ANALYSIS OF SOLID PHASE IMPACT ON CELLULAR CONCRETE PROPERTIES

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INTRODUCTION

Cellular concrete properties are traditionally associated with their average density. Therefore, e.g. if we increase concrete density, the strength will increase as well. However, even in concretes of equal densities properties vary quite significantly. Cellular concrete experts attribute the dependency of such nature to the nature of material porosity and the strength of the matrix material [1]. However, the structural pattern is the primary cause of variability in properties of composite construction materials, including cellular concretes. Since air inclusions cannot cause significant impact on the bearing capacity of cellular concrete frame (as well as on other properties), it was hypothesized that cellular concrete properties might be determined by solid component distribution pattern.

1. MAIN BODY

The innovative and distinctive feature of the above suggestion is that cellular concrete properties are associated with its porosity and porosity patterns by virtually all cellular concrete experts and researchers. No doubts appear with respect to the first assumption, since general porosity is directly related to material saturation with solid components that act as the bearing frame in cellular concretes. Therefore, the more the material is saturated with solid matter, the bigger its bearing capacity would be. A multitude of experimental results demonstrate that given the same concrete densities, the strengths will still vary quite significantly, which is also attributed to changes of material porosity properties. [2] shows that the nature of material porosity is not the primary determinant of its properties in the cause-and-effect linkage. It is also doubtful that a pore, which is essentially an empty space, can affect strength and other material properties. For example, heat conductivity. This is due to heat flow propagation speed being much higher in solid medium than in the air. Thus, it is more reasonable to associate the properties of highly-porous materials with the composition of their solid phase.

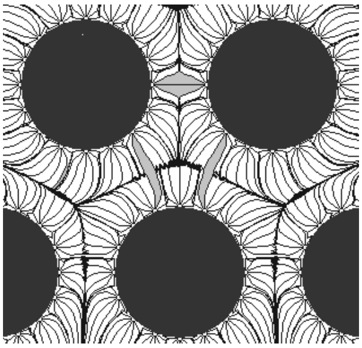
In order to support the above hypothesis, foam concrete, as a subcategory of cellular concrete, is represented as an open self-organizing system at all stages of its structure formation. The openness of the system lies in its ability to exchange energy, matter and information with the surrounding systems. Foam concrete can also be considered as a self-organizing system, capable of structure formation. For that purpose an organizing system has a formative "*principle*" represented by solidifying binding matter. The second essential condition to structure formation is presence of dissipation - spreading. The dissipating "*principle*" is ensured by system openness. The fact that foam concrete is a self-organizing system is additionally confirmed by presence of self-excited oscillations, typical for dissipative systems [3].

Cellular concrete in solid state can be regarded as a well-organized system. A. Merkin was the first to relate cellular concrete properties to the structural characteristics [4,5]. He recognizes two structure-forming elements in cellular concrete — "*pores*" and "*interior*" partitions. Qualitative properties were additionally determined for each of the elements. Thus, the pores are characterized by pore shape, size and pore size distribution. The interior partitions are characterized by thickness, density and strength. Various methods were developed to quantify these properties. Based on processing of the information on relation of these characteristics to physical and mechanical properties of cellular concretes, the author gives the following definition: *"The optimum cellular structure should be characterized by heterogeneous porosity distribution within the material in the form of polydisperse, closed pores shaped into regular polygons, separated with thin and dense interior partitions with identical sections and glazed pore surface. Pore shape must approximate regular dodecahedron".* The highlighted words demonstrate that cellular concrete properties are mostly attributed to the nature of porosity.

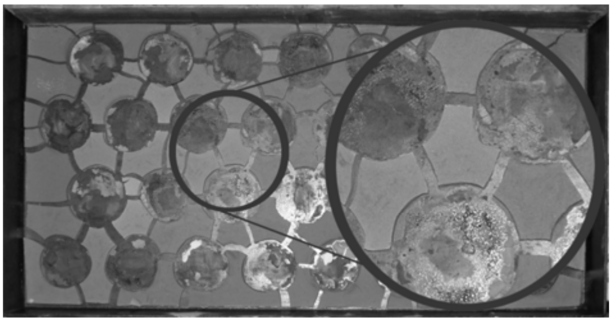
[6] suggests that the solid components of cellular concrete (interpore partitions) are reduced to two structure-forming elements - solid-phase particles (blocks, clusters and elements) and internal interfaces. It is shown that internal interfaces

emerge in cement stone due to objective contraction processes caused by cement stone hydration. Solid phase elements and internal interfaces form a dialectic interconnected unity of the two opposites. Their interconnection and indivisibility ensure integrity of the object. In such state “*cement stone*” or “*cellular concrete*” satisfies all system criteria, which allows it to be considered as an object-system. While material properties can be thus reduced to quantitative and qualitative characteristics of system interconnections represented by internal surfaces of phase interfaces.

