Improving indoor conditions in an Italian historical Church: the case study of Donnaregina Vecchia

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***Abstract*— Preserving the historical and artistic heritage is a topic of central interest, especially in countries that have particularly old heritage such as Italy. This study concerns the monitoring of environmental conditions of an ancient church in the center of Naples, a beautiful example of Italian Gothics, which, besides the absolute value of the architecture, even preserves works of art of special significance. The measurement campaign, performed during two typical winter weeks, was necessary to calibrate a dynamic energy model of the church. Then, a radiant floor was designed, to provide a space heating service for the Choir, used for conferences and events, so that the improvement of microclimatic conditions, in winter, can contribute to preserving artifacts (e.g., too cold conditions can induce cracks of wooden materials) and improve occupants' thermal comfort, without compromising the historical/artistic value of the church. The monitoring revealed that the indoor microclimatic conditions do not satisfy the ideal ranges for the conservation of the artistic heritage, and that the indoor environment is uncomfortable for the occupants. The positive effects of the new heating systems were also evaluated, by means of simulations performed starting from the calibrated energy model.**

Keywords—historical building, temperature and relative humidity monitoring, radiant floor.

I. INTRODUCTION

The conservation of historical monuments and works of art is a central theme in Italy, being an important part of its identity and economy. According to the UNESCO World Heritage List [1], Italy holds a significant share of world architectural heritage, which occupies 46% of the country's soil. In Italy, more than 4,000,000 of worldwide monuments are censed, with a high percentage of buildings built before 1919 [2]. In general, these buildings are built with massive thermal envelopes composed of local stones or bricks, and the building technique follows the local and traditional technologies. Their energy performances and thermal behavior can be very different according to the climate and the massive walls [2]. The conservation of the historical goods is largely related to the surrounding environment and to the chemical-physical iteration with the space in which they are located. Especially in buildings that house works of art, the conditions of the indoor environment, thermal, hygrometric, and lighting, are fundamental for the correct conservation of the assets. The design of systems for the microclimatic control of the indoor environment assumes a central role and involves the interaction with different competencies and professional figures. Indeed, a multidisciplinary approach to avoid deterioration of assets and work of art is necessary. In the first instance, before the design of a system for the microclimatic control, it is necessary to identify the optimal environmental conditions for the conservation of the artifacts, which can be very different based on their material and to their previous climate history. It is possible that the artifacts have adapted to environmental conditions [3], which, although not optimal for the conservation of the materials of which they are made, could have ensured its conservation, and avoided degradation phenomena [4]. Bringing the microclimatic conditions to the optimal ones defined by the law could cause degradation phenomena. It is therefore inevitable that a work of art adapts to certain climatic conditions, therefore varying the microclimate of an ambient, in this case, requires a much more careful and accurate study. To this aspect, there are also architectural-artistic constraints that limit and make the system design for energy refurbishment and building restoration even more complex. If on the one hand the need for a system that controls the microclimatic parameters, and which contains the temporal gradients and fluctuations, is increasingly compelling, on the other hand, the complexity of these systems and their size should not be underestimated. The finding of a proper space to locate the system for the microclimatic control, in an existing building of historical and artistic interest – in which the arrangement of plats' elements is limited – is a further issue that requires special attention. There is no single solution, but even more, in historical buildings, it is necessary to tackle the problem right from the design stage, by considering the singularity of the case and without underestimating the multidisciplinary approach. Providing heating and cooling, and proper microclimatic conditions for the work of art conservation means also avoiding daily and seasonal temperature fluctuation. In any case, as also remarked by Mecklenburg et al. [5], the chemical-mechanical properties of artworks should be verified to guarantee their conservation. In some cases, the use of an HVAC system, by varying the indoor temperature and relative humidity (RH), could damage the collections and artworks, that have acclimatized to specific microclimate conditions [6]. Definitely, the attention moves from the occupant's comfort to the artifact conservation. The possible phenomena of degradation could be even triggered by electromagnetic radiations coming from lighting bodies or natural light, air quality (air purity and pollutant concentration), and environmental conditions. In Italy, about the control of environmental conditions in museums, galleries, churches, libraries, and ancient buildings, two main standards were introduced: the UNI EN 15757:2010 [7] which replace the UNI 10969:2002, and the UNI 10829:1999 [8]. The first one is referred to the conservation of cultural assets and defines the temperature and RH to limit mechanical damages caused by climate, for the organic and hygroscopic materials. In particular, the standard specifies a method to identify the acceptable RH setpoint, which is based on an annual average calculation and on a 30-day central moving average (CMA30). The calculation of short-term fluctuations is based on the deviation of raw data from the CMA30. The variations of temperature are not specified by this standard (EN 15757). The standard (UNI 10829:1999) identifies the method for in-field measurement of temperature, RH, and lighting conditions aiming at preserving assets of historical and artistic interest. This standard provides an indication for the data processing, synthesis, and evaluation to combat degradation phenomena. It introduces statistical parameters to describe the dynamic phenomenon affecting the environment. About indoor environmental monitoring of historical buildings, different studies were developed by researchers. Lucero-Gómez et al. [9] described a flexible methodology to visualize the temperature and RH fluctuations in the "Scuola Grande di San Rocco in Venice" (Italy), which preserves Tintoretto's large paintings. The authors introduced a climatic excursion index useful to quantify the discrepancies of the temperature and RH fluctuations among the reference ranges. Silva et al. [10] analyzed the indoor climate of a thirteenth-century church in Lisbon (Portugal) relying on the standard EN 15757 and compared the data with those of other European churches. A new analysis method of indoor conditions in temperate climates was introduced, taking as reference the standard EN 15757, UNI 10829, and the ASHRAE specifications. The scope was to develop a method applicable to several case studies. The approach considered the risk of biological attacks and the differences between materials in the required stability conditions. Sciurpi et al. [11] described the monitoring of "La Specola" museum in Florence (Italy). The museum was affected by overheating problems during the summer, due to the absence of efficient solar shadings, and, as demonstrated by the measurement, the thermal and hygrometric conditions were not acceptable for the conservation of the exhibited objects. The authors identified and evaluated through a dynamic thermal simulation tool, different solutions to improve the microclimatic conditions but at the same time integrated into a historic building. Solar shading devices, double glazing, and solar control glasses were selected as possible passive strategies to reduce summer overheating and the most effective solution was identified. In the most effective case, the seasonal summer performance index (an indicator of indoor environmental quality) passes from around 40% to around 50%.

