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Analysis of the mode of squeezing out excess water for mixing concrete mixture in the process of peristaltic compaction

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Abstract. For the formation of a mixture of a given workability of the optimal conditions for the hydration of the binder, it is necessary to use concrete mixtures with a high moisture content. However, in order to optimize the properties of concrete, to obtain ultimate strength, it is necessary to remove excess mixing water. The physical and mechanical properties of concrete will be in direct proportion to the amount of residual mixing water [1, 2]. If the concrete mixture is compacted by squeezing out a certain amount of free water, then the strength of concrete will be in inverse functional dependence on the residual W/C, since it is this that determines the porosity of cement stone and concrete. Therefore, in order to obtain concrete of extremely high strength and density, the pre-laid mixture must be additionally compacted under conditions of maximum concrete dehydration. With complete mold tightness, the mixture is compacted only due to a slight decrease in the volume of entrained air, i.e. the effect of vibro-shock-peristaltic compaction will be insignificant. This effect will increase with an increase in the water permeability of the mold walls, since in the presence of filtration holes, free water under the action of the difference in pressure inside the mold and outside it will begin to move towards the filtration holes [3].

1. Introductions

The process of squeezing the liquid and gaseous phase out of the molded material is the main process of structure formation of concrete properties. The reason for the removal of liquid and gas from concrete is the pressure drop across the wall thickness of the pipe being formed towards the perforated surface of the formwork [1-3]. Removal of liquid and gaseous media of a concrete mixture is an exfiltration process, i.e. removal of liquid and gaseous fluids from the material into the environment [4 – 6].

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 [7-11]. 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 [12 – 17].

Therefore, in order 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 bond forces of water with cement particles and to move it in the system [23]. 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 magnitude of the normal pressure.

2. Methods

The efficiency of compaction of a concrete mixture by vibro-shock-peristaltic pressing depends on its composition, on the filtration capacity of the walls of the forms, inside which the compaction is carried out, as well as the level of the compaction mode. As a result of the analysis of modern technologies, it was found that physical modification is possible by removing excess mixing water added to the concrete mixture to give it the necessary fluidity and workability.

In the process of removing excess water and entrained air, the cement particles will begin to approach each other, which, in turn, will lead to the convergence of the grains of coarse and fine aggregates. The normal pressure transferred to the water and causing it to be removed will facilitate the approach of the particles until the external pressure is completely absorbed by the dispersed phase.

Removing free water during the consolidation process increases the use of the potential properties of the cement to increase the density, water resistance and strength of the concrete. Currently, in the technology of complex elements, several methods are known for dewatering a concrete mixture: centrifugation, pressing, evacuation, vibrocompression, etc. One of the most effective should be considered the method of vibro-shock-peristaltic pressing, since this can create the necessary conditions for maximum dehydration of the concrete mixture and concrete.

3. Results and discussion

For a quantitative description of the volumes of the squeezed liquid, we use the classical laws of filtration, taking into account the experimental data on the gas content of the liquid with air bubbles. Let us assume that the porosity of the concrete mixture is equal to the volume of liquid, in relation to the volume of all concrete is equal to

$$m_{ж} = A \cdot m_{б} \quad (1)$$

where $m_{ж}$ – is the porosity of the medium, equal to the volume of the liquid-gas phase;
A – coefficient characterizing the degree of saturation of concrete with the liquid phase;
$m_{б}$ – mass of concrete mix.

Since the liquid contains a gas phase, part of the pore volume is occupied by atmospheric air. Therefore, the ratio of the volume. occupied by air, to the entire volume of concrete mixture is equal

$$m_{в} = (1 - \mathrm{A}) \cdot m_{б} \quad (2)$$

Here $m_{в}$ plays the role of air-related porosity. Let us denote by $\vartheta_{в}$ the rate of extraction of air and excess mixing water from the concrete mixture. Then the projections of the air velocity on the walls of the conical filtration hole are determined by [7, 8]

$$\vartheta_{вx} = -\frac{\mathrm{C_в}}{\mu_{в}} \cdot \frac{\partial \mathrm{p}}{\partial \mathrm{x}}; \quad \vartheta_{вy} = -\frac{\mathrm{C_в}}{\mu_{в}} \cdot \frac{\partial \mathrm{p}}{\partial \mathrm{y}}; \quad \vartheta_{вz} = -\frac{\mathrm{C_в}}{\mu_{в}} \cdot \frac{\partial \mathrm{p}}{\partial \mathrm{z}}; \quad (3)$$

where $\mathrm{C_в}$ – is the coefficient of permeability of the concrete mixture by air;
$\mu_{в}$ – air viscosity.

