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ANALYSIS OF THE STRUCTURE OF THE DISPERSED GAS PHASE PRODUCED IN TURBULENT FOAM-CONCRETE MIXERS

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It was noted that the overall stability of foam concrete mixtures made by single-stage technology depends significantly on the measure of distribution of the dispersed gas phase involved in the mixing. The effect of the gas phase structure on the foam concrete mixture was evaluated by the value of the current consumed by the concrete mixer. The results of the experimental studies have shown the relevance of the scientific justification of mass transfer phenomena, that occur during mixing of raw materials in an industrial turbulent mixer. It was found that the process of dispersion of large-sized gas inclusions formed in the foam concrete mixture in the initial period of high-speed mixing is characterized by achieving the maximum power consumption at the mixer shaft. Then there is a slight decrease in energy consumption, in which there is an additional distribution of the dispersed gas phase, sufficient to attain stability of the foam concrete mixture.

Keywords: *Disperse gas phase, foam concrete mixture, surfactant, turbulent mixer, energy consumption, foaming agent, mass transfer process.*

Introduction

Turbulent mixers are currently used for the preparation of foamed concrete mixtures by single-stage technology. To achieve the properties required by practice, it is important to make mixtures in such a way that the structure obtained as a result of mixing in the concrete mixer, has aggregative and sedimentation stability during the whole period of its transition “from viscous to solid”, which lasts from 1 to 2.5 hours. According to different data, the following are required for this:

a) The initial raw material’s high dispersion [1,2],
b) Achieving high dispersion of the gas phase involved in the mixture [1,2],
c) Minimum possible content of foaming agent molecules in the liquid phase of the mixture for a given composition (density) [3-6],
d) The minimum possible period of phase transition “from viscous to solid” [7].

This list of factors governing the quality of foam concrete mixtures and cured concrete to date does not have mathematically clearly defined patterns. Therefore, the standards characterizing the requirements of foam concrete allow for the possibility to obtain materials of different densities and strengths from the same raw material composition.

On the one hand, such an approach to the quality of the material reflects the high demand for it in practice. On the other hand, it indicates insufficient scientific understanding of the mass transfer processes governing the structure and properties of gas-filled concrete.

Materials and Methods

The analysis of the list of factors controlling the aggregative stability of the mixtures and the quality of the hardened foam concrete allows us to state that ensuring the required level of dispersity of the raw materials does not need additional justification, and can be set before the preparation of the foam concrete mixture. All other factors are interdependent during the predominance of viscous bonds between the components of the mixture and, therefore, have a difficult to predict and extremely significant impact on the quality of hardened foam concrete.

It is important to understand that if the dispersed gas phase consists of large pores, then after the mixing process is completed, it cannot be fully retained in the structure of the cement-sand mortar (slurry) and the mixture placed in the formwork during the phase transition will partially lose it. This process will inevitably lead to a destruction of the aggregative stability in the foam mixture. It is possible to obtain the following results in hardened foam concrete, depending on its intensity:

- With a small amount of loss of dispersed gas phase, there will be a decrease in mechanical strength with some increase in the average density,
- With a significant loss of the dispersed gas phase, the period of destruction of aggregative stability will be followed by the phenomenon of sedimentation. The solidified material will have not only increased density at reduced strength, but also different values of strength across the thickness of the concrete body.

From the above it follows that obtaining high-strength foam concrete is possible only when the dispersed gas phase has the optimal dispersion for the given composition. Naturally, the question arises about how to fix this moment in practice.

Results and discussion

Theoretical analysis of mass transfer processes in the production of foamed concrete mixtures [7-9] suggests that the moment of reaching the maximum power consumption by the concrete mixer shaft may correspond to the completion of the first phase of air-entrainment. The reason for this established fact is the large size of gas inclusions. The three-phase dispersed system, the macro-homogeneity of which at this stage is ensured only by the capillary bonding forces, will most vigorously resist the movement of the working body of the mixer and, thus, require increased energy consumption.

Practice and our experimental studies show that to achieve the optimal dispersion of the entrained gas phase, it is necessary to continue mixing [6,10]. At this stage of preparation of foam concrete mixture, mass transfer processes will be characterized by the following features:

- The grinding of the previously involved large-sized dispersed gas phase will require an additional transition of the surfactants from the interparticle liquid to the foam films, and as a result of this process, the total surface of the “gas-liquid” phase interface will increase [11, 12],
- In the interparticle liquid of an intensively mixed foam concrete mixture, due to a decrease in the concentration of surfactants in it, the viscosity will naturally increase and, as a result, the capillary bonding forces between all components of a three-phase dispersed system [12].

At this stage of mixing, despite the increase in viscosity in the dispersed system, the energy consumed by the concrete mixer fluctuates and can decrease by 3.5–5.0% compared to the maximum power consumption.

Experimental studies of the above-justified mass transfer processes were carried out in production conditions with a turbulent mixer, equipped with a 30-kW asynchronous (induction) motor and a reducer (regulator valve). During the experiment, the current consumed by the electric motor during the manufacture of the foam concrete mixture was measured. The obtained results of the current required by the electric motor for the homogenization of raw materials are presented in tabular form (Table).

Table. Current required by the electric motor for the homogenization of raw materials

Mixing duration, (s)	0	10	30	60	90	120	150	180	210	240	270	300
Consumed current, (A)	30	30	40	49	54	55	53	52	53	52.5	52	52.5

Taking into account the order of introduction of raw material components into the mixer flask, analysis of the data (Table) shows that:

- At the stage of loading water and the initial quantity of solid components of raw materials into the running concrete mixer (the first 10 seconds), the power consumption of the mixer is almost constant and minimal,

- Continuous loading of water, sand, and Portland cement causes a significant portion of the mixing water to become physically bound, which leads to an increase in the viscosity of the composition, and the energy consumption required for the movement of the mixer's working body increases,
- After half a minute from the beginning of the mixing process, the foaming agent was added to the mixer, and the energy consumption increased up to 2 minutes from the beginning of mixing, due to the air entrainment and more complete transition of mixing water into a physically bound state,
- Further homogenization of the mixture components was occurred at such a level of current consumption, which is characterized by fluctuations of +3.5–5%.

We believe that the character of energy (current) consumption recorded in the experiment is due to the presence of mutually competing mass transfer processes during this period, consisting of:

- Grinding of the initially involved surfactant of the coarse-dispersed gas phase,
- The flow of physically weakly bound water from large foam films into smaller ones,
- Reduction of the residual concentration of surfactant in the inter-particle liquid.

All of the mutually competing features of mass transfer listed above contribute to improving the aggregative stability of foam concrete mixtures and, as a result, should contribute to an increase in the strength of hardened concrete.

Conclusion

The analysis of the features of the involvement and changes in the structure of the dispersed gas phase during the production of foam concrete mixtures in the turbulent mixer showed that the mixing duration is an important tool to ensure the quality of foam concrete mixtures, that is, their aggregative stability. Other things being equal, only the high dispersion of the gas phase contributes to the acquisition of aggregative stability of foam concrete mixtures in the period between the moment of their placement in the formwork and the phase transition "from viscous to elastic". From the performed industrial experimental studies, the effect of the mixing duration of the foam mixture components on the power consumption of the turbulent concrete mixer showed that the first phase of the formation of the dispersed gas phase requires the maximum power consumption. After involvement of the main volume of the coarse-dispersed gas phase, there is a slight decrease in energy consumption, sufficient for its additional dispersion, characterized by fluctuations in the range of 3–5 % of the energy consumption.

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