obtaining the desired fractions of quality aggregates requires artificial addition and fractionation of the resulting granules. The experience of using ICZB for the manufacture of parts and structures at the plants of ZHBK gave positive results, but in mass construction (hydraulic), he did not get spread due to insufficient study of physical and mechanical properties, weak efficiency of existing vibration equipment, insufficient development of new technological equipment for laying and sealing. In this regard, we believe that the research aimed at studying the physical and mechanical properties of ICZB and the further development of technological equipment, methods of laying and sealing for their widespread implementation, determine the relevance of this problem.

1. Introduction

Insufficient study of the physical and mechanical properties of fine-grained concrete mixtures and the inefficiency of the existing vibration equipment to obtain the design physical and mechanical properties of ICZB constrains its use in monolithic construction. Our research in the laboratory and in



experimental areas showed that ICZB has increased frost resistance (this is well explained), the lack of high-quality fillers in it sharply reduces its cost.

A number of researchers dealt with the problem of using ICZB for the manufacture of reinforced concrete structures (fixed formwork), and not for concreting monolithic structures under construction at the construction site. The results of their only indirect bearing on our problem [1, 2].

The main reason that constrains the widespread use of ICZB in monolithic structures lies in the inability to seal them with existing vibration equipment. In the future, it is necessary to continue research on the design and manufacture of the necessary vibration equipment.

The urgency of the task is due to insufficient experience of compaction of fine-grained concrete mixtures in the conditions of the construction site.

2. Purpose of research

In practice, a sufficient amount of experience in the use of ICZB to obtain structures and parts in the factory [8, 11]. However, laboratory, semi-production and production tests of various ISS compositions show that the existing equipment is ineffective in the conditions of the construction site. In this regard, studies aimed at studying the physical, mechanical and rheological properties of ICZB will provide an opportunity to obtain a clear, reasonable idea of the importance of specific parameters for the production of compositions and concretes with the necessary physical and mechanical properties.

3. Method of research

The selection of compositions was carried out according to the well - known technique of Yu.m. Bazhenov with subsequent adjustment, considering that the required properties of ICZB can be obtained with some lack of cement-water paste to fill sand voids.

As additives, widely known air entrainment (SNV), plasticizing (SDB) and slowing down hardening (SP) surfactants were used [9,10]. The experiments used cement M400 with compression activity of 45.3 MPa, bending-8.66 MPa. The sand was used with a size modulus from 2.0 to 2.8 with a dust particle content of not more than 1 % by weight.

4. Research results.

The results of tests on the compressive strength of different compositions showed THAT the lowest strength of the composition with the air-entraining additive start. This is probably due to the presence of a large amount of air in the concrete (porosity 8-12 %) [4, 6].

All studied compositions withstood 150 cycles of freezing and thawing according to GOST 10060-2012 (MGS) [3]. The best results were obtained for compositions with the addition of SDB in the amount of 0.25 % by weight of cement. In addition, tests were carried out for frost resistance at a temperature of 45 °C. All compositions withstood 15 cycles of thawing and freezing. The decrease in strength was from 1 to 6 %. The test results indicate a high frost resistance of the studied compositions of ICZB.

In parallel with the tests for frost resistance, the modulus of dynamic elasticity of the compositions is determined. The highest dynamic modulus of elasticity, equal to $33.8 \cdot 10^3$ MPa have compositions with up to-addition of SDB in the amount of 0.25 % by weight of cement.

Shrinkage deformation at an early age (7 days) was slightly higher than that of conventional, but after 180 days they were equal to conventional concrete (0.7 mm/m). MCSB were selected and analyzed for hydraulic structures. Water resistance of all samples from MKZB proved to be of the appropriate grade B-8. Of the studied compositions, MZB with the addition of SDB in the amount of 0.25% by weight of cement has the best properties.