In this investigation, the ancient church of "Santa Maria Donnaregina Vecchia" was selected as a case study, being a representative construction of the XIV century in Naples, holding frescos, valuable furnishings, and a marble statue, and presenting as main issues the absence of a system for the microclimatic control. Even with reference to the present literature, two main questions were addressed in this study about the historical church: Are the microclimatic conditions of the indoor environments of Donnaregina Vecchia currently optimal to guarantee the conservation of its artifacts? In addition, do the microclimatic conditions guarantee thermal comfort for the occupants? These are the questions we asked ourselves in the first instance and which led to the environmental monitoring of the ancient church and to the design of a system for microclimatic control. For now, the study has foreseen the monitoring during two typical winter weeks, in which the temperature and RH, were analyzed. In the next sections, a detailed description of the church is reported, and the monitoring campaign is described. The results of the monitoring were employed to calibrate the energy model of the church. Indeed, the church was modeled in DesignBuilder V6 software – a graphical interface of EnergyPlus – that allows the dynamic energy simulation of buildings. Unlike other studies, in this case, the energy simulations were carried out by using an hourly weather file updated with the external temperatures and relative humidity values measured during the monitoring period. The reliability of the digital model was verified by comparing the trends of the measured and simulated indoor microclimatic conditions during the monitoring weeks. Once the church model was validated, a system for the microclimatic control was designed, and the microclimatic control of "Santa Maria Donnaregina Vecchia" was contrived to verify if the designed system was suitable to avoid damage to the works of art and control the microclimatic conditions. This study is an example of the improvement of indoor microclimatic conditions in ancient buildings which holds works of art, to guarantee the conservation of the artifacts, and to improve indoor thermal and hygrometric comfort for the occupants, without compromising the historical value of the building.

