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Journal of Cultural Heritage 11 (2010) 205–219
Journal of Cultural Heritage

Original article

An advanced church heating system favourable to artworks: A contribution to European standardisation

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Received 16 December 2008; accepted 24 February 2009
Available online 13 November 2009

Abstract

The European project FRIENDLY-HEATING (FH)*: comfortable to people and compatible with conservation of artworks preserved in churches* addressed the problems caused by the continuous or intermittent heating of historic churches, which disturbs the microclimatic conditions to which the building and the artworks preserved inside have acclimatised. As thermal comfort and the preservation of artworks often conflict with each other, a balance between the two needs is necessary. The proposed heating strategy is to provide a small amount of heat directly to people in the pew area while leaving the conditions in the church, as a whole, undisturbed. This novel heating system is based on some low-temperature radiant emitters mounted in a pew to provide a desirable distribution of heat to the feet, legs and hands of people occupying it. Due to little heat dispersion, this novel system not only significantly reduces the risk of mechanical stress in wooden artworks and panel or canvas paintings, fresco soiling and cyclic dissolution-recrystallization of soluble salts in the masonry, but is energy-efficient. The detailed environmental monitoring was conducted in the church of Santa Maria Maddalena in Rocca Pietore, Italy over a 3-year period to verify the performance of the novel heating system in comparison to the warm-air system that was active earlier in the church. The methodology and results of this comprehensive and multidisciplinary study were included in three draft standards of the European Committee for Standardisation intended for use in the study and control of environments of cultural heritage objects.

Keywords: Church heating; Preservation of cultural property; Warm-air heating; Pew heating; Heating carpets; Localized heating; Thermal comfort; European standardization

1. Introduction

A great deal of artistic wealth has survived for centuries in unheated buildings, if only dampness and related mould growth were avoided. Thick walls are a typical feature of many historic buildings, and help to smooth out the daily cycles of air temperature (T_A) and relative humidity (RH) and attenuate the seasonal ones, creating a natural microclimate favorable for the preservation of many artworks. The natural microclimate can be significantly altered after heating is introduced, especially in the case of churches, due to the necessity to raise the temperature (T) to an acceptable level in a short time and at low cost. Different heating systems and regimes are used, and various aspects of church heating have been extensively reviewed [1–5]. In many cases, the comfort requirements have had dramatic consequences on artworks preserved in churches, mostly managed by people who fail to grasp the implications of heating on the preservation of artworks.

This paper will concentrate on the everyday problems generated by heating for the thermal comfort of the congregation, i.e. typical church heating operated a few times a week during services or, on less frequent occasions, operated continually during the cold season in churches used on a daily basis. The paper will deliberately leave out the exceptional case of conservation heating, operated to stabilise RH on an acceptable level throughout the whole year by adding or withholding heat. Conservation

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doi:10.1016/j.culher.2009.02.008

heating is especially efficient in preventing dampness in buildings during the rainy seasons.

Continuous heating is sometimes considered a favorable strategy, which avoids cyclical changes in T and humidity. In cold climates, however, even modest heating can cause excessive RH drops due to a very limited amount of water vapour contained in the cold air. For instance, when the external T_A is $-10\,^{\circ}$C and the internal T is $+10\,^{\circ}$C, the indoor RH drops to extremely low levels e.g. 10 to 20% when outdoor RH is 50 to 100%, respectively. Low RH levels are damaging artworks. For example, they can cause the excessive shrinkage of wood leading to irreversible stretching and eventual cracking. Rapid heating for 1 or 2 hours is sometimes claimed to be a good strategy as it is considered too short to damage artworks. However, sharp variations in T cause sharp variations in RH and both can be dangerous. Therefore, clarification of safe heating strategies, based on sound science, is needed.

The European Funded Commission project *Friendly-Heating* (FH), implemented between 2002 and 2005, started with analysing the main risks for preservation and pointing out the pros and cons for each heating methodology and using many case studies [1]. Then, research was undertaken to develop a heating system which would provide direct confined heat just to people sitting without dispersing too much heat in the church as a whole reducing, thus, the variability in T and RH in the proximity of artworks.

