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Thermal properties of the vernacular buildings envelopes: the case of the "Sassi di Matera" and "Trulli di Alberobello"

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Abstract
The stone and the clay are the basic elements of the existing architectural heritage in the Mediterranean area, both historical and monumental. The study cases taken into account are the "Sassi of Matera" and the "Trulli of Alberobello." The thermohygrometric performances of the "Tufo of Matera" (commonly denoted as calcarenite sandstone) and the "Stone of Fasano" (commonly denoted as calcareous stone), which are the base materials of the buildings "Sassi" and "Trulli", were quantified through measurements in situ, realized with nondestructive methodology and analyses in laboratory. The behavior of these constructions has finally been better described with dynamic simulations developed by the software EnergyPlus. This study demonstrated that the thermal mass of these structures mainly affect the indoor microclimate, stabilizing the inside temperatures and thus annulling the great thermal daily oscillations of the external temperature. The results of the measurements and numerical simulations confirmed that the seasonal thermal storage of these structures allows comfortable temperatures during the summer season, with values below 26°C, and stabilizes the indoor temperatures during the winter season, through the release of the heat stored during warm season.

Keywords: Massive envelopes; Thermal conductance in situ; Transient plane source method; Dynamics thermal properties; Vernacular building microclimate.

1. Introduction
Since antiquity, buildings were conceived as a means to defend from the external climatic adversities. Till date, the buildings constructed in the Mediterranean area are usually assembled in masonries with great thicknesses, to achieve good protection from the external environment. The thermophysical properties of the materials and construction techniques typical of these buildings give rise to very good thermal performance. The study cases taken into account are the "Sassi of Matera" and the "Trulli of Alberobello." Through measurements in situ, realized with nondestructive methodology and laboratory analyses, it has been possible to quantify the thermohygrometric performances of the “Tufo of Matera” (commonly denoted as calcarenite sandstone) and “Stone of Fasano” (commonly denoted as calcareous stone), which are the base materials of the buildings "Sassi" and "Trulli." Our previous studies have pointed out the principal causes of dampness observed in the walls of some structures of "Sassi of Matera," and evaluated the heat loss depending on the percentage of water contained in the material [1,

2]. However, further studies have addressed the analysis of microclimatic parameters and dampness in the walls of a rocky church crypt [3], the energetic behavior and the microclimate of different hypogeous structures in the site of the "Sassi of Matera" [4, 5], and the thermal behavior of different opaque envelopes in dynamic conditions [6]. In the last years, some studies tried to describe the thermal mass influence on the global energetic balance of buildings, applying quasi-steady-state calculation methodologies [7, 8]. In this paper, the thermophysical behavior of massive envelopes has been reported. The research has been combined with an ampler study that dealt with the energetic diagnosis for the recovery of ancient neighborhoods, "Sassi of Matera" and "Trulli of Alberobello." The analysis was carried out through energetic diagnosis with the use of nondestructive methodologies in situ, experimental tests in the laboratory, and numerical simulations in dynamic thermal conditions. The tests in situ, aimed at the measurement of thermal conductance in situ (complying to ISO 9869) and indoor microclimatic parameters, the experimental investigations in laboratory done with TPS (Transient Plane Source) method, and the dynamic simulations made with the software EnergyPlus and complying to UNI EN ISO 13786 confirmed that these structures work as "natural regulators" of thermohygrometric comfort.

