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The influence of the Mediterranean climate on vernacular architecture: a comparative analysis between the vernacular responsive architecture of southern Portugal and north of Egypt

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Abstract: *Mediterranean vernacular architecture was developed not only with respect to environmental and climatic factors but also with respect to culture, traditional construction materials and morphology. Despite the far distance between Portugal and Egypt, it was possible to find similar vernacular strategies under the influence of the Mediterranean climate and both Roman and Arab cultures. The paper adopted an explanatory qualitative analysis and comparative synthesis methods for vernacular passive and climatic responsive strategies for two regions. Covering from site planning, building design till building materials used through considering topography, resources, historic and cultural aspects. The outcomes of this research allow for understanding how different passive solar strategies and the use of natural energy sources can contribute to achieve appropriate indoor comfort conditions for contemporary practice. The paper draws a set of recommendations for more in-depth quantitative survey and energy efficiency measurements in Mediterranean climate.*

Keywords: *Climatic responsive, vernacular architecture, Mediterranean climate, Roman and Arab cultures, comparative analysis, Sustainable Building*

1. Introduction

The wide area of the Mediterranean basin, with a plurality of territories and the presence of numerous cultures, provided a rich variety of architectural manifestations. The Mediterranean vernacular architecture we value nowadays as a model for sustainable and energy efficient architecture building product, is in fact the outcome of a cumulative effort to sustain a living in the relation with local constraints and the available resources. Therefore, vernacular architecture is a type of construction that should be studied from sustainability point of view, since the strategies that are now the basis of sustainable construction are derived from aspects and characteristics of this type of architecture [1].

In this context, several studies have revealed the good thermal performance of vernacular buildings in the Mediterranean climate context using both qualitative analysis and quantitative measurements for building performance, emphasizing the benefits of using local materials [1]–[4]. The approaches used in vernacular constructions to mitigate the effects of climate are usually low-tech and not very dependent on non-renewable energy. Moreover they do not

require special technical equipment, which makes them suitable for contemporary passive building design [5]. However, some studies have shown challenges in adopting such techniques for contemporary applications [6] due to several limitations owing to changing weather condition and valuable resources along the years. From here, this paper aims to highlight the need to learn from the vernacular know-how and methods in order to rehash an optimum adaptation of contemporary buildings to climate, environment and culture.

2. Methodology

The paper is applying a qualitative approach through explanatory qualitative analysis and comparative synthesis methods for vernacular climatic responsive strategies used in Mediterranean vernacular architecture. The application was on cases/examples from southern part of Portugal and northern part of Egypt. The comparative analysis was based on systematic comparison of different passive climatic responsive strategies with focus on passive cooling strategies to understand similarities and differences. The analysis was the guidance for lessons learnt for the further possible contemporary application and the recommendation for qualitative survey for more robust evaluation for such passive strategies.

3. Characterization of the Mediterranean climate in Southern Portugal and Northern Egypt






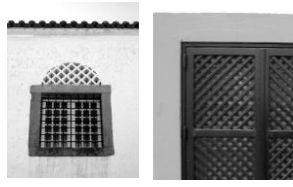










The Mediterranean climate is a type of climate mainly from the regions in the Mediterranean Basin, but it also can be found in other parts of the world. The inland southern Portugal has a Mediterranean climate, sub-type Csa according to Köppen climate classification, hot and dry during summer [7]. In summer the mean values for maximum air temperature vary between 32-25°C, reaching sometimes maximum temperatures of 40°C or 45°C, being July and August the hottest months [7]. The annual average rainfall is below 500 mm, being July the driest month (below 5 mm) [7].

The Egyptian land lies within the hot desert climate (BWh) according to Köppen climate classification. The climate in northern part of Egypt is a hot Mediterranean climate that is quite different from the climate in the rest of desert areas of Egypt. Prevailing winds from the Mediterranean Sea greatly moderate the temperatures of the northern coastal line, making the summers moderately hot and humid, while the winters moderately wet and mild [8]. Temperatures range between a minimum monthly average of 9.5 °C in winter and 23 °C in summer, while a maximum monthly average of 17 °C in winter and 31 °C in summer [8]. The annual average rainfall is around 200 millimeters [8].

4. Climate-responsive strategies used in Mediterranean vernacular architecture

Mediterranean vernacular architecture is known and recognized by being a practical, effective, sustainable climatic and environmental responsive building outcome [9]. In the past, when energy was not readily available and active systems did not exist, builders had to experiment and develop passive ingenious systems that optimize indoor comfort and respond to particular human needs and climatic conditions through the available resources [9]–[12]. Table 1 presents in a comparative way several climatic responsive vernacular strategies showing different adaptive passive solutions in Mediterranean regions in both countries.

