Application of graph theory in the energy efficient architectural design

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Summary. Energy-efficient house is considered as a structure consisting of individual elements (volumes). To analyze their relationships with the architectural design of objects suggested to use one of the methods section of mathematics – graph theory. There are basic principles of the theory, which can be used to generate functional and spatial structure of the energy-efficient-building.

Key words: graph theory; energy efficient; construction design; geometric model.

INTRODUCTION

So far, there was a steady region of interaction of architecture and mathematics has thus fairly clear structure: a certain number of tasks of urban development and architecture bulk solved certain mathematical or geometric methods. Currently developed various methods of geometrical description of the building. They can be divided into four main types – image by using the grid and lattice of identical cells, complex networks and grids, as polyhedral and polygons as graphs. Section mathematics "Graph theory" gives a large variety of methods to solve architectural problems. They allow you to adjust the functional relationships within objects, optimize search design solutions, perform compositional analysis on various aspects, etc. based on the models that can be put in the language of graph theory, which is more abstract, based on concepts that focus on binary relations between parts, of which the whole is composed.

PURPOSE OF WORK

The object of this article is to highlight the main principles of the individual elements linked together in a single structure – energy efficient building. The article examines how energy efficient building structure with individual elements (volumes) and highlights the main principles on which these elements are linked together, which can be used in the formation of functional-spatial structure of energy efficient building.

MATERIALS AND METHODS

Architecture and mathematics are stable interaction region that has thus quite clear structure: a range of tasks Urban Development and Architecture bulk solved some mathematical or geometric methods. Currently are developed various methods of geometric description of the building. They can be divided into four basic types - image by using the grid and lattice of identical cells, complex networks and grids, as polygons and polyhedra, in the form of graphs. Mathematics Chapter "Graph theory" provides a large variety of methods to solve architectural problems. They allow you to adjust the functional links within sites, search optimization design

solution, to compositional analysis on various aspects etc. according to the models, which can be summarized in the language of graph theory, which is more abstract, based on concepts that focus on the binary relation between parts of which composed a whole.

RESULTS AND DISCUSSION

Shaping is fundamental and primary step in the design of energy efficient buildings, which have different influences interaction. To streamline the process of spatial energy efficient facility is necessary to investigate the structure of the object. The structure of the architectural object can be represented as separate structures, which are combined with each other on different principles of their organization.

To optimize the design process at the stage of formation is proposed to develop a model of the internal structure of the object, its geometric shape model and its interaction with the environment in which you can manage and optimize based on the total energy evaluation model.

The basis of the geometric model are the structural elements of the object (a certain amount, for example – functional areas) and their relationships with each other, formed through interaction of technical parameters of each element to each other, as well as the interaction of elements of the environment. Changing rates of individual elements or changing relationships between them (spatial elements relative to each other) will lead to changes in the overall index of efficiency of the building. Thus it is possible to control the energy efficiency index object on the stage of a geometric model of the object

To that end, at the stage of defining the basic design tools and at the stage of the structural model is necessary to determine the parameters of each structural element of design and engineering solutions, as well as the relative positions of each structural element relative to each other.

Thus, the model which could be implemented design technique is complex structured and, in particular, contains geometric components that describe the structure of the object and the system of physical interactions and influences.

GRAPH THEORY ANALYSIS OF INTERCOMMUNICATION TOOL AS ELEMENTS SPACE-PLANNING STRUCTURE WITH PROJECTING ENERGY EFFICIENT HOUSING

As you know, graph on the applied aspect – a mathematical model of the system in which the vertices are denoted its elements, and ribs – the presence of any binary relation between them. For various types of graphs using orientation may vary, restrictions on the number of links, and additional data on the top or edges.

