Short Reports

METHODOLOGY OF IT-BASED MATHEMATICAL MODELLING IN ARCHITECTURE AND TOWN PLANNING

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The modern practice of task solution in architecture and town planning is characterized by high level of an application of mathematical modeling methods which are based on the system analysis of social, economic, technological and other processes and objects of an urban environment in combination with anextensional and high-quality information support including the use of developed specialized information technologies, high-performance computing means and effective telecommunication. Such a combined process of IT-based mathematical modeling includes necessary information acquisition (according to aim), which defines the information model of the studied object, processing of the obtained data (its structuring) and the algorithm of this datatransformation (encapsulation), formation of the object's mathematical model, model geometrization (computer visualization), performance of geometrical building (transformations), carrying out of searching and calculation researches (for the model optimization, variability and validity).

Any architectural or town-planning object (a public building, a construction, a buildings ensemble, a transport network, an industrial complex, etc.) can be considered as a difficult system possessing certain morphology, a functional orientation, system integrity, an environmental characteristic, etc. Studying of such multielement systems is connected with a need to consider and estimate a set of various factors in the conditions of the uncertainty and insufficient knowledge. That's why it is necessary to carry out the qualitative data analysis, identification of essential characteristics (for investigated or designed project), definition of the structure (configuration, topology), of communications, of relations (internal and external), of functionality and procedural features in order to create a model of the object. Further it is necessary to express (to reflect) the revealed characteristics through parameters of the model. Exactly the methodology of the system analysis includes identification of all backbone communications, relations, factors, structures [1].

IT-based mathematical modelingof the architecture objects includes three interconnected basic components:

– mathematical formalization of the description of the studied (projected) object, which allows to execute a calculation of the geometrical characteristics defining a form of an object (volume and three dimensionalindicators), calculation of bases and foundations, calculation of load-carrying structures of buildings and constructions, definition of limit states, loadings (operational, wind, natural, etc.), calculation of stability of a construction, optimization of materials choice, economic calculations, design of engineering systems and many other things;

– the information support including information technologies and algorithmic means, allowing to create data baseswith the information description of an object, their processing (the organization or structuring) and the analysis, computing operations, computer visualization;

– geometrization – geometrical interpretation and visualization of working data bases.

Geometrical representation of the object is the most important part of an architectural design. For example, geometrization of the building shapeallows to realize the volume and three dimensional characteristics of the object (composition, the three dimensional organization, an art expression), to reveal the geometryfeatures of the object in the view of aerodynamics, environmental friendliness, profitability, to define optimum placement of constructive elements, to estimate building volume (and, therefore, the materials consumption), to choose rational technologies of construction (to plan construction works), etc.

A main feature of IT-based mathematical modelingof the architecture objects is the formation and the use of coordinated, internally coordinated, calculated information about a designed project, a compliance of created models and construction documentation. IT-based mathematical modelingprovides maintenance in the whole process of an architectural plan realization by the following chain:

composition – design – working documentation – construction.

Thus, IT-based mathematical modelingof the architecture object is a process of creation of visualized model of the object on the basis of the mathematical description of dependences characterizing the object and the relations, geometrization of the object and the information cover which is realized in the corresponding program environment of applied hardware-software means.

Designing of architectural object, town-planning complex (planning structure) is carried out on the basis of the developed conceptual composition of a certain architectural space characterizing an author's plan concerning used forms, elements, designs, their interrelation (considering the principles of proportionality and scale), intended for realization of a certain functional purpose and a semantic artistic image. A conceptual model is defined as volume and three dimensionalcomposition in which the functional, constructive and esthetic qualities of architecture reflecting technological effectiveness, environmental friendliness, reliability and the figurative decision (i.e. a combination of benefit, durability, beauty), are interconnected. The possibility

of technical realization of an architectural composition is defined by the level of existing (applied) construction technologies, by a set of materials with the properties providing a form and a design with given parameters (qualities, characteristics).

