

The Question of Modeling a Structure Structural Insulation Materials for Energy-Efficient Civil Buildings



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Abstract— This article presents theoretical studies on the mathematical modeling of the structure of constructive thermal insulation building materials. The developed principle block is a diagram of the methodology of structural and simulation modeling of cellular concrete.

Keywords: simulation modeling, algorithm, program, methodology, heat engineering, cellular concrete.

I. INTRODUCTION

Designing energy-efficient civil buildings is an urgent task that is being dealt with worldwide. According to international organizations [1,3], almost half of the energy generated per year is spent on creating comfortable living conditions. One of the main reasons for such energy consumption in the Republic of Uzbekistan is the low heat-shielding properties of external building envelopes [2,4-6].

The creation of new effective heat-insulating, structural-heat-insulating building materials for external building envelopes with predetermined sets of properties should, in our opinion, be solved through the prism of developing a methodological strategy based on the latest achievements of science and practice.

The issues of modeling the structure and properties of structurally insulating building materials, its general and particular solutions, are reflected in a series of works [7–13, 17].

The article presents the theoretical research of mathematical modeling of the structure of the created material using cellular concrete as an example. A study of the physical mechanical properties of structurally insulating building materials in the form of mathematical dependences on their internal structure and external influences under specified operating conditions allows us to identify factors that ensure the formation of an effective material structure, as well as evaluate the durability and reliability of structures without lengthy and costly full-scale experiments.

The development of a mathematical model of complex

structured systems, such as cellular concrete, as shown by analysis of studies performed at different times, should reflect and describe the stages of formation of the structure of the material being created, the mutual orientation and conjugation of structure-forming elements, as well as the consideration of their joint functioning at different levels. The solution to such a multi-level problem seems possible when using the apparatus of structural-simulation analysis [6,14-15].

The essence of structural-simulation modeling is to reproduce using a given system of equations with variable parameters, as a result of iterative procedures, to obtain a realistic picture of the structure of the material and, most importantly, the ability to obtain system responses to external and internal influences and analyze them. This method, which includes a rational combination of a probabilistic and deterministic description of the structure under study, allows you to directly relate the structure and properties of the composite material. Therefore, one of the goals of the research is to develop a methodology for structural and simulation numerical simulation of the cellular structure of a cellular concrete. This methodology is based on the implementation of the numerical experiment “model-algorithm-program”, based on the representation of the studied macrostructure in the form of a multi-level hierarchical model. In turn, this model should implement the algorithms of physical and mechanical processes, which, ultimately, will make it possible to predict the properties of the material under given operating conditions, as well as design compositions with an effective structure.

The solution to the problem of optimizing the strength and heat-insulating properties of cellular concrete is based on the features of its macrostructure, characterized by a pore density distribution in the volume of the material, pore cross-section, their size and type of packaging.

Therefore, when designing a model of the composite being developed, it is imperative to evaluate the consideration of structural elements in a given size range.

Based on the foregoing, the conceptual basis of the simulation of the structure of cellular concrete seems possible to present in the form of the following procedures:

initial analysis in the distribution of pores within the boundaries of a given matrix, it will be possible to achieve an imitation of the structure of pores, micro cracks and inclusions. This analysis allows you to establish the actual location of pores in space;

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II. RESEARCH METHODOLOGY & RESULTS

obtaining a simulation model of a system of a specific composition using the statistical mechanism for generating the distribution of structural elements in accordance with the selected size distribution function. In this case, the shape of the placed elements, determined by belonging to a separate structure-forming phase, is taken into account. The matrix basis is the structure of the previous level of modeling, considered as a continuum. All this relates to the micro, meso and macro levels of the material.

In the multilevel approach adopted, the property parameters defined for models of the previous level are used as input data related to the matrix component of the model of the next level. Such hierarchical construction of a general model of the structure of cellular concrete allows you to link structural features from micro to macro levels.

Based on the foregoing, the methodology of structurally modeling simulation modeling can be presented in the form of a fundamental block diagram (fig. 1).