II. THE CASE STUDY: THE FOURTEENTH-CENTURY CHURCH OF DONNAREGINA. THE VALUES TO BE RESPECTED IN AN INTERVENTION OF BIOCLIMATIC IMPROVEMENT

The original church of Donnaregina, built in XIV century is due to the will of Charles II of Anjou, who started, since 1293, to rebuild the monastic complex of San Pietro ad Montes, in ruins after a serious earthquake, in the north side of the city of Naples, across the ancient walls. This reconstruction was also supported by Mary of Hungary, his wife, through a strong devotion and numerous donations. To her was dedicated an extraordinary marble tomb made by Tino da Camaino and Gagliardo Primario (1325-26), still present in the Nave of the Church. The plant of the church, completed around 1320, follows the Franciscan rule and presents a single hall covered with trusses, which ends with a cross-vaulted Apse ribbed on a pentagonal plan, preceded by a rectangular module, characterized by high mullioned windows. The Choir, not finding a place behind the Apse or in the Nave, was placed on two rows of octagonal pillars, which support cross vaults. The church, therefore, presents a first tripartite space of double height and a second space of full height, bright and imposing for its Gothic forms. A very rich cycle of frescoes, almost certainly attributable to the school of Pietro Cavallini, further embellishes the church, as evident in Fig. 1. Around 1620, the church underwent substantial changes because the nuns commissioned Giovanni Guarini the construction of a new church, closer to the tastes of the time. Given the impossibility of extending the construction towards the current largo Donnaregina, the Choir of the nuns of the new church almost completely invaded the Apse of the fourteenth-century church, now used as a warehouse. When, in 1861, the convent was suppressed, the fourteenth-century church was acquired by the municipality of Naples and used for various and improper functions that favored the degradation.

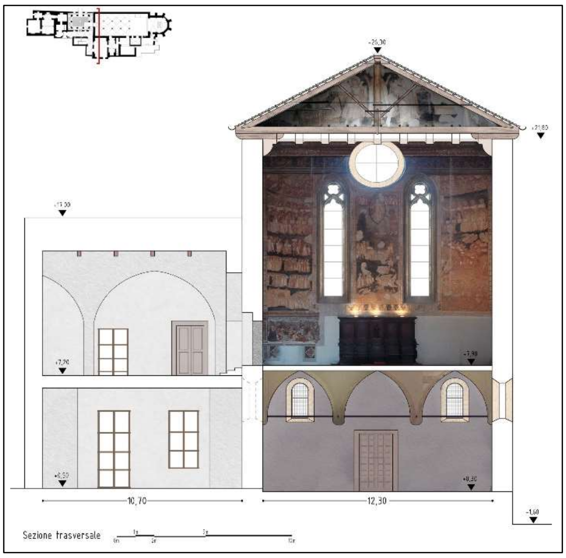

Fig. 1. Cross section of "Santa Maria Donnaregina Vecchia", elaboration by A. Rosati, P. Peluso.

The church was used as a school, accommodation for the poors, the seat of the Court of Assizes, hosted the work of the Municipal Commission of the Conservation of Monuments, undergoing significant alterations, including the division of the lower space into separate rooms with walls that occlude the original octagonal pillars. The restoration of the fourteenth-century complex of Donnaregina Vecchia was entrusted to Gino Chierici in 1928, following numerous and heartfelt appeals from many intellectuals of the time, including Emile Bertaux. At that time, Gino Chierici held the position of Superintendent of Medieval and Modern Art in Campania. The intervention of restoration of Gino Chierici brought to light the fourteenth-century structures, through numerous additions, eliminated the addiction of the twentieth century restoring the octagonal pillars, recomposed the original appearance of the Apse by resizing the seventeenth-century Choir, and redistributed internally the sculptural apparatus. The most arduous and pioneering intervention was certainly the liberation of the Apse. The wall of the seventeenth-century Choir that cluttered the fourteenth-century polycentric Apse housed a youthful fresco by Francesco Solimena, made with tempera colors and therefore impossible to tear off. To overcome this technical impossibility, Gino Chierici designed a complex "machine" which, by exploiting the considerable difference in height between the two churches, made it possible to move the entire back wall of the Choir of the new church, preserving the precious fresco. After having properly pre-consolidated the frescoes and immobilized the wall, seven low walls were created with rails on which steel rollers placed under the wall to be moved would slide. With the help of ropes and numerous workers, after several months of preparation, the wall was moved about six meters in just 45 minutes. This undertaking, accomplished under the wise direction of Gino Chierici, in addition to restoring the Gothic magnificence of the church of Donnaregina Vecchia, favored the definition of a new operational approach to the discipline of restoration. Coming to recent years, since 1975, the church has been the seat of the School of Specialization in Architectural Heritage and Landscape of the University of Naples, and it still retains this destination today, thanks to an agreement signed between the City of Naples, the University of Naples "Federico II" and the Archbishop's Curia of Naples.

