THE RATIONAL USE OF ENERGY RESOURCES FOR CREATION THE REQUIRED MICROCLIMATE PARAMETERS IN RUSSIAN ORTHODOX TEMPLES

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The features of the establishment and maintenance of the required parameters of the microclimate in the Russian orthodox churches discusses. Constructive features of the orthodox churches of various architectural forms and styles, which affect on design of natural ventilation systems is considered. The features of experimental studies in the wind tunnel which conducted to find the aerodynamic coefficients are described. The mathematical relationships to determine the consumption of candles, which obtained on the basis of statistical data and experimental studies, is considered. Recommendations for the design of heating systems in the prayer halls of the temples are given.

Keywords: orthodox temples, microclimate, aerodynamics, aeration, consumption of candles

Considering the various orthodox temples, located on the territory of the Russian Federation, it is possible to trace the history of Russian architecture, long more than a thousand years. The parallel development of the stone construction and wooden architecture played an important role. Many elements, which has the first embodiment in the wood, subsequently used in the stone construction. Of course, at the same time remained a sacred meaning inherent in each element, both in the external architecture (the number of domes, form of dome, etc.), as well as in the interiors (filling the iconostasis, burning candles, etc.). Each temple is considered as a unique structure, and, in solving various engineering tasks, each of them requires an individual approach.

Currently, this issue is very relevant, since many of temples are restored from the ruins or buildings, which use for other purposes (workshops, warehouses) that have become established as a result of the ravages of the Soviet regime. Recovery of each temple is a complex and individual task. The department of heat and gas supply of Nizhny Novgorod State University of Architecture and Civil Engineering for many years conducted research and practical activities in the field of creation the required parameters of the microclimate in the orthodox temples.

In solving such problems in the first all pay attention to the architectural and design features of the temple: tent temple, in the form of “ship”, cross-domed, tiered temple, etc. And here the important role played by the history of the construction of the temple, for example, in Nizhny Novgorod, a temple built by the order of the merchant Strogonov built in a unique style, which subsequently received the name “Strogonovskoe baroque (baroque of Strogonov)”. The architecture of the temple is important for the experimental determination of aerodynamic coefficients – the dimensionless variables, showing what proportion of dynamic pressure becomes static pressure. Knowing the value of aerodynamic coefficients can calculate the area of natural ventilation systems in the prayer hall.

Natural ventilation (aeration) in the temples has a number of advantages compared with mechanical: does not consume electrical energy, much cheaper, relatively low-cost installation, does not violate the interior of the church, has the property of self-regulation that can reduce the thermal load on the heating system. But this calculation of aeration system requires consideration a number of factors that may generally be determined using experimental studies. Similar experiments are conducted in a wind tunnel, and the model of temple itself is drained by pipes in places of possible location of the intake and exhaust transoms. The most effective it is considered the installation of air-supply transoms in the lower tier of the window openings of the prayer hall, and the transom exhaust set at the top of the window openings of the drum over the prayer hall [1, 2, 3, 4]. However, this is only possible if the vault of the prayer hall is not separated from the drum by a partition.

For all of five domes have access in the Rozhdestvenskaja (Stroganovskaja) Church (str. Rozhdestvenskaja, Nizhny Novgorod), which gives a large variation in the placement of the exhaust transoms in the temple, in the Krestovozdvizhenskij cathedral (st. Okskiy s’ezd, Nizhny Novgorod) have access just to central dome and in the church of Zhen-Mironosic (str. Dobrolyubov, Nizhny Novgorod) vault fully hardwired (in this case, the exhaust transoms can only use a portion of the upper tier of window openings of the prayer hall).

Fig. 1. Explored temples:
a – The Church of Zhen-Mironosic; b – Rozhdestvenskaja church;
c – Krestovozdvizhenskij cathedral; d – Spasopreobrazheniskij cathedral

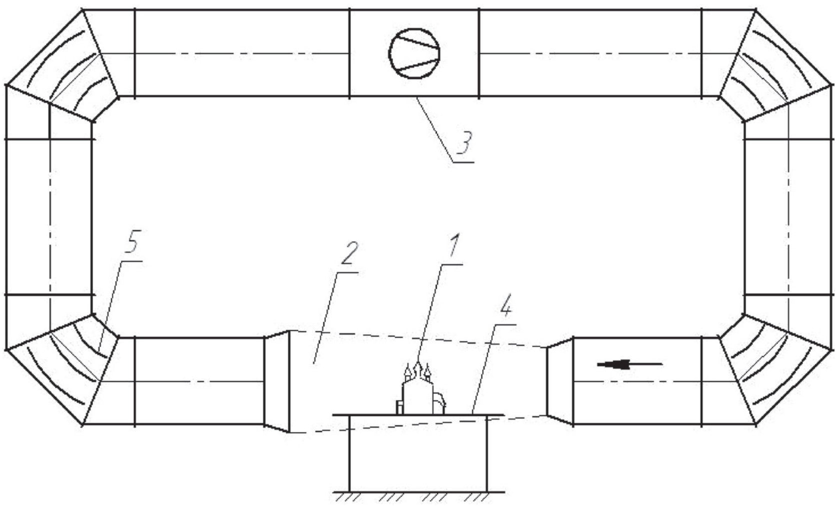

Fig. 2. Experimental setup:
1 – the investigated model of the object; 2 – the working area of a wind tunnel;
3 – axial fan; 4 – stand for model building; 5 – guide ribs

