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CHURCHES HEATING: A CHOICE BETWEEN CONSERVATION AND THERMAL CONFORT

BY

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Abstract. In this paper is presented a numerical approach of the indoor climate environment created inside of an Orthodox monastery. In Cetatuia monastery the heating system used in present is with static heaters. The numerical model has the proposes to subject to comparison another heat system: floor heating in order to have a better understanding of the differences between them. Historical buildings and churches constitute a problem because they have enormous volumes and the envelope has a low efficiency. Thus, nowadays, the original use of the church in changing. Where a lot of churches are in need of a major restoration or renovation, adapting the heating system becomes an important point of study. Performance requirements for church heating systems with respect to preservation, energy consumption, thermal comfort and aesthetics are formulated then we have to made the most suitable design of a heating system in a particular monumental church. Simulation models and tools and their application have the start work to ensure the best performance of all equipment’s. The comparative results showed that the existing heating system is inefficient and has a lot of damage for the artworks and the painting inside the church.

Key words: heating system; heating system modeling; indoor climate; conservation; underfloor heating; static heating system.

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1. Introduction

Churches constitute an inestimable wealth, consisting of sacred and liturgical items as well as the patrimony preserved in museums and historical buildings. The structure of old monumental churches differs a lot from contemporary buildings. The structural materials were wood, bricks and stone.

Cold churches have been used for centuries. But now, the increasing demand for thermal comfort has made heating systems quite common, and they often cause more or less evident damage. In dry, cold climates, heating generates a climatic condition totally different from the natural, unheated climate to which artworks have become acclimatized and in most cases this large difference in levels of climatic factors and their variability in not tolerable.

Churches preserve many kinds of valuable artworks, each of them with a specific vulnerability, painting on walls and wooden panels are subjected to cracking, swelling, blistering, and soiling. Frescos mostly to efflorescence and blackening, wooden artifacts to cracking, metals to corrosion, textiles to fading and soiling. In most cases, heating is derived from two major needs: economy (installation, use and maintenance) and thermal comfort, conservation requirements are only rarely considered (Camuffo & della Vale, 2007). In this article two heating metrologies are analyzed: static heaters – heating the whole room and then allowing people to enter, and floor heating – keeping the room cool and warming people with low radiant heating named underfloor heating.

Comfort is a subjective parameter that describes to what extent humans find the indoor climate acceptable. People find temperature as a important factor to describe the state of comfort, compared with order parameters. The comfort temperature range depends on the level of activity, clothing, age; the typical range of comfort is between 12º,…,15ºC for churches. The relative humidity parameters has the range value of comfort between 70%,…,30% (Hudişteanu *et al.*, 2014).

Conservation of materials in the building requires an indoor climate that minimizes ageing and degradation of the materials that are to be preserved. This depends on the materials and the type of degradation processes that are prevalent in the building. For materials, relative humidity is often the most important climate parameter (Hudişteanu *et al.*, 2014).

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Cost are always a limiting factor and we must consider this from the beginnig. A solution that is too expensive is useless(Hudişteanu *et al.*, 2014).

2. Problems with Static Heaters

Central heating has the advantage of utilizing well known traditional techniques. The whole volume is heated and the thermal comfort is achieved, at least in theory. In this case heat tends to rise and to warm the upper part of the church, which contain the artworks. In the ceiling and the wall plaster at the upper part the dissolution-recrystallization cycles of soluble salts (Arnold & Zehnder 1991; Bläuer-Böhm *et al*., 2001) appears and has devastating action on the artworks integrity (Lăzărescu, 1999).

3. Problems with Underfloor Heating

With the underfloor heating the heat is more uniformly distributed and the environment becomes thermally comfortable. However the underflooring heating cause convective air motions and the surface blackening. Underfloor heating causes irreversible damage to the floor and to the tombs and the archaeological remains (Lăzărescu, 1999).

4. Case Study

The problem studied in the article take into account the present heating system of the Cetatuia church monastery. The plan and the section drawing of the monastery are presented in Figs. 1 and 2.