2. Constructive characteristics of the "Sassi of Matera" and "Trulli of Alberobello"

In the South of Italy, the sites of the "Sassi of Matera" (Figure 1a) (classified as humanity world heritage in 1993) and "Trulli of Alberobello" (Figure 1b) (classified as humanity world heritage in 1996) are two exceptional examples of Mediterranean traditional buildings, each with its housing forms and bioclimatic solutions. The geographical area of the two sites is characterized by a Mediterranean climate, with moderate winters and warm summers. The geographical coordinates of the site are: 40° 39' 50" N, 16° 36' 37 ' E, and altitude of 401 m for the site "Sassi," and 40° 47' 25" N, 17° 52' 30" E, and altitude 462 m for the site "Trulli." Climatic conditions are also nearly identical with maximum summer temperatures greater than 40°C and minimum winter temperature that rarely go down 0°C. Even if the present structures are characterized with local materials, namely, "Tufo of Matera" for the structures of the "Sassi of Matera," and "Stone of Fasano" for the structures of the "Trulli of Alberobello," they are different with regard to form and constructive techniques. "Sassi of Matera" has been entirely built with calcareous sandstones. The blocks, tied up with mortar, forged regular masonries in height with thicknesses that vary from a minimum of 30 cm to a maximum of 50 cm. The vaulted roofs have been built internally using tufo and externally using hip tiles. The interior flooring is made of burnt brick. However, with regard to the structures of the "Trulli of Alberobello," these were conceived as real detachable dray constructions, having been realized through simple overlap of stone layers. In this way, it is possible to create numerous voids of air inside the masonry, which hinder the thermal flow passage. The masonries thickness, in this case, not only varies in height, but is also different inside the same structure, reaching elevated thicknesses of more than 1.50 m. Furthermore, the roofs of these structures, made entirely with dry stones, have a conic form [9].

Figure 1. (a) "Sassi" site and (b) "Trulli" site

The experimental path adopted puts in evidence two fundamental aspects for the energetic analysis of historical traditional structures: the validity of nondestructive measurements in situ of the

thermohygrometric parameters of the envelopes to get a correct energetic diagnosis and the use of dynamic simulations to verify the seasonal behavior of these structures.
The adopted methodology was to compare the nondestructive measurements carried out in situ with laboratory tests. Through this double analysis, it was possible to verify and quantify the thermal characteristics of the envelopes of the Mediterranean tradition and also to demonstrate their capacity to assure internal comfort conditions.
Measurements of the indoor microclimatic parameters were made and compared with dynamic simulations developed using the software EnergyPlus. These allowed quantifying the excellent seasonal thermal behavior of these structures when compared with external climatic variables.
The measurement procedure of thermophysical properties of materials in situ required a data logger, a thermo flux meter, and four thermocouples. By putting the sensors in a homogeneous surface portion representative of the wall, complying to ISO 9869:1994, the following thermal parameters were measured in situ: thermal flow, internal and external surface temperatures. From the knowledge of such temporal trend, it was possible to calculate the thermal conductance of the wall in calcarenite sandstone and calcareous stone [10]. The measurements were performed from June to July 2007 on walls of different thicknesses. This period was selected because it is characterized by high indoor–outdoor temperature differences, ideal to minimize the measure errors. The conductance calculation method can give a reliable result, if the average thermal flow is greater or equal to 5 W/m^2 and the thermal gradient from inside to outside is higher than 10°C. The data acquired in situ were subsequently elaborated with the methods typical of dynamic systems analysis: the average method and the "black box" identification method. In the average method, the wall conductance is calculated from the measured values of surface temperatures and thermal flow using the expression:

$$C = \frac{\sum_{j=1}^{N} q_j}{\sum_{j=1}^{N} \left(T_{SIj} - T_{SEj}\right)} \quad \frac{W}{m^2 K} \tag{1}$$

As N increases, the ratio converges to a steady value not influenced by the ability of wall heat storage (thermal mass). In the "black-box" method, the wall is identified as a generic system with two entries (temperatures) and one exit (transmitted heat flow). The parameters that identify the system are determined from the sampled values of temperatures and flow (Figure 2).