Models of all these above mentioned temples and the Spasopreobrazheniskij Cathedral (Sormovo, Nizhny Novgorod) were tested in a closed subsonic wind tunnel (Fig. 2) to obtain a result of the values of aerodynamic coefficients fields. The measurements were made for each point for the eight directions of airflow: north, northeast, east, southeast, south, southwest, west and northwest (Fig. 3) [4].

Equally important in the design of natural ventilation is the study of the internal aerodynamics of the temple. In addition to the heating systems the large amount of heat released from the candles, lamps and parishioners. Moreover, the magnitude of heat from the candles can be comparable to the capacity of the heating system.

To account for the consumption of candles were conducted statistical and experimental studies in various churches in Nizhny Novgorod in the different periods of the year, including during the patrornal feasts, when in temples is marked the maximum quantity of the parishioners.

In the church of the Archangel Michael (in the territory of Nizhny Novgorod Kremlin) located 170 nests under candles in sconces and consumption of candles on the average is 0,78 kg/h.

In the Zhen-Mironosic church (str. Dobrolyubova) located 448 nests under the candles, the average consumption – 2,15 kg/h.

In the Uspenija Bozhiej Materi church (lane Krutoj) located 438 nests under the candles, the average consumption – 1,58 kg/h.

In the Prepodobnogo Sergija Radonezhskogo church (str. Sergievskaja) located 496 nests under the candles, the average consumption – 2,38 kg/h.

In the Voznesenija Gospodnja church (str. Il'inskaja) located 313 nests under the candles, the average consumption – 1,44 kg/h.

In the Vsemilostivejshego Spasa church (str. Maksima Gor'kogo) located 735 nests under the candles, the average consumption – 3,38 kg/h.

In the Krestovozdvizhenskij cathedral (st. Okskiy s'ezd) located 526 nests under the candles, the average consumption – 2,21 kg/h.

In churches of Zhen-Mironosic and Uspenija Bozhiej Materi in spite of a comparable number of nests under candles, the average candles consumptions differs significantly (in the first temple is 26 % more). Both these temples belong to the type "ship" [5, 6] and have separated vault of the prayer hall from drums, and as a result, through the drums of the temple