Internal interfaces evolve in cement stone of interior partitions of cellular concrete at early stages of material structure formation. The system is initiated in cellular concrete upon introduction of porophore into the cement mix. Since that moment the gas inclusion starts playing an active role in elaboration of the future interior partition configuration. Geometry of interior partition in its turn depends on the shape of the gas inclusion. In normal conditions a gas bubble has a spherical shape and a minimal surface. Upon introduction to the cement mix, which is “*alien*” and “*uncomfortable*” to it due to the density differential, it is forced to change its shape. During this period of system self-organization intense reshaping of air inclusions takes place, accompanied by dynamic transformation of the nature of system porosity. The process is slowed down as the binder becomes hydrated and the cement mix becomes more viscous. Duration of the period depends on stability of the cellular concrete mixture and the time needed for the plastic strength of the cement mix to accumulate. Formation period of the so-called primary structure of cellular concrete is completed upon cement mix reaching the condition when the air inclusions no longer can change their shape. This is where the structure forming role of air inclusions ends. The role is limited to formation of geometry of the interior partition. The next stage of cellular concrete structure formation occurs during the period of intense hydration of the binder and strengthening of cellular concrete frame. The process affects directly the interior partitions. First fissures start appearing in the interior partitions during this period. Later they develop into internal interfaces. The internal interfaces emerge due to contraction of the system volume caused by hydration of the binder. Locations of the first fissures are determined by configuration of the interpore partition. It is virtually impossible to quantify length of the internal interfaces in real-time, since their visualization is problematic. This task can be solved by modeling. Physical and computer modeling was used to study the solid phase structure of materials with cellular porosity. Examples of such models are shown in Figure 1.



a.



b.

Figure 1. Models of materials with cellular porosity: *a) computer model; b) physical model.*

Similar models were used to study the influence of pore packing, their shape, porosity, water/solid ratio on structural characteristics of the solid phase (interior partitions). Figure 2 shows the bar chart describing the influence of pore shape on the lengths of internal interfaces and confirming that structural characteristics of the interior partitions can be affected by the pore shape.

Internal interface length was measured in pixels on the overall length of interface surfaces.

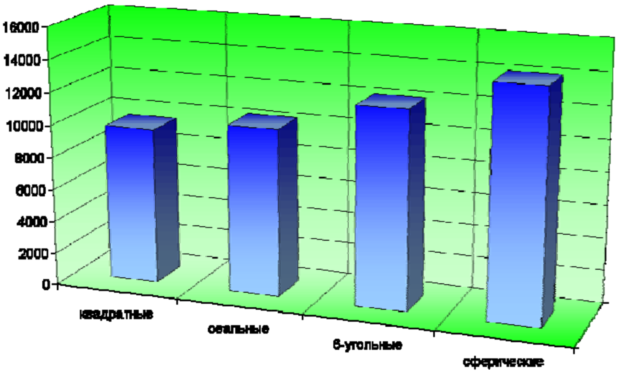
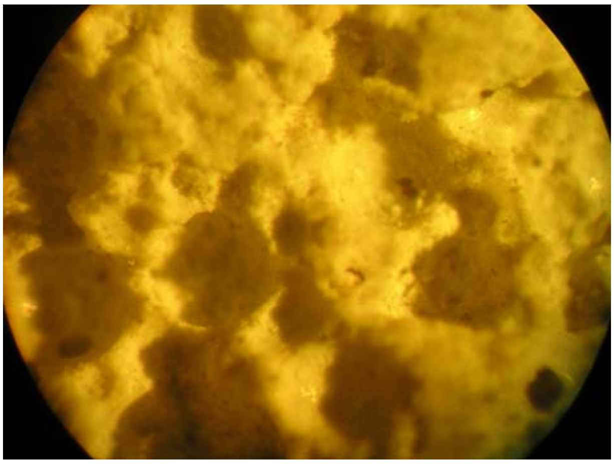


Figure 2. Influence of the shape of gas inclusions.

The conclusion provides experimental results confirming the correlation between foam concrete strength and rheological properties of the structure-forming medium.

The figure shows photo fixations of foam concrete structures of equal densities (600 kg/m3) with x50 zoom.

a.



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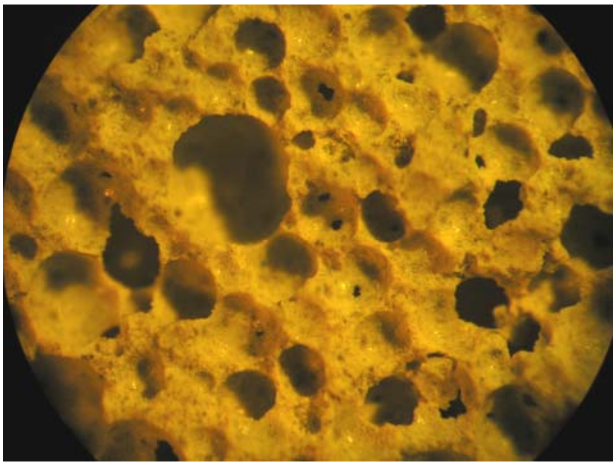

Figure 3. Photo fixations of foam concrete structures a) W/S 0.35; b) W/S=0.55.

Foam concrete was obtained under different initial rheological conditions of structure formation, i.e. under water-to-solid ratios of 0.35 and 0.55. It can be seen from the photos that the pore shape is closer to spherical, when the W/S ratio is greater. Interior partitions have smooth surface. In the first case foam concrete strength was equal to 1.1 MPa, whereas in the second case it was equal to 2.3 MPa.

2. CONCLUSION

The analysis undertaken has shown that qualitative properties of cellular concrete are formed as per the following sequence: cellular concrete mixture - porosity - pore shape – interior partition configuration - solid component characteristic - property. Solid component characteristics are crucial to formation of cellular concrete properties. Development and improvement of evaluation methods for solid component properties of cellular concretes with subsequent seeking for correlations with the properties “sensitive” to material structure characteristics may appear as one of the directions for improvement and streamlining of cellular concrete processes.

References

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