PAPER • **OPEN ACCESS**

Passive Cooling Strategies for the Enhancement of Historical Buildings: A Comparison between Ventilation Chimneys and Courthouses

To cite this article: Eleonora Laurini *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **690** 012049

View the article online for updates and enhancements.

You may also like

- Numerical study for the ventilation with solar chimney under effect of different location and the shape of the section opening window
Ahamed Q. Mohamed, Ahmed K Alshara and Hussein M. Mitlaik
- Enhancement of natural ventilation of a circular greenhouse with double wall solar chimney
D. Misra and S. Ghosh
- Forced and natural ventilation of a room with a combined solar chimney and Earth - to - Air Heat Exchanger system
V T Nguyen and Y Q Nguyen

244th Electrochemical Society Meeting
October 8 – 12, 2023 • Gothenburg, Sweden
50 symposia in electrochemistry & solid state science
Abstract submission deadline:
April 7, 2023
Read the call for papers & **submit your abstract!**

This content was downloaded from IP address 193.204.141.48 on 06/02/2023 at 11:02

Passive Cooling Strategies for the Enhancement of Historical Buildings: A Comparison between Ventilation Chimneys and Courthouses

Eleonora Laurini[1], Mariangela De Vita[2*] and Pierluigi De Berardinis[1]

[1] Department of Civil Construction-Architectural and Environmental Engineering, University of L'Aquila, Via Giovanni Gronchi 18 – Zona Industriale di Pile, L'Aquila, Italy
[2] Construction Technologies Institute CNR, Via G. Carducci 32 C, 67100, L'Aquila, Italy

*Email: devita@itc.cnr.it

Abstract. The balancing of protection needs and performance improvement are essential to keep in use valuable buildings. For this reason, it is fundamental to evaluate the effects on the energetic behaviour and conservation issues caused by retrofit measures in historical structures. The research aims at the performance improvement of Architectural Heritage promoting passive cooling strategies through a comparison between ventilation chimneys and historical courthouses. The architect J. R. Gordon (1863-1937) designed seventeen courthouses in Texas, twelve of which are still existing and functioning at this time. Reinterpreting the period's attention in mechanical systems' innovations for ventilation, cooling and heating, Gordon's courthouse buildings exploits natural ventilation as a strategy for achieving buildings' passive cooling, in the hot and humid climate areas of the Texas state, in a design process that evolved over time to become more technologically sophisticated and climatically efficient. This research investigates the design and construction features and climatic response strategies of Gordon's different types of court houses, specifically examines and assesses their natural ventilation effects. This study discusses the climate-responsive approach, moving from already established models to the creation of new climate responsive typologies of ventilation chimneys through a process of typological metamorphosis.

1. Introduction

The enhancement of cultural heritage through energy efficiency interventions is a topic widely tackled and discussed by scientific research, international regulations and governments [1,2]. Performance control of historical buildings is a fundamental tool to contain environmental damage reducing polluting emissions, building management and maintenance costs.

Although the architectural heritage certification in the energy sector has still a long way to go, designers and restorers are called to deal with the theme of the performance of these buildings.

Tackling the energy retrofit of a protected heritage involves aspects of design relating to apparently conflicting areas and methods of intervention, which should be wisely kept together in a coherent and shared vision in occasion of the restoration of the building. On the other hand, what often happens is that the different professional technicians involved do not interact with each other in the various phases of the retrofit process, so design actions proceed by independent sections.

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

Retrofit projects with a high degree of compatibility consists in the adoption of passive strategies with a low material impact on the building: these represent an effective possibility to operate in respecting values of the historical buildings thanks to reversible and minimally invasive interventions.

In the energetic enhancement of cultural heritage it is necessary, first of all, to refer to the performance improvement, in which the designer is required to identify the best performance quality that can be pursued with reference to the context and the original state of the building. The energy performance improvement has the objective of getting as close as possible to current standards of safety and comfort [3]. Pursuing these objectives is possible both through the active control strategy [4] - intervention on the plant systems, maximizing the yield - and the passive control strategy - through intervention on the envelope, by inserting / enhancing devices that allow to control the heat exchange between the building and the external environment [5]. Energy retrofit can be tackled by adopting the two strategies alternatively or simultaneously.

This work is developed to evaluate the efficiency of the main passive cooling systems applicable in the enhancement of cultural heritage: ventilation chimneys and courthouses. In the presented methodology, the efficiency of the systems analysed is verified through energy simulation programs.

2. Passive Control Strategies

Passive control strategy is a valid tool for intervening on the performance of historical buildings and, if supported by active strategies, it can contribute substantially to achieving excellent performance levels without forcing the overuse of HVAC systems. One can include among the passive control strategies both the interventions to be carried out directly on the building envelope – vertical and horizontal structures, opaque and transparent – modifying its original thermo-physical characteristics, and the use of devices and technologies with low material impact, integrated or overlapped on the envelope, such as ventilation chimneys and light pipes [5].

2.1. Interventions on the Envelope

The intervention on the envelope during the restoration of a valuable building involve insulating materials that can be used outside and / or inside, in addition or alternatively, to the installation of insulating glass windows. The choice of the most suitable intervention can depend heavily on the state of preservation / degradation of the structure and on its particular characteristics in terms of values to be protected. Moreover, the possibility of applying more or less invasive solutions substantially refers to the degree of invasiveness required by the structural intervention; vice versa the structural intervention must be calibrated considering the conservative needs suggested by the architectural restoration [5].

