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BUILDING ENVELOPES PERFORMANCE QUALITIES: THE "SASSI" OF MATERA (ITALY)

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ABSTRACT

As a constantly important feature of the architecture, in both formal and technical-building aspects, with which it has established a biunique relation, the stone has always been able to guarantee performance qualities suitable for living conditions in each single century. In time, the technological process, on one hand, and the complexity of anthropical activities, on the other, have caused the breaking of this relation, generating a more and more increasing demand for performances. This necessity, supported by an increasing complexity/stratification of building envelope and also by the use of materials no more directly available near the building area, has caused a change of the equilibrium between man and environment, consolidated in time.

The study faces the recovery theme of the historical and monumental building, characterized by an "imposing" envelope, in which all the performance are entrusted at the same component and/or material (the stone masonry), pointing out the formal aspects, strongly correlated with static and technological ones. The complexity of this approach, also referred to restraints imposed by the built heritage, do not allow a wide range of solutions, and fix the necessity to value the envelope characteristic restoration and implements a possibility to developed the building performance. This is reversible and compatible choice, fully respectful of environmental characteristics. The aim of the research is to verify, by means of a series of tests for monitoring the "comfort indoor", how it is possible to obtain performance requirements corresponding to quality standards that the residence requires, even in a particularly important architectural context, as the ancient "Sassi" of Matera.

INTRODUCTION

The architectural culture has always been characterized by the use of stone. In fact the buildings substantiate the symbiotic relationship between this material and architecture; this relationship becomes an expression of identity and belonging to a specific place where each building, both historical and new construction, point out the context in which it is included.

The stone use in the architectural field has produced numerous - highly complex and heterogeneous - applications; in the past, it was used mainly as structural material.

Then it has been gradually losing this feature to perform a purely formal one, mainly determined by the introduction of new materials and technologies in the modern building systems. In fact, the technological process, on the one hand, and the complexity of human activities, on the other hand, have broken off the relationship between architecture and stone. It has generated a growing performance request to building envelope, in terms of quality, wellbeing and comfort "indoor", which could no longer be satisfied by the stone used in a "traditional way". This requirement, also substantiated by the use of materials not directly available near the construction site, leads a change of balance between man and environment, well established over the time. Vice versa, today, the stone use becomes no more a "forced" choice, but a "rational" choice, because it is able to transform the architecture in a hallmark of a particular place. So, the concept of architecture as a construction product of particular place, gradually regains credit and application. In this process, undoubtedly the natural stone becomes one of the main references to the modern architectural culture.

The research - included in a being widest research - aims to determine the methodological and operating recovery aspects of the ancient “Sassi di Matera”. It starts from a morphological analysis of specific architectural environment, aiming to assess the possibility of obtaining the performance requirements required by the residence quality standards, even in the buildings built using traditional construction systems, that are expression of this symbiotic relationship between man and environment, above said. Through tests “in situ” to monitor the comfort "indoor" (as defined by UNI EN ISO 7730 1997 and UNI EN ISO 7726 2002, the EEC Directive No. 106/89), the research aims to highlight the ways in which a building envelope, realized by local stone, is able to guarantee a good wellbeing condition and remarkable quality performance.

FROM STONE TO ITS "ANTHROPIZATION": THE “SASSI DI MATERA”

The man work don’t traces simply the existing environment, but changes it producing a interventions stratification, based on management - not always harmonious – of the surrounding space. And this transformation process is an irreversible step that is appointed to change definitively the environment structure, changing its shape. In fact, in some areas of southern Italy, and especially in the area of “Murgia di Matera”, terracing and shepherd shelter, the archaic methods to defend oneself from the heat and cold, to preserve the products, to collect the water and to carry it in tanks, represents a yet identifiable matrix on which grows the urban fabric, despite the countless stratifications, produced by the different interventions, prevents from understanding the original shape.

From excavated structures it passes, afterwards, at the implementation of the built structures, initially imagined as a natural continuation of the first one. Then they reach their formal and typological autonomy. And this is the process that has overseen the growth and development of the ancient “Sassi di Matera”, in which the relationship between excavated structures and built structures reaches its highest expression and morphological formalization.

They stands on the eastern slope of “Murge di Matera” and seem “to fall" into one of those karst ravines that are called locally "gravine". These ravines furrow the surrounding upland in a regular way and grant a particular character to the city as a part of the entire landscape, helping to define its unique stratigraphy and lithology. The eastern side shows the horizontal stratification of dense and crystal limestone, which form the Apulian upland. They are surmounted for a short distance by a pliocene calcareous sandy soils, that are a clear yellowish color, locally known as "tufo".