By analogous equations we express the projections of the speed of extraction of excess mixing water:

$$\vartheta_{\text{ивх}} = -\frac{\text{С}_{\text{вр}}}{\mu_{\text{вр}}} \cdot \frac{\partial \text{p}}{\partial \text{x}}; \quad \vartheta_{\text{иву}} = -\frac{\text{С}_{\text{вр}}}{\mu_{\text{вр}}} \cdot \frac{\partial \text{p}}{\partial \text{y}}; \quad \vartheta_{\text{ив}z} = -\frac{\text{С}_{\text{вр}}}{\mu_{\text{вр}}} \cdot \frac{\partial \text{p}}{\partial \text{z}}; \quad (4)$$

where $\text{С}_{\text{вр}}$ – is the coefficient of permeability of the concrete mixture to water (aqueous solution) *;
$\mu_{\text{вр}}$ – the viscosity of the aqueous solution of the mixture.
In addition to the above equations, we also use the equation of continuity of the fluid flow through the capillary channel directed to the filtration hole. For an elementary column of concrete mixture with a volume of dx · dy · dz, the mass of the flowing liquid during time dt is:

$$-\left[\frac{\partial(\text{р}_{\text{ж}} \cdot \vartheta_{\text{ж}x})}{\partial x} + \frac{\partial(\text{р}_{\text{ж}} \cdot \vartheta_{\text{ж}y})}{\partial y} + \frac{\partial(\text{р}_{\text{ж}} \cdot \vartheta_{\text{ж}z})}{\partial z}\right] \cdot dx \cdot dy \cdot dz \cdot dt \quad (5)$$

Due to the fact that the mass of the liquid changes due to the change in saturation A, the increment $m_{\text{ж}}$ during the time dt is equal to:

$$-\text{р}_{\text{ж}} \cdot \frac{\partial m_{\text{ж}}}{\partial t} \cdot dx \cdot dy \cdot dz \cdot dt = -\text{р}_{\text{ж}} \cdot m \cdot \frac{\partial A}{\partial t} \cdot dx \cdot dy \cdot dz \cdot dt \quad (6)$$

Equating equations (5) and (6), after reduction, we obtain the continuity equation for the flow of squeezed fluid

$$\frac{\partial \vartheta_{\text{ж}x}}{\partial x} + \frac{\partial \vartheta_{\text{ж}y}}{\partial y} + \frac{\partial \vartheta_{\text{ж}z}}{\partial z} + m\frac{\partial \text{A}}{\partial t} = 0 \quad (7)$$

* Note: when determining the permeability or viscosity of an aqueous solution of a concrete mixture, it is necessary to take into account the clinker minerals of cement dissolved in water.
In the case of steady filtration, this equation will be simplified:

$$\frac{\partial \vartheta_{\text{ж}x}}{\partial x} + \frac{\partial \vartheta_{\text{ж}y}}{\partial y} + \frac{\partial \vartheta_{\text{ж}z}}{\partial z} = 0 \quad (8)$$

Now we will compose the air balance equation, assuming the process is isothermal, as a result of which the air density at the applied pressure is:

$$\rho_{\text{в}} = a \cdot p \quad (9)$$

In addition, we take into account the part of the air dissolved in the volume of the liquid, which is proportional to the pressure:

$$M = s \cdot p \quad (10)$$

where a and s – are constants.
p – pressure.
Let us compose the continuity equation for the air flow similar to the continuity equation for liquid (7)

$$p_{\text{в}} \cdot \vartheta_{\text{в}x} \cdot dy \cdot dz \cdot dt = a \cdot p \cdot \vartheta_{\text{в}x} \cdot dy \cdot dz \cdot dt \quad (11)$$

