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Cite as: AIP Conference Proceedings **2612**, 040030 (2023); https://doi.org/10.1063/5.0118299
Published Online: 15 March 2023

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Modification of Concrete Mix During Pressing

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Abstract. According to A.V. Satalkina [1], the Americans pointed out the need to remove excess water after the concrete mixture was placed in a mold at the beginning of the century. I.N. Akhverdov [2] indicates that in the process of cement paste compression with (W / C) beginning = - 1.65 [W / C] cement particles, displacing water, approach, and at a relatively low-pressure P = Po = 0.065 MPa, the solvation shells can touch * (The solvation shell is flattened at the places of mutual contacts between the particles *). At large values (P> 0.065 MPa), mainly the diffuse layer of water is squeezed out, and its displacement can continue until only adsorption water remains in the cement-water system (in this case, the system will consist of connected grains zero). The potential energy expended in compressing diffuse water layers can be estimated from the general law of conservation of energy. In the process of concrete compaction, the potential energy of interaction between the surface layers of water and the solid phase is overcome. The convergence of particles of the solid phase will occur at a significant expenditure of energy, which is necessary to overcome the disjoining pressure. When particles approach each other, it is necessary to expend energy, which will be spent on reducing the thickness of the surface layer (work of desorption), which leads to the appearance of significant repulsive forces between the particles.

INTRODUCTIONS

As a result of the analysis of modern technologies, it was established that physical modification is possible by removing excess mixing water added to the concrete mixture to give it the necessary fluidity and workability.

As shown above, the removal of free water during compaction of the mix increases the use of the cement's potential properties to increase the concrete's density, water resistance, and strength. Currently, in the technology of complex elements, several methods of dewatering a concrete mixture are known: centrifugation, pressing, evacuation, vibrocompression, etc. One of the most effective methods should be considered the method of vibro-shock-peristaltic pressing, since this can create the necessary conditions for maximum dehydration of the concrete mixture [3, 4].

Based on the foregoing, it can be assumed that high-strength concrete, used, particularly for the manufacture of low-pressure and free-flow pipes, can be obtained by compacting the mixture by vibro-shock compaction with intensive dewatering.

In the production of pipes, the squeezing out of free mixing water from the concrete mixture was carried out through the perforated surface of the outer shape, covered with a special filter cloth [5-7].

The main disadvantage of using such filters is the high consumption of manual labor. Therefore, the task of these studies is to find such filters that would have a simple, easily accessible design in industrial conditions and squeeze free water out of the concrete mixture in a relatively short period. For this purpose, we investigated conical through holes arranged on the surfaces of the forms used [8]. The optimality of these filtration holes was assessed by comparing their performance, i.e. allow free water to pass as much as possible with a low loss of cement paste. The geometry, density and shape of the holes require special research.

The process of squeezing the liquid and gaseous phase out of the molded material is the main structure formation process and modification of concrete properties. The reason for the removal of liquid and gas from concrete is the

The Third International Scientific Conference Construction Mechanics, Hydraulics and Water Resources Engineering (CONMECHYDRO 2021 AS)
AIP Conf. Proc. 2612, 040030-1–040030-7; https://doi.org/10.1063/5.0118299
Published by AIP Publishing. 978-0-7354-4337-2/$30.00

pressure drop across the wall thickness of the pipe being formed towards the perforated surface of the formwork. Removal of liquid and gaseous media of a concrete mix is an exfiltration process, i.e., removing liquid and gaseous fluids from the material into the environment [9, 10].

The main role in the formation of a particularly dense concrete structure is played by the process of concrete dewatering. Squeezing out excess mixing water from the concrete mixture under the applied normal pressure is a filtration process [11-14]. An important role in it is played by the difference in the chemical potentials of the interacting phases and various gradients that arise in the system depending on the type of energy source under the influence of which free water moves. The movement of free water under the influence of the moisture gradient occurs towards less moistened pores until the moisture is completely equalized.

