# Underground spaces and indoor comfort: the case of "Sassi di Matera"

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## Abstract

Underground architecture, like the "Sassi" in Matera, makes people imagine life in the past and reconsider present life in these places "without time" and how to "live" them, again like in the "past". This scientific research focuses on the quality of indoor living in this particular type of architecture.

Today indoor comfort is essential, because 85-90% of time is spent in closed spaces (rooms, work environment, etc.). Closed air, can be for people, more polluting and harmful than open air, as, inside we also have other harmful agents (germs, gas, dust and so on) whose danger is often undervalued.

Today it is very important while projecting to consider first of all the quality of indoor air and comfort.

The aim of this research is to analyse the thermal and hygrometer performance of underground spaces and to show how traditional Mediterranean masonry offers, also today, a high level of indoor comfort.

We did this with tests "in situ" monitoring indoor comfort (as low requests UNI EN ISO 7730 1997 and UNI EN ISO 7726 2002, by directive CEE n° 106/89).

The experiment was verified through the experimental applications in the restoration of two urban buildings in ancient "Sassi" in Matera, reconverted into hotels, the "Locanda di S. Martino" and "Hotel S. Angelo", that demonstrates as said before and how these building are suitable with the performance requirement that is required from residence environments (European Directive 2002/91/CE and Italian low D.lgs 192/05 – 311/06) even if they are built with traditional technologies.

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# 1 Introduction

The action follows not simply the existing environment, but it turns producing a stratification of interventions based on management that are not always harmonious in the space. This process of transformation is an irreversible step, an action that is intended to permanently change the structure of a place changing also significantly the shape.

The instrument of this anthropization process of space is the stone which, with its unique technical characteristics and morphological-formal, becomes the obvious sign of this process.

The use of stone in architecture, in fact, has produced numerous applications, complex and highly heterogeneous between them from: the structures dug into the rock to built-up structures; initially they conceived as a natural continuation of the first, reaching then, their own formal autonomy and typological realizing the basic cell constructive called "lamia" or "lamione". And this is the process that has overseen the birth and development of the ancient districts "Sassi di Matera", in which the relationship between structures and built dug reaches its highest expression and formalization morphological.

The research included in a broader study, still ongoing is aimed to define the methodological and operational aspects of the recovery of these districts; part-type from morphological of this specific architectural context and aims to assess the possibility of obtaining performance requirements meet the quality standards today required by residence in building even in buildings with technical and constructive traditional features.

Through tests "in situ" aimed at monitoring of comfort "indoors" (as defined by UNI EN ISO 7730 1997 and UNI EN ISO 7726 2002, the EEC Directive N. 106/89), the study aims to highlight methods in which these spaces can guarantee good comfort conditions and considerable quality performance.

# 2 Indoor comfort

The term "indoor environment" is used to indicate all those confined environment of life and work that includes housing, offices, premises for recreational and/or social where people spend most of their life. Indeed, on average, the population spends more than 70% of their time in these environments undergoing, in fact, a prolonged contact with potential pollutant sources contained therein.

So the assessment of indoor comfort becomes a prerequisite for global comfort. This condition can be reached considering the air-quality comfort and thermo-hygrometric comfort.

The air-quality comfort mainly concerns the indoor concentrations of a variety of substances chemical predominantly nature: among these the most important ones are carbon dioxide, carbon monoxide, sulphur dioxide, radon, formaldehyde and all those volatile organic compounds that have serious consequences on the health of people.

It follows that to reach air-quality comfort we must maintain the values of concentration of these pollutants less than determinate minimum levels set by rule. This is possible mainly through a constant replacement of air which is dimensioned depending on the type of environments, their destinations use and the average capacity of people.

The thermo-hygrometric comfort, instead, is a function of a number of parameters: environmental (temperature, relative humidity, wind speed, solar radiation and atmospheric pressure), linked to physical activities (energy metabolic M), related to clothing worn (thermal clothing Icl) and the percentage of metabolic energy used for carrying out the physical activities (performance mechanical – value).