The current condition of scientific and technical base significantly expands possibilities of the architecture. The proposed solutions which nowadays definethe architectural compositions (and a search of new conceptual representations), are carried out according to an evolutionary formula:

materials → technologies → forms.

New construction technologies in combination with the materials possessing more perfect formbuilding and plastic properties stimulate the development of the architectural objects having an exterior with unusual esthetic qualities.

At the same time the form and a design are interconnected. The design is the carrier of esthetic information. The form has to correspond to the purposes of the object (within conceptual composition), to the constructive scheme defining its structure, to correspond to applied materials.

The form and product design significantly depend on a material. The design follows logic of a material (its construction properties). As a whole many constructive schemes are in a direct connection with concrete materials (though there are also rather universal constructive schemes which can be made of various materials).

Constructive elements, carrying out certain functions and providing a necessary stability, rigidity and object durability (as a whole and of separate parts), have the typology and are made of the corresponding construction materials. At the same time there is certain autonomy of constructive elements. For example, for the same constructive frame of the building the external cover from various materials is selected, the various decor and the constructive solution of details is applied. Or, on the contrary, while keeping the form and design of an external cover of the building, its internal three dimensional structure and a design are significantly changed.

Projection in the conditions of the developed city environment (of the concrete architectural space) demands the careful considering of all factors of an existing context, including town-planning continuity, visual analysis, ecological safety, economic sufficiency, a historical and cultural binding that has to find a reflection in a conceptual statement of the project and defines a validity of offered architectural composition. Unfairly rough change of volume and three dimensional characteristics (for example,construction of high-rise buildings in the historical centers, destruction of composite and three dimensional integrity of the developed architectural environment) lead to change of morphology of a historical place, of a city panorama, to a breaking of planning structure that defines a dissonance and a mismatch of the architectural environment components.

Any constructive decisions in architecture compositions have to be mathematically proved. The mathematical solution of an architecture composition defines not only design and technological parameters of a designed project, but also its esthetics.

For example, the choice of a form and a design of a 30 StMaryAxeskyscraper in London (its geometrical features) were defined, first of all, by technological, ecological and economic aspects [2]. This is an optimization (in a combination) of such factors, as buildingstability, the most natural air ventilation (conditioners economization) and sunlight inflow (heating and lighting economization). The heliciformdesign (the plan of one floor is turned by some degrees againstthe underlying floor) allows improving ventilating properties. As a result the building possesses a considerable energy saving feature in comparison with other objects having the comparable sizes.

Designed project visualization is an evident representation of architecture composition in perspective and panoramic images, models, three-dimensional computer models (3D models). Information technologies and computer graphics software allow makingthe process of the architecture object visualization quicker, substantial and convincing. Computer visualization of the architecture object, providing its representation, is a tool of search, analysis and decision making of functional, esthetic and constructive tasks in architecture and town-planning practice.

The technology of «the virtual building», connectedwiththe information database, is built on the concept of parametrical modeling of the object – on the ability to coordinate (to consider) all made changes and to provide constant co-ordination of all elements of the model. Thus, the parametrical model of the building actuallyunites a 3D model and external data, at the same time the model is correctly updated at its separate elements changes, providing the corresponding visual image. Changing any of its parameters leads to an automatic change of other related parameters and elements of designed structure, even drawings, visualization, specifications, working documentation.

Improvement of application methodology of IT-based mathematical modeling in architectural tasks allows to expand a range of the directions of conscious search of new architectural forms, to extendthe research of forming aspects (from positions of modern volume and three dimensional approaches, including a fractal morphogenesis), to make the analysis of a three dimensional configuration of the city with higher quality and to develop a perspective town-planning model.

References

1. Babich V.N., Kremlev A.G., Kholodova L.P. Methodology of systems analysis in architecture //Architecton: Proceedings of Higher Education. – 2011 – No. 34.– P. 3–8.

2. Babich V.N., Kremlev A.G. IT-based mathematical modelling for addressing architecture and town-planning challenges //Architecton: Proceedings of Higher Education. – 2012. – No. 37.– P. 3–9.