Good frost resistance was obviously provided by the absence of a large filler. A series of experiments and practice have shown that the frost resistance of concrete is provided by the resistance of a large aggregate to alternate freezing and thawing, which is not present in the ICZB. To study the rheological properties of ICZB, a model of sealing equipment was designed and manufactured [7, 5].

The model we have adopted (figure 1) to the greatest extent meets the listed requirements. In its study the following assumptions are made:

- A rigid fine grained concrete mixture is modeled as a viscous elastic material with a modulus of

elasticity E and a damping coefficient b_2 ;

- Plastic deformation does not affect the dynamics of the seal.

As will be shown below, the effectiveness of the vibration profiling on the compacted material depends on its setting, i.e. the set of basic parameters. This setting is carried out by selecting the value of the load to the working body in accordance with the selected frequency and amplitude of the driving force. vibration profiling may be instantaneous, but a preliminary preload of the springs is transformed in the inertial (figure 2).

The vibration lamp is modeled by the inertial mass M_1 , to which a driving force is applied, created by an unbalanced vibration exciter and the force of the inertial loading of M_0 . The layer of compacted fine-grained concrete mixture was modeled by an elastic element and a viscous damper. The parameters of such a shock vibration limiter depend on the elastic modulus E of the concrete mixture, its absorbing properties b_2 , and the size of the vibration tube. The study of the adopted dynamic system was carried out by methods of mathematical analysis.

For the production task was composed of differential equations of motion of vibration equipment. The basic equation without considering plastic deformations has the form:

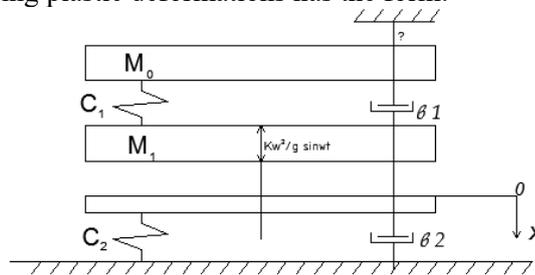


Figure 1. The estimated model for the study of the system "fibro scan – concrete mixture" M_0 is the mass of the inertia-free load, b_1 and $C / 1$ are the damping and stiffness coefficients of the springs on which the inertia-free load rests, M_1 is the mass of the vibrating parts of the vibration profiling, b_2 and $C / 2$ -damping and stiffness coefficients of the limiter (fine-grained concrete mix), Δ – the value of the preload of the springs from the gravity of the inertial preload.

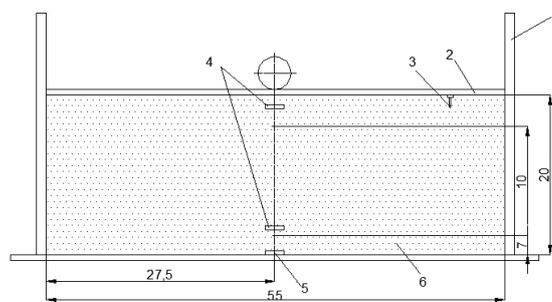


Figure 2. The scheme of placement of sensors. 1-tray formwork, 2-vibration ramming unit, 3-separation sensor, 4 - sensors for measuring accelerations in concrete mix, 5-pressure sensor, 6-fine-grained concrete mix, 7-vibration platform acceleration sensor.

$$M_1 \frac{d^2x}{dt} = C_1x X - b_1 \frac{dx}{dt} + M_1 * g + c * \Delta + \frac{k\omega^2}{g} * \sin\omega t \tag{1}$$

By

$$0 < X < 0, \quad R \left(X_1 \frac{dx}{dt} \right) > 0 \tag{2}$$

where

$$R\left(X_1 \frac{dx}{dt}\right) = C_2 * X + b_2 \frac{dx}{dt} \quad (3)$$

$$M_1 \frac{d^2x}{dt^2} = C_1 x X - b_1 \frac{dx}{dt} + M_1 * g + c * \Delta + \frac{k\omega^2}{g} * \sin\omega t - C_2 * X + b_2 \frac{dx}{dt} \quad (4)$$

by

$$X > 0, \quad R\left(X_1 \frac{dx}{dt}\right) < 0 \quad (5)$$

K – static moment of mass of vibration exciter unbalances;

ω – circular frequency of driving force change;

$R\left(X_1 \frac{dx}{dt}\right)$ limiter reaction;

C_1, b_1 – coefficient of stiffness and damping in the suspension load.

