Quality assurance in the design of heating systems in green building

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Abstract. The article considered the issue of thermal stabilization of buildings, formed a mathematical model for the room. The applied systems of thermoactive structures are described, their strengths and weaknesses are determined. Other methods of "passive" cooling systems are considered, it is determined that the main air conditioning systems are not fully used is technically and economically feasible, however, as complementary systems for the off-season must be taken into account. The heat supply system using a heat pump and a low-potential source (sewage) is described. This system allows for more efficient use of the evaporative-condensation cycle by operating with a smaller temperature difference between the heat pump flow and the low potential source. It is shown that the main attention should be paid to the development of alternative heating systems and the use of renewable energy sources. A significant part of the equipment used cannot always be considered as part of the overall strategy for the formation of an ecological building. The use of forms of heating based on low-potential sources will improve the environmental performance of residential and industrial buildings.

1. Introduction

The operating principle of thermoactive building systems (TABS) is based on the thermal inertia of buildings. The "active" element of the combined cooling or heating system operates by embedded pipes in the structural concrete slabs of the building [1]. At the same time, cold ground water can flow in the pipes, chilled water to maintain the air conditioning system or even complete replacement [2]. In winter, these systems can be used to heat concrete structures using low-grade heat sources. TABS operate at temperatures close to ambient temperature, which facilitates the integration of renewable energy sources [3]. The main advantages of TABS systems:

- the cooling demand is spread over a longer period during the daytime and partly shifted from daytime to nighttime. This allows you to reduce peak loads and use lower capacity air conditioning units;
- rejection of suspended ceilings allows to reduce the height of the building, providing significant savings in building materials;
- heating or cooling systems with temperatures close to room temperature can be used.

This increases the energy efficiency of heat pumps, condensing boilers, solar collectors, ground heat exchangers:

- night ventilation can be used for cooling;
- low cost of installation, operation and maintenance.
2. Materials and methods

Paper [4] presents the results of mathematical modeling comparing the primary energy use and ventilation performance of thermoactive construction versus conventional office building systems for the continental climate of Omaha, Nebraska (USA) with pronounced heating and cooling periods.

TABS for heating is carried out using a geothermal heat pump and for cooling using a geothermal heat exchanger without an additional compression cycle of the working fluid [5]. It was found that the coordination of TABS and the traditional system is critical, that is, the supply air temperature and the temperature of the active layer greatly affects the performance of the system as a whole [6]. The small contribution of TABS to support heating shows the need to adapt the ventilation system configuration to TABS. Main energy intensity 189 kWh / m² was recorded for the case of TAS (thermoactive system); in contrast, a conventional air conditioning system consumes 229 kWh / m², a difference of 20%. It is possible to observe clear advantages of the TAS with respect to thermal comfort: during the summer cooling periods, the radiation temperature of the TAS body is on average 2 °C lower than for the traditional system [7].

Based on these results, the use of traditional ventilation in combination with thermoactive designs is a very promising alternative to traditional systems, offering significant primary energy savings as well as thermal comfort benefits provided by TAS and combined with low-potential exergy heating and cooling [8].

Important factors that determine the heating and cooling capacity of radiant panel systems:
- coefficient of heat transfer between surface and room, acceptable minimum and maximum surface temperatures based on comfort requirements;
- the dew point temperature in the room and the intensity of heat transfer between the pipes and the slab material.

3. Results and discussion

The intensity of heat transfer depends on the orientation of the surface and its temperature relative to the room temperature (respectively, for heating or cooling) [9]. The radiant heat transfer coefficient in most cases is approximately 5.5 W / (m² · °C), the convective heat transfer coefficient will depend on many factors [10].

Due to the high inertia of the TABS systems, the room temperature will vary within the limits that do not violate the comfortable state of the thermal regime of the room. In works [11] and [12] it is shown that people perceive temperature changes within the comfortable range as acceptable if its level does not exceed 4 °C / hour. Typically, in buildings with a TABS system, the temperature drift is (0.5 - 1.0) °C / hour.

