The method of optimization of energy-efficient engineering solutions by varying criteria in CAD

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Abstract. With the development of information modeling systems for buildings and structures, the task of modeling the thermal and energy processes of heat exchange between the enclosing structures of a building and the environment becomes easily solvable. In addition to this priority task, the tasks of calculating the microclimate in the premises are solved, taking into account natural and artificial lighting, aerodynamic properties of the heating system, ventilation and air conditioning. Solving these problems allows choosing the most appropriate architectural and planning solutions that will save energy consumption in the future.

Introduction

The present approach and the way of organizing the processes that are performed in the course of design decisions in the last stages of project development takes a lot of time and affects the main sections.

Federal Law No. 261-FZ of November 23, 2009 provides for the section "Measures to ensure compliance with energy efficiency requirements and requirements for equipping buildings, structures and structures with energy consumption meters" ("Energy Efficiency"), which contains design solutions aimed at optimizing architectural, constructive, engineering-technical and other design solutions for the requirements of the functional purpose and production processes provided for the period of operation buildings and structures.

Methods

In the classical approach, the following sections of the project documentation are first developed: architectural solutions, structural and space-planning solutions, information on engineering equipment, networks of engineering and technical support, a list of engineering and technical measures, content of technological solutions. The decisions taken in these sections are based on the development of the project "Energy Efficiency", which defines the energy-saving class of the building. The energy efficiency class of the building is determined by SP 50.13330.2012 "Thermal protection of buildings, which are represented by such concepts as normalized consumption characteristic of heat consumption, which is larger and will not be. Techniques that lack unified and uniquely formulated approaches (methods) for assessing the energy efficiency of various engineering solutions for construction objects (buildings and structures) based on computable objective criteria.

Having received a deviation in the values and in the class of energy efficiency, it is necessary to make adjustments to the project documentation (Fig. 1). Such a process can seriously affect the time

and effort spent on the project. At the same time, again, there are no strict requirements for the development of solutions using energy-efficient systems and alternative energy sources.
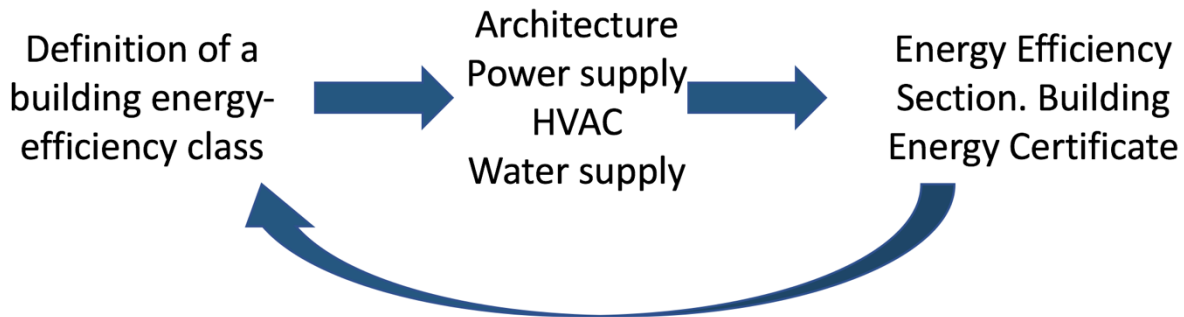

Figure 1. The classical approach to the design process

It is proposed to create a method (algorithm, mathematical model, information technology - software product) that allows to optimize a set of engineering solutions for buildings and structures of various purposes.

The input parameters will be formalized representations of criteria for evaluating energy-efficient engineering solutions for the design of construction projects (buildings and structures), formulated on the basis of the analysis of world experience (in terms of normative and technical documentation and the results of scientific research).

Criteria:

1. k_i – is a criterion for evaluating the type (characteristics) of a building.
2. y_{ij} – the criterion of a set of engineering systems.
3. z_{je} – the criterion of energy efficiency of applied engineering systems.
4. g_a – criterion of limiting conditions (availability of resources and their limits, convenience of location and others).
5. o_b – the criterion of optimality (cost, payback, achievable energy efficiency class and others).

After calculation, according to the developed method, it is possible to formulate a combination of a set of design solutions that will be used in the development of project documentation, which will exclude the possible temporary and labor costs for correcting incorrect decisions.