When creating a geometric model of the architectural design of the building, particularly energy efficient, you will need to take into account both the energy influence over the environment (climate zone temperature and humidity profile, wind conditions, insolation regime, local microclimatic conditions) and all the internal interactions connections in buildings that formed space-planning, design and engineering solutions. Consideration of these factors will help to dry the schematic graph to model object interactions, optimizing that, you can influence the quality indicators of the architectural object (in particular - the energy balance), changing the model elements (graph elements).

Based on geometric models of any building (including energy efficiency) is its structural elements (certain amounts, "Thermoblocks" – functional and spatial zones) and their relationships with each other, formed on the basis of technical indicators each interaction element with each other, as well as the interaction of elements of the environment. The change of parameters of individual elements or changing relationships between them (spatial elements relative to each other) leads to changes in the overall energy index of the building. Thus theoretically is possible

to control measure energy facility at the stage of the geometric model of the object.

Creating a geometric object model starts with defining spatial relationships between elements of the object (house) – Fig.1.

In 1960 Henry Painter introduced the concept of "Count communication» («Bond graph»). Count communication is a graphical representation of a physical dynamic system. It is similar to a known block diagram and remotely on a directed graph, with the main difference that the arc relations graph are bidirectional exchange of physical energy (Fig.2), while in block diagram and oriented graphs they are a unidirectional flow of information. In addition, the connection graph can be valued. This means that the analysis can be performed on several parameters of different dimensions.

As a simulation tool, bond graphs can be used for the conceptual design phase. Counts connection consists of variables (forces), components and certain bonds. Bond graphs were used in many physical fields such as mechanics, electronics and hydraulics for modeling processes of energy transfer and behavior change system. Similarly it can be used in architecture, as well as architectural composition is a system as a set of parts, between which there are links from metabolic processes.

Each link connecting together certain elements (nodes), submitted instant action energy (dE/dt) or force. The flow in each arc indicated by a pair of variables is called "variable power", the result (the product) by the instantaneous power connection. Variable power at each node can be divided into two types: "effort" and "flow". The effort is multiplied by the flow and gets the power that is "variable power". Examples of force-force, torque, pressure or pressure; flow-speed, current and volumetric flow.

Links with other features. One is the "half-arrow" – signs convention. Provided they indicate the direction of positive energy flow. Choice of positive direction is arbitrary, with the caveat that you need to be consistent throughout the column to the selected destination.

So, for the energy assessment of the building must be selected in the model building spatial volumes ("Thermoblocks"), which are a set of closed or open spaces inside the building with a specific functionality and internal microclimate (temperature and humidity conditions).

The next step in creating a geometric model of the building is the analysis of the list of border space between data volumes, their geometry, orientation and location relative zones. By spatial boundaries include - foundation, floors, walls, floors, coatings. In this list there are design and cuts with their geometric, design and engineering and technical indicators that are essential for energy simulation.

The geometric model of energy efficient building in completed form should be a tool that will allow architects to monitor and control all the parameters architectural design that have an impact on energy efficiency of the building. Energy rating geometrical model in all stages of design will allow the architect to make informed decisions concerning energy efficiency. The inclusion of this analysis workflow architectural design will facilitate the creation of projects that meet construction standards in the field of energy efficiency.

STAGES OF FORMATION OF ENERGY EFFICIENT BUILDING SYSTEM MODELS

Methods of creating residential building project are a set of techniques or operations concerning its design. Methods of designing energy efficient architectural objects are related to the need and characteristics of urban union system, space-planning, architectural design and engineering decisions that affect the formation of energy-efficient facility. Thus, the model, which could be implemented design technique is difficult structured and, in particular, contains geometric components that describe the structure and system object physical interactions and influences.