Therefore, to remove free mixing water from the concrete mixture under the action of pressure, it is necessary to perform work (energy consumption) to overcome the binding forces of water with cement particles and move it in the system. Naturally, the main task of studying the transfer of excess mixing water from a concrete mixture is to determine the dependence of the parameters of the vibro-shock-peristaltic effect and the filtration rate on various technological parameters and the value of normal pressure

METHODS

Under the vibro-shock action of peristaltic waves on the concrete mixture, natural vibrations of the aggregate grains are excited in it, which, in turn, lead to a certain dilution of the cement paste and the redistribution of liquid in it. In the viscoplastic cement paste of the mixture, a turbulent hydrodynamic process occurs, which, under the influence of peristaltic wave pressure, is accompanied by the squeezing out of the water from the layers of the mixture closer to the core, which leads to concrete compaction. In these cases, filtration channels directed towards the outer form are formed, through which excess water is filtered under the action of peristaltic pressing. The outer form, in turn, has numerous specially arranged filtering conical holes [13, 14]. The whole process of initial vibration compaction, squeezing out water and water-air phase, as well as subsequent hyperexposure of concrete, can be represented as a complex three-stage process. This process is complex and consists of three stages, different in terms of the mechanism of action:

The stage of re-laying the components (the first stage of compaction). It consists of the destruction and restructuring under the influence of vibration of the unstable structure of the skeleton of concrete aggregates. The grains forming it at the moment of destruction of the structure under the influence of their own mass tend to occupy the lowest position, change their mutual orientation and form a new stable structure. In it, the grains of fillers are no longer randomly placed but the most advantageous in terms of obtaining a minimum volume of the skeleton. Simultaneously with the restructuring of the skeleton, the bulk of the air is removed, mainly through perforated filtration holes. After the end of the first stage, no more than 3 ... 4% of the total volume of the concrete mixture remains,

Considering the features of the behavior of the concrete mixture at the first stage of vibration compaction, it can be seen that the re-laying of the components proceeds intensively only in the absence of significant static loads on the mixture. This creates the conditions for optimal re-laying of the concrete mix components. Experiments show that the time required to complete the first stage of compaction in active ("vibroboiling") layers of a concrete mixture is relatively short, and even for rigid mixtures does not exceed 20 ... 30 s.

The stage of convergence of the components (the second stage of compaction). It begins when the restructuring of the structure of the concrete mixture has ended and after this change in the order of the aggregate grains in it is practically unrealizable by conventional means. In the conducted experiments of convergence, separation, the relative shifts of the aggregate particles occur as a result of redistribution over the volume of the mortar component and cement paste due to the removal of the residual part of the air, as well as excess mixing water through the filter holes of the perforated outer shape. In contrast to the first, the second stage of compaction proceeds intensively under extremely constrained conditions, using the applied combined vibro-shock-peristaltic influences.

It takes a longer time to complete the second stage than the first. The duration of this stage depends on the stiffness of the concrete mixture, the wall thickness of the structure to be concreted, the vibration-impact-peristaltic pressing mode, the filtration capacity of the form and the initial value of W / C. For example, in the manufacture of unreinforced concrete pipes (with a diameter of 1000 mm, a length of 1500 mm and a wall thickness of 150 mm) from moderately hard mixtures, the stage of convergence of the components lasted 3 ... 5 minutes, i.e. almost two orders of magnitude larger than the first stage. The completion of the second stage is clearly determined by the end of significant deformations of the concrete mixture, after which the structure of fresh concrete can be considered established. Further vibration practically does not increase the density and strength of concrete and does not improve its surface quality.

The stage of complex compaction of the concrete mixture (the third stage of compaction). Experiments show that after the end of the second stage of compaction, it is still possible to achieve some additional (compression) compression by combining intense peristaltic pressure with a shear reciprocating movement of the outer perforated shape relative to the vibration core. Since this measure is carried out without stopping the vibro-impact action, the beneficial effect in the form of increasing the strength and density of concrete is achieved in a relatively short time (up to 1 ... 3 min.). The effect under consideration is achieved as a result of squeezing out the residual part of the excess mixing water with air dissolved in it and hyperexposure of the contacts between the aggregate grains.

It can be seen from the previous that the process of compaction of the concrete mixture at different stages obeys different laws. At the first stage, the concrete mixture behaves as a viscous-free-flowing medium subjected to vibration movements. At the second stage, resisting the cohesion of the components and the squeezing out of the water-air phase, the mixture reacts to the external sealing effect as a visco-elastic-plastic body characterized by a certain deformation modulus. At the third stage, the optimal combination of the filtration properties of the concrete mixture and the perforated form becomes crucial. In this case, the freshly formed mixture is deformed according to the multicomponent media dynamics laws.

