Triad «Structure, Information, Fractality»

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Abstract. It is focused on the point that, factually, the material’s structure is a primary cause of its properties. The elements of hardened cement stone (inner interfaces), which are the source of its properties, are revealed. It is supposed that the inner interfaces branched chain (patterns) are carriers of certain information. It is proposed to describe this information in quantitative values by fractal dimensions. With such approach the research process is described by sole triad «structure-information-fractality». This article states experimental results proving the effectiveness of the approach proposed.

Constructional materials properties define their relevant functional purpose in the field of construction. Production of composite building materials with given properties is carried out by sequence of technological operations in conformity to the scheme: «composition - technology - property» [1]. For the purpose to determine material stress-strain properties it was developed many tools, devices, ways and methods. One of the basic research methods used with this scheme is a pattern «black box». It was suggested by Ross Ashley, one of the founders of cybernetics [2]. The drawback of this approach is that the research process does not specify the reason of the result obtained. At the same time, contemporary research community have no doubt that materials properties in chains of cause-effect relationship, are attributed, in the first turn, to the character of their structure [3,4]. In this case the above stated chain will feature one more element «structure». Exactly a structure character is a primary cause of the properties of the material obtained. In studying of the material, a researcher becomes a participant in «subject - object» relationship. In this case material and its structure will be «object» of the research. That means that the structure of the material is objective factor, and the research is of subjective nature. Effectiveness and validity of their results depend on many factors: what scientific paradigm is observed by researcher, what methods and tools he uses etc., in other words, what volume and quality of information he has.

The special meaning was attached to the term “information” in XX century. Information (informatio - informing, explanation, narration) is, in a broad sense, an abstract concept, which has many meanings depending on a context [5], and, in its narrow sense, - findings (data, messages) irrespective of form of their representation. Information determines properties of objects and phenomena in space and time. Thus, the research object is informational but cannot convey it to you directly. One of the methods due to which a researcher can obtain this information is disclosing of material structure.

For this purpose, in the first turn, it is necessary to define the term of “structure”. Let’s consider it by way of example of “cement stone”, which is base material for various kinds of concrete. The hydration of cement is accompanied by reduction of the total volume of the system [6]. Eventually, after doing so, the cement stone will develop a branched chain of inner faces of inner interfaces (II).
II are located between separate solid-phase units (elements). This is the ground to consider the cement stone structure as a sum total of interrelated elements making the sole unit. In such representation the cement stone structure meets all the features of the concept «system». Its separate solid-phase units are the elements of the structure, and inner interfaces serve as connections between the elements. These connections ensure the integrity of the object, which is the main definition of any system, and the terms «structure» and system become identical. Besides, in studying of the research object one will be able to see the ground for application of systemic laws, in this particular case it means bringing the object properties into correlation with qualitative and quantitative links’ characteristics, namely II. In other words, the more will be a total inner interface length, the better endurance the material will have.

As you can see on picture1, II makes various figures, patterns in cement stone. In terms of physics, this structure represents percolating cluster \[7\]. There are grounds to suggest that the patterns are particular for each structure. We can also suggest that the patterns are carriers of some piece of information. However, it appeared to be complicated to decode this information. The task also becomes more difficult due to the fact that, in terms of classical mathematics and geometry, it is impossible to describe their shape due to their “curvedness”, to do it we would need some translating program.

The first scientist who noticed that there are no straight lines, “correct” geometrical figures in nature etc. was Mandelbrot. He became the author of Fractal Geometry and introduced the term “fractal” (fractionary) \[8\]. To make a qualitative assessment of the line curvedness grade (deviation from directness), wall and surfaces roughness, Mandelbrot suggested using of fractionary dimensions (Hausdorff-Besikovich dimensions) – the dimensions which differs from the whole-numbered topological dimensions \((0, 1, 2, 3)\), for example - \(1.56\). This number is an index of grade of line deviation from its directness, that means this is not a direct line, but also not a flat figure, since the line is not closed. The more the number approximates to the digit \(2\), the more curved the line will be. By using of mathematical methods, mathematicians made many various fractals. The most famous among them are: "Koch snowflake", "Cantor set", "Mandelbrot set", "Sierpinsky carpet", "Menger sponge" etc.

The other, not less important fractal property is self-similarity. The simplest case is a fractal the small part of which contains the information about the whole fractal. Starting his research exclusively from mathematical operations, eventually Mandelbrot came to philosophical conclusion on a fractal nature of the whole world. Everything is structured according to the fractal principle. This concerns both shape, and contents of the informational objects and phenomena of the world. Fractals can describe with high level of preciseness many physical phenomena of the real world which cannot be described using simple geometrical figures. For example, shapes of mountains, clouds, roots, branches and leafs of the trees, blood vessels, patterns of population growth, shifting from orderliness to chaos etc.