In intervening on the thermo-physical characteristics of the vertical structures, opaque or transparent, it is always necessary to guarantee transpirability and permeability with the purpose of protecting the conditions of the masonry linked to hygroscopic and the possible formation of interstitial condensation, humidity or moulds. Furthermore, the technological solutions are linked to the level of transformability of the architecture suggested by the analysis of the values [3].

Although proceeding in the transmittance of the envelope allows the achievement of the performances of buildings observing the reference standards for new constructions, the risk of irreparably modifying the transpiration of the masonry, with the possibility of damaging the structure and the valuable elements, suggests to intervene with caution by adopting irreversible solutions. Finally, it must be considered that the building envelope, in the case of historical buildings, generally presents in itself characteristics such as to ensure a good thermal inertia – because of its important mass - and at the same time adequate transpiration. Therefore, the opportunity and the real need to intervene on the thermo-physical property of a historical envelope must always be evaluated with extreme scrupulousness.

2.2. The Integration of Compatible Technologies

Additional strategies for controlling the performance of a building consists in the predisposition of devices that regulate lighting and air exchange using daylight and natural ventilation respectively. Lightshelf, skylight, lightube, special glasses and / or films, ventilation chimneys and the integration of light structures - temporary and reversible like technical textiles - can be important allies of the performance of a historic building, using advanced technologies and with an extremely high performance.

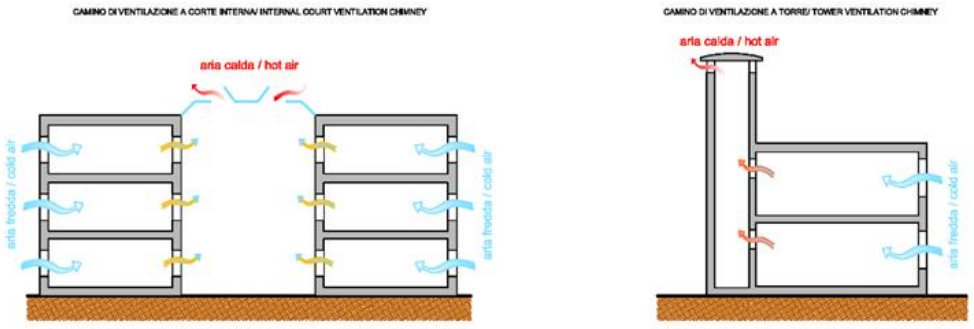
These devices derive their origins from passive bioclimatic regulators used in Arab and Roman architectures, such as for example velaria, wind towers and light / ventilation ducts. The activation of natural ventilation phenomena, exploiting the principle of the chimney effect and the maximization of daylight exploitation, can be pursued through more or less invasive interventions, also depending on the morphological characteristics of the building on which to intervene. Often, in the restoration of a historical architecture, one can encounter buildings already equipped with caves or skylights with sections large enough to be used both as ventilation chimneys - with small activation devices - and as light ducts, while in many other cases the vertical connection systems are suitable for the installation of new devices [6].

A large majority of the solutions related to this area of intervention, despite having significant repercussions on the performance of the building as a whole (building-plants), from a merely executive point of view, can be considered unrelated to structural interventions, consisting of lightweight and often self-supporting structures. A closer relationship exists in the field of restoration, going to change in many cases the appearance of the building. In general, as for the other categories of retrofit solutions, these technologies also deserve a compatible approach to design: the recognizability and reversibility of the intervention guarantee good compatibility of the installation.

To date, literature and legislation have few tools for the interdisciplinary design of these devices, bringing out a methodological gap both in technological renewal and in the definition of compatible interventions. The suggestion to calibrate, according to the original state of the building, the degree of invasiveness allowed by the intervention, represents a track to follow, not excluding prior technological solutions significantly improved and, in any case, compatible with the restoration of the product and therefore not avoiding, in the evaluations for the choice of the devices to be installed, from the preliminary avoiding on the type of structural intervention and its measurement.

3. Passive Cooling through Ventilation Chimneys and Courthouses

Ultimately, we could group together the typologies into two macro diagrams that can be represented as follows in figure 1:



(a) (b)

Figure 1. Chimney typologies schemes: (a) internal atrium building (b) tower or ventilation duct.

The first one on the right represents a tower or ventilation duct, while the one on the left represents an internal atrium building. In conclusion we can affirm that the most suitable typology for a temperate climate is represented by the duct while for the tropical climate the best configuration is represented by the building with an internal courtyard, a type used by the architect in his courts of justice [7].

4. The Ventilation Chimney

The oldest “thermal machine” built by man is the fireplace, which lends its name to a phenomenon known in bioclimatic architecture as a chimney effect, connected to the natural ventilation of a building. Very often, in fact, our buildings behave like giant chimneys, inside which the air circulates according to pressure differences. These differences are responsible for the natural ventilation of the building, fundamental for the air exchange of the rooms and the thermo-hygrometric well-being of the occupants.

The differences in pressure between the different floors of a house, obviously minimal (in the order of a few thousandths of the atmosphere) increase with the height and the temperature difference between inside and outside.