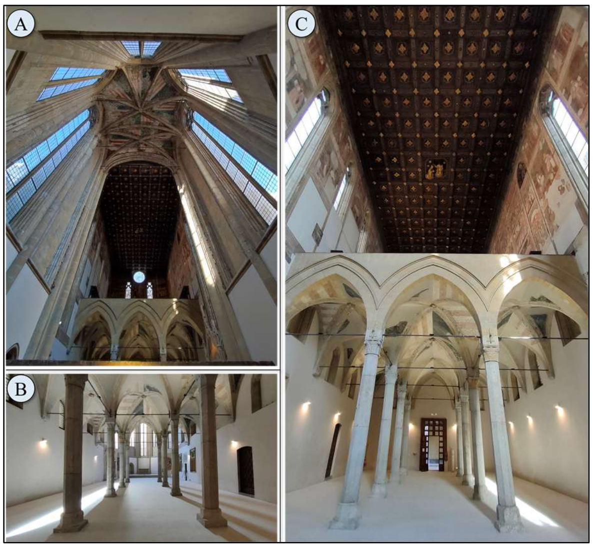

Fig. 2. The church of "Santa Maria Donnaregina Vecchia": a) the Apse, b) the Nave, c) the Nave and the Choir

The Choir of the fourteenth-century church, in particular, is the scene of the didactic activity of the School and of numerous seminars and conferences that enjoy the relevant pictorial frame of the fourteenth-century fresco cycle, also restored by Chierici, and of the thick tuffaceous walls of the medieval building. A photographic representation of the church is reported in Fig. 2.

III. Methodological Approach

A. The indoor and outdoor monitoring

The space under exam is very large (around 39 m long and 12 wide) and high (26 m), so, for appropriate monitoring of indoor microclimatic conditions, 12 sensors were installed at different height levels. Starting from the Nave and the Apse, two sensors were positioned respectively at 2.1 m and 1.8 m. In the Choir, which is at 7.6 m from the Nave level, the sensors were located at two different heights: 0.46 m and 3.15 m, as depicted in Fig. 3. From the same figure, the planimetric distribution of the sensors is even evident.

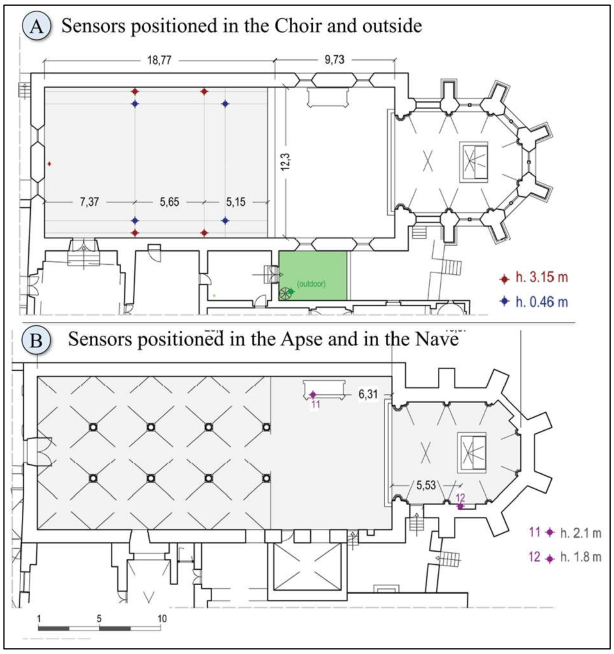

Fig. 3. The sensors' position in the Choir (a) and in the Nave and Apse (b)

This was properly established to monitor the possible differences between temperatures and RH of the differently oriented sides of the church and in accordance with the guidelines of UNI 10829:1999 [8]. The standard suggests that, in spaces with a height greater than 5 meters, the measurements of temperature and RH should be performed at 3 m vertical distance, in a time interval not exceeding 1 hour. In addition, the monitoring significant points should be identified using a horizontal grid with a 5 m side, that can be more or less dense according to the spatial arrangement of the objects to be protected. In "Santa Maria Donnaregina Vecchia" the monitoring grid is denser right next to the fourteenth-century frescoes. The measurement period of the church microclimate started on 26/01/2022 at 12 A.M. and ended on 09/02/2022 at 9 A.M, with a recording interval of 15 minutes.