The current European regulations about thermo-hygrometrical performance classify indoor environments in three different types: environments "moderate" environments "severe hot" and environments "severe cold", each of which must comply with different levels of comfort.

The research focuses on thermal environments "moderate", namely those where the indoor conditions remain almost equal without considerable heat exchanges located between subject and environment that have significant effects on the overall heat balance (i.e. homes, offices, businesses, etc.).

They are characterized by thermal parameters variables within a limited range (as determined by the standard ANSI / ASHRAE 55-1992 - Thermal environmental conditions for human occupancy and UNI EN ISO 7730/1997 - Moderate thermal environments. Determination of PMV and PPD indices and specifications of condition of thermal comfort). They are:

- Air temperature (Ta) between 10 and 35°C;
- Temperature radiant (Tr) between 10 and 40°C;
- Relative Humidity (Ur) of between 30 and 70%;
- Air speed (Va) of between 0 and 1.5 m/s.

In environments "moderates" must assess the deviation of actual conditions than those comfort heat-humidity (temperature varies between 18-26°, relative humidity ranging between 50-60% and speed of air less than 1 m/s). The methodology used for assessing indoor comfort is out experimentally measurements using in-situ monitoring parameters microclimatic interior and surface temperatures.

## 3 The study case: underground spaces in "Sassi di Matera"

The site is a part of the architectural complex particularly significant, already a heritage of UNESCO since 1993: the ancient "Rioni Sassi di Matera", they are at an altitude of about 401m above sea level and are characterized by an aggregation of cells elementarily-called " the neighbourhood" that open towards the south-west.

The configuration of the complex morphology of the "Rioni Sassi" is that they can fully exploit the micro-climatic conditions of the site, characterized by hot and humid summers and mild winters.

The hypogea houses are arranged to horseshoe around a central atrium, (the "neighbourhood"), with exposure to the south; this exhibition allows a greater depth for the central caves, because they receive more sun and can more prolong inside the bench rock in which they are dug. The same homes are sloping inwards and so allow sunlight to penetrate in winter to the end, to heat and make healthy even the most hidden parts, while in summer, when the sun is highest, the most internal remain cooler.

In the site it is monitored three different types of hypogeous (with similar size and characteristics) of two hotel, the "Locanda di San Martino" and the "Hotel S. Angelo", different but similar at the same time in the forms and architectural peculiarities. They made it possible to compare environments with the same technological characteristics. In particular were considered a hypogeum not restored and a hypogeum restored, both in the "Locanda S. Martino" and a hypogeum restored and arrangements for use in "Hotel St. Angelo".

The monitoring was performed in the period from 10/04/2007 to 19/06/2007, a period characterised by a strong thermal excursion daily.

The instrumentation used was an environmental monitoring station with "multiacquisitore" LSI BABUC/A, equipped with 5 microclimatic probes:

- a probe globothermometric, for measuring the average temperature radiant;
- a probe psicrometric, for measuring the temperature of dry, humid temperature, temperature and dew on Relative Humidity;
- a probe anemometric portable hot– wire, for measuring the speed of the air;
- two thermometric probes (PT100), for– the measurement of surface temperature.

The measurements were carried out using fixed locations within the hypogea, placing the unit at a height of about 1.70 meters above the ground (average human height) and in the middle of the space.

In the hypogea restored and arrangements for use measurements were made with air conditioning off and considering two different conditions of operation of local: with plant recirculation of environment on and with plant recirculation of environment off.

For each local monitored were detected 7 signals with a frequency acquisition equal to 15 minutes, corresponding to the values of:

- Temperature dry-bulb air (Ta);
- Temperature wet-bulb to forced ventilation (Tw): from Ta Tw and the unit automatically gives the dew point temperature (Te) and relative humidity (Ur);
- Air speed (Va);
- Wet-bulb temperature and natural ventilation (Tnw);
- Temperature globo-thermometer of Vernon (Tg), from which the unit automatically derives the average temperature radiant (Tr);
- Surface temperature inside of the wall;
- Surface temperature of the external wall.

### 3.1 The behavior energy of not restored underground space

For architectures hypogea not restored means all those architectures that are in total state of disuse for many years.