It must then be considered that any gas, if heated, expands proportionally to the increase in its absolute temperature. The expansion produces a decrease in the specific weight of the gas which therefore tends to rise towards the top. Even the air is subject to this phenomenon that can be exploited to naturally ventilate a home and keep it at optimal temperatures both in winter and in summer.

In a multi-storey house, the lighter air will rise to higher levels, is the warmer one, creating a pressure higher than atmospheric one, unlike what will happen to the lower floors, where the pressure will be slightly less than atmospheric one.

Doors and windows play an important role in the regulation of natural ventilation, and one must know how to place them because they determine the position of the neutral point of the house, or the point (variable according to the open frames) in which the internal pressure is equal to the external one.

How the presence and arrangement of openings affect, the type of ventilation chimney, the presence of multiple levels in the home, is precisely what this chapter aims to clarify by carefully analysing different case studies [8].

4.1. The Case Studies Studied

Below we find a schematic representation of the cases studied, and the air flow is qualitatively evaluated. The study consists of 11 types of ventilation chimney coupling and openings differently located on the walls of the room.

One assumes the presence of medium-sized rooms (about 20 square meters), the position of the building in the two climate zones at the antipodes (tropical climate in San Antonio in Texas and temperate in Rome in Italy), if indeed it is true that some properties can be varied (see configurations of the various types of ventilation chimneys), some features remain unchanged because they are intrinsic to that particular place. Among these, it is certainly worth mentioning the climate zone that plays a fundamental role in achieving thermo-hygrometric well-being. It is interesting, therefore, to understand the functioning of the same systems analysed, positioning them in different climate zones [9].

The modelling was carried out in Design Builder taking into account the presence of only natural ventilation, and the results were evaluated for the entire summer period from June to August taking into account the average values.

The following figure 2 is a summary of the different types analysed:

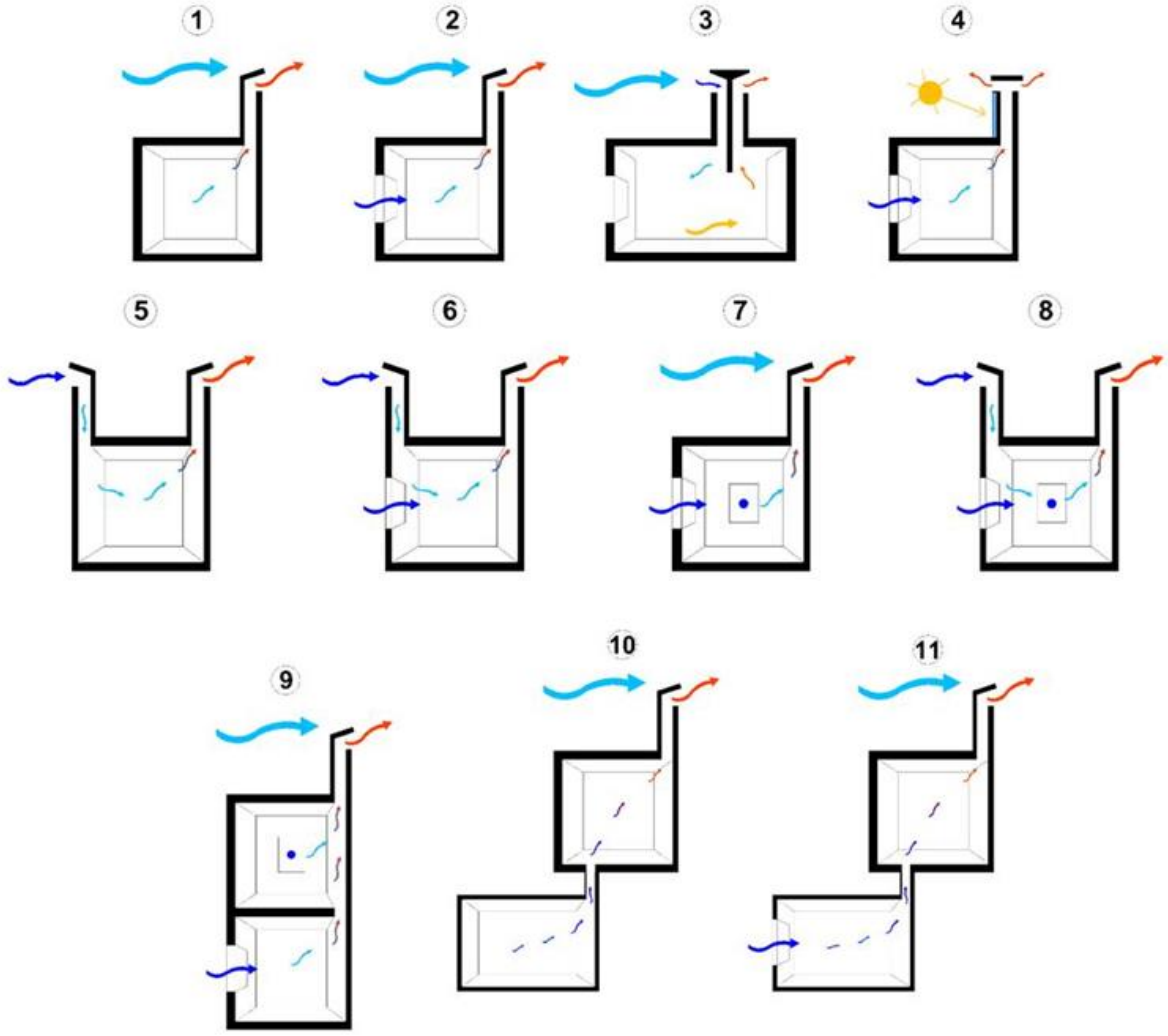


Figure 2. Different types of ventilation chimneys analysed.