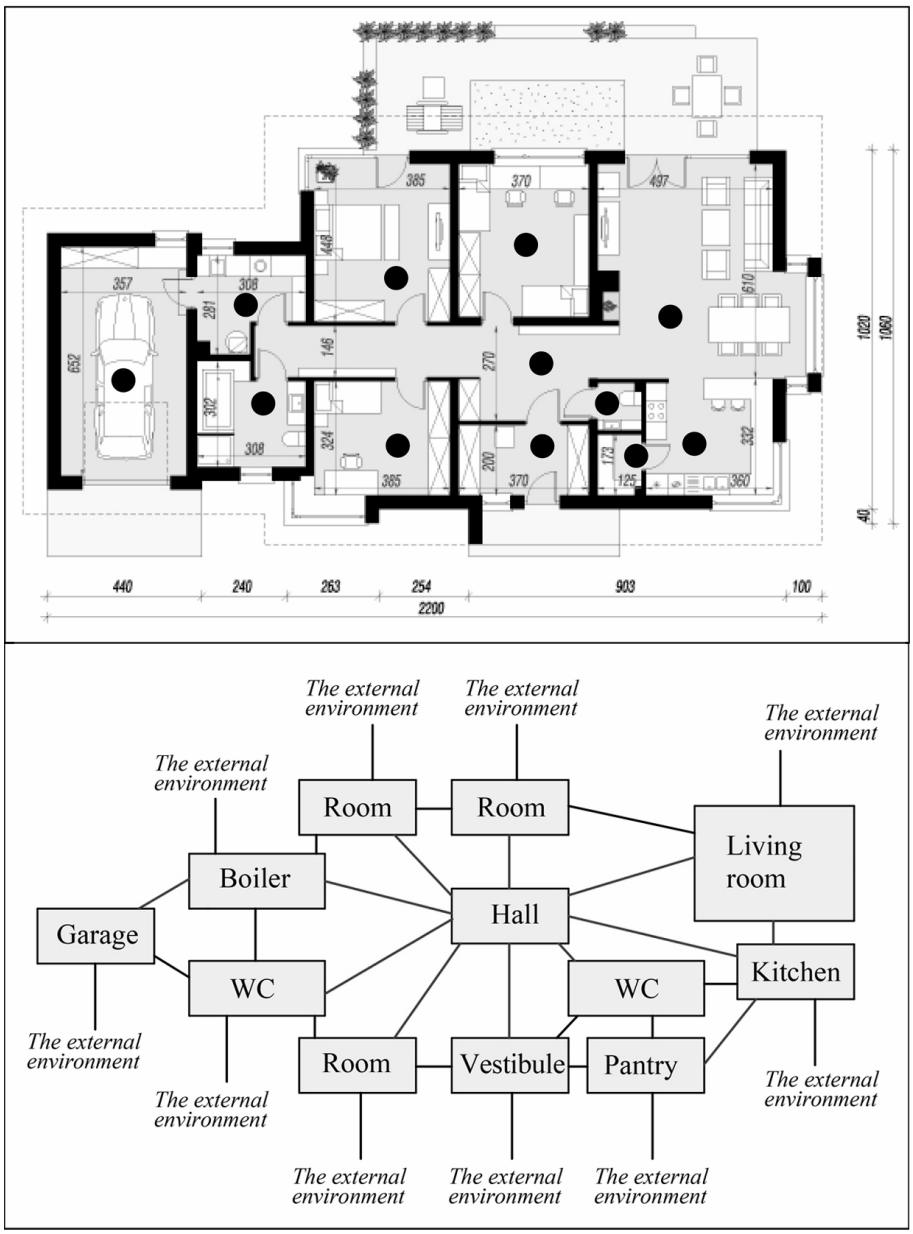

Fig. 1. Plan-story building and an undirected graph connections between elements

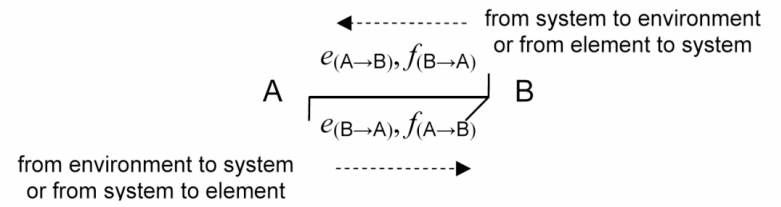

Fig. 2. Variables (power) elements and relationships defined in the "Bond graph" [5]

For structuring the process of formation of energy efficient buildings is proposed to divide it into three stages, with emphasis on the stage of forming a geometric model of the object as a determining step.