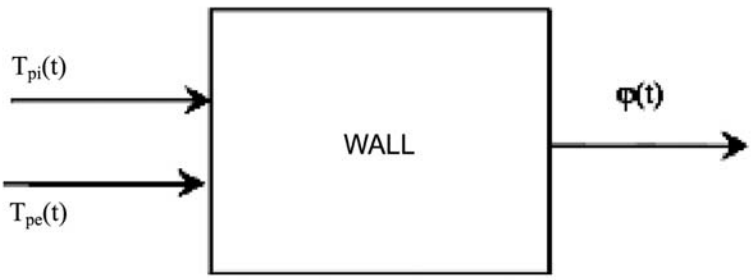

Figure 2. Black-box method

With regard to the laboratory tests, these were realized on material samples directly withdrawn in situ. Through different analyses, it was possible to determine the materials' thermophysical parameters that comprise the envelope (calcarenite sandstone and calcareous stone) useful to integrate and validate the results achieved through the in situ measure of conductance. The analyses, done in the laboratory of Technical Physics of the Polytechnic of Bari, were performed on some samples of calcarenite sandstone and calcareous stone of Fasano. The goal of the laboratory tests was to experimentally find the thermophysical properties of different blocks: density, dampness, thermal conductivity, thermal diffusivity, and specific heat. For the measurement of thermophysical properties in the laboratory, the TSP (Transient Plane Source) method was used. This method is characterized by a probe that works both as a heat source and a temperature meter. This indicates that the time–temperature trend of the electric resistance, which works as a planar heat source, is reconstructed from the measure of the electric resistance of the same source, variable with its temperature and the knowledge of the temperature coefficient of the material of which it is made. A single measure allows for the determination of diffusivity, thermal conductivity, and specific heat of the material [11]. In this way, it is possible to

analyze the dependence of thermal conductibility and heat capacity on the dampness content in the hygroscopic construction materials. Measurements with the TSP technique were realized before sample desiccation to obtain thermal parameters under real conditions of humidity content.
Finally, the microclimate analysis was developed both by measurements in situ, through the use of a measurement unit of the indoor microclimatic parameters, and thermal simulations in dynamic conditions with EnergyPlus [12]. Through the measurements in situ, it was possible to analyze and verify the trend of parameters influencing the microclimate (air temperature, mean radiant temperature, relative humidity, and air speed) for a time of about 10 days [13].

3. Results of the measurements in situ

The measurement campaign of the materials, realized from June to July 2007 with maximum values of indoor–outdoor temperature difference, consisted of the measurement of thermal conductance of two different typologies of building wall: a wall in blocks of calcarenite sandstone assembled with mortar, typical of the constructions of "Sassi of Matera," and a masonry made with dry calcareous stones of Fasano, typical of the constructions of "Trulli of Alberobello."
The measurements were carried out for a period of about 10 days. The data picked up in situ allowed determining through the average and black-box methods, the thermal conductance of the wall.
With this particular type of construction of the monitored walls, it is not possible to use other methods of determination of thermal conductance considering the geometric and structural variability of the wall section. The structure of the typical wall of "Trulli" has a geometric and material composition, difficult to characterize in a detailed way. In fact, between two layers of compact calcareous stone, we observed a significant air gap that is filled with yard discard material of various natures.

3.1 Masonry in Calcarenite sandstone of the "Sassi of Matera"

The measurements were made on a 48-cm thick wall of blocks. The external surface temperature of the masonry had a cyclical trend for the whole measurement period with values between 40 and 20°C, while the inside surface temperature was constant at around 20°C (Figure 3). This result shows the very good thermal performance of the monitored masonry in dynamic conditions. The high thermal mass annulled the climatic variations of the external environment.