And it is precisely the situation of total abandonment that often leads such architectures to situations of high relative humidity inside causing the formation of lichens and bacteria on the walls.

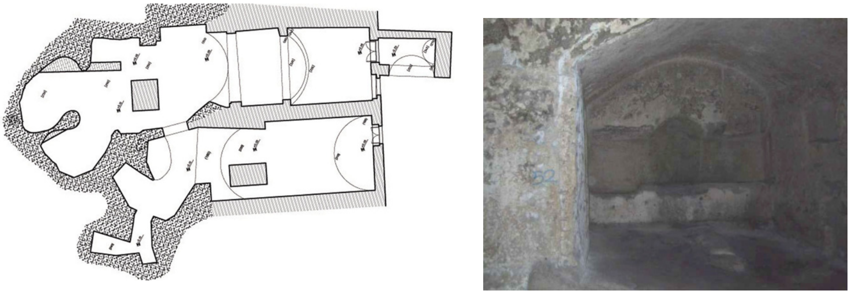

Figure 1: Not restored underground space.

The main characteristic of this type of environment is having a constant trend of microclimatic conditions during the indoor campaign measurements. Explicated in detail the individual values monitored we can say that the evolution of internal temperature had very small fluctuations (13-15°C), the average temperature radiant has remained constant during the measurement period (16°C), as well as the Relative Humidity (95%); as regards the speed and change of air, these values were next to zero.

Chart A refers to the entire period of monitoring.

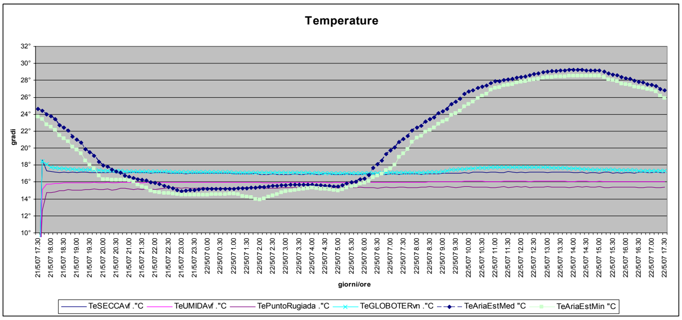


Chart A - Temperature of not restored underground space

As you can see from the charts, the slightest deviation of the values of dry-bulb temperature compared to the wet-bulb temperature and the dew-point temperature is the main cause high relative humidity indoor, allowing thus to lichens and bacteria to attacking the internal surfaces of the walls. In fact most of moisture present on masonry surfaces is caused to the continuous absorption of high humidity in the air a contact with the walls and a tiny amount of the migration of water present in rock.

Monitoring of these environments allows us to understand the nature of moisture present on surfaces walls of these environments, and we can say that in such environments humidity caused to rising capillary infiltration of water through the walls is virtually absent.

### 3.2 The behavior energy of restored underground spaces

Let us now consider architectures hypogea restored, but has no system of operation and use. This classification includes all those architectures already recovered from the aspect static-functional and wholesomeness of the premises. The values monitored, as described above, refer to a hypogea architecture that is part of a complex used as accommodation.

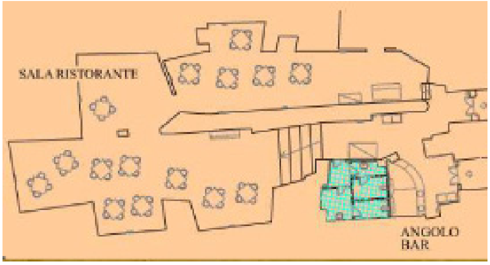

Figure 2: Restored underground space.

Again, the main characteristic of this type of architecture was to have microclimatic conditions indoor constant, even if with different values than the type not restored.

In fact the values of measured of the internal temperature air had increased by an average of 2°C compared to the type not redeveloped, stable at around 15°C, on the contrary the values of average temperature radiant remained identical (16°C).