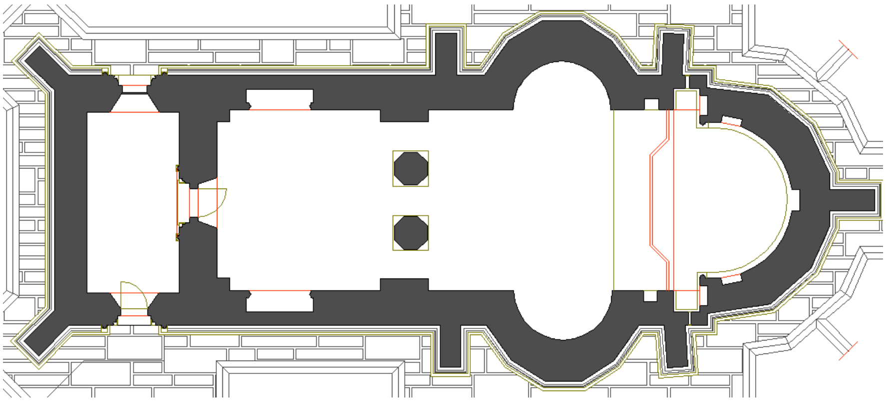

Fig. 1 – Plan view of the Cetatuia monastery.

Having the plan and the section drawing give the possibility to model the monastery church.

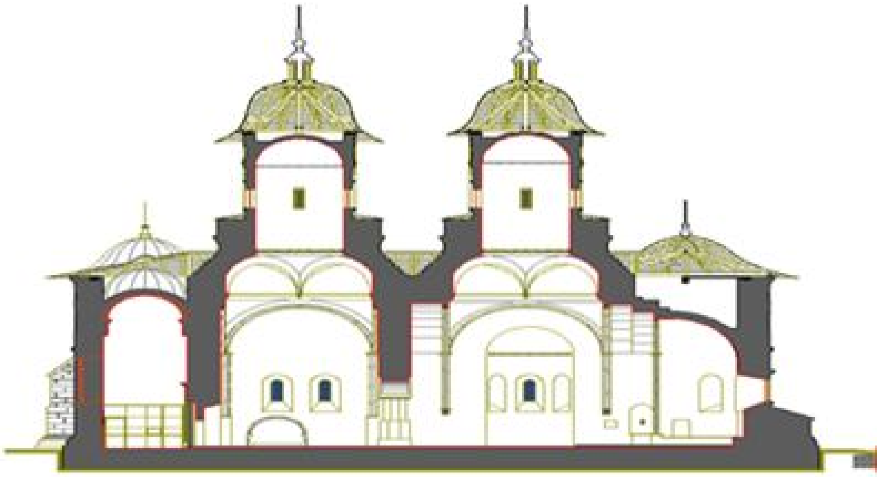

Fig. 2 – Section view of Cetatuia monastery.

5. Numerical Modeling

The numerical model is realized using Ansys-Fluent software, in steady state regime. The type of flowing is the laminar. Having the section drawing it was created a 2d model for the longitudinal section of the church. The geometrical dimensions were those of the real building. There were created two model of simulation, one with static heaters (Fig. 3) and one with underfloor heating (Fig. 4). The external conditions imposed to the walls and windows in

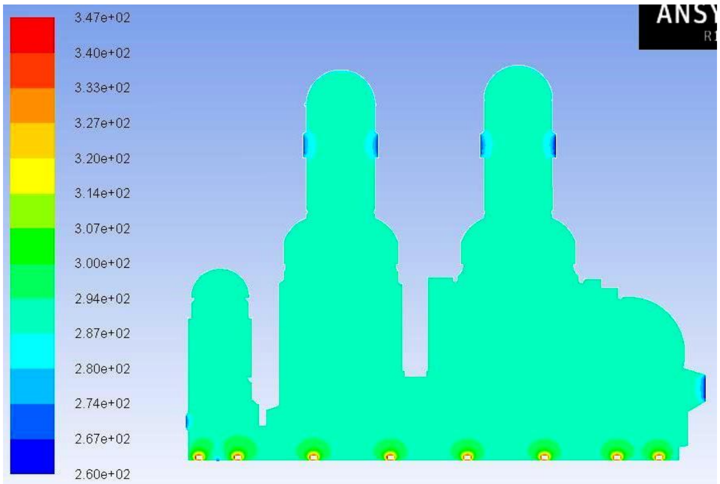

Fig. 3 – Church with static heaters modeling – Temperature Spectrum.