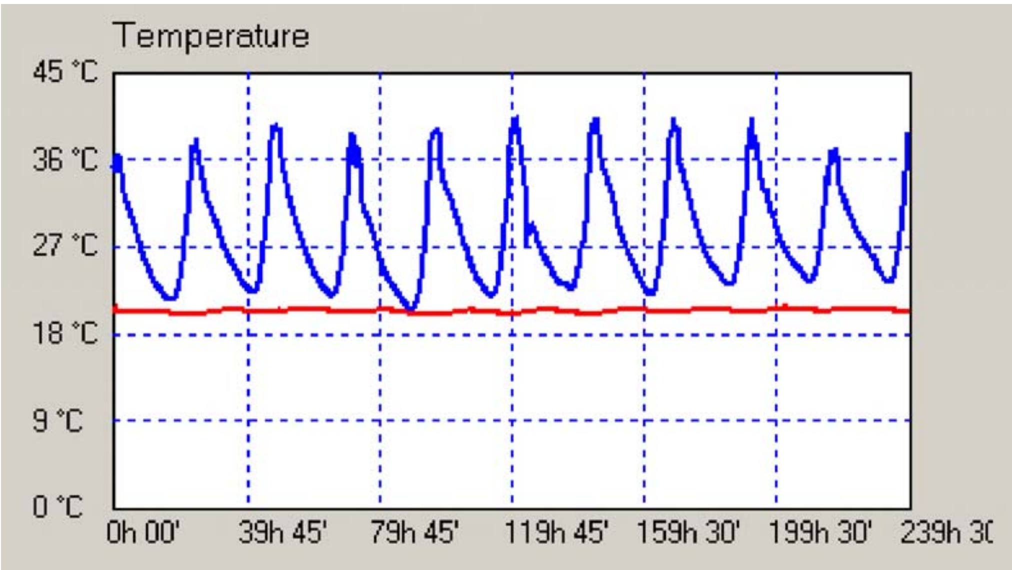

Figure 3. Superficial temperatures of the masonry in calcarenite sandstone (red line indicates the internal temperature and blue line indicates the external temperature)

Using the average method for the calculation of thermal conductance, the value C_{mean} = 1.366 W/m^{2}K (Figure 4a) was obtained, which corresponded to an average thermal conductivity of the material constituent of the wall equal to $\lambda_{average}$ = 0.655 W/m K (= 1.366 W/m^{2}K × 0.48 m).
However, using the black-box method, the following values of thermal conductance and average conductivity were obtained: C_{mean} = 1.356 W/m^{2}K and $\lambda_{average}$ = 0.651 W/m K (Figure 4b).

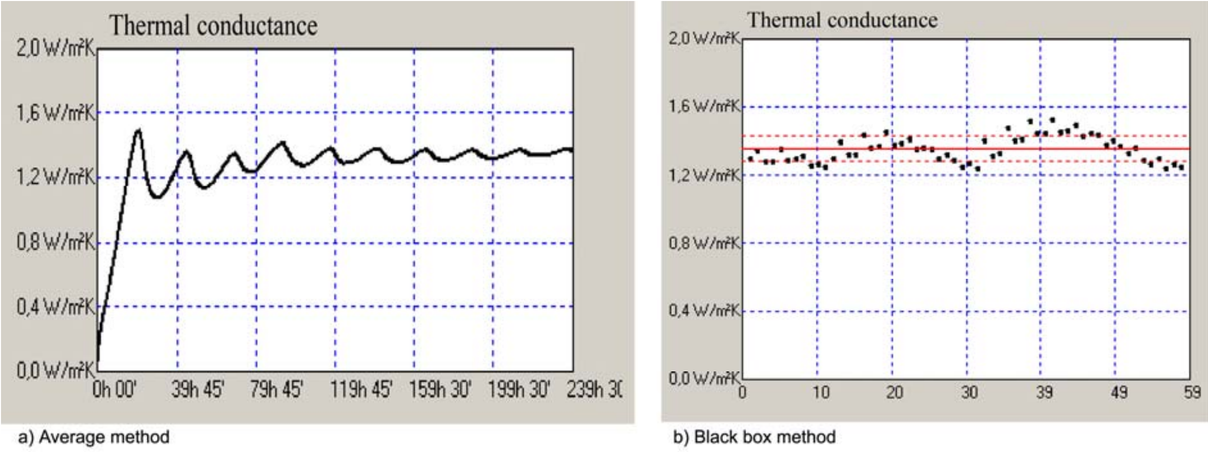

Figure 4. Conductance values calculated with (a) the average method and (b) black-box method

3.2 Masonry in Calcareous stone of the "Trulli of Alberobello"

The measures of thermal conductance in situ were made in correspondence to a thickness of 74 cm (around 100 cm above the floor). The masonries in the considered building presented a variable thickness from 56 cm on top to 92 cm on bottom.

The external surface temperatures of the masonry had a cyclical trend for the whole measurement period with values between 34 and 19°C, while the inside surface temperature was constant at around 24°C.

Using the average method for the calculation of thermal conductance, the value C_{mean} = 1.823 W/m^{2}K was determined; it corresponded to an average thermal conductibility of the material constituent of the wall $\lambda_{average}$ = 1.349 W/m K (= 1.823 W/m^{2}K × 0.74 m).