The Relative Humidity, however, had a sudden drop of 20%, by reference to values more acceptable (about 65%), but still high respect on the standards. With regard to the speed and parts of air, again measured values are close to zero. The Chart B refers to the entire period of monitoring.
temperature, wet-bulb temperature and dew-point temperature, in the hypogeoum not restored is almost nothing. Indeed, this difference has contributed to lowering relative humidity environment.

This analysis has highlighted the importance of indoor microclimate control as a prerequisite to design a proper (and effective!) intervention rehabilitation thermo-hygrotermic of the “Sassi of Matera”.

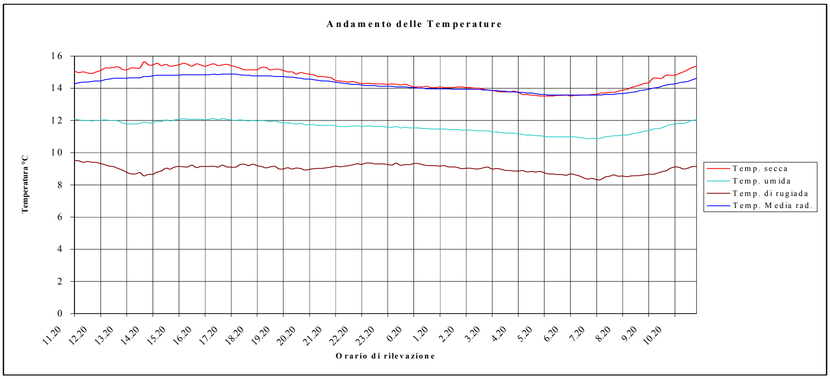


Chart B - Temperature of restored underground space.

Controlling indoor microclimate it will get comfort levels close to the minimum required by regulations of reference (indoor temperature of 18-20°C and relative humidity 50%).

### 3.3 The behavior energy of a rate of operation and use underground spaces

It is here described the behaviour thermo-hygrometric of a hypogea restored and operating system for many years.

In this configuration it was possible to make measurements with the planting of recycling and treatment of the environment on (UTA - air handling unit), which change air without conditioning. In this way the air blown into the air pushes vitiated air outwards in a natural way through the "light above" (small window above the front door), given appropriate open.

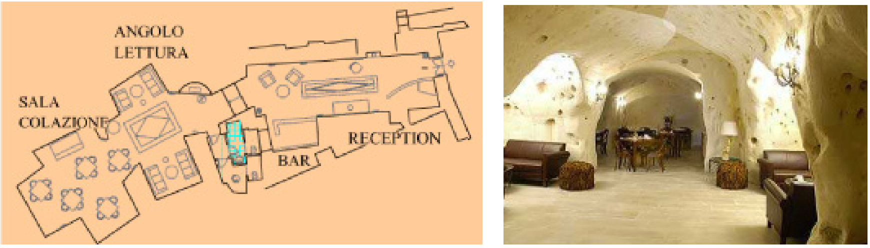


Figure 3: Rate of operation and use underground spaces.

The measurements made in this configuration made it possible to check the impact of the loop on the parameters of indoor comfort. It was also possible to verify the behaviour of environments hypogea in two different configurations: with recycling and fan system on and with recycling and fan system shut down.

 
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The most important content found is that in those environments setting the UTA so as to change 5 volumes/day has obtained an drop relative humidity who rose from values around 65% valued at around 50% (value of comfort). Even in this configuration the temperature has had a constant evolution, but with slightly higher values (around 18°C).

The Chart C refers to the entire period of monitoring. So from these charts shows that in order to obtain adequate conditions of comfort thermo-hygrometric in the environments hypogea of "Sassi di Matera" we must anticipate, already in the process of recovery, a adequate recycling and fan system of the environment more that an air conditioning system.