For example, energetic measure of heat exchange processes is calculating by this formula:

$$C^E = \frac{E_i}{\sum_{i=1}^n E_i} \qquad (1)$$

where,

E_i – energetic capacity of this process for the adopted period of time, tons of equivalent fuel(t.e. f.).;

$\sum_{i=1}^n E_i$ – total energetic capacity of all heat processes in observing building, t. e. f.

Material processes measure is calculated as follows:

$$C^M = \frac{M_i}{\sum_{i=1}^n M_i} \qquad (2)$$

where,

M_i – material capacity of this process for the adopted period of time, thousand Kg.;

$\sum_{i=1}^n M_i$ – total material capacity of all mass transfer processes in observing building for the adopted period of time, thousand Kg.

Thus, quantitative expression of the significance of each process (cr) is a relative dimensionless weight coefficient characterizing the share of this process in the overall balance of heat and mass transfer processes of changing the state of parameters of building.

The proposed method for providing pre-project energy consumption calculations for engineering systems over quadratures and the type of buildings (internal premises) or other formulated parameters. Since the regulatory documentation of the Russian Federation in the field of energy efficiency is primarily tied to solutions "architectural solutions" (heat insulation, heat transfer), when today, a major role is played by a serious issue of electricity and heat consumption by standard regulatory and technological needs. While the use of alternative energy sources and replacement of a certain level of indicators does not directly affect the energy efficiency index.

Based on the calculation of energy consumption, the system forms a set of engineering systems that will initially meet the required parameters and form a class of energy efficiency of the building.
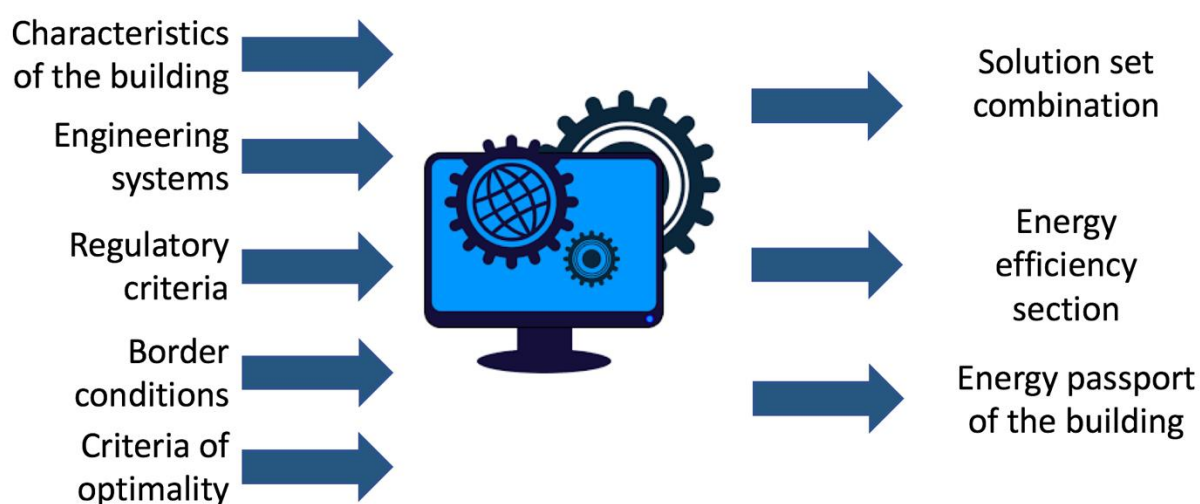

Figure 2. Method for optimizing energy efficient engineering solutions

Set of engineering systems is formed from a database with a set of engineering systems and a description of their energy consumption (Table 1).

Table 1. Example of set of heat system

#	Engineering system	Type	Processes	Expression	Description
1	Heat system	Radiator heating (infrared)	Air heating	$$Q_{air}^{r.h.} = G_{air}c_{air}\rho_{air}(T_{airtempf} - T_{airtemps})$$ $$E_{air}^{r.h.} = \frac{k_{waterin}y_{waterin}H_{waterin}Q_{air}^{r.h.}}{c_{water}(T_{w.s.} - T_{w.f.})}/(\eta_{н.}\eta_{п.})$$	$Q_{air}^{r.h.}$ – The thermal power required to heat the air in a radiator heating system, W $E_{air}^{r.h.}$ – electric power required to supply the heat transfer medium in the radiator heating system for air heating, W