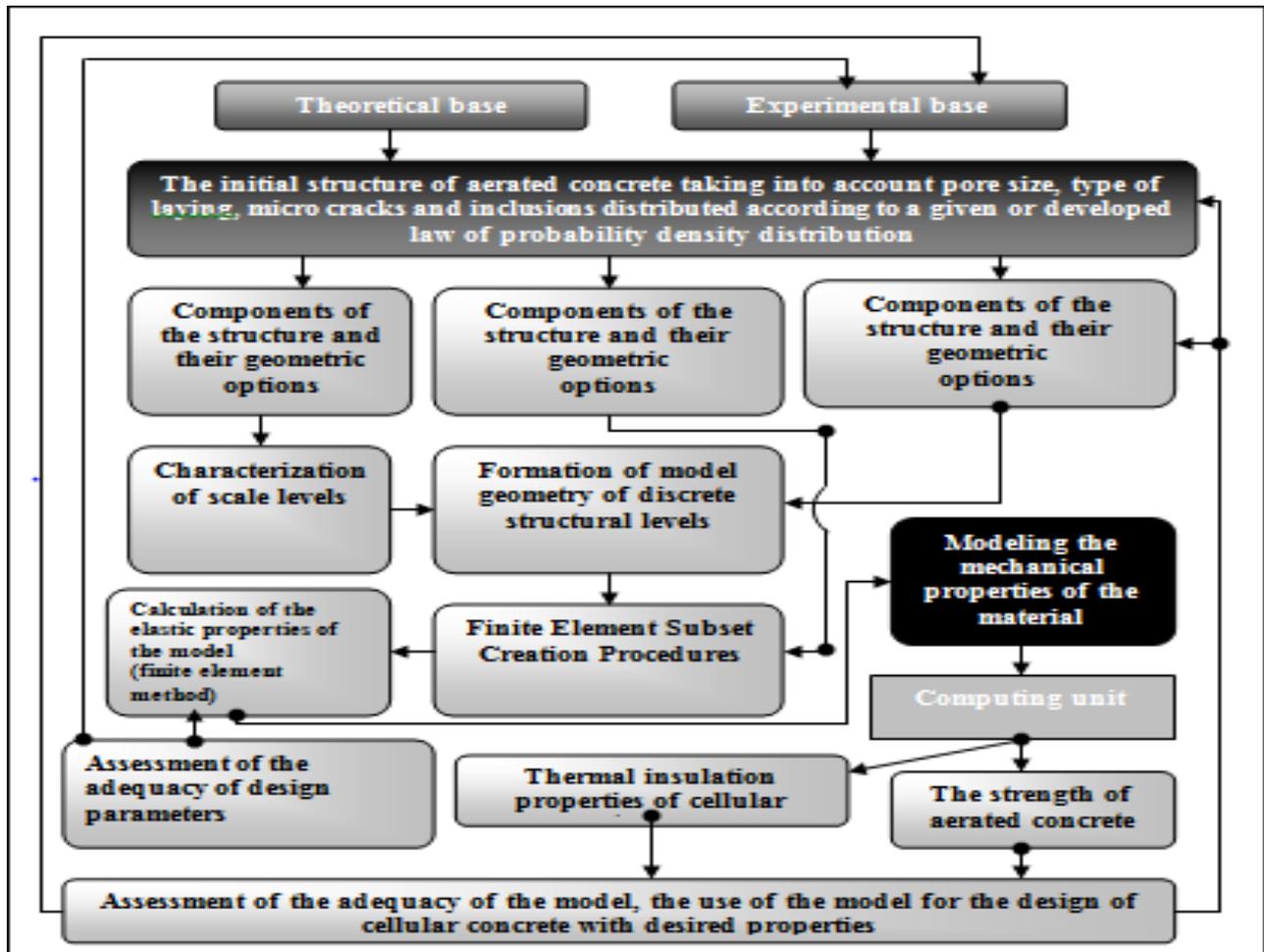


Fig.1. Principal block - methodology diagram structural and simulation modeling of cellular concrete

Modeling the properties of the structure of aerated concrete involves a certain general stage associated with the creation of models of various structural levels and scale approximations. The objective of this stage is to develop the initial model, which approximates the strength and thermal insulation properties, taking into account the bonds of individual components, as well as the structure of cellular concrete as a whole. As external influences, the applied compressive loads and temperature variations of the external environment are taken.

Let's consider presented on fig. a basic block diagram in more detail and explain the functions of individual blocks. At the first stage, based on the known theoretical data on the structure of cellular concrete, characteristic structural levels associated with the structure of the material are established. The physical and mechanical parameters of the components of individual structural levels are determined. Theoretical aspects are aligned with experimental data and, if necessary,

based on statistical methods, the structure or relationship of technological factors with the structure of the material and the properties of the components is adjusted. Next, a flat geometric model of the structure of various scale approximations is formed taking into account the given or probabilistic nature of the relative positions of the components. Then, when creating a numerical model, the finite element method procedure is implemented [16-18], which allows us to represent the model as a single system consisting of components with different physical and mechanical parameters and determine the integral strength characteristics that are used as matrix parameters in the subsequent model scale approach. The formation of a numerical model of the material of the largest scale approximation corresponds to the completion of the first stage of modeling.



The adequacy of the model of characteristic structural levels is checked by comparing the calculated and experimental data.

The second stage of modeling is associated with the development of algorithms for reproducing material properties. These algorithms are associated with the determination of external loads acting in the model of various levels, the assessment of the results of these loads and, if necessary, the transformation of the original model (changes in the geometry of the structure, types of laying, etc.) based on a comparison of the results with the experimental base. As the final result, we consider the integral response to the effect corresponding to the studied property.

The adequacy of the generalized mathematical model, representing a set of models of different scale approximations, is also evaluated by comparing the results of calculations with experimental data. With the convergence of these results, the model is used to select the structure of cellular concrete with the required level of the investigated property. To do this, according to the developed method, parameters with a modified structure are checked - that is, there is a return to the first stage of modeling, but which no longer requires confirmation of the adequacy of the created models.

Thus, the proposed modeling methodology is similar to the experimental search for materials with desired properties. As the main physical prerequisite that determines the strength and thermo technical properties of cellular concrete, its internal structural features without relatively specific types of composites, additives, binders, etc.. This approach allows us to predict the degree of influence of individual factors related only to the geometry of aerated concrete, which makes it possible to conduct a focused search for rational technological solutions on the principle of "geometry - parameters - type", that is, from "structure to type".

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