simulation were the temperature of air –18ºC the convective heat transfer coefficient of 24 W/m2.K for the exterior walls and of 12 W/m2.K for the interior walls. Also the heat flux for the heaters and for the underfloor heating system is has been determined using STAS 6648 – church heating demand:

$$Q = \sum K_F S_F (t_i - t_e) + \sum S_P\, a_p (t_i - t_0),\ [\mathrm{W}], \tag{1}$$

where: t_i is the interior demand temperature; t_0 – interior temperature at what the heating system start.

6. Results

The numerical results were obtain as temperature spectrum and curved profiles that represents temperature variation along the height of the church.

It can be observed the difference in temperature and distribution of temperature in the occupation zone (Fig. 4). First 2 m from the height of the church are the most important because is this occupation zone in which the humans activities take place (Figs. 5 and 6). The static heaters heat the whole volume of air and in the case of underfloor heating the first 2 m are heat but the rest have a low and constant temperature. In case of static heaters the variation in distribution of temperature can be observed.

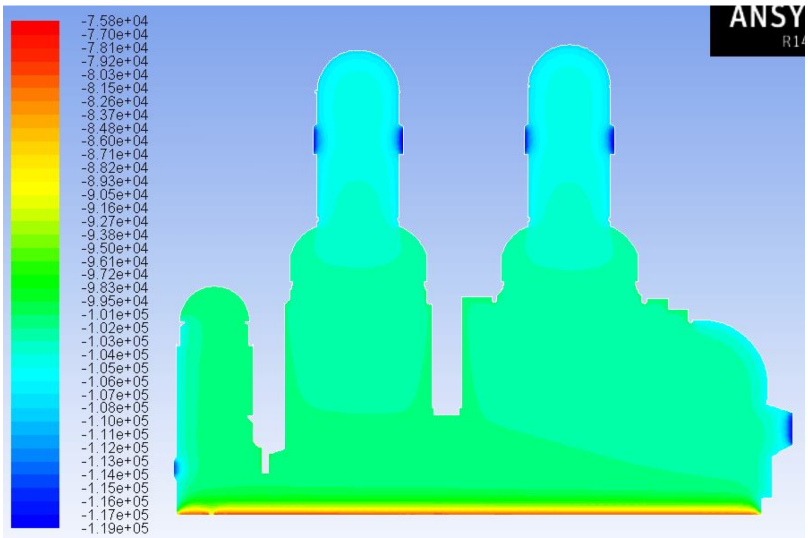

Fig. 4 – Church with underfloor heating modeling – Temperature Spectrum.

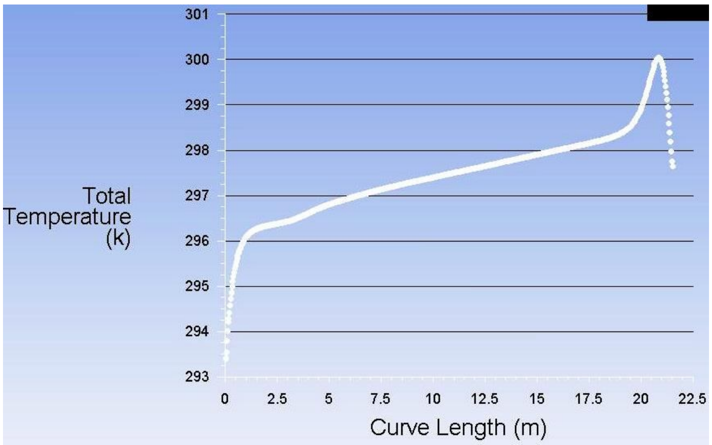

Fig. 5 – Profile of temperature distribution along the height of the church.