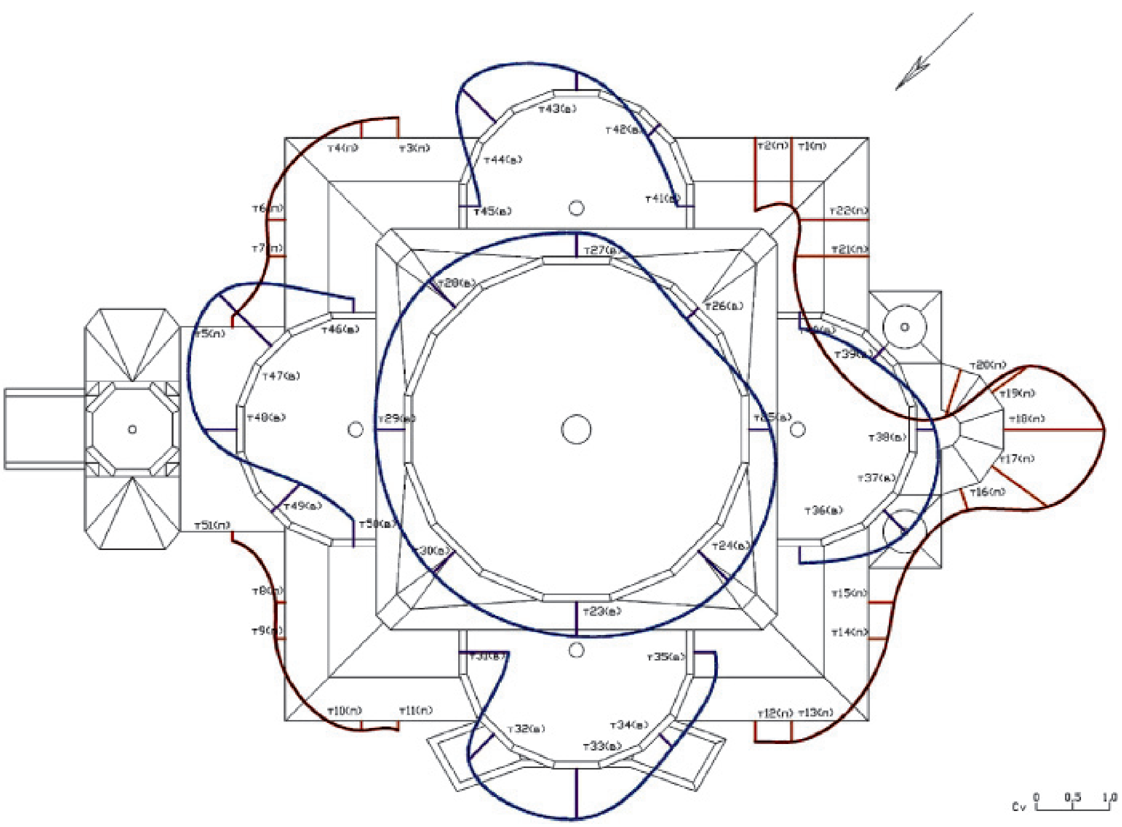

Fig. 3. The example of values of aerodynamic coefficient fields for the Spasopreobrazheniskij cathedral at the northeast wind direction

is not possible to carry out natural ventilation. However, the church of Zhen-Mironosic is a combined summer and winter of the church, so that in terms of the prayer hall has a half T-shaped without walls, while in the church of Uspenija Bozhiej Materi – T-shaped.

At 50 % filling parishioners of the prayer hall of an Orthodox church, according to statistics there is full occupancy candles in sconces nests. When the maximum filling parishioners of the prayer hall (during the main patronal feasts) in addition to the candles in sconces worshipers burned candles in their hands, but usually, their number does not exceed 30 %.

Form coefficient, which varies from 0,75 to 1,13 – an empirical value has been introduced by us to take into account the architectural and design features of temple.

The following mathematical relationships have been formulated based on our experimental studies and written in a general form:

$$G_c^{\min} = \frac{0{,}1 \cdot g_c \cdot n_c \cdot K_f}{1000}; \qquad (1)$$

$$G_c^{mid} = \frac{g_c \cdot n_c \cdot K_f}{1000}; \qquad (2)$$

$$G_c^{\max} = \frac{g_c (n_c + 0{,}3\, n_p) \cdot K_f}{1000}, \qquad (3)$$

where $G_c^{\min}$, G_c^{mid}, $G_c^{\max}$ – consumption of candles kilogram per hour, respectively, for the minimum (10 %), moderate (50 %) and maximum (100 %) of filling of the prayer hall parishioners;; n_c – the total number of nests under the candles in the temple, pcs; n_p – the maximum number of parishioners, person; K_f – form coefficient; g_s – the consumption of candles from one socket, gram per hour (ranging from 3 to 5 gram per hour depending on the season of year).

Theoretical and experimental research will allow conducting a more accurate calculation of the system of natural ventilation in the prayer hall. As aeration systems do not consume electricity, liberated electrical power, calculated on the mechanical system can be directed to drying the basement structure of the temple (in the heat gun), since over moistening of basement of the building cause additional heat losses through the zones of regular (seasonal) temperature changes.

Due to the drying of over moistening basement structures providing the required vapor permeability protecting the walls from precipitation and to create the required meteorological conditions of engineering systems can achieve savings of thermal energy in the temples of the order 7–15 % of total heat loss of the building.

A separate issue is the heating of the temple. Completely eliminate the release of soot from the combustion of candles is not possible, therefore, to reduce the deposition rate of the polarized soot on walling structure can be installed for heating churches radiators (with heat transfer about 50 % by convection and approximately 50 % by radiation) or registers of smooth pipes to the same redistribution of species heat. Set in the convectors for heating churches, which have about 75 % of heat transfer by convection and approximately 25 % – radiation should be after the thermal and aerodynamic research. Above the convector creates a powerful upward convection current which lead to intensive deposition of soot on the envelope surface above the heater. For the churches in the region, with an estimated outdoor temperature $t_{ext} \leq -20\,°C$, depending on their volume-planning and design solutions should be designed or radiator, or combined with radiant panel heating and air heating, or just air heating system.

A very controversial decision is the installation of under floor heating, as the convective flows generated over the heated surface of the floor in the temple, a negative impact on climate parameters, on people and on the stability of the candles burning in the cold season.

These tips may help in the work to achieve optimal economic effect and save interior of the church, protecting it from the negative effects described above.

More specific recommendations for each temple are selected individually, depending on the climatic influences, structural, architectural and stylistic peculiarities and other factors on the basis of the surveys, calculations or experimental studies.

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