Different typologies of dataloggers were installed:

- n. 10 Testo data-loggers 175 – H1, that measure temperature, and RH. The measurement uncertainty is ±0.4 °C (-20 to +55 °C) for temperature and ±2 % (2 to 98 %RH) at +25 °C for RH. One of these sensors was located outside;
- n. 2 Testo data-loggers 160 – IAQ, which measure temperature, RH, CO_2 concentration, and atmospheric pressure. The measurement uncertainty for temperature is ± 0.5 °C and for RH ±2 % at +25 °C and 20 to 80 % RH, and ±3 % at +25 °C and RH < 20 % and > 80 %. Both Testo data-loggers 160 were positioned in the Choir.

In total, 11 sensors were positioned in the church, and 1 was located outside to monitor the outdoor microclimatic conditions during the measuring period.

B. *The numerical model of the church*

The numerical model for the building energy simulation in DesignBuilder (more info at: https://designbuilder.co.uk/) was developed according to the data reported in Table I. The occupancy, as the lighting activation, was scheduled in compliance with the real profile of use of the church which is occasionally used for meetings. Besides the lighting system, any other electric device was considered. Currently, the church is not equipped with cooling, heating, or mechanical ventilation systems. Regarding the thermophysical properties of the envelope, these are typical of a fourteenth-century church: roof slab with wooden trusses above the Nave, roof slab in wrought lapillus above the Apse, and massive tufa walls of 1 m, coated with 3 cm of gypsum plasterboard only on the inside façade. The transparent envelope is characterized by single glasses with a solar transmittance of 0.48, and metal frames.

TABLE I. DATA FOR THE BUILDING NUMERICAL MODEL

Building Geometry			
Total Building Area [m^2]	829	Total Building Volume [m^3]	10.143
Gross Roof Area [m^2]	639		
Boundary Conditions			
Infiltration rate [h^{-1}]	0.5	Lighting system [W/m^2-100 lux]	2
Occupancy [person/m^2]	0.02		
Thermal Transmittances			
External walls [W/m^{2}K]	1.1	Ground floor [W/m^{2}K]	1.0
Pitched Roof floor [W/m^{2}K]	1.4	Roof floor [W/m^{2}K]	1.1
Glass (windows) [W/m^{2}K]	5.8	Frame (windows) [W/m^{2}K]	5.9

The calibration of the model was operated by comparing the mean measured and simulated indoor temperatures and RH of the Choir according to M&V guidelines [12]. The calibration was operated for the measurement period. The "Mean Bias Error" was calculated, by considering the measured and simulated temperature or RH. For the ASHRAE and U.S. DOE guidelines [12][13], in calibrated models, the MBE should correspond to MBE (%) $\leqslant \pm 5\%$.

IV. THE RESULTS OF THE MONITORING AND CALIBRATION OF THE BUILDING MODEL

As previously specified, the monitoring campaign both regarded the indoor environments of "Santa Maria Donnaregina Vecchia" and the external conditions. The measurements of the outdoor temperatures and RH are reported in Fig. 4. During the two typical winter weeks of monitoring, the outdoor maximum temperature has not exceeded 19.7 °C, while the minimum temperature was 6.6°C. The maximum daily temperature excursion occurred on February 8 and was 11.3 °C. Regarding the outdoor RH, the maximum values occurred between January 31 and February 1, and the minimum on January 29. These data were necessary for the calibration and validation of the numerical model of the church. Indeed, the hourly weather file of Naples (Naples.162890_IWEC) was updated by replacing the temperature and RH data from 26/01/2022 at 12 A.M. to 09/02/2022 at 9 A.M, with those measured during the outside monitoring. Fig. 5 and Fig. 6 report the trend of mean temperatures and RH measured in the Choir and the lowest part of the Apse. The following daily temperature excursions were registered, by excluding the first and the last day of monitoring, for which the hourly data for the whole day were not registered:

- Choir, the minimum daily temperature excursion is 0.71 °C, while the maximum is 1.55 °C;
- Apse, the minimum daily temperature excursion is 0.40 °C, while the maximum is 0.80°C.