TABS does not affect the humidity state of the indoor air, however, the advantage of these systems is that in buildings with TABS, the ventilation system is designed to assimilate harmful conditions (including humidity, CO₂ concentration in the air, but not excess heat), and the temperature regime of the premises provided by the TABS system, due to whereby the required performance of the ventilation system can be reduced. Since the required temperature of the water circulating in the TABS system in most cases does not exceed +19 °C, in many cases ventilation by opening windows and natural ventilation can also be used to cool the rooms, especially at night.

To avoid condensation on the surface or inside the structure, the surface temperature and moisture content of the air must be controlled. One method is to set a lower limit for the supply water temperature to the dew point temperature.

The performance of a radiant cooling system can also be increased if the ventilation system dehumidifies the air.

To ensure the temperature regime of the building, it is advisable to use a system that can simultaneously perform the functions of both heating and air conditioning. Because when using such a system, the capital costs of the installed equipment are reduced. One of such systems is thermoactive structures. This system is the optimal solution for the reconstruction of outdated heating systems, since there is no need to replace old systems with new ones, this is quite relevant for high-rise buildings that
were built (40 ... 50) years ago. At the same time, several important issues are actually being resolved, among which is an increase in the resistance to heat transfer of enclosing structures. As a result - bringing buildings to the existing energy efficiency standards. The issue of heating and air conditioning is being solved due to the fact that the heating circuits are located from the outside. The formation of condensation on the border between the insulation and the wall is practically excluded. This in turn avoids the formation of fungi. Also, the hydrophilic properties of most mineral wool heaters can be ignored, since the heating circuits of the system in winter have a temperature that is higher than the outside temperature. This allows you to avoid wetting the insulation, which leads to an increase in thermal conductivity, that is, a decrease in the total resistance of heat transfer and an increase in heat loss.

Next, we will consider a schematic diagram of the system's operation using thermal energy storage. The role of the battery in the system is achieving the possibility of nighttime electricity consumption at a reduced rate, and further use in the daytime. The accumulator is selected depending on the heat consumption of the building so that its volume is sufficient to cover the design load of the system. An important aspect for such a circuit design is the thermal inertia of buildings, which makes it possible to achieve a system operating time of about 10 hours per day.

A feature of the application of these systems is the mandatory device for reversible circulation of circuits. Since, in the absence, zones of overheating and underheating of the system necessarily appear, that is, a significant temperature gradient is formed, which must be avoided. Another method to solve this problem is to use a "coiled" pipe-laying scheme, but this significantly increases the length of the pipelines, which also increases the cost of the system. Therefore, in practice, they use the type of laying "Snake" and reversible circulation of the coolant.

Figure 1 shows a schematic diagram of a system using a heat pump and solar collectors as a heat source.

![Figure 1](image_url)

Figure 1. Thermal-hydraulic diagram of the building heat supply system using alternative sources.

In this scheme, the maximum efficiency of using solar energy is realized. In summer, solar collectors provide hot water supply. In the off-season and in winter, it is possible to accumulate heat for a low-temperature heating system. Also, when the temperatures that can be obtained from the solar collector are quite low, it is more advisable to use this low-grade energy to heat the heat pump evaporator, thereby increasing COP. When this circuit design is combined with low-temperature systems of thermoactive structures, the lowest energy consumption by the heat pump is achieved, since we have a low supply temperature to the heating system (to 25 ... 28 °C) and a relatively high temperature on the heat pump evaporator (up to 15 °C).

The advantage of the circuit shown in Fig. 1 is that most heat pumps, if they have a four-way valve, which performs the function of changing the direction of the reverse Carnot cycle, can work for both heating and cooling. Moreover, if a ground-water heat pump is used, it is possible to use the so-called
"passive" cold of the Earth. That is, it is possible to obtain a heat carrier with a temperature of 10 °C during a certain period of the year. That is completely sufficient for the effective operation of thermoactive insulation systems.