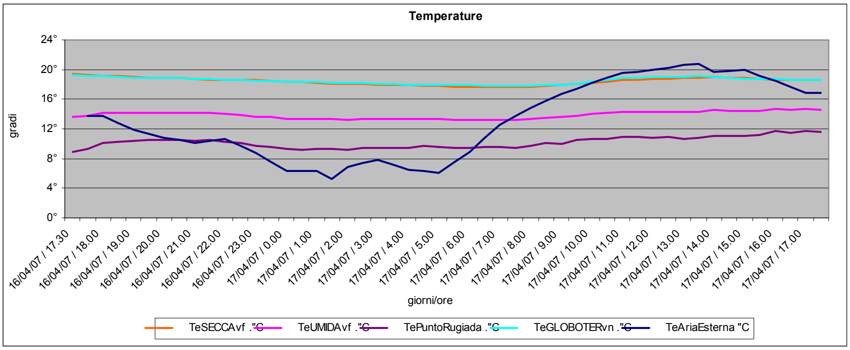


Chart C - Temperature of a rate of operation and use underground spaces.

Indeed assessing the UTA fairly compared to the size of the environment can to ensure acceptable levels of comfort, respectful of reference values established by legislation.

## 4 Analysis of the results

In conclusion, analyzing results obtained (Chart D) from measurements, we can make a critical and comparative summary between them, which may be briefly highlighted:

- Constant trend of internal temperature throughout the measurement period (13-15°C) for the hypogeum local not restored, 15°C the local hypogeum restored and 17°C for the local hypogeum restored and a rate of use; these values have been obtained against of the high thermal fluctuations daily with values exceeding 20°C (5°C night and daytime 28°C).
- The average temperature radiant of the walls has remained constant in the two configurations not restored and restored with value of (16°C), while the configuring restored and a rate of use had a slight increase reaching values of 18°C constant.
- The relative humidity has undergone large variation in the various configurations of local monitored. In fact, is has gone from high values,

approximately 95% for local hypogeum not restored, values of 65% for local restored and values of 50% for hypogeum restored and a rate of operation and use.

The last data even if it falls in the values established by rule, it is the upper limit of the range of tolerance for local with a similar use. This incident, however, is easily solved by setting a mechanical indoor air change of the domestic environments; in fact considering a replacement average volumes 5 volume/day the relative humidity inside drops to values around 50%, acceptable to the use of environment.

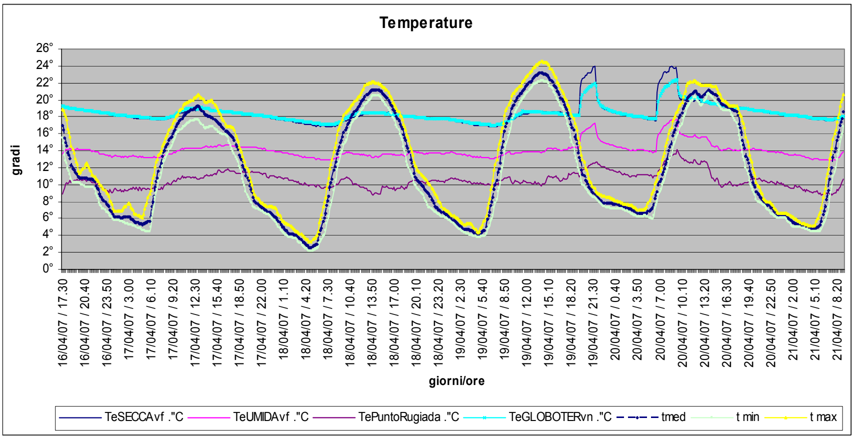


Chart D – Comparative chart.

## 5 Conclusions

The results of this evaluations shows that the parameters that govern the comfort "indoor" seem to assume, in the case of "Sassi di Matera", values respectful of recent regulations, although they should necessarily be repeated and extended in order to validate and to confirm the obtained data.

The research, therefore, shows how these architectures, realized with traditional techniques and materials, are an example of "sustainable construction", as can maximize the contributions in the solar cold season and minimise the hot season, taking advantage of the mass of the ground fly as thermal and encouraging natural ventilation of the environment. The "Sassi di Matera", therefore, seems to be almost a model of "bioarchitecture" in which natural stone, used "with wisdom", plays the key role of regulation. The study, in a further step, must systematize the data collected and deepen the study of "Sassi model" in order to reach the definition of methodological approaches and operational solutions to recovery the internal quality performance in similar contexts.

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