

Methods of achieving energy efficiency in buildings and their evaluation

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Abstract. Current research aims at studying the methods of assessing energy-efficient technologies. An overview of architectural and constructive solutions based on the principles of bioclimatic architecture has been presented. Solutions that are targeted at protecting the building from excessive solar radiation as well as increasing the level of energy efficiency of the building have been evaluated. Relevant architectural and construction schemes of buildings have been presented. The operation of phase-change materials and the effectiveness of their application in construction has been analyzed and compared with classical building materials. The experimental setup of N. Yu and his co-authors has been considered, and their studies devoted to the comparison of two phase-change materials such as GH-33 and GH-37 have been described. The method of climatic analysis of regions based on the Givoni chart has been studied. The climatic zoning of Libya based on the analysis of the average monthly maximum and minimum temperature proposed by P. C. Agrawal is presented. **Keywords:** phase-change material; Givoni chart; climate prediction; energy efficiency; architecture; resource saving.

1 Introduction

As construction industry is being developed, the problem of efficient energy consumption is becoming more and more acute [1–4], since a considerable part of the resources is spent on heating and cooling of buildings and constructions. The introduction of alternative energy sources requires a detailed study of the climate in a particular construction region. There are many researches devoted to the introduction of passive technologies in the construction of buildings. Elaborate study of the climate, its features and weather conditions forecast will give the opportunity to maximize the effectiveness of passive strategies. Also, using the analysis of the terrain as a basis, it will be possible to use original architectural and constructive solutions. Methods of assessing the rationality of alternative energy sources are rather scarce and therefore require further study and improvement [5–12].

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2 Experimental studies of phase change materials

The study of the possibility of applying phase change materials in the elements of building structures to increase energy efficiency and make the building environmentally friendly was carried out by such authors as Nan Yu, Chao Chen, Khamid Mahka-mov, Irina Makhkamova, Qiong Li and Jing Ma [13].

The study is based on the method of curing elements from precast concrete under fallow. The process includes four stages: static phase, heating, maintaining a constant temperature and cooling. Modeling consists of the following stages: dividing the building space into energy zones, compiling and solving energy balance equations that take into account energy input from various sources, air and moisture transfer, and heat losses [13].

The energy balance method was used to calculate the thermal load of the building. Modeling of moisture transfer was made by means of the correlation of heat and mass transfer [13].

The experiment was carried out using two models built at a scale of 1:3 in Jixian County. The north wall is made of a block brick with an expanded polystyrene board on the outside, whereas east and west walls are made of expanded polystyrene boards. The roof is sloping and transparent and contains insulation, which is laid from 10:00 to 17:00 [13].

To make a comparison, the authors opted for two types of phase change materials namely GH-33 and GH-37. The temperature and enthalpy of phase changes as well as the temperature at the construction interface with the phase change material and the wall were taken into account [13].

The results of the comparison are shown in Figure 1 [13].

As a result, the authors succeeded in proving the efficiency and rationality of using composite panels with a phase change material. When comparing the two models, the GH-37 panel appeared to be more effective. The method can be extended and improved. This will provide an opportunity to increase the selection criteria and the accuracy of the results [13].

3 Application of the Givoni chart

One of the authors Yusuf Yildiz has considered the application of passive systems in a changing climate of Turkish cities using climate scenario forecasting and the Givoni chart. Bioclimatic maps are a tool of analyzing architectural design using passive technologies. The researcher identified eight passive and three active strategies. They were compared with the Givoni psychometric chart, which made it possible to assess thermal comfort. This approach enabled us to determine the level of rationality of using one or another passive technology [14].