4.2. Some Performance Data on the Different Cases

The following table 1 shows the data obtained from the simulations:

Table 1. Climate comparisons of ventilation schemes on a tropical climate (San Antonio, TX) and tempered Mediterranean (Roma, it).

	DESCRIPTION	SAN ANTONIO (TX)			ROMA (IT)		
		AIR TEMP. (°C)	OPERATING TEMP. (°C)	RELATIVE HUMIDITY (%)	AIR TEMP. (°C)	OPERATING TEMP. (°C)	RELATIVE HUMIDITY (%)
SCHEME 1	ventilation chimney in a blind compartment	29,57	29,6	55,47	24,18	24,25	54,40

SCHEME 2	ventilation chimney in a windowed compartment on the opposite wall	27,19	27,58	63,27	21,42	21,84	64,48
SCHEME 3	ventilation chimney with internal partition in windowed compartment on opposite wall	27,51	27,97	62,1	22,89	23,29	58,88
SCHEME 4	ventilation chimney with solar collector in windowed compartment on opposite wall	28,62	29,16	58,77	24,35	24,81	54,43
SCHEME 5	double ventilation chimney on opposite walls in a blind compartment	27,83	28,03	60,79	23,23	23,39	57,66
SCHEME 6	double ventilation chimney on opposite walls in a windowed compartment	27,03	27,44	63,9	21,23	21,67	65,27
SCHEME 7	ventilation chimney in windowed compartment on opposite wall and side	26,72	27,43	62,49	21,23	21,92	65,63
SCHEME 8	double ventilation chimney on opposite walls in a windowed compartment on the opposite and lateral wall	26,69	27,42	65,65	21,17	21,88	65,95
SCHEME 9	double height ventilation chimney in windowed compartments (internal courtyard)	26,69	27,16	65,37	20,95	21,42	66,66
SCHEME 10	tower ventilation chimney in multi-level blind compartments	29,03	29,14	56,82	23,25	23,38	57,42

SCHEME 11	tower ventilation chimney in multi-level windows	27,37	27,72	62,01	21,49	21,85	64,08

Scheme 1, which represents a ventilation chimney connected to a blind environment, gives to both climate zones, temperature and humidity discomfort values. In other cases, instead, the numerical data are much more favourable. Below is a histogram with simulation data on the various schemes (on the x-axis) and the relative values of air temperature, operating temperature and relative humidity.

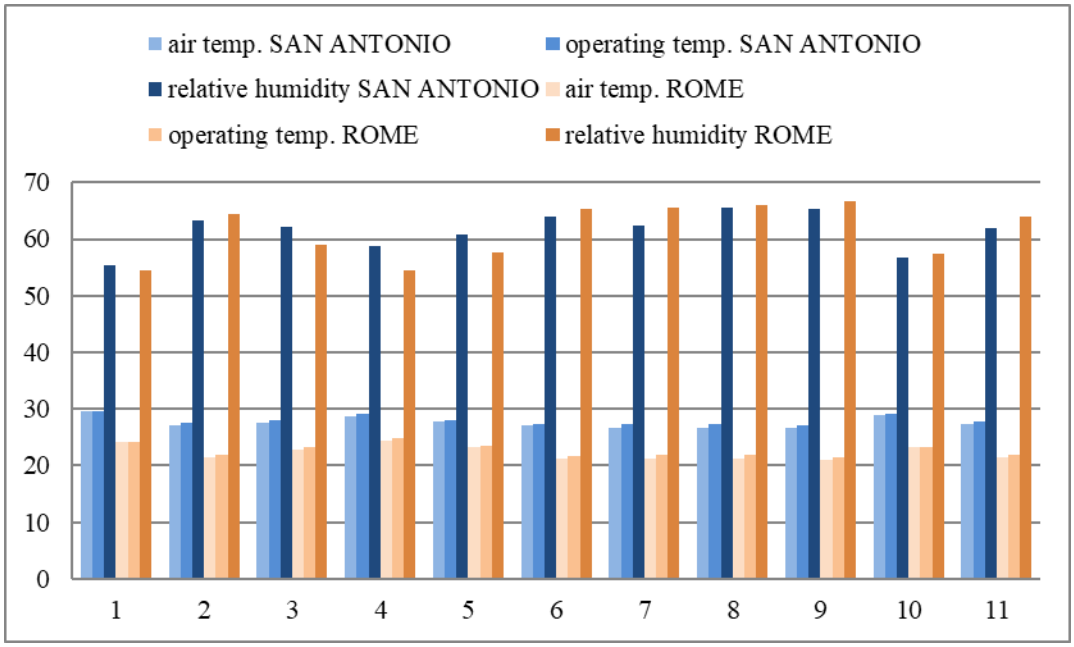


Figure 3. Histogram of simulation data on the various schemes (on the x-axis) and the relative values of air temperature, operating temperature and relative humidity.