Table 1. Climate-responsive strategies used in vernacular architecture from northern Egypt and southern Portugal

Strategy	Description	Figures	
		northern Egypt	southern Portugal
Urban layout and building form	<ul style="list-style-type: none"> • Compact urban layout reduces the number of surfaces exposed to the sun (<i>To the left map for Alexandria, Egypt from [13]</i>); • Narrow streets and covered galleries protect pedestrians from harsh summer periods. • Building's form is compact and the presence of <i>patios</i> in urban areas is frequent. On orientation, buildings seek the south quadrant to maximize solar gains in winter and to reduce them during summer. 	 	 
Shading and use of natural ventilation	<ul style="list-style-type: none"> • Proper shading for windows using screens (<i>mashrabiya</i>) or vegetation when heat gains are not desired. • The use of grids aims to foster cross air circulation in the building, ensuring privacy and thermal comfort; 		
Small openings	<ul style="list-style-type: none"> • Minimizing the size and number of openings reduces heat gains. 		
Evaporative cooling	<ul style="list-style-type: none"> • Fountains and pools, usually placed in patios and cloisters, serve to cool air by water evaporation. 		
Use of vegetation	<ul style="list-style-type: none"> • Vegetation is useful to provide shade and to increase air moisture via evapotranspiration process, helping to cool the air streams before reaching the building. 		
Materials and thermal mass	<ul style="list-style-type: none"> • The use of local materials, mainly earth and stone, is perfectly suited to local climate. Their good heat storage capacity stabilizes indoor temperature (that remain cooler during the day and warm at night). 		
Buildings' colour	<ul style="list-style-type: none"> • The use of light-colours for the building envelope, and especially the roof which is the most exposed to the sun, aims to reduce heat gains by reflecting solar radiation. 		

5. Discussion

Despite the distance between Portugal and Egypt and their opposite position in the Mediterranean basin, it was possible to find commonalities regarding passive vernacular strategies used in both countries. They are mainly due to the influence of Mediterranean climate but also a reflection of a common Roman and Arab cultural influence. As shown in Table 1, the strategies used in the two regions, and their purpose, are very similar. Due to a climate with hot dry summers, these strategies are more oriented to a passive cooling purpose. Some of these strategies are discussed below.

5.1 Urban layout and building orientation

On the urban level, the use of a compact layout is more adequate for these regions with hot summer periods than modern orthogonal and wide grid street planning. A compact urban fabric provides more shade between buildings minimising heat gains in summer and in winter reduces internal heat losses. At street level, narrow streets and covered galleries integrated in buildings' structure are more comfortable for pedestrians because they provide shade and reduce wind velocity specially during winter [14]. These sinuous streets act like "urban-patios", storing cool air during the night and promoting air crossing between streets during the day. In the morning, due to high thermal inertia, the walls and pavements of these streets remain colder than ambient air. Green public areas are also found useful to reduce the heat island effect and to increase comfort in urban space (green ground covers absorb 10% of radiation while a pavement absorbs 65% [14]).

Buildings orientation depends on several site conditions, like topography, so buildings seek the best orientation compromise. As shown in table 1, south quadrant-facing façades are the most common to receive less radiation during summer and more in winter. At the same time, east and west facing façades are avoided to minimise direct heat gains. In detached buildings the rear façade (without or only with a few openings) is oriented to the summer cool prevailing winds.

5.2 Passive cooling and natural ventilation

On buildings' scale, the more common passive cooling strategies are: i) the use of *patios*, to minimise sun-exposed surfaces, maximise shade and ventilation; ii) the use of vegetation in patios to increase the cooling effect of air; iii) the use of heavy thermal mass and dense building materials, like earth and stone, with high thermal storage capacity to balance temperature variations; iv) use of bright colours to reflect radiation.

Focusing on *Patios*, these are a special passive cooling building feature that is intrinsically related to Roman and Arab cultures. Frequently possessing vegetation and elements containing water, their presence has a great influence on buildings' microclimate. An experiment conducted in southern Portugal during summer showed that air temperatures in the *patio* always remained lower than those recorded for the city centre, with a maximum difference of around 9°C during daytime [3]. Another study in Egypt showed that shaded *patios* recorded from 5 to 8 °C difference than outdoor street temperature [15]. This is due to the effect of evapotranspiration and shade from plants and evaporative cooling of water.

Natural ventilation for overnight cooling is an important and useful passive strategy in a hot climate. Through the use of night flush effect using grids, like the *mashrabiya*, it is possible to

promote air circulation inside the building, removing diurnal thermal loads and increasing thermal comfort, without compromising privacy and security levels.