If air is used as a low-grade heat source and there is no possibility of using “passive” cold, the efficiency of air conditioning with the help of a heat pump is still at a high level due to a small temperature difference between the evaporator and condenser of the heat pump. At the same time, EER (Energy Efficiency Ratio) reaches values of 7 ... 8, in contrast to the application with a conventional air conditioning system, where this indicator does not exceed an average of 3.5.

The schematic solution provides for the separation of heating circuits along different facades of buildings. This allows you to change the temperature head depending on orientation to the cardinal points, that is, to increase the heat flux from the north side, and reduce it from the side of solar insolation. When choosing a method laying pipelines give preference to the Tichelman scheme (with the associated movement of the coolant), using its main advantage - the same coolant flow rate in each circuit of the system due to the same length of the circuits, as the formation of the covering layer - the same hydraulic resistance. This avoids significant temperature gradients, especially when a reversible circulation scheme is used with a certain switching hysteresis, which is determined experimentally for each building.

The use of this system makes it possible to achieve the heat transfer coefficient from the inner surface of the enclosing structures of the room reaches (5 ... 9) W/ (m²·°C), therefore, it is advisable to use the system in buildings with a glazing percentage that is less than 50%.

In the context of the application of a thermoactive heating system, the question of rapid heating of the room arises, since the proposed system is inertial and there is no way to dramatically increase the temperature regime in short periods of time. The automation system works according to algorithms to lower the temperature during the absence of people in the building. For efficient and quick heating or recooling of the room to optimal temperatures, it is advisable to use the system, the diagram of which is shown in Figure 2. Scheme of the operation of the air-cooled heating system using a heat accumulator.

![Figure 2. Thermal aerodynamic scheme of the system air heating-cooling.](image)

Used as a heat storage substance predominantly organic substances with a relatively low phase transition temperature (hydrated salts, paraffins, fatty acids), which are in capsules with a metal shell.

The amount of heat storage medium depends on the thermal load of the building. The accumulator is usually arranged in the central part of the building, the capsules are evenly distributed along the height and width of the building, this makes it possible to regulate the temperature in the rooms by installing fans on each of the floors. Heat input to the accumulator is carried out at night from an air-to-air heat pump.

Additionally, solar air collectors are installed, which on sunny days heat up the heat accumulator. At the same time, the cost of the air manifold is much lower than the usual one.

As for the technical characteristics of heating units, they are presented in table 1.
Table 1. The technical characteristics of heating units.

| Designation | Fan type | Engine power, kW/rev | Air capacity, m³/h | Length, L, mm | Thermal power, kW | Heat from to, kg | Unit weight, kg | Air heater |
|-------------|----------|----------------------|--------------------|---------------|------------------|-----------------|----------------|-----------|
| AO-1 | BO-3.55-02 | 0.18/1000 | 1600 | 900 | 16.9 | 15 | 50 | 98 |
| AO-2 | BO-3.55-01 | 0.37/1500 | 2500 | 900 | 23.0 | 15 | 45 | 100 KSk3-6 |
| AO-3 | BO-5.6-01 | 0.37/1500 | 3000 | 1000 | 25.9 | 15 | 45 | 110 |
| AO-4 | BO-4.5-01 | 0.37/1500 | 2800 | 950 | 25.0 | 15 | 44 | 105 |

4. Summary

The problem of real thermal modernization today is the absence or inoperative state of the ventilation system with mechanical induction of public buildings. The use of exclusively natural ventilation is not sufficient for most cases, due to the presence of a human factor of influence and the physical inability to provide a sufficient circulation rate. This system allows heating and ventilation to be combined into one system, which also saves in terms of capital costs. If you install an air recuperator, you can achieve even greater efficiency for this scheme.

We described the thermoactive insulation system, analyzed the diagrams of the heating systems and proposed several options for circuit solutions to ensure the set task. Both the simplest scheme of the heat supply system and the more advanced one were considered, which allows significant savings on thermal stabilization of buildings. Also shown is a schematic diagram of the distribution of heating circuits along the facade of the building. A scheme is also presented that allows you to quickly and efficiently provide additional space heating, or can be used in addition to the existing thermal stabilization system.

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