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Discrete and analog evaluation of the capillary-pore space of foam concrete in eco-friendly production

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Relevance. The aim of the study was to identify and study the analytical dependencies of technological parameters and aspects of the preparation of foam concrete depending on the concentration of foaming agents at various points in the formation of the capillary-porous structure. It is important to evaluate the possibility of using them to obtain environmentally friendly performance properties of "poro-concrete", as it is often used in the construction of agricultural facilities. In the course of optical studies, the carbon footprint in the components of the composite materials under study was tracked. The distribution of pore sizes across auto-modal clusters is determined. Dispersion analysis of surface sections of foam concrete was carried out. Based on the discrete analysis of the concrete structure, analog analytical dependences were obtained linking the studied properties of foam concrete with the parameters of density, eco-friendly, porosity, and other parameters. In the construction of agricultural facilities these properties are particularly important.

1 Introduction

The porosity of foam concrete, as a composite material of a special kind, is due to the presence of pores in the cement stone [1-3], pores in the filler itself, pores of the contact zone between the cement stone and the filler, as well as air extraction processes caused by the introduction of foam and significantly affects the environmental aspects of the production technology of foam concrete [4-7].

2 Research methodology

Pores in the hardening cement stone of expanded clay concrete are formed by evaporating water, and the nature of these pores is predetermined by the forms of connection of moisture with the material. In the works of A.V. Lykov, the classification of the forms of moisture connection with the material is given. According to this classification, the forms of communication are divided into chemical, physico-chemical and physico-mechanical. Chemical bonding is the strongest of all forms of bonding. It is broken only when the

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material is calcined. The physico-chemical bond in concrete manifests itself primarily as a moisture bond in the hydrate shells of cement gel particles [8].

The monomolecular layer of water around the cement gel particles is under high pressure caused by a molecular force field. The following layers of water are held in hydrate shells less firmly. The thickness of the polyadsorption layer is not the same. Studies carried out on the thermograph of Kazansky M.F. have shown that the thickness of this layer is about two diameters of water molecules. According to the research of B.V. Deryagin [9], the polyadsorption layer has dimensions up to 1.5×10-9 cm, and since the distance between the gel particles is 15-40 A, it can be assumed that the water in the hydrate shells of the gel particles is bound by an adsorption bond. When it evaporates, so-called "gel pores" are formed.

The water located between the aggregates of gel particles has a physico-mechanical connection with the material. This water is called "capillary", because it is held in the material by capillary pressure. When this water evaporates, "capillary pores" are formed, the probable size of which is from 5 × 10-7 cm to 50 × 10-4 cm.

In addition to the above-mentioned pores, so-called "contractional pores" may exist in cement stone. They arise due to the fact that the absolute volume of the system formed during the hydration of cement is always less than the absolute volume of the original "cement-water" system, i.e., contractional (chemical) shrinkage occurs during the hydration of cement. The contraction does not lead to a decrease in the total volume of cement stone, as a result of which there are "contractional pores" that occupy from 4 to 8% of the volume of cement stone.

It is convenient to differentiate pores by their origin, because this makes it possible to use the calculation method to determine the volumes of individual groups of pores. The most detailed classification of pores by origin was proposed by N.A. Moshansky [10]. But, according to this classification, it is difficult to establish a connection between the properties and the nature of porosity, because the origin of pores does not always determine its effect on durability. For example, pores of the same group (dead-end and through capillaries) have a different effect on the durability of concrete, and pores of different origin - contractional and microcapillaries - can be equally passive and dangerous during alternate freezing and thawing of concrete.

3 Results and discussion

Experimental methods for differentiating the porosity of concrete have become widespread. The determination of differential porosity by the Bechholz-Dumansky method is based on the release of pores filled with liquid, gas under pressure exceeding capillary forces. With increasing pressure, smaller pores will open. In the laboratory of VNIIG named after V.V. Vedeneev, a method has been developed for determining the size of pores in cement stone and in building mortars by forcing air through a cylindrical o6 tile with increasing pressure. This method determines the pore size from 1×10-4 to 0.05 cm.

The devices developed by R.E. Briling G.P. Verbetsky, Stal and Jones are based on the principle of determining porosity by pumping air from the pores of the sample.

A.S. Berkman and I.T. Melnikova used the method of mercury porometry to determine the porosity of wall materials. The method of mercury porometry was also used to study the porosity of cement stone [11, 12].

All the above-mentioned methods of differentiating the porosity of concrete can only be used with large assumptions to analyze the structural porosity of foam concrete as composite materials.

We will assume that the volume of pores Vall in foam concrete is composed of the volume of pores in cement stone Vc.s, the volume of air cells Vair. formed by viscous foam, and the pores inside the grains of the filler Vfiller. The volume of pores in a porous cement stone without filler is composed of the volumes of air cells Vp.c.s./ air., capillary pores "P1", gel pores "P3" and contractional pores "P2".

In a foam-porous cement stone, small, almost spherical cavities are obtained, surrounded by hydrated cement. In this case, the capillary pores of the interstitial partitions do not have a large extent, they are interrupted by air cells. And since the suction rate is inversely proportional to the diameter of the capillaries, the intensity of capillary suction decreases. Thus, air cells can be considered as closed spherical air bubbles of various diameters, which have a special effect on the strength, capillary suction, water absorption, durability and other properties of foam concrete [13, 14].