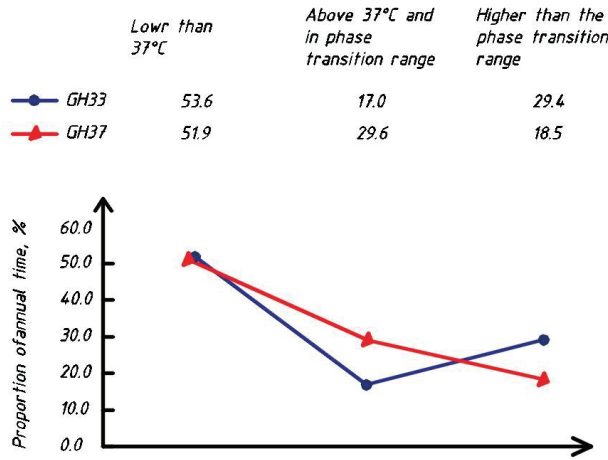


Fig. 1. The thermal state of the PCM layer between the inner surface.

4 Climatic zoning of countries

The aim of P. C. Agrawal's research is to consider various passive heating and cooling systems for buildings as well as to assess the possibility of their application in the climatic conditions of Libya.

Solar dehumidification and evaporative cooling are directly related to the use of sorbents (molecular sieve, silica gel), which are used to dry humid air. The use of triethylene glycol turned out to be quite effective. The organic matter is atomized to rapidly absorb air in the absorption chamber. Subsequently, the air temperature can be lowered in the evaporative cooler. By using hot air, residual moisture in triethylene glycol is removed from the solar collector and, thus, the substance accumulates. To increase the thermodynamic efficiency of the cycle, the use of heat exchangers at several points of the flow (between the weak one and the strong one) is allowed [15].

To analyze the effect of long-wave radiation in a cloudless sky, the author uses the Geiger equation. Heat loss has an inverse relationship with the amount of water vapor and clouds in the sky (Table 1). This method of cooling buildings is the most effective in conjunction with the Trombe-Michel wall or absorption systems. However, the disadvantage of this method is a need for a large open area on the roof [15].

Table 1. Effect of clouds on outgoing longwave radiation according to the data of P. C. Agrawal [15].

Cloudiness in tenths	Percentage of outgoing radiation
0	100
1	98
2	95
3	90
4	85
5	79
6	73
7	64
8	52
9	35
10	15

To assess the rationality of using one or another passive strategy in the regions of Libya, the climate of the country has been analyzed. The method based on the average monthly maximum and minimum temperatures in 24 regions of the country from 14:00 to 06:00 was taken as a basis. The measured temperatures were plotted on a psychometric chart. The following conclusions have been made: the need for heating in the central regions makes 40-50% per year, whereas in the south region this figure is 50-60 %; the need for cooling in the northern coastal region is 10-20 % per year, in the central region - 20-25 %, in the southern region 25-30 % per year; the need for sun shading in the coastal zone is 30-40%, in the central zone - 40-50 %, and in the southern zone - 50-55 % [15].

6 Engineering solutions in the field of designing building elements

Such authors as G. V. Mikheev, E. Y. Kaporozova, A. V. Yuri, T. D. Khaliullin, F. Khalili studied the aspects of bioclimatic architecture for more rational construction in terms of efficient use of climatic resources.

Bioclimatic architecture is an independent architectural direction that increases human comfort and ensures its rational coexistence with the environment [16].

In order to analyze climatic characteristics, the authors used the PD web application: Psychometric Chart, the Energy Plus database and the Givoni chart. This provided an opportunity to identify possible passive and active bioclimatic design strategies and determine the features of thermal comfort and energy efficiency in a certain area [16].

The authors present a number of architectural and design solutions to provide energy efficient consumption. Glazed galleries (Fig. 2a) operate on the principle of roof-baths. The adjoining greenhouse (Fig. 2b) provides a better insulation than the glazed version. A fairly common solution is the Trombe wall (Fig. 2c) installed on the south side of the building. Its design is a massive wall the outer surface of which is painted in a dark color with ventilation holes and a glass partition located at a certain distance. The principle of operation of the Trombe wall is to accumulate heat in the space between the wall and the glazing and transfer this energy inside the building using ventilation holes. As cold air passes through the lower holes and a heat flow comes from above, convection appears. [16].