It is also necessary to take into account that part of the air dissolved in the squeezed water moves with a speed $\vartheta_{\text{ив}}$
This air mass, according to (10), is equal to:

$$s \cdot p \cdot \vartheta_{\text{ив}x} \cdot dy \cdot dz \cdot dt$$

Thus, the mass of the squeezed water-air mixture is equal to:

$$-\left\{\frac{\partial}{\partial x}[(a \cdot \vartheta_{\text{в}x} + s \cdot \vartheta_{\text{ив}x}) \cdot \rho] + \frac{\partial}{\partial y}\left[\left(a \cdot \vartheta_{\text{в}y} + s \cdot \vartheta_{\text{ив}y}\right) \cdot \rho\right] + \right.$$

$$\left. + \frac{\partial}{\partial z}[(a \cdot \vartheta_{\text{в}z} + s \cdot \vartheta_{\text{ив}z}) \cdot \rho]\right\} \cdot dx \cdot dy \cdot dz \cdot dt \quad (12)$$

The mass of air contained in the selected elementary volume of the concrete mixture is composed of two parts. Part of the air is dissolved in water A · m · dx · dy · dz and is equal according to (10) s · ρ · A · m · dx · dy · dz
The other part of the air in the water in the form of bubbles is determined by the expression

$$p_{\text{в}} \cdot m_{\text{в}} \cdot dx \cdot dy \cdot dz = a \cdot p(1 - A) \cdot m \cdot dx \cdot dy \cdot dz \quad (13)$$

where $p_{\text{в}}$ and $m_{\text{в}}$ are determined from (2) and (9).
The total mass of air in the allocated volume of the concrete mixture

$$[s \cdot p \cdot A \cdot m + a \cdot p \cdot (1 - A) \cdot m] \cdot dx \cdot dy \cdot dt \quad (14)$$

in time dt will receive an increment

$$-\frac{\partial}{\partial t}[s \cdot p \cdot A \cdot m + a \cdot p \cdot (1 - A) \cdot m] \cdot dx \cdot dy \cdot dt \quad (15)$$

Equating expression (15) to the volume of the squeezed air mass, we obtain, after reduction, the following air balance equation

$$\frac{\partial}{\partial x}[(a\cdot\vartheta_{\text{в}x}+\ s\cdot\vartheta_{\text{ив}x})\cdot\rho]+\ \frac{\partial}{\partial y}\left[\left(a\cdot\vartheta_{\text{в}y}+\ s\cdot\vartheta_{\text{ив}y}\right)\cdot\rho\right]+$$
$$+\frac{\partial}{\partial z}[(a\cdot\vartheta_{\text{в}z}+\ s\cdot\vartheta_{\text{ив}z})\cdot\rho]+\frac{\partial}{\partial t}[s\cdot p\cdot A\cdot m+a\cdot p(1-A)\cdot m]=\ 0\quad(16)$$

Obviously, for the case of steady filtration, this equation takes the form:

$$\frac{\partial}{\partial x}[(a\cdot\vartheta_{\text{в}x}+\ s\cdot\vartheta_{\text{ив}x})\cdot\rho]+\ \frac{\partial}{\partial y}\left[\left(a\cdot\vartheta_{\text{в}y}+\ s\cdot\vartheta_{\text{ив}y}\right)\cdot\rho\right]+$$
$$+\frac{\partial}{\partial z}[(a\cdot\vartheta_{\text{в}z}+\ s\cdot\vartheta_{\text{ив}z})\cdot\rho]=0\quad(17)$$