The design and assessment of the novel system developed were based on extensive laboratory tests, numerical simulations using Computational Fluid Dynamics (CFD) [6] and direct measurements in two churches. Wooden artwork response [7–9] was monitored as well as the origin, distribution and transport of atmospheric pollutants [10–13]. This paper reports the results of comprehensive field monitoring, which was carried out during a 3-year period and concerned microclimate, heat diffusion and control, internal air motions and building response. Also, the thermal comfort of churchgoers was monitored in a number of independent ways in order to establish an objective methodology and assess a compromise between artwork preservation and thermal comfort. The final verification included a thorough control of the above environmental variables in the area where people are and around artworks, as well as the artwork response.

2. Churches selected for the study

Two churches with very cold indoor climate were selected in the Italian Alps to rigorously test the compatibility between preservation needs and thermal comfort for the novel heating system.

The first church was Santa Maria Maddalena in Rocca Pietore, situated at 1,143 metres above mean sea level in a small valley shielded from the winter sunshine, close to a glacier, with a daily minimum T between -10 and $-20\,^{\circ}$C. The church was built in the 15th century from local stone, and features one-metre-thick walls, and a nave with a chapel on either side, which were added in the 19th century. The building is relatively small and measures 25 m long. The nave is 8 m wide and 9 m tall, while the two side chapels are square, with each side measuring 4.5 m.

The church has various types of artworks, which was useful for the completeness of the research programme. These included wooden altarpiece, paintings on canvas and panels, choir stalls, a decorated organ-loft with modern organ, and frescoes from the 15th century. The magnificent altarpiece sculptured and painted by Ruprecht Potsch, dated 1518, is particularly valuable. It was cleaned and restored around 10 years ago. Originally, the altarpiece was used as recommended in 1523 by A. Stoss:

> *"Usually, the altarpiece wings should be kept closed, and only opened for important events. It should be cleaned twice a year. It should be softly lit to avoid any blackening from smoke: two small candles of pure wax are enough; additional candles should be placed far away"* [14].

The closed wings kept the internal microclimate particularly constant and protected the altarpiece against unnecessary smoke and dust deposition. The original use of soft candlelight reduced the generation of smoke and radiant heat from the flame. Stoss thus suggested a preservation-oriented management with limited regard to public enjoyment, and almost permanent self-protection. At present, the use is oriented to the enhancement of the public's enjoyment by keeping the wings permanently open, which makes sculptures exposed to environmental hazards and, consequently, increased risk to preservation, especially when the polychrome wood was blasted with warm air blown by the previous heating system, or when spot lamps light the altarpiece.

At the time of the last restoration, the church was provided with warm-air (WA) heating, planned for occasional use, mainly once or twice a week, for around 100 minutes of operation. Two grilles, one in the side chapel and the other in the nave (featuring blown-air velocities of 2.7 and 0.4 m/s, respectively), supplied warm air (70 – 80 °C) inside. After the WA heating was installed, some cracks increased in width, disfiguring the faces of the figures of Saint-Mary Magdalene and Saint-Catherine in the central part of the altarpiece. In addition, the warm air blown inside generated strong turbulence near the ceiling and the walls. The high air speed, elevated T_A and thermal gradients close to the walls were responsible for accelerating the deposition of smoke and dust particles via aerodynamic capture, Brownian motions, thermophoresis and electrophoresis. The surface blackening was worsened by downdraughts of cold air, which were formed on contact with cold surfaces. Around 10 years ago, the Superintendence to Artistic and Historical Cultural Heritage asked for accurate environmental monitoring to understand the causes of the rapid deterioration of the artworks just restored. The study identified the WA heating as the cause [15], but the congregation preferred to stay with the inadequate heating system rather than to return to the unheated church. The solution required a heating system that was at the same time comfortable to people and safe for artwork preservation, and when the FH project was launched, the choice of this church was natural, after it had been recognized as a very difficult problem needing a general solution.

The second case study was S. Stefano di Cadore, a church erected in the 14th century also situated in the Italian Alps. The church used infrared emitters heated by gas combustion and then a WA heating; however, none of these systems was able to create a thermally comfortable environment.