5.3 Building envelope and building materials

The envelope is building's most exposed surface to solar gains. To reduce them, small window-openings (retreated into the façade to get more shade) and light colours are adopted. The colour applied on outdoor surfaces has a tremendous effect on reducing the impact of sun on facades and on the indoor temperature [16]. Thus, the traditional whitewash painting is an important element against extreme solar radiation, allowing a reflectance of about 90% of all the radiation received [14].

On the materials, stone and earth (mainly rammed earth and blocks) are the main building materials in both regions. The high mass that characterizes earthen and stone constructions allows them to respond appropriately to the scorching summer. Several studies mentioned the good heat storage of earth and stone (Table 2) and how they stabilize indoor temperature and moisture [17], [18]. It is discussed how traditional earthen and stone interiors remain cool during the day and release warmth at night, the opposite of concrete, a material that, traps and holds high temperatures unbearably [19], [20]. Another advantage is that earth and stone can be easily recycled, either by re-using old stone blocks or earth bricks as building material or returning earth to the soil to grow vegetation. The use of materials that came from the same local climate where they are applied has greater adaptability, economical and increased durability. Moreover, they have less embodied energy and less environmental impacts than other conventional materials (Table 2).

Table 2. Properties of some vernacular and conventional building materials (source: [14], [21], [22])

Material	Density (kg/m ³)	Thermal conductivity λ -value (W/m.°C)	Thermal storage capacity (Wh/kg°C)	Heat transfer time lag (250mm thickness) (hour)	Embodied Energy (MJ eq./m ³)	Global Warming Potential (kg CO ₂ eq./m ³)
Rammed earth / adobe	1770-2000	1,00-1,20	0,23-0,30	10 / 9	943	38
Stone	2600-2800	2,30-3,50	0,22-0,24	5,5	1300	26
Concrete	2400	1,80	1,10	7	1450	264
Hollow bricks	1200	0,39-0,45	0,26	6	4245	357

The industrialization of construction systems and the massive use of HVAC systems homogenized the architectonic forms. In this sense, the majority of modern buildings does not show any particular concern about the relation with the surrounding environment, which is reflected in more energy consumption and consequent environmental impacts. Therefore, there is a need to learn and import climate-specific know-how from vernacular passive building technologies into our contemporary climatic responsive building practice. Thus, this study introduced Mediterranean vernacular building energy performance that end in a vernacular responsive building form.

In sum, vernacular is not only a learning example in climatic building performance but also a knowledge base of traditional building techniques; cost efficient buildings, intelligence in coping with material availability and in respecting local cultural and traditions. Vernacular architecture could contribute towards reducing waste and energy consumption through the use

of passive solar design and local materials, in a process of on-going development in which building techniques are adapted for specific cases, in accordance with territory and climate [23], [24].

6. Conclusion and recommendation

It seems to be a common sense that climate is an important issue to consider in building design. But in practice, our contemporary designs are very dependent on fossil energy over the life of the building due to reliance on mechanical means to control the indoor climate. Yet, this approach has lead to many drawbacks: not only has a building's initial cost risen considerably but also running costs for periodical maintenance is quite a burden. This study indicates that, although many vernacular dwellings still exist in the Mediterranean region, it is challenging -but desired- to package vernacular architecture traditions and qualitative design knowledge to modern sustainable building designs. It is imperative that instead of relying entirely on mechanical means, the architect should learn from vernacular passive strategies and direct their efforts to reach the best possible low energy and natural climatic control for their buildings. Then mechanical and active systems can be supplementary aids, to use only when the endogenous resources are not sufficient to meet the comfort needs of occupants.

Learning from the past, the future can use the potential of existing technology and improve it in order to change the current energy paradigm. A vernacular dwelling may not fit, in many cases, with current standards of comfort, but could give some clues about strategies to mitigate the use of non-renewable energy. Through the optimization of these strategies it will be possible to satisfy the desired standards of comfort while reducing the fossil energy consumption.

The paper results proved that vernacular climatic solutions set an approach for improving contemporary building energy performance and draws recommendation for further research below: i) More intensive quantitative studies and surveys are needed to adapt vernacular passive strategies to modern applications especially after the current climate change symptoms; ii) Effective vernacular strategies should be used as guidelines for our contemporary urban planning and building design regulations; iii) Mediterranean vernacular valuable endeavor can be, with additional scientific verification and simulation tools, a design guide for contemporary energy efficient buildings in Mediterranean climate; iv) Currently there are no national reference documents for vernacular passive construction performance in both countries. A reference document could be a good start for effective contemporary application.

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