Thus, six equations were obtained for the extraction of the water-air mixture from the concrete being compacted.
These equations characterize the unsteady mode of extraction of the liquid-gas phase.
Let us extend the obtained dependences to the case of steady filtration of a carbonated liquid. Let us transform the obtained equations, following the conclusions of S A Khristianovich [9, 22].
Comparing equations (3) and (4), we express the speed of air movement through the speed of water extraction:

$$\vartheta_{\text{в}x}=\frac{\text{С}_{\text{в}}\cdot\mu_{\text{вр}}}{\mu_{\text{в}}\cdot\text{С}_{\text{вр}}}\cdot\ \vartheta_{\text{ив}x};\ \ \vartheta_{\text{в}y}=\frac{\text{С}_{\text{в}}\cdot\mu_{\text{вр}}}{\mu_{\text{в}}\cdot\text{С}_{\text{вр}}}\cdot\ \vartheta_{\text{ив}y};\ \ \vartheta_{\text{в}z}=\frac{\text{С}_{\text{в}}\cdot\mu_{\text{вр}}}{\mu_{\text{в}}\cdot\text{С}_{\text{вр}}}\cdot\ \vartheta_{\text{ив}z}\quad(18)$$

Then, using equations (17) and (18), we express the projections of the air velocity through the projection of the rates of water extraction:

$$\frac{\partial}{\partial x}[(a\cdot\frac{\text{С}_{\text{в}}\cdot\mu_{\text{вр}}}{\mu_{\text{в}}\cdot\text{С}_{\text{вр}}}\cdot\vartheta_{\text{ив}x}+s\cdot\vartheta_{\text{ив}x})\cdot p]+\frac{\partial}{\partial y}[(a\cdot\frac{\text{С}_{\text{в}}\cdot\mu_{\text{вр}}}{\mu_{\text{в}}\cdot\text{С}_{\text{вр}}}\cdot\vartheta_{\text{ив}y}+s\cdot\vartheta_{\text{ив}y})\cdot p]+$$
$$+\frac{\partial}{\partial z}[(a\cdot\frac{\text{С}_{\text{в}}\cdot\mu_{\text{вр}}}{\mu_{\text{в}}\cdot\text{С}_{\text{вр}}}\cdot\vartheta_{\text{ив}z}+s\cdot\vartheta_{\text{ив}z})\cdot p]=0\quad(19)$$

Let us assume that the ratio of the permeability coefficients $\text{С}_{\text{в}}$ and $\text{С}_{\text{вр}}$, which are functions of water saturation of the threshold space, is also a function of their ratio

$$G=\text{С}_{\text{р}}/\text{С}_{\text{вр}}$$

Introducing these designations into the last equation, and then dividing this equation by $a=\mu_{\text{вр}}/\mu_{\text{в}}$ and, denoting $\alpha=s\cdot\mu_{\text{в}}/a\cdot\mu_{\text{вр}}$ in it, we get:

$$\frac{\partial}{\partial x}[(\alpha\cdot p+\ G\cdot p)\cdot\vartheta_{\text{ив}x}]+\frac{\partial}{\partial y}[(\alpha\cdot p+\ G\cdot p)\cdot\vartheta_{\text{ив}y}]+\frac{\partial}{\partial z}[(\alpha\cdot p+\ G\cdot p)\cdot\vartheta_{\text{ив}z}]=0\quad(20)$$

We rewrite the equation as

$$\vartheta_{\text{ив}x}\cdot\frac{\partial}{\partial x}(\alpha\cdot p+\ G\cdot p)+(\alpha\cdot p+\ G\cdot p)\cdot\frac{\partial\vartheta_{\text{ив}x}}{\partial x}+\vartheta_{\text{ив}y}\cdot\frac{\partial}{\partial y}(\alpha\cdot p+\ G\cdot p)+$$
$$+(\alpha\cdot p+\ G\cdot p)\cdot\frac{\partial\vartheta_{\text{ив}y}}{\partial y}+\vartheta_{\text{ив}z}\cdot\frac{\partial}{\partial z}(\alpha\cdot p+\ G\cdot p)+(\alpha\cdot p+\ G\cdot p)\cdot\frac{\partial\vartheta_{\text{ив}z}}{\partial z}=0\quad(21)$$

or

$$\vartheta_{\text{ив}x}\cdot\frac{\partial}{\partial x}(\alpha\cdot p+\ G\cdot p)+\vartheta_{\text{ив}y}\cdot\frac{\partial}{\partial y}(\alpha\cdot p+\ G\cdot p)+\vartheta_{\text{ив}z}\cdot\frac{\partial}{\partial z}(\alpha\cdot p+\ G\cdot p)+$$
$$+(\alpha\cdot p+\ G\cdot p)\cdot\left(\frac{\partial\vartheta_{\text{ив}x}}{\partial x}+\frac{\partial\vartheta_{\text{ив}y}}{\partial y}+\frac{\partial\vartheta_{\text{ив}z}}{\partial z}\right)=0\quad(22)$$