So, the temperatures are more stable in the lowest part of the Apse, and not in the Choir because this last is most affected by thermal dispersions with the outdoor through the roof and the external walls. In the lower part of the church, the main thermal losses concern the ground floor, directly connected to the ground, which has a stable temperature if compared to the outdoor air. The maximum mean temperature registered in the Choir is 13.3 °C, while the minimum is 9.7 °C. In the Apse, the maximum mean temperature is 12.4 °C and the minimum is 10.0 °C. The basement part of the Apse has a lower temperature if compared to the Choir due to the convective movement of air, which causes the stratification of the warmest air in the highest parts of the church. UNI 10829 [8] suggests ideal conservation values of temperatures and RH according to the typology of artifact or material.

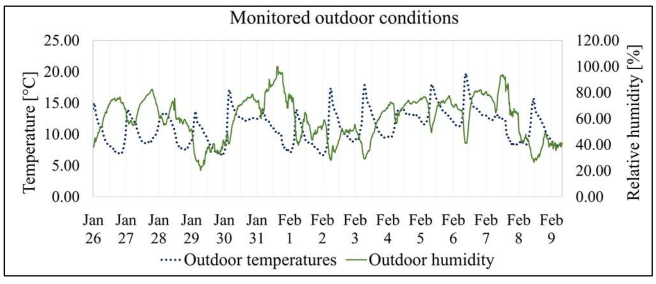

Fig. 4. Monitored outdoor conditions: temperature and RH

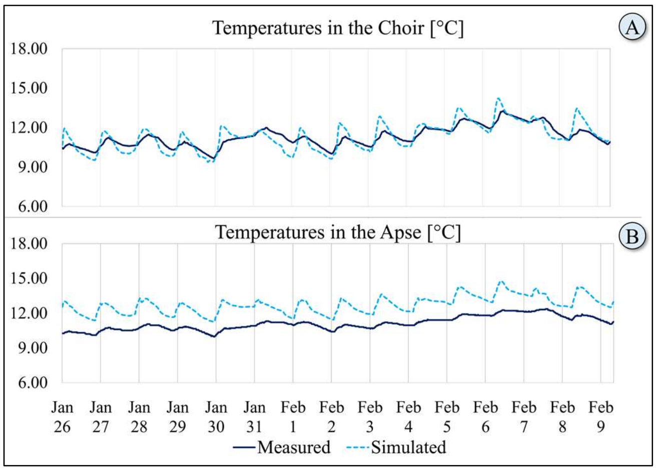

Fig. 5. Measured and simulated indoor temperatures

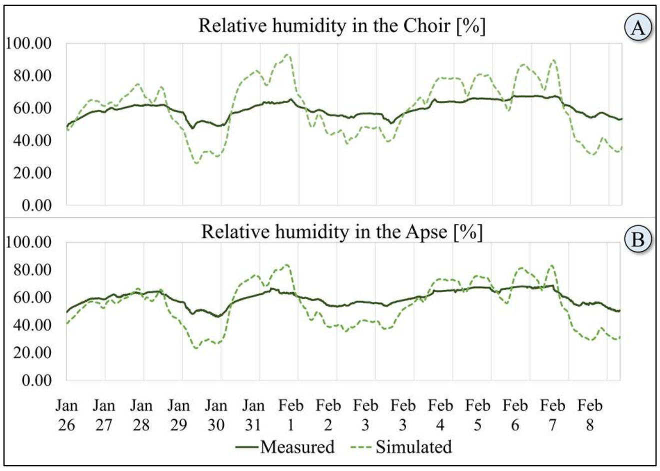

Fig. 6. Measured and simulated indoor RH in the Choir and in the Apse

In Table II, the reference values for the works of art held by the church are reported. It can be assessed that temperature in the Choir reaches too low values even for the correct conservation of frescos, that predominately characterize the Choir walls. In the Apse, the temperatures are appropriate for the conservation of frescos and painting, but not for the woodwork of art or marble statues. Regarding the RH, the maximum mean value in the Choir is 67.6% and the minimum is 47.4%; in the lowest part of the Apse, the maximum mean value is 68.7% and the minimum is 46.0 %. The conservation of the Choir frescos could be compromised by the values of RH being too high or too low. Similarly, in the basement part of the Apse, the high values of RH could cause damage to the marble tomb. By evaluating the thermal and hygrometric comfort according to the Fanger approach, even when the mean indoor temperature reaches its highest value in the Choir (T=13.3 °C, UR = 67.4%), the indoor ambient is severely cold with a PMV (Predicted Mean Vote) value of -1.6, and a PPD (Predicted Percentage of Dissatisfied) of 56.3%. In the apse, a similar situation occurs, with PMV value around -1.8 and PPD of 67% when the indoor mean temperature has its highest value (T=12.4 °C, UR=66.9%). It is well-known that PMV is based on the vote of a large number of people about the thermal comfort and it is shown on a scale from -3 to +3. The values are acceptable when between −1 and +1 (0 is the thermal neutrality). The PPD is related to the people's perception of cool or warm, and when the PMV is ±1, PPD is 25%; when PMV is ±0.5, PPD is 10%; when PMV = 0, PPD is 5%.

TABLE II. MATERIALS AND MICROCLIMATIC CONDITIONS

Material	Microclimatic conditions			
	***UR* [%]**	**ΔUR_{max} [%]**	***T* [°C]**	**ΔT_{max} [°C]**
Polychrome wood carvings, painted wood, paintings on wooden, icons, wooden clocks, musical instruments of wood	50-60	4	19-24	1.5
Stones, rocks, minerals, stable (porous) meteorites	40-60	6	19-24	-
Mural paintings, frescoes, sinopias (detached)	55-65	-	10-24	-
Wall paints, dry (detached)	45-50	-	10-24	-

Finally, with reference to the indoor conditions in the Church, in winter, these do not allow comfort conditions for the occupants and safety for the conservation of the works of art. Thus, it necessary to design a solution that could improve the microclimate inside Donnaregina Vecchia. An energetic model of the church was therefore developed and validated based on the mean values of temperature and RH in the Choir. By comparing measured and simulated data, concerning the indoor temperatures and RH, the following monthly average gaps were registered in the Choir: a) MBE = - 0.1% for temperatures; b) MBE = -1.1% for RH.