However, using the black-box method, the following values of thermal conductance and conductivity were found: C_{mean} = 1.870 W/m^{2}K and $\lambda_{average}$ = 1.384 W/m K.

4. Result of the thermal properties measured in the laboratory

The laboratory analyses were carried out in the Laboratory of Technical Physics of the Polytechnic in Bari. Measurements were performed on rock samples directly withdrawn in situ. The experimentation in the laboratory was aimed to determine the parameters necessary to validate the measures in situ of the thermal performance of the wall. Through the TSP method, it was possible to experimentally determine the thermal conductivity and thermal diffusivity from which the specific heat c_p was obtained.

4.1 The material "Tufo of Matera"

Analyses were performed on three samples extracted from a block of Tufo with dimensions 25×50×15cm, directly withdrawn in situ. Two different measurements were carried out for every sample for a total of six measurements. The measurements were performed under the same conditions of extraction, without any additional treatment (Table 1).

Table 1. Thermal properties of the calcareous Tufo of Matera

Provini	Conductivity **λ W/(m K)**	Diffusivity **α·10^6 m^2/s**	Volumetric thermal capacity **ρc·10^{-6}** J/m^{3}K	Mean temperature **T_m [°C]**
A	0.716	0.477	1.50	25.47
	0.679	0.475	1.43	25.85
B	0.578	0.398	1.45	26.43
	0.609	0.431	1.41	24.83
C	0.554	0.393	1.41	25.49
	0.663	0.445	1.49	24.29
Average values:	**0.633**	**0.437**	**1.448**	**25.40**

The measurement of the density and water content was carried out through a balance, an oven, a climatic room, and driers with silica gel. After having found the volume (V) and the weight of samples (M), these were inserted in a ventilated oven at a temperature of 105°C and were desiccated for 4 days. In this way, all the present water was evaporated, and the dry weight was found (M_s). Subsequently, the samples were cooled to room temperature in a container with silica gel. After 2 days, the sample was again weighed with the precision balance to obtain the dry weight after cooling (M_{sr}). In this way, it was possible to determine the density, $\rho = M_s / V$ [kg/m³], water content as weight percentage $W_{H_2O} = 100 (M-M_s)/M_s$ [%], and water content as weight percentage after cooling $W^*_{H_2O} = 100 (M_{sr}-M_s)/M_s$ [%].

In Tables 2 and 3, the results for the three samples are reported.

Table 2. Properties of the Tufo samples

Sample	Initial mass **M [g]**	Dry mass **M_s [g]**	Dry mass after cooling **M_{sr} [g]**	Volume **V [m³]**	Density **ρ [m³]**
A	697.37	696.02	696.41	0.463995	1501
B	779.56	778.06	778.52	0.503900	1545
C	741.34	739.75	740.23	0.477621	1550
Average value					**1547**

Table 3. Water content and weight percentage increase of Tufo

Sample	$M_{H2O}=M - Ms$ **[g]**	w_{H_2O} **[% b.w.]**	$w^*_{H_2O}$ **[% b.w.]**
A	1.35	0.19	0.06
B	1.50	0.19	0.06
C	1.59	0.21	0.06

4.2 The material "Stone of Fasano"

Analyses were performed on three samples directly withdrawn in situ from the structures of "Trulli of Alberobello." Two different measurements were made for every sample for a total of six measurements. The measurements were performed under the same conditions of extraction, without any additional treatment (Table 4).