As shown in figure 3, it is clear that the climate zone plays a fundamental role on the data obtained, but there are obvious differences in the data obtained from the configurations depending on the location of the building. But analysing the trend of the values on a line chart we can get clearer results:

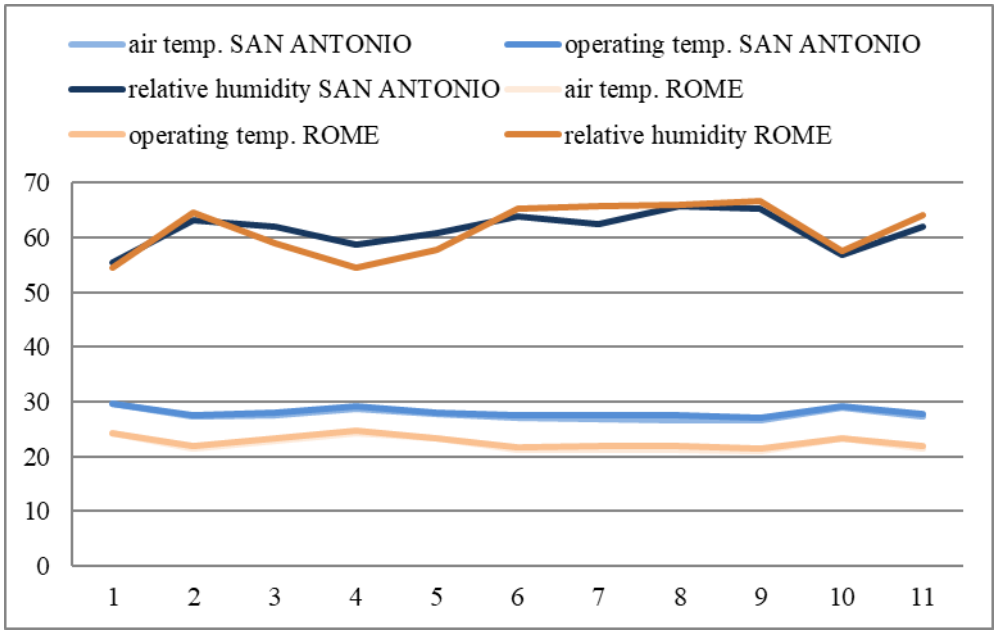


Figure 4. Trend of the same values of figure 3 on a line chart.

From the graph in figure 4 you immediately notice the difference in temperature (of the air and operating temperature), which remains constant in all the schematic simulations. In fact, it would seem that the lines are always parallel, a symptom of the fact that even if with small infinitesimal variations, the temperature variation thanks to the presence of chimneys or openings positioned in various forms remains constant. What instead produces a noticeable difference, are the relative humidity values visible at the top of the graph. Relative humidity is an important symptom of thermal washing, due to ventilation, and plays a fundamental role in the scale of thermo-hygrometric well-being. In the case of Rome, it is noted that the first chimney schemes favour the reduction of the relative humidity value, unlike what happens for the city of San Antonio where exactly the opposite occurs, since the most favourable situation is verified in the last simulations [10,11].

5. The Courthouses

In Texas James Rieli Gordon designed seventeen courts, twelve of which are still exist and currently operating. The typological metamorphosis in the design development of the courts have evolved over time to become more technologically sophisticated and climatically efficient. Figure 5 represents Texas court types. In his patented cruciform plan, Gordon incorporated ventilation through the well with courtyard, tower and circular staircase. In addition, Gordon has put the entrances in each of the four corners, using distinctive curved colonnades to capture the natural breezes. The restorers and researchers believe that this type of plant was designed to increase and regulate the comfort of the building's internal environment: "when air hits the building it gives heat out, forced through an opening expands the absorbing heat and rises through a central atrium emanates heat that then rises [and escapes] through the central tower " [12-14].

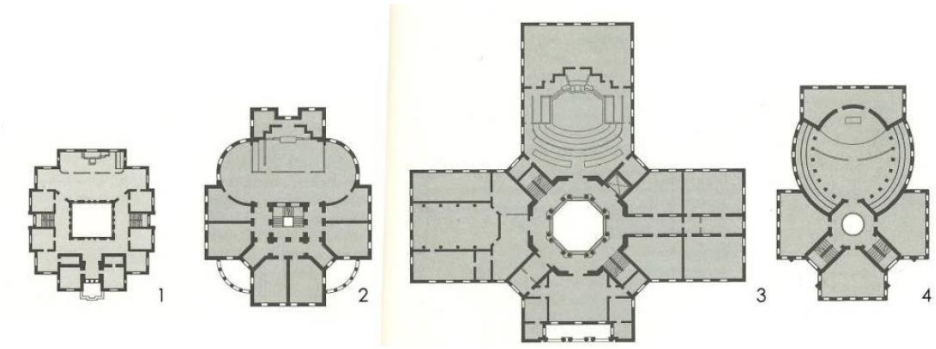


Figure 5. types of Courthouses. (from Meister, 2011)

5.1 A performance comparison between the types through the tool of dynamic simulations

The simulations were carried out assuming the positioning of these ventilation chimneys in different climatic locations. The results of the simulations led to the verification of the functionality of these devices, whose insertion and wise use, leads to the achievement of an optimal comfort in many cases optimal and without the aid of mechanical means. However, this does not appear to be absolute truth in any type of external condition. If indeed it is true that some properties can be changed (see configurations of the various types of ventilation chimneys), some characteristics remain unchanged because they are intrinsic to that particular place. Among these, it is certainly worth mentioning the climate zone that plays a fundamental role in achieving thermo-hygrometric well-being.