The MBE values are perfectly in the range suggested by [12][13] for calibrated models. The maximum temperature difference between measured and simulated data is 1.89 °C in the Choir and 2.77 °C in the Apse. The difference of specific humidity that corresponds to the temperatures with the maximum discrepancy between simulated and measured data, is 1.6 g/kg in the Choir. Therefore, based on these considerations, the model was deemed to be calibrated.

V. THE DESIGNED MICROCLIMTIC CONTROL SYSTEM

From the monitoring campaign of the two typical winter weeks, it emerged that the indoor microclimatic conditions do not satisfy the ideal ranges for the conservation of the artistic heritage, especially in the Choir which has frescoes of high cultural value. In addition, the indoor environment, according to the Fanger comfort model, is severely cold, and thus uncomfortable for the occupants. A novel heating system, to control the indoor microclimatic conditions, is required and should respect two main requirements: its integration should not compromise the historical and artistic value of the ancient church, and it should not involve high temperature variations, considering the phenomenon of acclimatization of the works of art. The choice fell on a radiant floor system to be located in the Choir. The plant solution with radiant panels, on the floor, ceiling or wall allows avoiding the terminals in the environment. The operating principle of radiant panels is based on the creation of a large surface heated at low temperatures. Through this microclimatic control system considerable and numerous advantages are obtained: the thermal gradient in heated rooms is reduced to the full advantage of the comfort; in addition, convective motions, and the consequent movement of powders are very low. Powering the system at a low temperature even allows exploiting more efficient energy components, such as heat pumps. A feature of this microclimatic control system, which is usually considered among the disadvantages, is given by the considerable thermal inertia that characterizes it: in the case of museums, if the impulsive variability of the loads is reduced, this solution would lend itself well to need for continuous operation. The very low induced stratification makes this solution suitable for indoor environments characterized by high developments in height. The system will be installed on the Choir floor, currently not of prestige, so the intervention is not invasive. The dimensions of the radiant surface are 15.1 m in length and 6.7 in width, and it is positioned as represented in Fig. 7. The radiant system is connected to air-to-water heat pump with a power of 12 kW, and a COP of 3, active for the whole day. The limited power of the system is a consequence of the limited surface at disposal, to avoid an invasive design. This concerns even an insulation layer of 4 cm below the radiant surface and a screed of 4 cm above it and before the pavement layer. The results of energy simulation show that, after the installation of the radiant floor, the mean temperature in the Choir has an increment (Fig. 8) during the examined weeks. The mean air temperature in the Choir is not lower than 12.6 °C and not higher than 17.2 °C. The daily maximum temperature excursion is 2.65 °C. By considering the thermal ranges reported in Table II, temperatures perfectly fall in the ranges for a correct conservation of frescos and mural paintings. Regarding RH, the curve undergoes a downward slip, so there is a clear reduction in the RH rate of the environment. The installation of humidification systems is foreseen to raise the level of relative humidity and to keep it in the range suitable for the conservation of both wooden furnishings and frescoes. The addition of a radiant floor system in the Choir, even if mild, involves variations in the microclimatic conditions of the Apse area too, with an increase of minimum mean temperature of about +0.6 °C. Regarding the thermal and hygrometric comfort for occupants, when the temperature reaches its highest value in the Choir, the PMV is -0.9 and the PPD is 22 %. According to the Fanger approach, the environment can be considered "moderate". An improvement of microclimatic parameters is measured, even if not optimal, mainly in the Apse.