This particular stone gives to the city its architectural uniqueness. Distinctive characteristic of this unique urban cluster is the coexistence of structures built and excavated into the rock, which extended further on the cave entrance, they become an indipendent elements and realize the basic constructive cell, called "lamia" or "lamione ". This one room structure, characterised by a considerable thickness bearing walls on the long sides, supporting the stone vaults. The only illumination source is the opening access. It has an internal configuration space quite similar to the cave, but it seem to be a “built cave”, not “excavated cave”.

The advantages and disadvantages of each other on one hand, and the circumstance that the cave excavation provides materials for the “lamione” construction, justifying the reason so the two types continue to coexist without completely replacing one another [10].

They seem to be able to provide good thermal insulation and optimal thermal and hygrometrical conditions, thanks to the inner part of masonry, realized by a inconsistent materials. The not load-bearing masonry in front part has several openings, as the main door and a little window above the door to guarantee the lighting.

The same type of wall characterized the behind part of “lamione”. The front wall has a particular shape that is reminiscent of the natural slope of the rock on which it was developed. In fact, the house shape is substantially influenced by the relationship between the rocky slope and the excavated cave. Its more frequent image shows the “lamione” leaning against the slope, almost it is a external continuation of the excavated structures, as said above.

In some cases it also appears on the isolated flat ground. It usually presents two levels not communicating between them: the lower level is spreading outside the cave and it has access from the bottom road, while the upper level is shaped as an isolated house and it has access from the top road [9].

THE BUILDING ENVELOPE STONE: THE "TUFO"

The natural stone that constituted the “Sassi di Matera” is the "tufo", as said above, a biocalcarenite consisting of shells and calcareous fossils and microfossils. The limestone sediments are massive or stratified according to the places in which they are. They have a size and a cementation level that are different from place to place [3]. According to the texture and toughness, the local “tufo” can be divided into different varieties: tenacious (i.e. “mazzaro” or “carparo”); “fossilifera” (size and content of fossil remains variable); “fine grains” (different shades of color and toughness not recognizable by the naked eye). The variety of toughness “tufo” in "Sassi di Matera" is not present, excluding some important buildings even if for some architectural details, like basements or ground attacks, corner connections or closing corners of the walls, bracket and corbels, arch of doors and windows: therefore it is used for those elements that are subject to collision or accelerated wear [4].

Most of the buildings, instead, use a fine grain type of “tufo”. The two different typologies of “tufo” differ in the constituents size: the first one it is represented mainly by conglomerates and micro conglomerates; the second one it is represented from sandy limestone. These two rock varieties are typically characterized by high porosity and a particular form of deterioration. It shows itself in the formation of cavities, interconnected between them and not evenly distributed. The masonry surfaces affect to this deterioration - also determined by anthropic and environmental factors as well as ascent capillary phenomena - are often covered by a powder disintegration.

The easy workability of local stone has always allowed the use of square blocks. The art of Matera builder consisted in use of a several measures stone blocks. They realized a no longer than a few millimeters mortar mitre joints, as it is usual between reasonably squared stones. Unlike the rough stone wall, where the stone unevenness between a stone ashlars and the other one leaves gaps that must be filled with mortar. The "opus quadratum" used in Matera presents on the wall surface a carefully drawed close blocks that has a very small mortar thickness. Instead, interior spaces between ashlars stone and the other one are usually filled with good mortar slivers to reconstruct structural continuity, using inconsistent material [5].

The wall cavities, even if partially filled with inconsistent material, improve the isolation and transpiration wall capacity but form, at the same time, a weakness point of the static structure. The scrap part, that is the 20-30% of total production and comes from cutting, it is often recovered to achieve fills and collected or - more rarely - it is reduced in a dust, called "tufina", to prepare the mortar and plasters.

THE BUILDING ENVELOPE AND THE COMFORT "INDOOR"

As it is well known, the indoors air can be more polluted and harmful to humans than the external one, because, in addition to external pollutants, in the internal part of building there are different harmful agents, whose danger is often underestimated. To the chemical pollutants (carbon monoxide, carbon dioxide, etc.) or physical pollutants (gas radon, natural and artificial electromagnetic fields), jointed the biological pollutants (mold, bacteria, fungi, etc.). The importance of high internal air quality (IAQ - Indoor Air Quality) is even greater when it considers that the urban population spend 90-95% of their time in confined environments.