Using equation (8), we come to the conclusion that the three term in parentheses is equal to zero, then

$$\cdot\frac{\partial}{\partial x}(\alpha\cdot p+\ G\cdot p)+\vartheta_{\text{ив}y}\cdot\frac{\partial}{\partial y}(\alpha\cdot p+\ G\cdot p)+\vartheta_{\text{ив}z}\cdot\frac{\partial}{\partial z}(\alpha\cdot p+\ G\cdot p)=0\quad(23)$$

From the course of hydrodynamics, the differential equations of fluid flow lines are known:

$$\partial x/\vartheta_x=\partial y/\vartheta_y=\partial z/\vartheta_z$$

Therefore, in equation (23), the components of the water extraction speed $\vartheta_{\text{ив}x}, \vartheta_{\text{ив}y}, \vartheta_{\text{ив}z}$can be replaced with proportional quantities dx, dy, and dz. Then we get

$$(\alpha\cdot p+\ G\cdot p)\cdot dx+\frac{\partial}{\partial y}(\alpha\cdot p+\ G\cdot p)\cdot dy+\frac{\partial}{\partial z}(\alpha\cdot p+\ G\cdot p)\cdot dz=0\quad(24)$$

In this equation, the differential of the function $(\alpha\cdot p+\ G\cdot p)$ in the direction of the streamline is zero. Therefore, along the current line

$$\alpha \cdot p + G \cdot p = p(a + G) = const = \varepsilon \quad (25)$$

From a physical point of view, the parameter ε is the conditional peristaltic peristaltic pressure at which the permeability of the hyperelastic concrete mixture by air $C_в$ and water (aqueous solution) $C_{вр}$ are equal to each other ($C_в/C_{вр}$= 1).

This parameter was found according to the experimental data of the study of the permeability of a hypersolid concrete mixture (Fig. 1).

Change in the permeability of a hypersolid concrete mixture by air and liquid phase

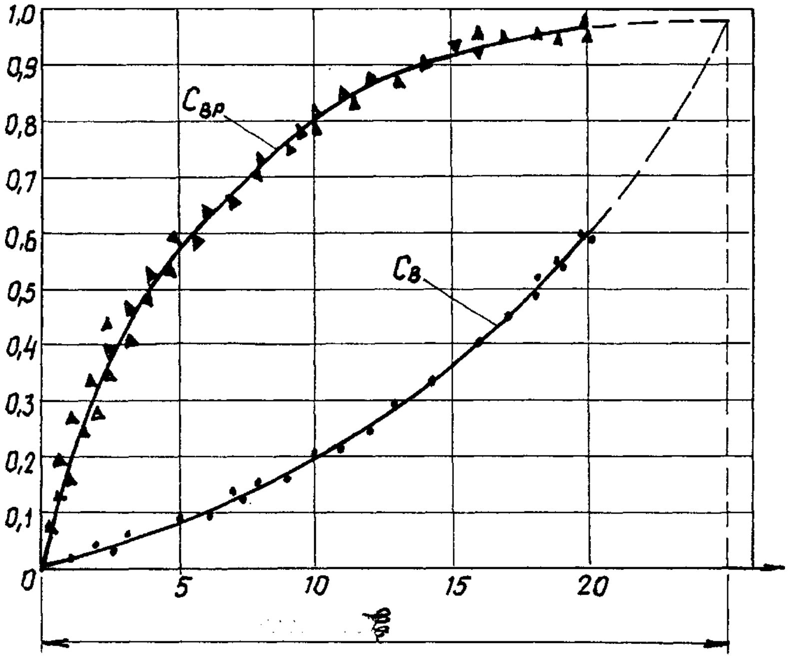

Figure 1.