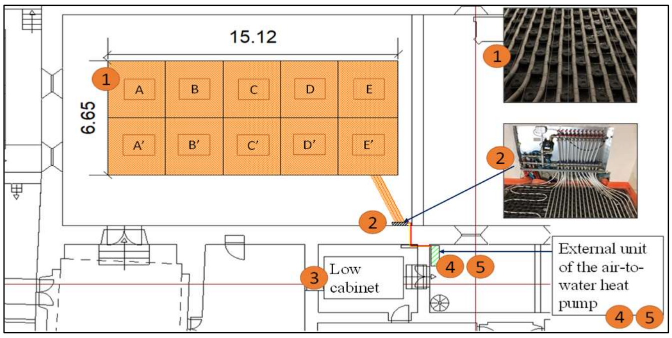

Fig. 7. The radiant floor positioned in the Choir

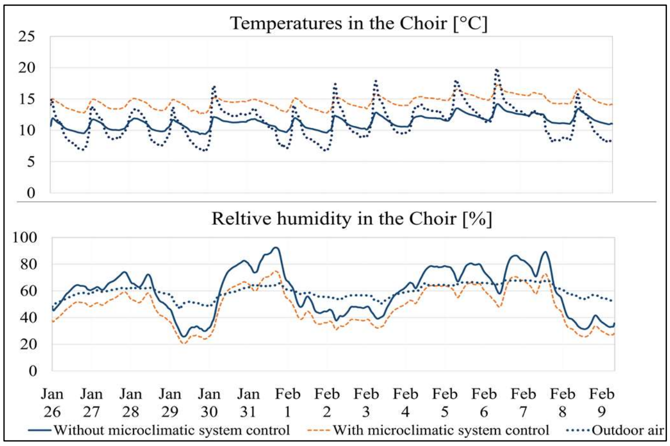

Fig. 8. Temperatures and RH before and after the addition of a radiant floor

Conversely, the Choir, used for events, obtains thermally comfortable conditions. Finally, the intervention guaranteed an improvement of thermal and hygrometric comfort conditions, even if not optimal, and an improvement of the T and RH values for the correct conservation of the works of art.

VI. Conclusions

This study concerns improvement of indoor microclimatic conditions of the ancient church "Donnaregina Vecchia" located in Naples, holding valuable frescos, furnishings, and marble sculpture. The microclimatic monitoring during two typical winter weeks revealed that indoor temperatures and RH were not optimal for the conservation of artifacts, and that the indoor environments were uncomfortable according to the Fanger approach. A dynamic model of the church was developed and calibrated, and a system for the microclimatic control was designed to improve indoor microclimatic conditions. The solution was a radiant floor in the Choir, that does not affect the historical value of the church and improves both occupants' comfort and the microclimatic conditions for the conservation of the artifacts. Indeed, the mean air temperatures in the Choir were not lower than 12.6 °C and not higher than 17.2 °C during the two winter typical weeks. Regarding RH, there was a clear reduction in the RH rate in the environment. The next step will be the humidifiers' check, already designed, to keep the RH rate in a suitable range for conservation of wooden furnishings and frescoes.

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