Table 4. Thermal properties of the calcareous stone of Alberobello

Provini	Conductivity **λ W/(m K)**	Diffusivity **$\alpha \cdot 10^6$ m²/s**	Volumetric thermal capacity **$\rho c \cdot 10^{-6}$** J/m³K	Mean temperature **T_m [°C]**
A	2.681	1.241	2.16	29.82
	2.701	1.246	2.17	28.96
B	2.610	1.263	2.18	32.27
	2.548	1.254	2.16	31.11
C	2.678	1.249	2.20	30.56
	2.656	1.265	2.18	30.56
Average values:	**2.646**	**1.253**	**2.18**	**30.55**

Furthermore, these samples were weighed before proceeding to their desiccation in a ventilated oven at a temperature of 105°C for about 4 days. At the end of desiccation, the samples were weighed to determine the dry mass, and subsequently, they were cooled to room temperature in dryers with silica gel. After reaching the room temperature (later around 2 days), the samples were again weighed to determine the dry mass after cooling. We obtained an average value of the dry material density equal to 2680 kg/m³ with a negligible damp content in the natural material and dried material after subsequent cooling.

5. Thermal dynamic properties

A further analysis was carried out to estimate the thermal mass property of the previously described masonries. Through the calculation method complying with the UNI EN ISO 13786 [14], it was possible to describe the thermal behavior of the masonries under time-variable boundary conditions, that is, under a sinusoidal variation of the thermal flow and temperature on the inside--outside surfaces. The thermal dynamic properties estimated were: the thermal transmittance, thermal periodic transmittance, decrement factor, and time lag (Table 5).

Table 5. Thermal properties complying with UNI EN ISO 13786.

	Masonry In Calcarenite Sandstone	Masonry In Calcareous Stone
Thermal transmittance	1,108 W/m^{2}K	1,392 W/m^{2}K
Periodic thermal transmittance	0,093 W/m^{2}K	0,025 W/m^{2}K
Decrement Factor	0,084	0,018
Time lag	15,7 h	21,7 h

6. Indoor microclimate analysis

The analyses were conducted by environment monitoring in situ and dynamic simulation with EnergyPlus software [12].

The analyses in situ, conducted in June 2007, measured the microclimatic parameters of the indoor environment: air temperature, mean radiant temperature, relative humidity, and air speed. The measurements lasted for about 10 days. The indoor and outdoor temperatures monitored are shown in Figure 5. From the figure, a time-constant trend with very small deviations of 1–2°C is evident, when compared with the external temperatures that show a variation of more than 15°C from day to night. Besides, it can be observed that the indoor temperatures are in the range of 24–25°C, within the comfort values for the considered period.

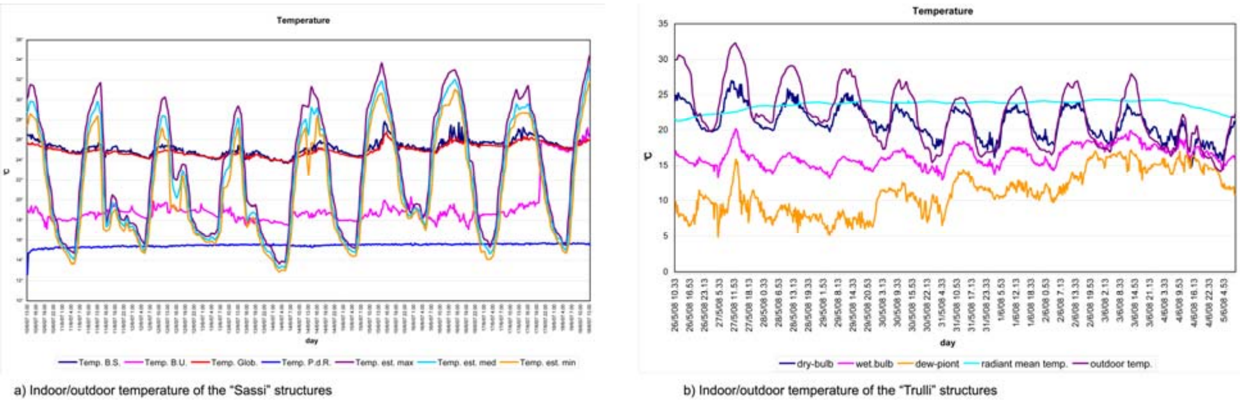

Figure 5. Indoor microclimate parameters of (a) the "Sassi" buildings and (b) "Trulli" buildings

The dynamic simulation with EnergyPlus was performed for one year, considering the values measured in situ as thermal parameters of the walls (Figure 6). The most interesting result was the constant seasonal trends of the inside temperatures with values oscillating between 10 and 12°C during winter and between 25 and 26°C during summer.