$C_{вр}$ − coefficient of permeability of concrete mix with water (water solution);

$C_в$ − coefficient of permeability of concrete mix to air;

ε − is the conditional pressure characterizing the equalization of the air and liquid permeability of the concrete mixture.

The experimental data obtained make it possible to determine the volumes of the water-air phase squeezed out at a given pressure, as well as to find the conditional pressure ε, which is characteristic of equalizing the gas and liquid permeability of the concrete mixture.

These data also make it possible to construct a function *H* depending on the relative pressure $\bar{p} = \bar{p}/\varepsilon$

From dependence (25) we obtain

$$\frac{p}{\varepsilon} = \bar{p} = \frac{1}{\alpha + G}$$

The resulting dimensionless value $p = p/\varepsilon$ will be called the coefficient of peristaltic shock pressure causing the extraction of the water-air phase from the concrete mixture.

Then, in equations (4), we replace the pressure p by $\bar{p}$ and obtain

$$\vartheta_{ивx} = -\frac{C_{вр}}{\mu_{вр}} \cdot \varepsilon \cdot \frac{\partial \bar{p}}{\partial x}; \quad \vartheta_{ивy} = -\frac{C_{вр}}{\mu_{вр}} \cdot \varepsilon \cdot \frac{\partial \bar{p}}{\partial y}; \quad \vartheta_{ивz} = -\frac{C_{вр}}{\mu_{вр}} \cdot \varepsilon \cdot \frac{\partial \bar{p}}{\partial z}; \quad (26)$$

Introducing the function *H*, which represents the integral sum of the dimensionless pressure $\bar{p}$ and the permeability of the concrete mixture squeezed out with an aqueous solution, in the range from 0 to the final value $\bar{p}$. Then the function

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$$H = \int_0^{\bar{p}} \text{С}_{\text{вр}} \cdot d\bar{p}$$

Therefore, instead of Eq. (26), we have

$$\vartheta_{\text{ив}x} = -\frac{\varepsilon}{\mu_{\text{вр}}} \cdot \frac{\partial H}{\partial x}; \quad \vartheta_{\text{ив}y} = -\frac{\varepsilon}{\mu_{\text{вр}}} \cdot \frac{\partial H}{\partial y}; \quad \vartheta_{\text{ив}z} = -\frac{\varepsilon}{\mu_{\text{вр}}} \cdot \frac{\partial H}{\partial z} \quad (27)$$

We found this function *H* from the experimental curve of the relationship between $\text{С}_{\text{вр}}$ and $\bar{p}$.
Since the ratio x/mвр in equations (27) can be taken constant, we come to an important conclusion. The equations for the extraction of the water-air phase are similar to the equations for the filtration of an incompressible liquid.
Then, substituting equation (27) into the continuity equation, we obtain that the function *H* satisfies the Laplace equation:

$$\frac{\partial^2 H}{\partial x^2} + \frac{\partial^2 H}{\partial y^2} + \frac{\partial^2 H}{\partial z^2} = 0 \quad (28)$$

Thus, we have reduced the problem of squeezing the water-air phase to the problem of filtration of a homogeneous incompressible liquid. This conclusion is important in the sense that the methodology for solving problems of filtration of a homogeneous incompressible fluid has now been developed in sufficient detail.
The use of the obtained dependencies is possible with the experimental determination of the permeability coefficients of the hypersolid concrete mixture.
Figure 2a shows the curves of changes in the integral permeability coefficients C of the concrete mixture and sand [10, 18, 19].
In Fig. 2b on the abscissa, expressed as a percentage, the saturation of the pores with the liquid and the saturation with the water-air mixture, on the ordinate - the ratio $\text{Св}/\text{C}$ and $\text{Свр}/\text{C}$, where $\text{C} -$ is the integral coefficient of permeability of the compacted concrete
In the case of a decrease in the initial W / C of the concrete mixture, when the liquid occupies a small part of the pores (the value of A is small), the ratio $\text{Св}/\text{C} \to 1$, and the ratio $\text{Свр} \to 0$. In real concrete mixtures (W / C = 0.35 ... 0.50), the ratio $\text{Свр}/\text{C}$ increases rapidly, remaining a linear function of A.