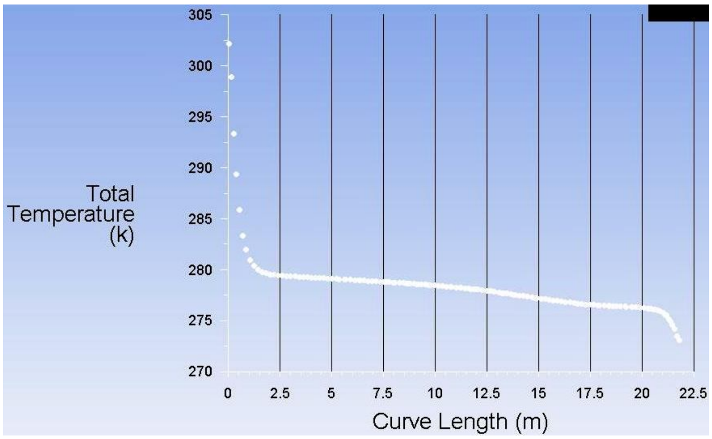

Fig. 6 – Profiles of temperature *vs.* height distribution in case on underfloor heating.

4. Conclusions

In this case study, the local radiant heating system is a nice alternative for the “old” static heating system that heats the whole air volume of the church. First, the heating capacity of the local system is lower than that of the churches static heating system. Secondly, whereas the static heating system needs to be operated for several hours before the service starts, the local heating system needs only to be operated from 15 min. before the service until the end of it. Therefore, the heating costs of the underfloor heating system will be importantly lower than those of the static heating system.

From the viewpoint of conservation, it is positive that the air convection is relatively small, and also in the whole church, is only heated very slowly and does not reach high temperatures. There are no abrupt variations in air temperature (thus also none in relative humidity) which could cause damage to monumental objects. And the stratification in air temperature above a height of about 2 m, which existed when operating the hot air heating system, is not present with the local heating system. The heat is present in the zone where the people are seated.

From the viewpoint of thermal comfort, more research has to be performed in order to rate the human thermal comfort in the church. The situation is very complex, because it is a quite cold exterior climate (–18°C) in winter.

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ÎNCĂLZIREA BISERICILOR: O ALEGERE ÎNTRE CONSERVARE ŞI COMFORT

(Rezumat)

În ultimul timp a devenit tot mai necesară, căutarea de soluții privind încălzirea bisericilor şi a clădirilor cu valoare istorică deosebită, care să asigure păstrarea nealterată a patrimoniului pe care-l găzduiesc. Un sistem de încălzire destinat bisericilor trebuie să îndeplinească nişte cerințe deosebite. Este necesară foarte multa atenție, în alegerea sistemului de încălzire datorită sensibilității obiectelor de cult, la schimburile de temperatura şi umezeală. În consecință trebuie evitate situațiile extreme, care pot fi dăunătoare obiectelor din lemn si picturilor.

Luând în considerare aceste cerințe, se impune necesitatea încălzirii în biserici de asemenea manieră, încât să se poată asigura un minim de 12°C, ținând cont că participanții la slujbă, sunt îmbrăcați în haine de stradă. Din punct de vedere energetic, un factor de importanță majoră, este repartiția de caldură. Aceasta trebuie dirijată în zona ocupată de credincioşi, într-un mod cât mai uniform, evitându-se încălzirea inutila a volumului de aer, situat la peste 2…3 m înălțime de la pardoseală.

Cu ajutorul programului de simulare Ansys-Fluent, s-a demonstrat că sistemul de incălzire cu corpuri statice, prezintă unele dezavantaje care nu îl recomandă in clădirile de cult. Deasemenea cerințele noi care există pentru clădirile de cult se poate realiza folosind încălzirea în pardoseală. Eficiență şi rentabiltatea sistemul a fost si este în continuare menținută.