So, for example, as a result of the pressure that occurs in the capillaries when water freezes, its excess is squeezed into these kind of spare "tanks", each air cell plays the role of a kind of "compensator" for the pressure of freezing water. The volume of pores in a porous cement stone without filler is composed of the volumes of air cells V p.c.s../ air., capillary pores, gel pores and contractional pores.

To calculate the volume of air, capillary, contractional, gel pores and total Vp.c.s../ all.. the porosity of cement stone, depending on the "W/C" and the degree of hydration of cement α, the following formulas are used (the volume of pores is given in fractions of the volume of foam concrete):

$$VV_{\text{p.c.s./ air.}} = 1 - VC_c + BB_S \quad (1)$$

or

$$VV_{\text{p.c.s./ air..}} = 1 - \alpha_{y.c.} \cdot \alpha_{c.d} \quad (2)$$

$$P_1 = \text{В} + \text{В}_{\text{ц}} - 0{,}5 \cdot \alpha \cdot C \quad (3)$$

$$P_2 = 0{,}9 \cdot \alpha \cdot C \quad (4)$$

$$P_3 = 0{,}2 \cdot \alpha \cdot C \quad (5)$$

$$V_{\text{p.c.s./ air.}} = 1 - VC_c + 0{,}21 \cdot \alpha \cdot C \quad (6)$$

where,

Vc =1/ρc is the specific volume of cement at its density of ρc in (m3/t). If ρc = 3.1, then Vc = 0.322, while the consumption of cement "C" should be expressed in t/m3, and the consumption of water "W" and foaming agent "Bf" - in fractions of the volume of 1 m3 of concrete; αp.s.- the volume mass of the porous cement dough, kg/m3, αc.d.– the volume mass of the cement dough, determined by the formula:

$$\alpha_{c.d.} = \frac{\frac{1+B+B_f}{C}}{\frac{B_C+B+B_f}{C}} \quad (7)$$

The above formulas make it possible to calculate the average porosity values needed when considering durability. They make it possible to separate the volume of air cells from the volume of the pores of the cement stone itself, as well as to determine the capillary, contractional and gel porosity of the interstitial partitions.

An important factor in reducing the total and capillary porosity of cement stone, i.e. improving the quality of the material of the interstitial partitions (at low values of W/C) is the completeness of cement hydration. In some cases, with an increase in W/C, i.e. the capillary porosity of the interstitial partitions, it is possible to obtain an effective material due to the formation of small evenly distributed air pores.

The introduction of expanded clay gravel into the porous cement dough changes the pattern of pore distribution in foam concrete. The ability of a porous aggregate to absorb water allows us to consider a large porous aggregate as a component that regulates the structure of a porous cementing agent and regulates the properties of the composite.

The following formulas can be used to estimate the relative volume of pores of various types in porous, sandless lightweight concretes (porosity is measured in fractions of the volume of concrete):

$$\text{В}_{all} = \text{В}_{c.s.} + \text{В}_{air.} + \text{В}_{filler.} = 1 - \frac{\alpha_{c/o}}{\rho_c} \tag{8}$$

$$\rho_{c.s.} = (B + \text{В}_f)_{tru} - 0{,}5 \cdot \alpha_c \tag{9}$$

$$P_1 = (B + \text{В}_f)_{tru} - 0{,}5 \cdot \alpha_c \tag{10}$$

$$V_{air} = 1 - [VC_c + \left(B + \text{В}_f\right)_{tru} + \frac{m_{\text{к}}}{\alpha_{\text{к/o}}} \tag{11}$$

$$V_{filler} = 1 - [1 - \frac{\alpha_{\text{к/o}}}{\rho_{\text{к}}}] \cdot V_{\text{к}} \tag{12}$$

where,

Вс, Вк - respectively the density of porous lightweight concrete and expanded clay gravel (t/m3); αb/o, αk/o - average density of porous lightweight concrete and expanded clay gravel in a piece (t/m3); (B + Bf)tru is the total consumption of water “B” and foaming agent “Bp” minus the water absorbed by the porous aggregate, a fraction of the volume of 1 m3 of concrete; mk - mass of expanded clay gravel (t/m3); Vk is the volume of expanded clay gravel, a fraction of the volume of 1 m3 of concrete.

When deriving the formulas, it was taken into account that due to the suction of part of the water by a porous aggregate from a porous cementing agent, the true water-cement ratio in hardened concrete will always be less than the water-cement ratio at the time of preparation of the concrete mixture. This entails a change in the volume of the pores of the cement stone. Therefore, to calculate the porosity of the binder (cement stone) in lightweight concrete, it is necessary to know the true water-cement ratio and the content of bound water.

4 Conclusions

Currently, information modeling technologies are becoming the heart of the main Estimates of the pore volumes of foams dynamically changing in the process of structure formation of the capillary-pore structure of expanded clay foam concrete using "Plato Bodies" by optical-analytical methods are made.

Based on the conducted studies and processing of the results obtained, it was found that the most likely determining bubble size of gas emulsions and foams increases with a decrease in the concentration of surfactants. The amount of "work for the formation of air bubbles" remains constant.

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