Curves of changes in the permeability of a concrete mixture depending on the degree of saturation of its liquid-air phase

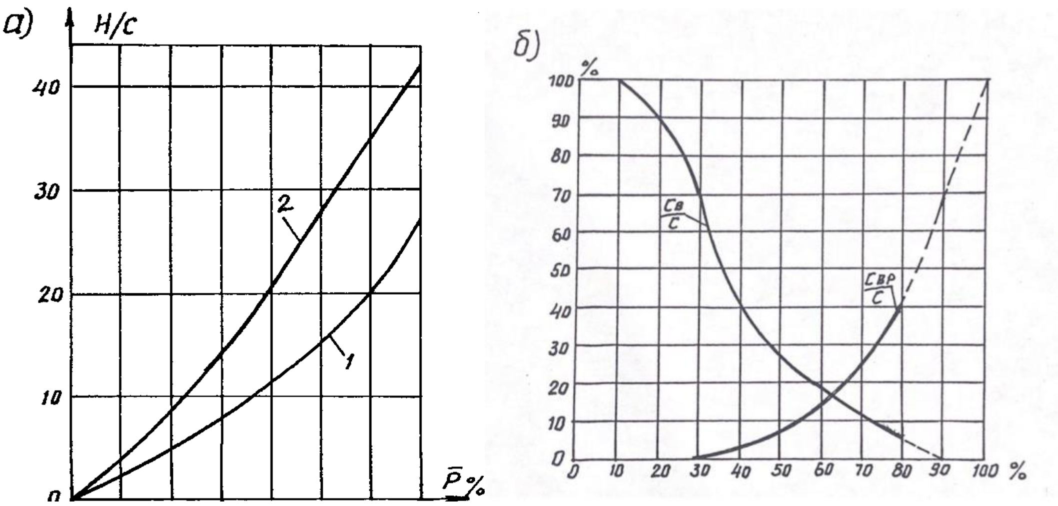

Figure 2.
a - integral permeability; b - partial permeability of concrete.
1 - concrete mix; 2 - fine-grained sand.

4. Conclusions

1. Analysis of experimental data leads to the conclusion that the braking effect of water on air is much less than the braking effect of air on water. However, under conditions of peristaltic peristaltic compaction, almost complete removal of the gas phase of concrete occurs.
2. Equations were obtained on the regularities of the movement of the water-air phase depending on the applied pressures and 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 laws of filtration, taking into account the degree of gas contamination of the liquid with air bubbles and the final intermittent mode of squeezing water.