The analysis of the site is in fact fundamental to understand also the characteristics of the ventilation of the same (direction of origin of the wind, frequency of origin in a given direction and average speed). To the characteristic frames are added the climatic data of the area (temperature and relative humidity), which therefore lead to always having different results with the same element designed. It is therefore interesting to understand the functioning of these analysed systems, positioning them in a different climate zone and with variable functional and dimensional characteristics.

The first schemes represent ventilation chimneys realized through real chimneys similar to towers, while the last schemes were made in place of multi-level buildings with vertical connections at double heights similar to courtyards.

Table 2. Climate comparisons of ventilation schemes on the tropical climate (San Antonio, TX) and temperate Mediterranean (Rome, IT) and the location of Pittsburgh.

		SAN ANTONIO (TX)			ROMA (IT)			PITTSBURGH (PA)		
	DESCRIPTION	AIR TEMP. (°C)	OPERATING TEMP. (°C)	RELATIVE HUMIDITY (%)	AIR TEMP. (°C)	OPERATING TEMP. (°C)	RELATIVE HUMIDITY (%)	AIR TEMP. (°C)	OPERATING TEMP. (°C)	RELATIVE HUMIDITY (%)
SCHEME 1	ventilation chimney in a blind compartment	29,57	29,6	55,47	24,18	24,25	54,40	22,535	22,62	51,12
SCHEMA 2	ventilation chimney in a windowed compartment on the opposite	27,19	27,58	63,27	21,42	21,84	64,48	19,47	19,94	61,21

	wall									
SCHEME 3	ventilation chimney with internal partition in windowed compartment on opposite wall	27,51	27,97	62,1	22,89	23,29	58,88	20,41	20,90	57,78
SCHEME 4	ventilation chimney with solar collector in windowed compartment on opposite wall	28,62	29,16	58,77	24,35	24,81	54,43	21,79	22,34	53,56
SCHEME 5	double ventilation chimney on opposite walls in a blind compartment	27,83	28,03	60,79	23,23	23,39	57,66	20,74	20,98	56,5883
SCHEME 6	double ventilation chimney on opposite walls in a windowed compartment	27,03	27,44	63,9	21,23	21,67	65,27	19,30	19,78	61,94
SCHEME 7	ventilation chimney in windowed compartment on opposite wall and side	26,72	27,43	62,49	21,23	21,92	65,63	19,03	19,79	63,27
SCHEME 8	double ventilation chimney on opposite walls in a windowed compartment on the opposite and lateral wall	26,69	27,42	65,65	21,17	21,88	65,95	18,97	19,76	63,51
SCHEME 9	double height ventilation chimney in windowed compartments (internal courtyard)	26,69	27,16	65,37	20,95	21,42	66,66	18,83	19,3367	63,90
SCHEME 10	tower ventilation chimney in multi-level blind compartments	29,03	29,14	56,82	23,25	23,38	57,42	21,43	21,57	54,31
SCHEME 11	tower ventilation chimney in multi-level	27,37	27,72	62,01	21,49	21,85	64,08	19,53	19,90	60,95

windows

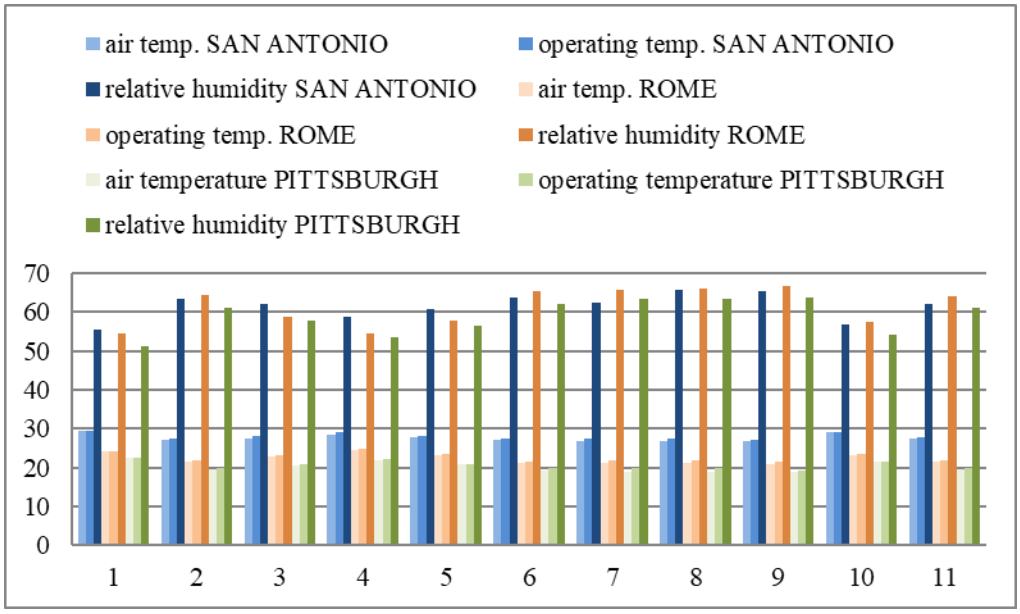


Figure 6. Histogram of simulation data on the various schemes (on the x-axis) and the relative values of air temperature, operating temperature and relative humidity.