Attention should be paid to the qualitative difference between the vibration compaction of the concrete mix and the hyperextension of concrete in the case under consideration. The usual one-stage compaction is replaced by a high-intensity three-stage hyperexposure, as a result of which the compaction coefficient Ku approaches the theoretically possible value of one. Three-stage hyperexposure will be especially effective in obtaining a concrete mixture with optimal vibration viscosity, elasticity and ability to absorb energy in the process of vibro-shock vibrations [15]. This important conclusion determines the need to develop a reliable method for assigning concrete compositions that meet the specified conditions. At the same time, using the research of O.A. Savinova, E.V. Lavrinovich et al. [16-26], the concrete mixture can be represented as a viscous liquid with a constant viscosity coefficient.

In addition to determining the optimal composition of concrete, it is also necessary to determine the concrete mixture's physical and mechanical properties. The integral characteristic of concrete deformability or the effective modulus of deformation of a concrete mixture is determined most simply. To do this, consider the above-described first stage of compaction of the concrete mixture by vibrocompression.

RESULTS AND DISCUSSION

Let us determine the energy expended in compressing the concrete mixture by external vibropressing forces, which increase during the compression process from zero to the final Pvp. First, let's define the elementary work of external forces, which will be equal to the product of the force Pe and the displacement$d\varepsilon$ (Fig. 1).

$$dW = P\varepsilon \cdot d\varepsilon \tag{1}$$

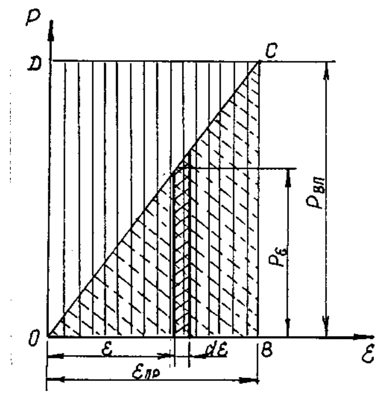

FIGURE 1. Scheme for determining the energy of compaction of a concrete mixture

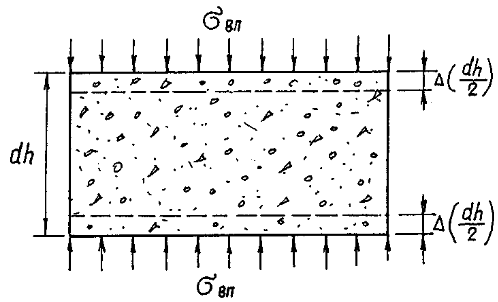

FIGURE 2. Elementary layer of the concrete mix to be compacted

In work [22, 23] it was proved that at P over 2.2 MPa, between the deformation ε and the forces, there is a dependence of elastic resistance according to the well-known Hooke's law.

$$\Delta h = \frac{P \cdot h}{E \cdot F} \tag{2}$$

Whence the pressing pressure is equal to:

$$P\varepsilon = \frac{E \cdot F \cdot \Delta h}{h} \tag{3}$$

Or, passing to the relative deformation ε = Δh / h, we find:

$$P\varepsilon = E \cdot F \cdot \varepsilon \tag{4}$$

Substituting the expression $P\varepsilon$ into the equation of the elementary work of pressing, we find

$$dW = E \cdot F \cdot \varepsilon \cdot d\varepsilon \tag{5}$$

We obtain the total energy spent on pressing the mixture by integrating the expression in the range from zero to the final value of displacement ε_{pr}.

$$W = E \cdot F \int_0^{\varepsilon pr} \varepsilon \cdot d\varepsilon = \frac{E \cdot F \cdot \varepsilon_{pr^2}}{2}. \tag{6}$$

where E is the modulus of elasticity of the compressed mixture, MPa;
F is the cross-sectional area of the sample, cm2;
ε_{pr} is the ultimate relative deformation.
Expressing the potential energy through the applied force $P_\varepsilon = E \cdot F \cdot \varepsilon = P_{vp}$, we get:

$$W = \frac{P_{vp} \cdot \varepsilon_{pr}}{2}. \tag{7}$$

Thus, the work of the pressing force is equal to half the product of the final pressure $P_{vp}$and the compression deformation ε_{pr}. Graphically, the compaction diagram from the pressing forces is expressed by the area of the triangle of the OCV diagram (Fig. 1). In our case, with a vibro-shock application of pressure Pvp, if the force is applied almost instantly, then the work of hyperelasticity will be twice as large as with static pressing. The geometry of the compaction diagram is expressed by the area of the rectangle ODSV (Fig. 1).