Such values, during summer and a good part of the intermediate season, are constantly within the comfort limits of 18–26°C (Figure 6). Thus, in this way, from an energetic and economic point of view, indoor comfort conditions are attainable without the aid of expensive air-conditioning systems.

During winter, the trend of indoor temperatures often approaches the maximum value of the external temperature of 10–12°C, which is 6–8°C below the comfort limits. These values are easily attainable through the use of some simple plant systems, such as a firewood heater. In this way, with low consumption of nonrenewable sources, it is possible to assure the least indoor comfort levels.

This is mainly owing to the seasonal-type heat storage in these structures (in winter, mass releases the heat stored in summer), thus guaranteeing almost acceptable indoor-temperature levels in the coldest winter periods even in the absence of a heating plant. On comparing the measured values with the limit values prescribed by the actual Italian normative on the Energy Performance of Buildings (D.lgs 311/2006) [15], these massive walls were found to give rise to a good thermal indoor comfort, with a high steady-state thermal transmittance and a periodic thermal transmittance lower than the law limits (D.P.R. 59/2009) [16]. For these complex structures, the use of simplified methods for energetic performances analyses does not produce acceptable results. Reliable energetic analysis of these structures needs measurements in situ as well as numerical dynamic simulations.

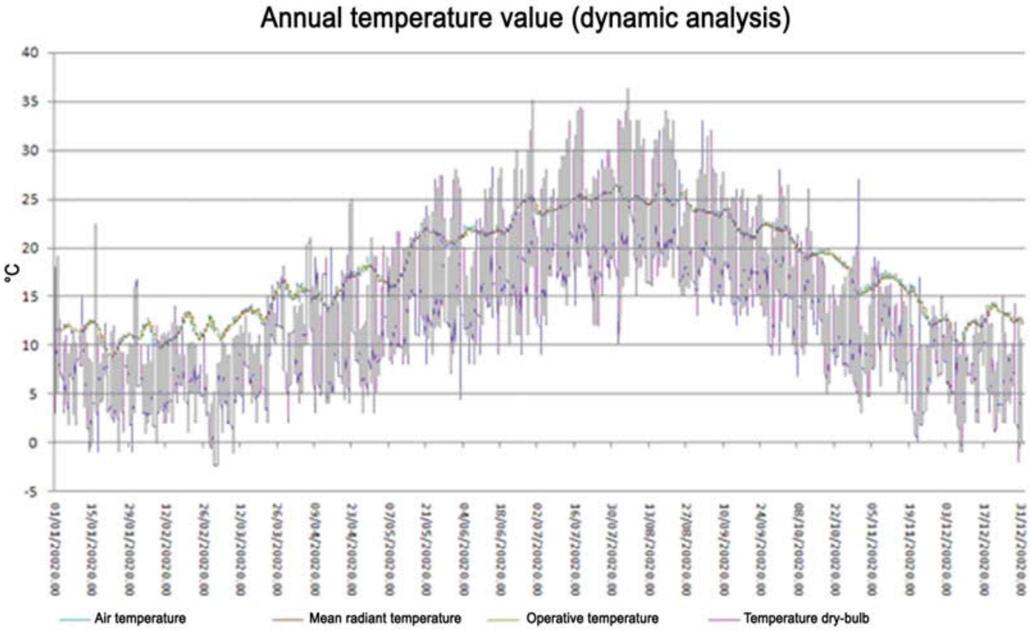

Figure 6. Dynamic simulation of indoor/outdoor temperatures of the "Sassi" buildings