X – the coordinate of the vibration lamp; counted from the undamped position of the limiter;

The design model is characterized by 8 parameters: $C_1, C_2, b_1, b_2, \Delta, M, K, \omega$. In order to reduce the number of independent parameters we reduce the new variables:

$$Z = \frac{x}{k} * M_1 * g = \frac{x}{a_\infty} \quad (6)$$

$$\tau = \omega t$$

where: $a_\infty = \frac{K}{M_1 * g}$ - amplitude of oscillations of the working body under the action of the driving force $\frac{K * \omega^2}{g} \sin\omega t$ in the absence of connections in the air, τ - dimensionless time.

Divide 1 and 4 equations and switching conditions 2 and 5 by the amplitude of the driving force $\frac{K * \omega^2}{g}$.

The equations take a dimensionless form:

$$\frac{d^2z}{d\tau^2} = p - \mathfrak{Z}_1^2 * Z - \varepsilon_1 * \mathfrak{Z}_1 * \frac{dz}{d\tau} + \sin \tau \quad (7)$$

by

$$Z < 0 \text{ или } Z > 0, r\left(Z, \frac{dz}{d\tau}\right) > 0 \quad (8)$$

$$\frac{d^2z}{d\tau^2} = p - \mathfrak{Z}_1^2 * Z - \varepsilon_1 * \mathfrak{Z}_1 * \frac{dz}{d\tau} + \sin \tau - \varepsilon_2 * \mathfrak{Z}_2 * \frac{dz}{d\tau} \quad (9)$$

by

$$Z > 0, r\left(Z_1 \frac{dz}{d\tau}\right) < 0 \quad (10)$$

where

$$r\left(Z_1 \frac{dz}{d\tau}\right) \mathfrak{Z}_1^2 * Z + \varepsilon_2 * \mathfrak{Z}_2 * \frac{dz}{d\tau}; p = \frac{(M * g + C * \Delta) * g}{K * \omega^2} \quad (11)$$

From the condition of vibration isolation, we can assume, what $\mathfrak{Z}_1 = 0.2$; $\varepsilon_1 = 0.2$ for all variants of the calculation. In this case the system is characterized by three independent parameters;

$$\mathfrak{Z}_2^2 = \frac{C_2}{M\omega_2}; \varepsilon_2 = \frac{b_2}{\sqrt{M*C_2}}; p = \frac{(M*g+C*\Delta)*g}{K*\omega^2} \quad (12)$$

In this work the dependencies were investigated p и Z от \mathfrak{Z}_2 в области $0.15 \leq \varepsilon_2 \leq 1.05$, with \mathfrak{Z}_2 changed from 0 before 5.

When you search for stable periodic modes of vibration equipment considered such regimes, which provided the maximum magnitude of the stroke speed vibration equipment *ceteris paribus*. Such regimes were considered the most effective. On the basis of the obtained results, graphs are constructed (figure 3; Fifgure 4). for figure 3) the boundaries of the existence of the most effective regime are determined. Solid lines correspond to the upper limits of the zone of the most effective modes. From the graph (figure 3) it follows that the magnitude of the shock acceleration is approximately in direct proportion to the magnitude of the dimensionless parameter \mathfrak{Z}_2 .