This is a wide problem and for a long time to the bio-medical attention. In 1987 the World Health Organization has recognized the Silk Building Syndrom (SBS) and the Building Related Illiness (BIS) and defined them as a complex of symptoms that occur in one or more occupants of the same building.

This highlights the importance of the design process and the need to define a building envelope that is able to satisfy the requirements required from contemporaries quality standards. The building envelope, in fact, acting as a “osmotic filter” with the outside environment, becomes the regulator of inner thermal and hygrometrical conditions, securing an indoor wellbeing. It is the same in the case of recovery of built heritage, and is particularly important when they are equipped with special historical and architectural values. The research aims to verify how, even in a significant architectural area - as the ancient “Sassi di Matera” - it is possible to achieve satisfying performance requirements required to the current standard applied to housing [8].

The main environmental parameters that affect air quality in confined environments are the internal temperature, relative humidity, ventilation, artificial lighting, soundproofing, the absence of pollutants gas such as carbon dioxide, products of combustion, volatile organic compounds (now commonly referred to by the acronym VOC-Volatile Organic Compounds) and radon. In this analysis, it reports the first results of the evaluation of internal temperature, relative humidity and the presence of radon.

THE CASE STUDY: THE “SASSO BARISANO” IN MATERA

The case of study (Fig. 1) includes the terraced valley that develops in the direction of West, in “Sasso Barisano”, at the bottom of the cliff, called “Civita”, and involves two lines of the expansion of the original medieval core of the city: the “Casale Vetere " and the "Casale". The original landscape morphology was more articulated and complex than the present one; over time has been transformed into a series of enclosures that depart from the main routes to the rock ridge of “Civita”.

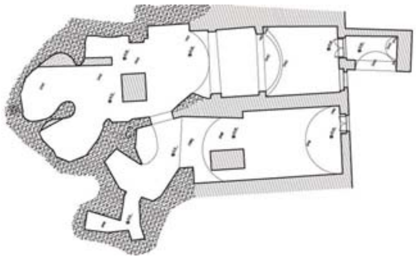


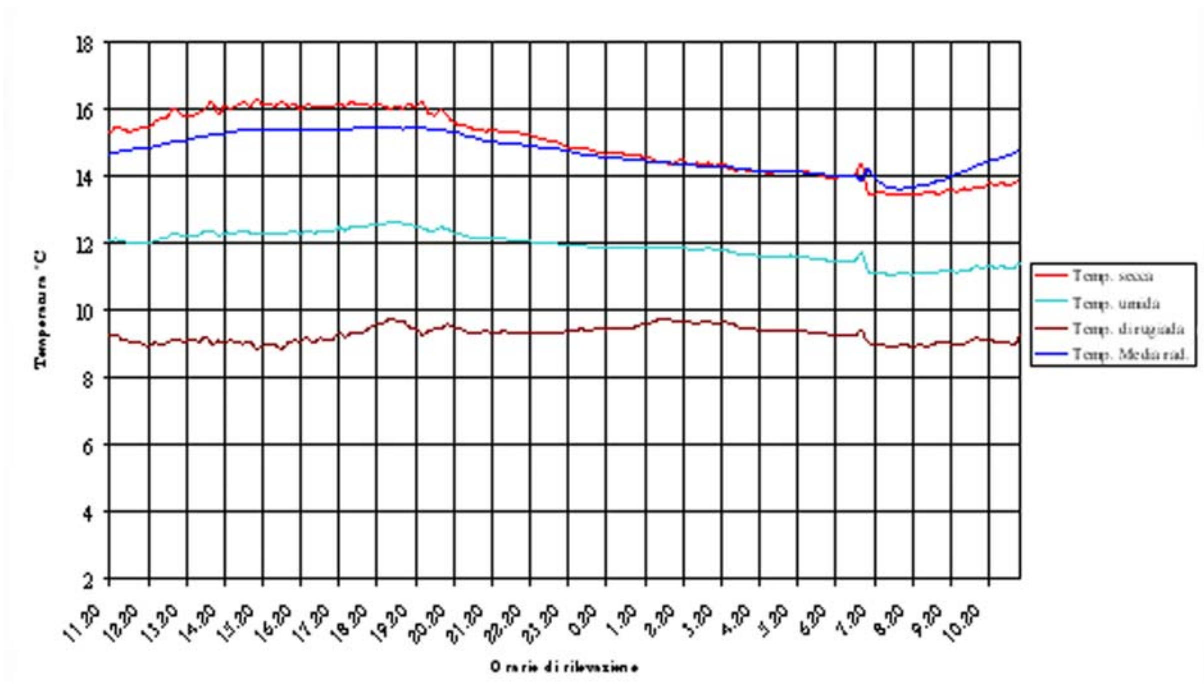
Figure 1 – The case study

The area is located in a strategic position between “Sasso Barisano” and “Sasso Caveoso” and behind “via dei Fiorentini”, and grow on 6 levels with a surface of about 1000 mq each one. Having identified some homes - both recovered and currently inhabited - it proceeded to the verification and monitoring of comfort indoor in this kind of structure, completely built with “tufo”. The considered area, realized with typical local constructive systems, is established entirely by local stone and not shows any type of pathology [6] [7].