	Wall heating	$Q_{wall}^{r.h.} = kF(T_{room} - T_{outside})$	$Q_{wall}^{r.h.}$ – thermal power, "necessary" for heating the walls in the radiator heating system, W;
		$E_{wall}^{r.h.} = \dfrac{k_{waterin} y_{waterin} H_{waterin} Q_{wall}^{r.h.}}{c_{water}(T_{w.s.} - T_{w.f.})} / (\eta_{н.} \eta_{п.})$	$E_{wall}^{r.h.}$ – electric power required to supply the heat transfer medium in the radiator heating system for wall heating, W
Convection heating	Air heating	$Q_{air}^{c.h.} = G_{air} c_{air} \rho_{air}(T_{airtempf} - T_{airtemps})$	$Q_{air}^{c.h.}$ – thermal power required to heat the air in a convection heating system, W
		$E_{air.}^{c.h.} = \dfrac{k_{waterin} y_{waterin} H_{waterin} Q_{air}^{c.h.}}{c_{water}(T_{w.s.} - T_{w.f.})} / (\eta_{н.} \eta_{п.})$	$E_{air.}^{c.h.}$ – electric power required to supply the heat transfer medium in the radiator heating system for air heating, W
	Wall heating	$Q_{wall}^{c.h.} = kF(T_{room} - T_{outside})$	$Q_{wall}^{c.h.}$ – thermal power, "necessary for heating walls" in a convection heating system, W
		$E_{wall}^{c.h.} = \dfrac{k_{waterin} y_{waterin} H_{waterin} Q_{wall}^{c.h.}}{c_{water}(T_{w.s.} - T_{w.f.})} / (\eta_{н.} \eta_{п.})$	$E_{wall}^{c.h.}$ – electric power required to supply the heat transfer medium in the radiator heating system for wall heating, W
Air heating	Air supply	$E_{waterin}^{a.h.} = \dfrac{G_{air} * H}{\eta}$	$E_{waterin}^{a.h.}$– electric power required for air supply in the air heating system, W

	Air heating	$Q_{air}^{a.h.} = G_{air}c_{air}\rho_{air}(T_{airtempf} - T_{airtemps})$	$Q_{air}^{a.h.}$ – thermal power required to heat air in an air heating system, W
	Wall heating	$Q_{wall}^{a.h.} = kF(T_{room} - T_{outside})$	$Q_{wall}^{a.h.}$ – thermal power required to heat walls in an air heating system, W
Air heating in conjunction with radiator heating	Air heating	$Q_{air}^{a.h.r.h.} = G_{air}c_{air}\rho_{air}(T_{airtempf} - T_{airtemps})$	$Q_{air}^{a.h.r.h.}$ – thermal power required to heat air in an air heating system in conjunction with radiator heating, W
	Air supply	$E_{waterin}^{a.h.r.h.} = \dfrac{G_{air} * H}{\eta}$	$E_{waterin}^{a.h.r.h.}$ – electric power required to supply air in an air heating system in conjunction with radiator heating, W
	Wall heating	$Q_{wall}^{a.h.r.h.} = kF(T_{room} - T_{outside})$	$Q_{wall}^{a.h.r.h.}$ – thermal power, "necessary for heating the walls in an air heating system in conjunction with radiator" heating, W
Air heating in conjunction with convection heating	Air heating	$Q_{air}^{a.h.con.} = G_{air}c_{air}\rho_{air}(T_{airtempf} - T_{airtemps})$	$Q_{air}^{a.h.con.}$ – thermal "power required to heat the air in an air heating system in conjunction with convection heating," W
	Air supply	$E_{waterin}^{a.h.con.} = \dfrac{G_{air} * H}{\eta}$	$E_{waterin}^{a.h.con.}$ – electric power required to supply air in an air heating system in

| Wall heating | $Q_{wall}^{a.h.con.} = kF(T_{room} - T_{outside})$ | conjunction with convection heating, W $Q_{wall}^{a.h.con.}$ – thermal power, "necessary for heating the walls in an air heating system in conjunction with convection heating," W |

Conclusions

The method of optimization of energy-efficient engineering solutions for variable criteria in CAD will increase the quality of decision-making when choosing a set of engineering energy-efficient solutions, improve the quality of energy efficiency assessment of the designed buildings, minimize the time and costs for processing design solutions, modern technologies will allow integration of the method with BIM programs and programs energy modeling.

Acknowledgements

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