Also in this case. Shown in table 2 ad in figure 6, it is clear how the climate zone plays a fundamental role on the data obtained, but there are obvious differences in the data obtained from the configurations depending on the location of the building.

Going to better analyze the trend of the values on a line chart we can get clearer results (figure7):

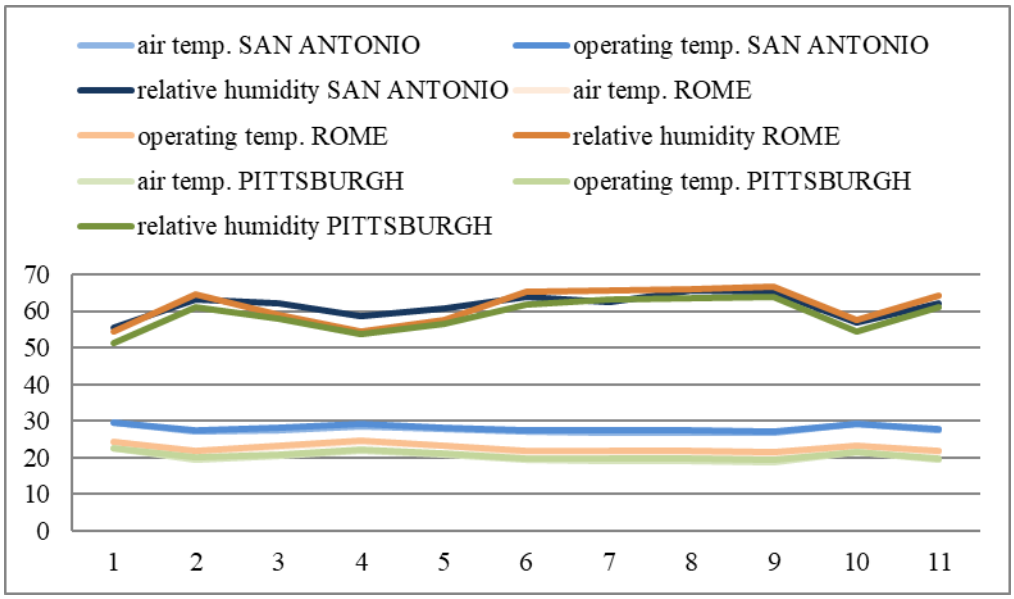


Figure 7. Trend of the same values of figure 5 on a line chart.

Even in the case of Pittsburgh, as in the case of Rome, it is noted that the first chimney schemes favor the reduction of the relative humidity value, unlike what happens for the city of San Antonio where exactly the opposite happens, as the situation is more favorable is verified in the latest simulations.

The first schemes represent ventilation chimneys realized through real chimneys similar to towers, while the last schemes were made in place of multi-level buildings with vertical connections at double heights similar to courtyards.

This confirms that in less warm climates such as Rome or Pittsburgh, ventilation chimneys are more efficient than the court type.

6. Conclusions

The natural ventilation of the buildings can be classified first of all based on its function:

• Ventilation serves primarily to improve the quality of indoor air, guaranteeing supplies of external air to replace stale indoor air.

• If conditions permit, ventilation can also be used for cooling, or rather for the reduction of temperature inside a building, with improvement of internal wellbeing conditions.

First of all, it is important to clarify the main "motors" of ventilation that generate the energy necessary to make the air flow inside the buildings, overcoming all the load losses that arise. These are basically the wind and the chimney effect, regardless of the type of natural ventilation.

The wind always generates on the exposed side of a building an overpressure which is accompanied by a depression on the opposite side. This pressure difference activates the passage of air from one side to the other of the building. This type of ventilation is often called "passing" or "crossed" and usually the flow is horizontal. It also triggers in the absence of opposite passages on the windward and downwind sides, but in this case the effect is more limited.

The second "engine" for natural ventilation is the so-called "chimney effect". It occurs when a stratification in height of air is created at different temperatures. The warmer air, as is known, is less dense and tends to stratify upwards, while the denser remains at the bottom. In this way a gradient of pressure decreasing from the bottom to the top is created which can be exploited to trigger the ventilatory movement which will necessarily be ascending [15].

The ventilation due to the chimney effect depends on the difference in temperature between the lowest point and the highest point of the air stratification. The greater the difference, the greater the scope. Even the difference in height is important, the higher the stratification, the greater the flow rate. In the example to the right of the above figure we see a so-called solar chimney. It is a device used to trigger ventilation, thanks to the overheating generated by solar radiation that passes through a glass and an absorbent surface expires. The difference in flow rate will be greater in the case on the right, since the difference in altitude between the air heated by the sun and the outlet is greater [16].

It is not always necessary to schematically divide the two types of ventilation, very often it is indeed useful to use mixed systems, such as those represented above.

There are limits to the applicability of cooling by ventilation:

CASE A: Typical winter situation. Inside an environment there would be an internal temperature in the absence of plants (Twh) equal to 13°C. The activation of the systems brings the internal temperature to 19 ° C. The introduction of external air at 5°C implies an additional load for the latter, so it is necessary to limit it to the legal minimum for renewal.