1. Pre stage.

Pre-analysis is a phase formation of the target set for the design. Methodological analysis is creating a certain view of the object of design from the perspective of the design goals. The methodological approach provides a fundamental orientation predesign analysis, creates conditions for the formation of ideas, basic concepts and building the target set.

Pre-stage includes collection and analysis of information (the study of theoretical models of energy efficient housing design, analysis of the environment and its effects on the object) and determine the means that will be used in the design (schematic diagrams of space-planning structure of your design and engineering judgment).

2. Stage forming a geometric model of the internal structure of the object and its interaction with the model environment.

Step involves creating a geometric model of the object based on the structural model, its analysis and optimization.

The basis of the geometric model are the structural elements of the object (for example – functional areas) and their relationships with each other, formed through interaction of technical parameters of each element to each other, as well as the interaction of elements of the environment. Changing rates of individual elements or changing relationships between them (spatial elements relative to each other) will lead to changes in the overall index of efficiency of the building. Thus it is possible to control the energy efficiency index object on the stage of a geometric model of the object.

To that end, at the stage of defining the basic design tools and at the stage of the structural model is necessary to determine the parameters of each structural element of design and engineering solutions, as well as the relative positions of each structural element relative to each other. This stage is a cyclical process, which alternates analysis and synthesis.

As an instrument for analyzing, the relationships of the structural elements of the object and their interaction with the environment are proposed to create a geometric model as a graph.

As a result of the synthesis of data from all elements of object interconnections emerging overall system energy balance of the building, which is a measure of energy efficiency of the facility. Equalizing the figure with the standards of energy efficiency and, in the case of non-compliance with regulations, adjusting parameters of individual elements and their interconnections, it is possible to adjust the degree of efficiency of the object.

Thus, we obtain the energy balance control system object that can become the basis of CAD construction projects on the criterion of efficiency.

3. Stage optimization and creative improvement project architectural object.

This stage is a comprehensive method of architectural design, the essence of which lies in the simulation, creating the design model of the object in accordance with the practical, aesthetic and socio-cultural features as a basis for the geometric model.

Spatial structure of the compounds in the second stage of design can be represented as a graph. Architect, coding in the graph structure necessary references are manipulated by choosing different options.

RESEARCH OF FEATURES OF FUNCTIONAL AND SPATIAL ENERGY EFFICIENT BUILDINGS

If we consider the house as a structure consisting of individual elements, you need to identify the main principles on which these elements are linked together.

There are three principles of formation of functional-spatial structure of energy efficient building.

1 principle. It involves differentiation volumes for functional and social factors. The

nature of the use of space points to the basic requirements for housing - the number and characteristics of functional processes in the areas of domestic buildings.

If we consider individual housing, we can distinguish major groups of premises, which in turn are divided into individual cells and planning areas:

- General family Group (living room, kitchen, bathroom, office, etc.),
- Individual Group (bedrooms, bathrooms, closets, etc.),
- Group Service premises (boiler, etc.),
- Communications (Stairs, corridors).

Synthesizing the internal structure of the building on this principle is the main method of designing all time.

2 principle allows for the connection of internal and external spaces of the building with the influence of the environment. This is about mutual dependence and planning functional elements (quantity and quality of space inside the house) and climatic factors (climate zone, temperature and humidity conditions, wind mode, insolation, the presence of natural threats (seismic), local microclimate conditions – surrounding construction, geology, soils, water resources, flora areas). We consider the organization of the site and introduced its division into discrete units, garden, elements of landscape design, and some temporary buildings and structures, exterior decoration, etc.). And, most importantly, the interdependence of functional-planning elements and climatic factors transformed to create certain desired spatial organization of receptions in the building.