7. Conclusion

The comparison of the measurements in situ of the thermophysical parameters with those in the laboratory for two particular structures (building of "Sassi of Matera" and "Trulli of Alberobello") confirmed the reliability of measurements in situ on these complex structures. The noninvasive technique of measurement in situ is without doubt one of the most interesting evaluation tools of thermal performances of building materials. An interesting example was the case of the measurements done in situ on homogeneous walls (masonry in calcarenite sandstone of "Sassi of Matera"), where the thermal conductance measured perfectly matched the laboratory value of thermal conductivity. However, the same measurements done on non homogeneous walls (masonry in calcareous Stone of "Trulli of Alberobello"), demonstrated that only through measurements in situ, it is possible to obtain thermal conductance of the wall, thus confirming it as the only available method to obtain an experimental measurement. Another interesting consideration stated from the research carried out is that these buildings succeeded in annulling the climatic oscillations of the external environment as a result of their high thermal mass. These traditional buildings are typical of the Mediterranean area that exhibits summers with high external air temperatures and diurnal oscillations. The steady-state thermal transmittance and the periodic thermal transmittance of the walls under investigation produced comfortable indoor conditions without the aid of expensive air-conditioning systems. This is mainly owing to the heat storage in these structures that ensures almost acceptable indoor temperature levels in the coldest winter periods, even in the absence of a heating plant (in winter, mass releases the heat stored in summer). Thus, it can be concluded that the massive envelopes of the Mediterranean tradition, such as the structures of the "Trulli" and "Sassi," are natural regulators of the indoor microclimate.

References

[1] Pelanne M. (1977). Heat flow principles in thermal insulations. J. Building Phys., 1, 48-80.
[2] Cardinale N., Guida A., Ruggiero F. (2001). Thermo-hygrometric evaluation in recovery of rocky buildings of the "Sassi of Matera". J. Thermal Envelope & Building Science, 24, 301-315.
[3] Cardinale N., Ruggiero F. (2002). A case study on the environmental measures techniques for the conservation in the vernacular settlements in Southern Italy. Building Environment, 37, 405-414.
[4] Cardinale N., Rospi G., Stazi A. (2010). Energy and microclimatic performance of restored hypogeous building in south Italy: The "Sassi" district of Matera. Building and Environment, 45, 94-106.

[5] Guida A, Rospi G., Pagliuca A. (2008). The bearing walls like a "natural thermal governor": the case of "Sassi di Matera". Proceedings of 8th Int. Seminar on Structural Masonry, Istanbul. (ISSM08).

[6] Augenti V., Stefanizzi P. (2008). Considerazioni su soluzioni di involucro opaco in regime termico dinamico. Costruire in laterizio, 125, 50-53.

[7] Timo K., Gudni J., Petri P., Per H. (2008). Accuracy of energy analysis of buildings: a comparison of a monthly energy balance method and simulation methods in calculating the energy consumption and the effect of thermal mass. J. Building Phys., 32, 101-130.

[8] Cardinale N., Ruggiero F. (2000). Energetic aspects of bioclimatic buildings in the Mediterranean area: a comparison between two different computation methods. Energy Buildings, 31, 55–63.

[9] Cito L. A. (1987). Il recupero dei Trulli: alcuni aspetti tecnologici connessi alle caratteristiche climatiche ed ambientali. Proceedings 1th Int. Seminar of Dry Stone Buildings, Noci.

[10] ISO 9869: 1994, Thermal insulation – Building elements – In situ measurement of thermal resistance and thermal trasmittance.

[11] Bondi P., Rizzo G., Stefanizzi P. (2000). Misura di proprietà termiche con il metodo della sorgente piana: considerazioni teoriche e sperimentali. Proceedings of 18° Unione Italiana di Termofluidodinamica, Cernobbio, 45-58.

[12] EnergyPlus, energy simulation software, http://apps1.eere.energy.gov/buildings/energuplus/.

[13] Kristin G., Filip D., Felix D., René V., Dario C., Adriana B., Giovanni S., Hans-Jürgen B., Monika W. (2004). Indoor environment and conservation in the Royal Museum of Fine Arts, Antwerp, Belgium. J. Cultural Heritage, 5, 221–230.

[14] UNI EN ISO 13786: 2008, Prestazioni termiche dinamiche dei componenti per edilizia

[15] D.lgs n. 311 del 29/12/2006, "Disposizioni correttive e integrative al d.lgs n. 192/2005.

[16] D.P.R. n. 59 del 02/04/2009, Regolamento d'attuazione del d.lgs 192 del 19/08/2005.

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