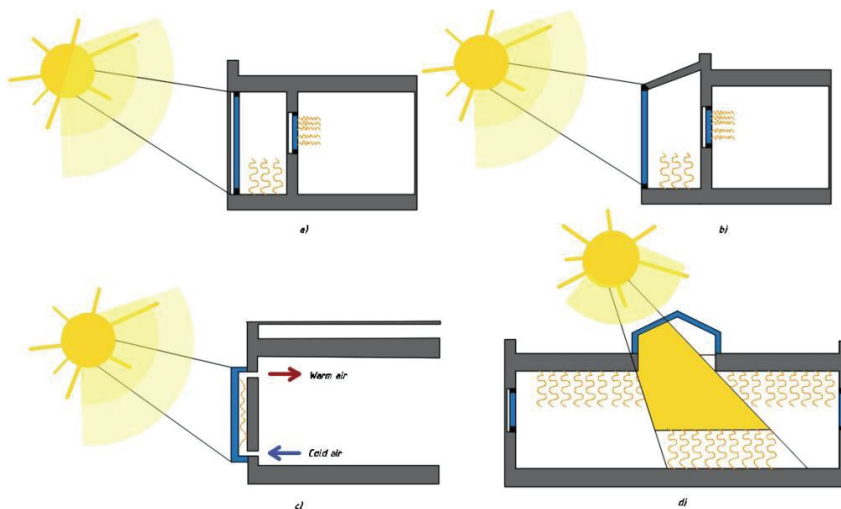


Fig. 2. Passive solar heating methods (a – a glass gallery; b - an adjacent greenhouse; c – a Trombe wall; d – a zenith lamp).

One of the aspects of bioclimatic architecture is protection of the construction from excessive solar radiation. The authors suggest the following sun protection methods: additional vegetation, designing a porch, installing blinds, using horizontal lamellas (Fig. 3) [16].