References

[1] Akhverdov I N 1961 *High strength concrete* (Moscow: Stroyizdat) p 163
[2] Akhverdov I N 1981 *Fundamentals of the physics of concrete* (Moscow: Stroyizdat) p 464
[3] B. Khasanov and T. Mirzaev, “Production of extra-strong concrete axisymmetric products,” in E3S Web of Conferences, 2019, vol. 97, doi: 10.1051 / e3sconf / 20199706011.
[4] Chekhovsky E G 1970 *Laboratory work on soil science and soil mechanics* (Moscow: Stroyizdat) p 97
[5] Berg O Ya 1974 *Physical foundations of the theory of strength of concrete and reinforced concrete* (Moscow: Stroyizdat) p 95
[6] Berg O Ya, Pisanko G N and Khromets Yu P 1971 *High strength concrete* (Moscow: Stroyizdat) p 208
[7] Aravrn V I 1940 *Filtration in anisatropic-permeable soil* // Proceedings of the Leningrad Institute, No. 1 p 125
[8] Kuzmin V N, Arkhipkin A A and Lavrinev P G 1983 *Manufacturing of lattices for covering sewer canals of livestock farms* // Concrete and reinforced concrete. N3. p 24-25
[9] Cherkasov I I 1963 *Results of mass tests of high-strength concrete pipes* // Tr. NIYAVVS.. no. 28. S. 38-45.
[10] Efros A L 1982 *Physics and geometry of disorder* (Moscow: Nauka) p 176
[11] Bazarov, D., Norkulov, B., Vokhidov, O., Uljaev, F., Ishankulov, Z. Two-dimensional flow movement in the area of protective regulatory structures. IOP Conference Series: Materials Science and Engineering. 2020. 890(1). DOI:10.1088/1757-899X/890/1/012162.
[12] Bazarov, D., Uralov, B., Matyakubov, B., Vokhidov, O. The effects of morphometric elements of the channel on hydraulic resistance of machine channels of pumping stations.Mater.Sci. Eng. 2020.869(072014). DOI:10.1088/1757-899X/869/7/072015.
[13] Bazarov, D., Uralov, B., Matyakubov, B., Vokhidov, O., Uljaev, F., Akhmadi, M. The effects of morphometric elements of the channel on hydraulic resistance of machine channels of pumping stations. IOP Conference Series: Materials Science and Engineering. 2020. 869(7). DOI:10.1088/1757-899X/869/7/072015.
[14] Obidov, B., Vokhidov, O., Shodiev, B., Ashirov, B., Sapaeva, M. Hydrodynamic loads on a water drain with cavitation quenchers. IOP Conference Series: Materials Science and Engineering. 2020. 883. Pp. 012011. DOI:10.1088/1757-899x/883/1/012011
[15] Krutov, A., Bazarov, D., Norkulov, B., Obidov, B., Nazarov, B. Experience of employment of computational models for water quality modelling.E3S Web of Conferences. 2019. 97. DOI:10.1051/e3sconf/20199705030.
[16] Korniyenko, S. V., Vatin, N.I., Gorshkov, A.S. Thermophysical field testing of residential buildings made of autoclaved aerated concrete blocks. Magazine of Civil Engineering. 2016. 64(4). Pp. 10–25. DOI:10.5862/MCE.64.2.
[17] Korsun, V., Vatin, N., Franchi, A., Korsun, A., Crespi, P., Mashtaler, S. The strength and strain of high-strength concrete elements with confinement and steel fiber reinforcement including the conditions of the effect of elevated temperatures. Procedia Engineering. 2015. 117(1). Pp. 970–

979. DOI:10.1016/j.proeng.2015.08.192.
[18] Bazarov, D.R., Vokhidov, O.F., Lutsenko, L.A., Sultanov, S. Restrictions Applied When Solving One-Dimensional Hydrodynamic Equations. Proceedings of EECE 2019, Lecture Notes in Civil Engineering 70. 2019. Pp. 299–305. DOI:10.1007/978-3-030-42351-3_26.
[19] Bazarov, D., Markova, I., Norkulov, B., Isabaev, K., Sapaeva, M. Operational efficiency of water damless intake. IOP Conference Series: Materials Science and Engineering. 2020. 869(7). DOI:10.1088/1757-899X/869/7/072051.
[20] Bazarov, D., Uralov, B., Matyakubov, B., Vokhidov, O., Xidirov, S., Matyakubov, B. River channel deformations in the area of damless water intake River channel deformations in the area of damless water intake. 2020. DOI:10.1088/1757-899X/869/7/072014.
[21] Obidov, B., Choriev, R., Vokhidov, O., Rajabov, M. Experimental studies of horizontal flow effects in the presence of cavitation on erosion – free dampers. IOP Conference Series: Materials Science and Engineering. 2020. 883. Pp. 012051. DOI:10.1088/1757-899x/883/1/012051.
[22] Bazarov, D.R., Mavlyanova, D.A. Numerical studies of long-wave processes in the reaches of hydrosystems and reservoirs. Magazine of Civil Engineering. 2019. 87(3). Pp. 123–135. DOI:10.18720/MCE.87.10.
[23] Kattakulov, F., Muslimov, T., Khusainov, A., Sharopov, S., Vokhidov, O., Sultanov, S. Water resource saving in irrigation networks through improving the efficiency of reinforced concrete coatings. IOP Conference Series: Materials Science and Engineering. 2020. 883. Pp. 012053. DOI:10.1088/1757-899x/883/1/012053.