For example – the minimum front enclosing surfaces, elongated latitudinal orientation of the building facade to the south, modeling the internal structure taking into account passive solar insolation and heating, reducing the area of the northern facade using slope roofing, glass facades differentiation (maximum windows on south facade, minimal – on north), consideration lifting height of summer and winter sun – protection from overheating southern facade (performances of a roof, slats, extension), the use of passive systems use solar radiation (direct radiation).

3 principle of formation of functional and spatial structure of energy efficient buildings include the use of known techniques inherent in energy efficient buildings.

Maximum compact plan and volume, thermal zoning and planning functional groups in the building, excluding technical premises with heating circuit, the color of the building surfaces, which improves heat flow, placement techniques to improve planning and reduce heat flow - partial hollow building in the ground, placing Atrium premises, installation of buffer zones (for heat accumulation - built and added to the greenhouse southern orientation, insulated to prevent heat loss - unheated buffer areas of the northern facade); features construction materials enclosing structures, ensuring minimal heat transfer coefficient, triple glazing of filling the space between the panes with argon gas or low-emission glass, creating airtight building shell inside the entire surface protecting, ensuring the tightness of connections of transition (the exclusion of "cold bridges").

Based on principles proposed modeling can be found willing cooperation of combinations of three-dimensional elements of different types of groups that can be classified in terms of energy efficiency.

Different combinations of elements interaction groups planning buildings can be summarized in table ready geometric variations functional and spatial solutions. In other words, we can assume that under given conditions based on the number of items can be given in advance to identify all possible variants of their arrangement and the selecting are only efficient in terms of energy efficiency.

Using these principles of forming the structure of energy efficient buildings, you can speed up and streamline the design process and to create spatial relationships of combinations of elements of a building under specified conditions. In further research is planned to create a geometric model of the object by using the principles of formation of its functional and spatial structure.

CONCLUSIONS

1. It considered the possibility of using one of the methods branch of mathematics Graph theory in architectural design of energy efficient buildings as an analysis tool designed object relationships. There are highlighted two main elements create a geometric model of energy efficient buildings - spatial cell ("Thermoblocks") and their relations (constructions). Highlight geometric and engineering source data and spatial structures of cells that bind them are required for energy analysis of the geometric model building. In further studies will be conducted analysis of all possible links between vertices, edges are planned scheme.

2. The article was systematized stages of the design of energy efficient buildings, as well as allocated determining step simulation, which can carry out the management of geometric model of the internal structure of the object to improve the overall energy efficiency.

3. The article deals with energy efficient building as a structure of individual elements (volumes) and highlights the main principles on which these elements are connected to each other, which can be used in the formation of functional-spatial structure of energy efficient buildings. Using these principles of forming the structure of energy efficient buildings, you can speed up and streamline the design process and to create spatial relationships of combinations of elements of a building under specified conditions.

4. The geometric model of energy efficient building in completed form should be a tool that will allow architects to monitor and control all the parameters architectural design that have an impact on energy efficiency of the building. Energy rating geometrical model in all stages of design will allow the architect to make informed decisions concerning energy efficiency. The inclusion of this analysis workflow architectural design will facilitate the creation of projects that meet construction standards in the field of energy efficiency.

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ПРИМЕНЕНИЕ ТЕОРИИ ГРАФОВ В СТРОИТЕЛЬНОМ ПРОЕКТИРОВАНИИ

Аннотация. Энергоэффективный дом рассмотрен в виде структуры, состоящей из отдельных элементов (объемов). Для анализа их взаимосвязей при архитектурном проектировании объектов предложено применить один из методов раздела математики – теорию графов. Показаны основные принципы теории, которые могут быть использованы для формирования функционально-пространственной структуры энергоэффективного здания.

Ключевые слова: теория графов, энергоэффективность, энергоэффективная архитектура, структура архитектурного объекта, проектирование, геометрическая модель.