CASE B: Intermediate season. Free solar supplies are sufficient to give an internal temperature of 20°C. Also, in this case the intake of outside air must be reduced to the minimum required by law.

CASE C: Intermediate season. The solar inputs are such as to bring internal temperatures of 27°C compared to a much milder outdoor temperature. In this case it is necessary to introduce air from the outside to passively cool the building without resorting to the systems. This is the only case in which we can talk about cooling ventilation. This situation can also occur in the summer period at night.

CASE D: Summer season. The outside temperature is beyond the comfort limits. It is not possible to resort to natural ventilation because it would represent an increase in internal conditions. Air intake should be limited to the minimum required for renewal as it is a load for cooling systems.

Through these cases it is possible to confirm the difference in behavior of the same device according to the climatic zone [17], since its operation is directly influenced by the external temperatures. Designing a good cooling device is therefore a very difficult task, although the same must be adapted to the site in which it will be used and, above all, to integrate with existing historical structures [18,19].

Acknowledgments
Thanks to Prof. P. De Berardinis and Prof. S. Ciranna for being the scientific leaders of the research, the UTSA (University of Texas at San Antonio) and the Dean J. Murphy and Prof. A. Lombardi for supporting this topic.

Author Contributions
Although this contribution was conceived as a whole paper by all the authors, M.D.V. wrote sections 1 and 2; E.L. designed the research, constructed the models, performed the simulations and wrote sections from 3 to 6. P.D.B. supervised the research and the paper.

References
[1] Pracchi V 2016 Efficienza energetica e patrimonio culturale: un contributo alla discussione alla luce delle nuove linee di indirizzo, *in Proceedings of 32th International Conference on Scienza e Beni Culturali: Bressanone, Italy* (June 28-July 1, 2016) pp 717-726
[2] Mibact 2015 Linee di indirizzo per il miglioramento dell'efficienza energetica nel patrimonio culturale
[3] Pretelli M, Ugolini A, Fabbri K 2013 Historic plants as monuments preserving, rethinking an re-using historic plants *Journal of Cultural Heritage* **14S** 538-543
[4] De Vita M 2019 Architectural Heritage and retrofit measures: the improvement of buildings performance through passive compatible strategies, In: *Proceedings of the XXXV Internazional Congress Scienza e Beni Culturali* (1-5 July 2019, Bressanone, Italy)
[5] Laurini E, De Vita M, De Berardinis P, Friedman A 2018 Passive Ventilation for Indoor Comfort: A Comparison of Results from Monitoring and Simulation for a Historical Building in a Temperate Climate *Sustainability* **10** 1565
[6] Lucchi E, Pracchi V 2013 a cura d,i Efficienza energetica e patrimonio costruito La sfida del miglioramento delle prestazioni nell'edilizia storica, Maggioli Editore: Sant'Arcangelo di Romagna, 2013
[7] Laurini E, 2019 History meets science between Abruzzo and Texas, Architecture, Restoration and Environmental Control of Historical Buildings, pp 89-103, Edizione Quasar, 2019, ISBN 978-88-7140-966-5
[8] Laurini E, Taballione A, Rotilio M, De Berardinis P, 2017 Analysis and Exploitation of the Stack Ventilation in the Historic Context of High Architectural *Environmental and Landscape Value, Energy Procedia*
[9] Larkin, T J, and Bomar G W 1983 *Climatic Atlas of Texas* (Austin, Texas: Texas Dept of Water Resources) LP-192
[10] Burgett J M, Chni A R, and Oppenheim P 2013 Specifying residential retrofit packages for 30 % reductions in energy consumption in hot–humid climate zones *Energy Efficiency* **6** 523-543
[11] Dupont W, Rashed-Ali H, Manteufel R, Thomson T, and Sanciuc L 2016 Energy Retrofit of Older Houses in Hot and Humid Climates *APT Bulletin: The Journal of Preservation Technology* **47**(1) 50-58
[12] Chandra S, et al 2012 Pilot residential deep energy retrofits and the PNNL lab home PNNL-21116, Pacific Northwest National Laboratories

[13] Cavalo J 2005 Capturing energy-efficiency opportunities in historic houses *APT Bulletin*, **36**(4) 19-23
[14] Meister C, 2011 *James Riely Gordon, His Courthouses and Other Public Architecture* (Lubbock, TX: Texas Tech University Press)
[15] Culver, J H and Randall, B 2010 Saving Energy in Historic Buildings: Balancing Efficiency and Value APT Bulletin, 41(1) 5-12
[16] Florian T, Rashed-Ali H, and Von Schramm V 2011 Post-occupancy evaluations of high-performance homes *Presented in GreenBuild2011 International Conference and Expo* (October 4-7, Toronto, Canada)
[17] Frederick-Rockwell B, 2015 The 'Monster problem': Texas architects try to keep it cool before air conditioning ARBIS *Journal of the Southeast Chapter of the Society of Architectural Historians* **26** 40-53
[18] Frederick-Rockwell B, 2013 *Environmental Integrity: Interpreting Historic Indoor Conditions* MS Thesis in Historic Preservation (Austin: The University of Texas at Austin)
[19] Morbidelli M, Principi S, 2012 *History of Architecture* In: Baratin, L, Acierno, M, Muratore, O, 2012 Instruments and Methodologies for Cultural Heritage Conservation and Valorization Ancona: il Gabbiano, pp 24-37