Many theoretical fractals can serve as patterns for composite building materials. For example, «Menger sponge» is a pattern for cellular concrete.
Thus, if a cement stone structure as patterns from inner interfaces is a carrier of information, which may be interpreted in terms of fractal geometry, then the logical triad возникает логическая триада «structure-information-fractality» will appear. In common terms, triad is understood as a unity made by three separate members/parts. There are many triads, for example, Hegel triad Гегеля. This is an association of any opposite concepts and any third concept, which mediates (that is, shows) an internal unity of two opposite concepts [9]. In our case the concepts «structure» and «information» cannot be considered as exact antithesis. At the same time, proceeding from the definitions of these concepts, it is also hard to find out any similar signs of them. The introduced third concept “fractality” is exactly the element of the triad which allows us to show the internal unity of the first two concepts.

The Department of Production of Building Products and Construction of Odessa State Academy of Civil Engineering and Architecture have developed computer programs on determining of fractal dimensions of building composites structure.

In the earlier research [9] it was discovered that the strength of macroporous materials (cellular concretes) is not directly proportional to the strength of solution component that is a base material for structural support. At the same time the strength of construction dense composites on mineral cementitious matters is directly proportional to cement-water ratio. The table 1 states the results of experiment on determining properties of non-autoclaved cellular concrete and dense solution component, from which this cellular concrete was produced. The experiment involved changing of rheological conditions of obtaining cellular concrete due to water requirement of mortar mix, which was measured by the diameter of spread of mortar mix throughout Suttard’s viscometer. After preparing of solution component of the given water requirement its certain part was selected and it was used for shaping of prism samples, with the dimensions 4x40x160 mm. Foam was added to the rest part of the solution in the amount required for obtaining cellular concrete of average density of 600 kg/m³ in dry state. The samples were tested in the age of 28 days.

Table 1. Cellular concrete and solution component properties

| Properties                                | Diameter of solution spread, mm |
|-------------------------------------------|---------------------------------|
|                                           | 200    | 240    | 280    | 320    | 360    |
| Water-cement ratio                        |        |        |        |        |        |
| 0.5                                       | 0.59   | 0.63   | 0.67   | 0.69   |
| Average density, kg/m³                   |        |        |        |        |        |
| 620                                       | 618    | 612    | 608    | 615    |
| Humidity, %                               |        |        |        |        |        |
| 25.3                                      | 24.4   | 23.7   | 27.9   | 28.7   |
| Cellular concrete strength, MPa           |        |        |        |        |        |
| 0.2                                       | 0.9    | 1      | 1.1    | 1.3    |
| Solution component strength, MPa          |        |        |        |        |        |
| 36.7                                      | 34     | 28.4   | 25.6   | 24.3   |

The above stated results prove the hypothesis that if the water-cement ratio increase the solution component (solid) strength will decrease and cellular concrete strength will decrease. In this connection it was supposed that the properties of porous materials are determined by the nature of solid phase spreads (interporous parting walls), i.e. by the nature of structure [10].

In order to study the structure formation of materials and porous structure an experiment which modelled various environmental rheological conditions was conducted. The study was carried out using pattern material. As an analogue to cement paste, water-slurry mortar with various water-slurry ratio was used. Besides, the dimensions of pores in the porous materials patterns were changed. Patterns were kept in closed premises at the temperature of 22±2°C. When removing free water (drying out), the changes in patterns appearance were observed. At the first stage separate fractures appeared in the continuous medium of dense-structured materials’ patterns. Further, on its drying out, the fractures spread and closed on each other finally making chain of inner interfaces. At first pore simulators were inserted into the of porous materials pattern, and after reaching certain strength by the material patterns were extracted. Formation of inner interfaces ran in interporous walls. The final view of the patterns you can see at the picture 2.
In the center of the patterns you can see fractal dimensions’ values. In the right upper corner there is a graph of change of fractal dimensions depending on water-cement ratio. As it is observed, in dense-structured materials patterns (upper row) increase of water-cement ratio results in decrease in fractal dimensions, and in porous material patterns—vice versa. Besides, a fractal dimensions’ value depends on pores dimensions: the smaller pores, the more is fractal dimensions’ value. Thus, it allows to establish a direct informational cause-effect link between a fractal nature of a structure and physical-mechanical properties of materials, which, in its turn, provides possibilities of artificial making of materials with the given structure and synthesis of the material with prognosable properties.

Resume
1. Physical-chemical processes accompanying the hardening process in the cement stone results in formation of a branched chain of inner interface as various patterns. Inner interfaces are represented as the structure elements, on nature of spreads of which the cement stone properties depend.
2. It is supposed that II patterns, being characteristics of structure are the carriers of certain information, which is supposed to be assessed in quantitative values using concepts and methods of fractal geometry. Fractality, being a universal quality of nature, is an element of the triad «structure-information-fractality» manifesting internal unity of these first two. Application and implementation of the proposed triad open the possibilities for artificial making of materials with the pre-set structure and synthesis of the materials with prognosable properties.
3. The article states the results of experimental studies which proved the effectiveness of the proposed approach. The experimental studies allowed us to explain various water-cement ratio influence on the change of strength of materials of dense and porous structure.

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