Fractality in architectural forms and in organization of space in buildings

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Abstract. In the paper, questions of form-building in architecture on the basis of fractal analysis in the design of unique structures are considered. The properties of the fractal and the principles resulting from these properties are studied. Examples of architectural elements with various fractals and their influence on the shape and structure of buildings are given. In this study, consideration is given to the organization of space in the complex of structures.

1 Introduction
The fractal principle of the development of natural and geometric objects is used in the elements of architecture and in space both inside and around the complex of buildings. After the appearance of fractal geometry in architecture, it began to develop a new design direction, which can be characterized as a conscious fractality of architectural forms. This is the birth of amazing in shape and structure of buildings.

2 Fractality of nature and urban environment
Fractals are mathematical models of complex structures that have the property of self-similarity and can represent a collection of broken curves or surfaces with a sharp change of curvature [1,2]. Fractal structures began to be studied in the natural environment, and then created artificially. Benoit Mandelbrot in his work "Fractal Geometry of Nature" defined the term "fractal", introduced the concept of fractal dimension, defined the basic concepts of this scientific direction [3]. Mathematicians created famous fractal models, using the possibilities of computer technology.

Recently, attention has been paid to the problem of creating a comfortable urban environment of nature, taking into account the characteristics of nature [4,5]. Understanding the fractal nature affects the architecture of the city, its development in the direction of integrating environment. But it should be noted that the fractality of the urban environment also affects natural phenomena.

So, with wind load in the space of the Moscow-City complex (Figure 1), in certain areas there is a multiple increase in wind. In the event of unfavorable climatic conditions, this leads to emergencies.
In the design of modern bridges are conducted aerodynamic tests, which allow to improve the structure and protect against negative impacts. When building skyscrapers and houses with high floors, it is also necessary to carry out such studies on the models of buildings of the entire architectural complex of buildings. This will allow architects to give recommendations to improve the organization of space around the facilities and buildings of the form itself. The use of curved surfaces and different number of storeys will allow changing air flows and protecting a person from negative impact.

3 Analysis of fractal structures in architecture
Fractals have the following properties: self-similarity; ability to develop; have fractional dimension; blurring and fuzziness of contours; chaotic dynamics.

We will analyze fractal structures in architecture. The form of elements in architectural structures can repeat themselves in each fragment at any scale with small modifications. The hierarchical principle of organization of space or construction of a structure is applied. Architectural forms most often include a small number of repetitions of self-similar elements that can have fractal dimension.

Although there is a large enough number in the world architecture. An example of a fractal with a fractional dimension is the "Palace of the Winds" (Figure 2). In Figure 3 and Figure 4 shows examples of an object with self-similar elements. The stepped well of Chand Baori in India is one of the examples of the types of such wells with fractal elements in the design. Other properties of the fractal, such as the ability to develop, chaotic dynamics, the study does not pay attention.
At the present time, a fractal architecture is developing, which divides naturally formed (intuitive and conscious) and artificially created. Many architects intuitively used fractal principles in their structures [6,7]. Such principles are: the hierarchical principle of organization; the principle of continuous shaping; the principle measure of singularity; the principle of the uncertainty of borders; the principle of dynamic chaos. The self-similarity of forms in structures occurs very often (Figure 5). The property of fractality is transferred to the internal space, repeating the style and structure (Figure 6).

For the Milan Cathedral also this form and organization of the internal space is inherent (Figures 7 and 8).
Pyramid-shape structures commonly used in building churches, bell towers, castles (Figure 9). Spiral-like forms can be seen in natural objects (Figure 10) [8,9]. The same elements exist in architecture and design.

If earlier the fractal properties of the most commonly observed in the architecture in the buildings (Figure 11), but now it is often used in the organization of space within a building or complex of all structures (Figure 12). Architect Zaha Hadid often used this property in the construction of its projects of unique buildings. Using fractality in the design of buildings allows you to find new forms, a new style of the most unique object [10]. And this is conscious architecture.
An example of the organization of space in the form of a geometric fractal is the Borobudur temple (the island of Java, Indonesia). The spatial structure of a complex is a collection of a repeating contour with fractional dimension. The non-linear architectural fractal is the "Mason's Well" (Sintra, Portugal). The stochastic fractal is the temple of the Holy Family (Barcelona, Spain). Geometric fractal is a castle Castel de Monte

The application of the theory of fractals in the analysis of shape formation in architecture gives new opportunities in the design of unique structures.

Conclusion
The fractal analysis of the architecture of the urban environment is based on the identification of repetitive self-similar forms in the elements of structures, the combination of different types of fractals in the space of the urban environment and their interaction. Fractal space of the city creates its unique uniqueness. Creation of buildings unique in form and organization as an internal space, so the whole complex became possible only in connection with the appearance of new materials.

In the construction of unique structures, polymer composite materials and composite structures are constantly used. Due to this, it is possible to use curvilinear shapes and a complex structure of space in structures during design. In this regard, modern architects have new opportunities for creativity.

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