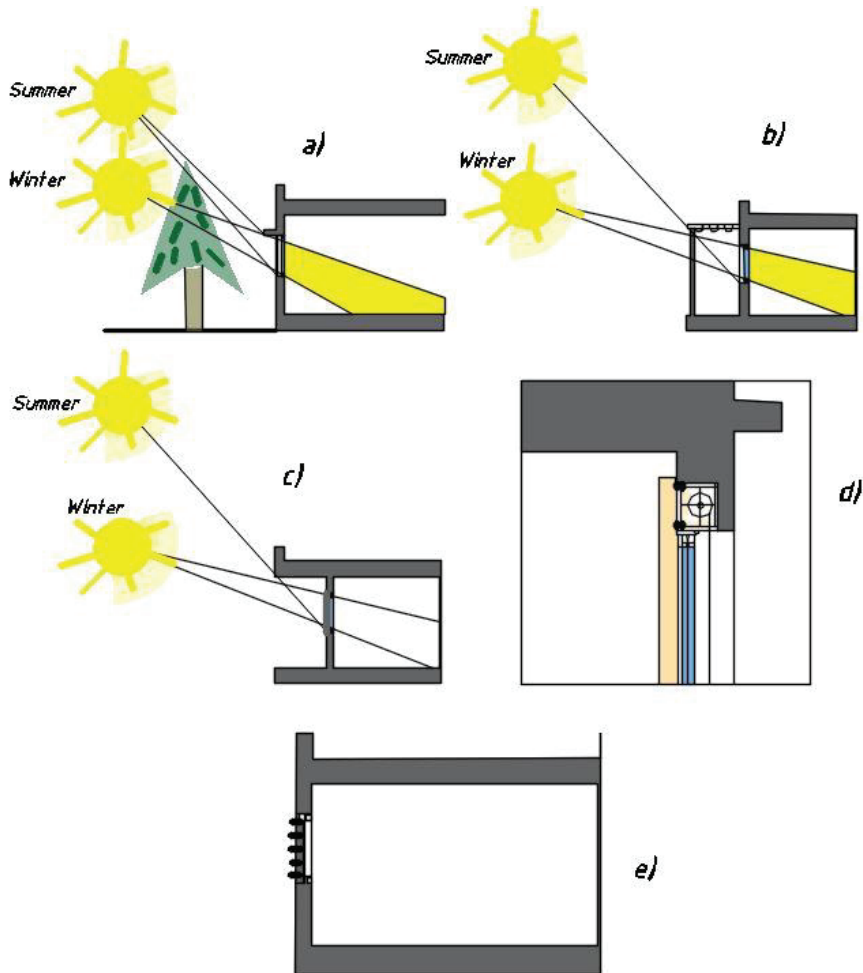


Fig. 3. Methods of sun protection (a – plants; b – gazebos with plants; c – porch; d – blinds outside; e – lamellas).

Such option as cooling the room due to the high thermal mass has been considered. Thus, a degree of natural cooling of the building depends on the amount of heat accumulated by it during the day. An improved version of this method is the use of materials with a phase change in enclosing structures [16].

Evaporative cooling can be performed in several ways such as vegetation, roof and/or indoor spraying, etc. (Fig. 4). It is more efficient to implement such solutions in dry climates [16].

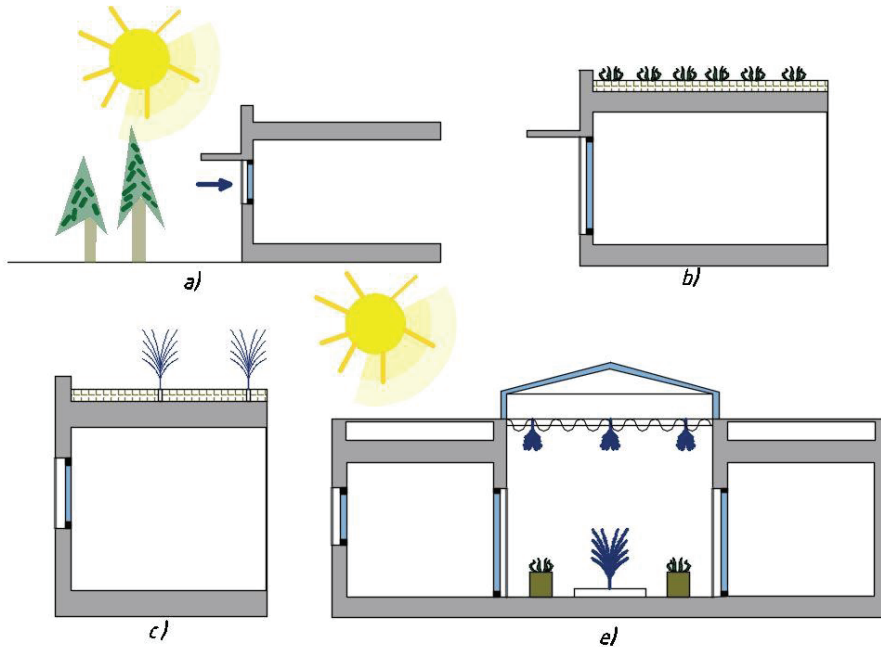


Fig. 4. Methods of cooling by evaporation (a – plants; b – green roof; c – spray water on roof; d – indoor water spraying).

7 Conclusion

The study considers methods of evaluation of the energy-efficient technologies and their effectiveness, which are based on climate analysis carried out using the Givoni chart and according to the method developed by P.C. Agrawal. The methods are quite informative, although they require improvement that will provide a more accurate rational strategy. An analysis of the phase change material operation led to the conclusion that it is possible to use them as a part of a composite panel to increase energy efficiency of the construction. Structured by G. V. Mikheev, E. Y. Kaporozova, A. V. Yuri, T. D. Khaliullin, F. Khalili, architectural and constructional solutions based on the principle of the greatest efficiency in a particular climate allow us to choose the most suitable options for a particular region.

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