The measurements were made using an instrument called BABUC (fig. 2) in an enough deep underground structure and they were collected in five days (in the last week of April). The data acquisition occurred in continuously, every 10 minutes. The sampling period was chosen on the environment conditions; in environments where variables detected remain largely constant in the day, as in this case, it is enough a measure of 10 - 15 minutes for each “homogeneous” area. The areas could be considered "homogeneous" if, at an given moment, the air temperature, the average radiant temperature, the air speed and the relative humidity can be considered uniform.

Figure 2 – BABUC

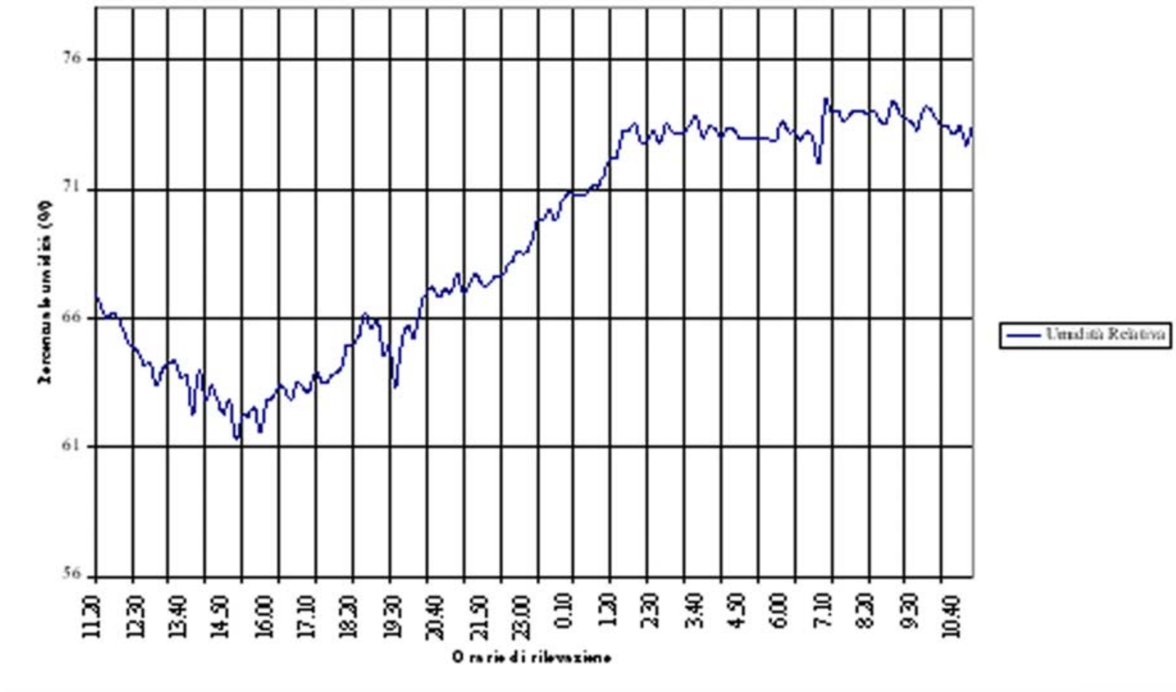
The unit BABUC was positioned at the center of the room, with sensors placed at 1,5 m on the floor, away by transient or not relevant to the assessment factors.
The diagram show a relative stability of values; the comparison between the various measurements point out that the relative value and the average temperature is consistently contained within the set of values (20-25 ° C), that are considered optimal from the norm UNI EN ISO 7730 1997, "Moderate thermal environments.



Tables A

Determination index PMV and PPD and specific conditions thermal wellbeing" and the more recent UNI EN ISO 7726, 2002, "Ergonomics of thermal environments - Tools for measuring physical quantities".

The results, reported in Tables A and B, indicate that both the temperature and the relative humidity of the air in the room where the test is carried out, they seems to guarantee the indoor wellbeing. Additional measurements, made in other environments and in different climatic conditions [1] [2], seem to point out the same characteristic. This information shall be confirmed and "systematized" by further measurements campaigns.