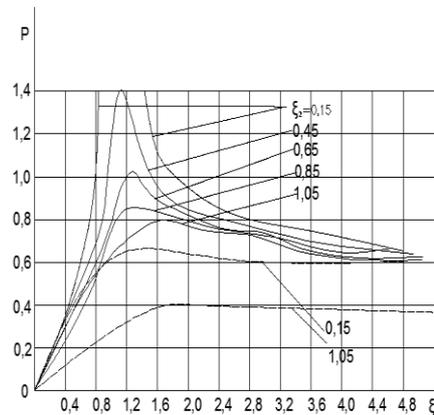


Figure 3. Dependence of the ratio (P) of the gravity of the vibrating parts of the vibration tube to the amplitude of the driving force from the dimensionless parameter ξ_2 .

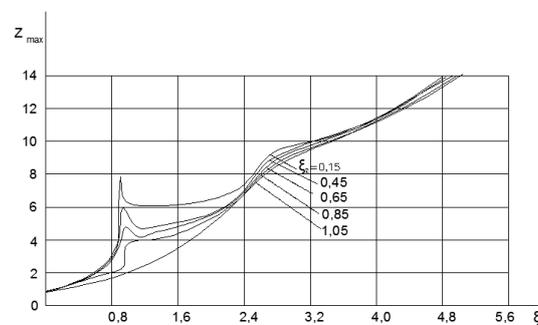


Figure 4. Dependence of shock acceleration \dot{Z}_{max} on the vibration lamp from the dimensionless parameter ξ_2 .

As shown by the study of vibro-viscosity MKZB, using a ball viscometer vibration viscosity of fine-grained concrete mixtures was 5-7 more than for conventional. Increasing the vibro-viscosity leads to a deterioration of the compaction conditions, increased porosity and therefore-to a decrease in strength. A series of experiments on the sealing of the ICSB found that circular vibrators are not effective. After their work in a concrete mix there are not floating glasses. The best results were shown by plane vibration emitters used in massive structures.

To clarify the quantitative and qualitative assessment of the relationship between the thickness of the mixture (h), the stiffness of the mixture (G) and the ratio of the mass of the shock-vibration machine to the amplitude of the driving force ($\frac{Q}{P_0}$) in laboratory conditions a series of experiments was carried out using the method of mathematical planning of the experiment.

Compaction of the mixture was carried out by a laboratory shock-vibration machine, which provides the ability to change the amount of load. The purpose of the experiments is to find the optimal parameters of the sealing machine when concreting flattened structures of a certain thickness (h).

In the study, a trial semi-replica of the type was adopted 23-1. The main parameter is the volume mass of the compacted mixture (γ_0), which was controlled after each experiment by cores taken from the freshly compacted mixture. After performing all calculations, the regression equation is obtained:

$$\gamma_0 = 2,92 - 0,37 \frac{Q}{P_0} + 0,066h - 0,09\mathcal{K}$$

When analyzing the regression, it follows that the stiffness of the ICS is within the studied limits (10-20 sec.) has a greater impact on the quality of the seal than the thickness of the mixture layer. The largest coefficient was the ratio of the force of the weight of the shock-vibration machine to the amplitude of the driving force. This confirms the results of computational and theoretical studies.

5. Summary

1. Fine-grained concrete mixes can be applied at concreting of massive (for example, hydraulic engineering) constructions with their compaction by plane vibration emitters.
2. Spread designs it is recommended to seal the sliding vibration lamp with adjustable tightening weight.
3. Fine-grained concrete mixtures are able to replace conventional ones with an acute shortage of large aggregate
4. For achievement of the greatest effect at compaction of fine-grained concrete mixes in each concrete case it is necessary to make adjustment of a vibration lamp on an effective mode.
5. There are areas of effective regimes in dimensionless form (figure 2) and adjust the parameters of vibration lamp need to produce the top borders of these areas. For this ξ_2 , the effective mode area is bounded by the lower dashed line
6. One of the main characteristics that determine the compaction effect of fine-grained concrete mixtures is the impact acceleration.

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