In samples pressed under high pressure, the water between the particles of the solid phase is in the form of thin films, the packing density of the particles is maximum, which increases the structural strength of both the freshly formed product and the hardened concrete.

In the process of compacting the concrete mixture, the compaction work is performed not only by external forces but also by internal forces of elasticity. The work of internal forces during compression can be calculated as follows. In fig. 2 shows the element dh of a compacted concrete mixture, which is acted upon by normal stresses G_{vp}, which are external forces for a given layer. Internal forces will be directed in the direction opposite to displacement. Therefore, the work of internal forces during pressing is always negative.

The elementary work of internal forces for an element dh is calculated by a formula similar to formula (5)

$$dW = -\frac{G_{vp} \cdot F \cdot \Delta(dh)}{2}, \tag{8}$$

but $\Delta(dh) = \frac{G_{vp} \cdot F \cdot dh}{E \cdot F}$,

where $G_{vp}$is vibration pressing stress, MPa.

Consequently,

$$dW = -\frac{G_{vp^2} \cdot F^2 \cdot dh}{2 \cdot E \cdot F} \tag{9}$$

We find the total energy of compaction from the action of internal forces by integrating both sides of equation (9) over the height of the sample h

$$W = -\frac{1}{2}\int_0^h \frac{G_{vp^2} \cdot F^2 \cdot dh}{E \cdot F} = -\frac{1}{2}\frac{G_{vp^2} \cdot F^2 \cdot h}{E \cdot F} = \frac{P_{vp^2} \cdot h}{2 \cdot E \cdot F} = \frac{E \cdot F \cdot \Delta h^2}{2 \cdot h} = -\frac{E \cdot F \cdot \varepsilon_{pr^2} \cdot h}{2} = \frac{E \cdot V \cdot \varepsilon_{pr^2}}{2} \tag{10}$$

where $\Delta h = \frac{P_{vp} \cdot h}{E \cdot F}$ is the elastic part of the compression deformation of the concrete sample.

A quantity equal to the work of internal forces but having an opposite sign is called the potential energy of deformation. Thus, the potential energy during compression of the concrete mixture will be determined by the formula:

$$U = -W = \frac{1}{2} \cdot \frac{G_{vp^2} \cdot F^2 \cdot h}{E \cdot F} = \frac{1}{2} \cdot \frac{P_{vp^2} \cdot h}{E \cdot F} = \frac{E \cdot F \cdot \Delta h^2}{2 \cdot h} = \frac{E \cdot V \cdot \varepsilon^2}{2} \tag{11}$$

The potential energy per unit volume of the formed element is called the specific potential energy:

$$U = \frac{U}{V} = \frac{U}{F \cdot h} = \frac{1}{2} \cdot \frac{G_{vp^2} \cdot F^2 \cdot h}{E \cdot F \cdot F \cdot h} = \frac{1}{2} \cdot \frac{G_{vp^2}}{E} = \frac{P_{vp^2}}{2E} \tag{12}$$

or

$$U = \frac{E \cdot V \cdot \varepsilon^2}{2V} = \frac{E \cdot \varepsilon^2}{2} \tag{13}$$

Thus, in compressed dispersed systems, including concrete mix, there is an increase in potential energy. With an almost instantaneous application of vibro-shock-peristaltic pressure Pvp, the specific potential energy also doubles

$$U = E_\delta \cdot \varepsilon_{pr^2} \tag{14}$$

Consequently, the energy of hyperelastic compaction is twice the specific energy of compaction during static pressing, and the accumulation of the specific potential energy of the compacted concrete mixture is proportional to the product of the square of the relative elastic compression deformation $\varepsilon_{pr}$by the modulus of elasticity of the compressed concrete mixture E_δ.

The squeezing of water from the mixture to be sealed will end when the difference in external pressure at the ends of the capillaries is overcome by the internal capillary pressure. In this case, the pressure of filtration resistance is proportional to the viscosity forces of the liquid phase.

CONCLUSIONS

1. It has been shown that physical modification of concrete is carried out by squeezing out excess water, which occurs in laminar, turbulent and intermittent modes.
2. Equations were obtained about the regularities of the movement of the water-air phase depending on the applied pressures and the parameters of the permeability of the concrete mixture and the filtration holes of the mold.
3. It has been proved that a quantitative description of the process of squeezing the water-air phase can be made using the classical filtration laws, taking into account the degree of gas contamination of the liquid with air bubbles and the final intermittent mode of squeezing water.

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