Tables B

In the same environment, it has been tested the measuring to verified the presence of gas radon. It is a gas produced by the decay of the uranium and is everywhere in soil and rocks, particularly those of volcanic origin in granites, in sandstone, in “tufo”, all used as building materials. The radioactivity associated with each type of material or environment is measured in bequerels (Bq). The monitoring of radon is carried out through the use of passive detectors with baskets to activated charcoal, with a detector PACKARD PICO-RAD (fig. 3), which is a preliminary inspection device for measuring the radon concentration in inner part of a building.

Figure 3 - Detector PACKARD PICO-RAD

The methodology followed in this tests consisted, as in the previous case, in direct survey concentration of radon in the building through the arrangement of detectors at various levels. The test follows the directives of the Agency for the Environment of the United States (EPA), about their employment procedures, maintaining, for example, the external doors and windows closed and placing at least two detectors next to each other.

After the detectors were brought in a radiation protection laboratory where was measured the radon level detained inside baskets of activated charcoal. In the basket were added to 10 ml of sparkling cocktails, and after 8 hours, were carried out measures with a scintillation counter. The calibration factor used by the laboratory, is provided by PAKARD, the same that returns the average concentration of radon in the air expressed in pCi /l.

However, the method used is valid only for quick response quality control, considering the low exposure time. The real control of radon average concentration should be based on measures conducted for a period of one year, after the identification of potentially dangerous areas, using a method as PICO-RAD. The European Community, with the Recommendation 143, 21 February 1990, and the EURATOM No 99/143, adopted by Leg. No 17/03/1995 230, "Implementation of directives 89/618/Euratom 90/641/Euratom, 92/3/Euratom in the field of ionizing radiation," established criteria for the protection of the people against exposure to indoor radon. The National Institute of Health, with the collaboration of ENEA, made in the 1994 sample survey in Italy analysing over 4000 houses distributed in 210 municipalities, noting an average concentration of Radon of 77 Bq / mc; only in 1% of the cases were found a concentration above 400 Bq / m, which is the threshold value established by the norm.

If the values is higher than that fixed by the standard, it is necessary to proceed with precautions interventions in the case of built heritage, even if some researchers have recently applied to the World Health Organisation (WHO) to lower this limit to 200 Bq / mc for new construction.

Luogo	PIC #	Concentrazione Radon		Media Bq/m^3	Netto Bq/m^3	Incertezza A %, k=1	Incertezza B %, k=1	Incertezza totale %, k=2
		pCi/l	Bq/m^3					
Locale 1.2-5	300	4,8	177,6	186,85	44,4	7,00	5,33	17,59
	301	5,3	196,1					
Locale 1.3-3	310	4,6	170,2	168,35	25,9	1,55	5,33	11,10
	311	4,5	166,5					
Locale 2.1-2	320	5	185	177,6	35,15	5,89	5,33	15,89
	321	4,6	170,2					
Locale 3.8-4	330	4,8	177,6	203,5	61,05	18,00	5,33	37,54
	331	6,2	229,4					
Locale 3.6-3	340	5,6	207,2	201,65	59,2	3,89	5,33	13,19
	341	5,3	196,1					
Locale 4.2-3	350	4,9	181,3	175,75	33,3	4,47	5,33	13,90
	351	4,6	170,2					
Locale 5.2-5	360	4,5	166,5	173,9	31,45	6,02	5,33	16,07
	361	4,9	181,3					
Testimone	380	3,9	144,3	142,45		1,84		
Testimone	390	3,8	140,6					

Tables C

The analysis of the results, as pointed out in Table C, shows that the values of the radiation level moves from minimum values of 25.9 Bq/m3 to maximum values of 61.05 Bq/m3, characteristic values of an area with a low level of gas radon.

CONCLUSIONS

The results, although they should be necessarily repeated and extended for a better validation and confirmation of the obtained data, show that the parameters governing the indoor comfort seem to assume in "Sassi di Matera" values respectful of recent regulations guidance. A key role is carried out by building envelope that, in addition to marking and note the relationship "osmotic" with the environment, becomes the means to guarantee the housing and residential requirements required by daily life.

The "Sassi di Matera", therefore, seem to be almost a model of "bioarchitecture", where natural stone, used "with wisdom", carries out the role of environmental regulation. The research, hereinafter, must systematize data collected and deepen the study of "Sassi model" in order to reach the definition of methodological approaches and operational solutions for the recovery of internal quality performance in similar contexts.

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