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Identification and analysis of passive energy resources applied in constructions of "La Mancha" region, Spain

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ABSTRACT: The high thermal gradient, which is characteristic of the climatology of La Mancha (interior region of Spain) has historically required high standard building performances for all permanent construction efforts. This document springs from the sources gathered from the analysis of 10 vernacular dwelling structures located in the region, buildings whose constructive characteristics have not evidently changed in the last century and whose fundamental function is residential. Within this framework, authors have proceeded to identify some constituent components and parameters of these dwelling structures, like their storage chambers, the thickness of their walls, the quantity and dimensions of their openings, their distribution and their surface to volume ratio. Of the energy analysis conducted, authors conclude that the constructive characteristics analyzed are not only folkloric singularities but also the efficient reply to the energy criteria imposed for the time and place.

1 INTRODUCTION

La Mancha region constitutes a large part of the Iberian Peninsula, extending for approximately 35,000 sq. km. Its elevation varies from 200 m at the border with Portugal's Alentejo region, to 800 m in the Albacete area. Despite the geographical, climatic and cultural differences, this large Iberian plateau displays common basic features (Feduchi, 1976).

Multiple historical, cultural, geographical and climatic factors and determinants have been identified in this vast area of study.

La Mancha's vernacular architecture has reflected and at times played a leading role in this dynamic synergy. For this reason, it has always aroused a deep interest in different authors, both literary writers as well as traditional architecture specialists. This continued attention towards the intrinsic values of La Mancha's traditional architecture has persisted (Fig. 1), despite its apparent simplicity or lack of decorative or monumental references (Fisac, 1985).

Figure 1. Vernacular architecture of La Mancha, 1960 (Centro de Estudio CLM).

1.1 *Background of La Mancha's vernacular architecture*

Among these constructions is the typical La Mancha's dwelling, both place of residence and storage for tools and crops. (Serrano, 2006) These humble buildings are the end result of a continuous sedimentation of influences of different origin and provenance. With a common denominator: the efficiency and functionality of the resources employed. (Jérez, 2004) Thus, when looking at these constructions we can distinguish echoes of different cultural contexts. The possible heritage of Roman architecture is suggested by the presence of inner courtyards. Berber culture can potentially be noticed in the use of indigo in base-

Figure 2. An example of La Mancha's construction (Fisac).

boards and openings. La Mancha's architecture is steeped in influences, sediments, layers and substrates that are often difficult to identify, or even detect. In any case, behind this apparent simplicity of construction lie aspects always related to energy efficiency and, ultimately, to an extreme functionalism (Fig. 2). In this sense, the present paper tries to unravel some of the resources related to the reduction of energy consumption that have been employed in these constructions, concerning three factors, specifically: natural ventilation, thermal inertia and reduction of openings (Serna, 1985).

To carry out the necessary research, we have chosen the easternmost part of La Mancha (provinces of Albacete and Cuenca), where most traditional buildings are preserved today. The study is focused on ten vernacular constructions located in the municipalities of Cenizate, Casas de J. Nuñez, Ledaña, Madrigueras, Mahora, Motilleja and Navas de Jorqueras.

2 PASSIVE ENERGY RESOURCES IN VERNACULAR ARCHITECTURE

2.1 *Climatic conditions of La Mancha region*

There are numerous passive strategies for reducing energy consumption in La Mancha's vernacular architecture. Specifically, the research discussed below proposes the parameterization and analysis of three basic strategies of La Mancha's constructions: the presence of an upper attic chamber with natural ventilation (known as *camara*), the great thickness of the walls built with the rammed earth or masonry techniques, and the reduced wall/opening ratio of the envelope (Neila, 2002).

To that end, first we discuss the climatic conditions where this architecture can be found. In the climate of La Mancha, the months from late fall to early spring (November-March period) are characterized by extremes of rather low temperatures and high relative humidities. There are also two periods of thermal comfort (April–May and October), and a third period (June to September) with high temperatures and low relative humidity. With this data, combined with the study of psychometric charts (Givoni, 1998) applied to the specific case of La Mancha, it has been possible to establish a range of thermohygrometric comfort (20°C–26°C and 20%–80% RH). It really is an interesting parameter, favoured by a series of bioclimatic construction strategies such as natural ventilation, the presence of envelopes with high thermal inertia, and the reduction of openings in the envelope (Yáñez, 1988).

2.2 *Data collection and analysis*

After determining the climatic characteristics of the area, we proceed to a rigorous data collection through a previously drafted template for detailing various construction and bioclimatic parameters. Thanks to this data collection stage, we can systematically specify the structural characteristics (details, dimensions, volumetry, Fig. 3) as well as possible contextual information (territorial and municipal data, Fig. 4) on the ten case studies. The templates also include a photographic dossier and a photogrammetric restitution of the elevations, to facilitate the graphic and metric characterization of the analyzed building.This is, in any case, a first sampling designed to establish a method and detect performance and efficiency dynamics of some of the three construction strategies indicated.

The analysis was conducted using the CE3X tool (Fig. 5), a software application approved by the Spanish Ministry of Industry, Energy and Tourism for retrieving the energy certification of an existing building. (IDAE, 2012) After selecting the tool used in the analysis we proceed to enter data relating to ventilation, envelope and solar factor. This way the program generates results linked to global CO_2 emissions.

The presence of the chamber, the high inertia of the walls, and the use of small size openings were evaluated in the 10 models corresponding to the original buildings, and later some of the parameters of these models (chamber height, wall thickness, wall/opening ratio) have been compared and modified to assess the real effectiveness of traditional construction systems (Neila, 2002).

2.3 *Results*

In the natural ventilation chamber, two contrasting scenarios have been proposed: one where the initial heights of the vernacular chamber get modified, setting chambers 4 and 10 meters high; and on the other hand, a second scenario with a contemporary construction solution (PUR thermal insula-

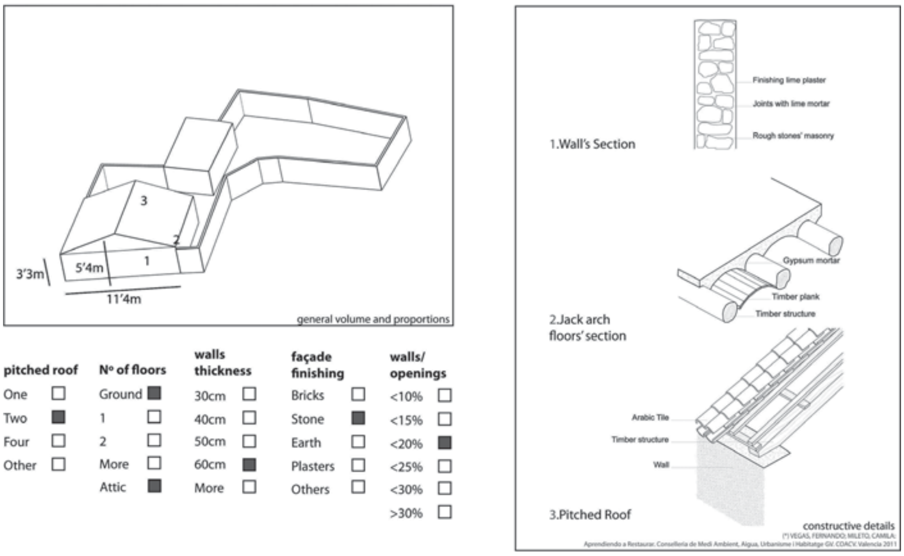

Figure 3. Case-study example: Details and volumetry of a vernacular construction located in Madrigueras (Authors).

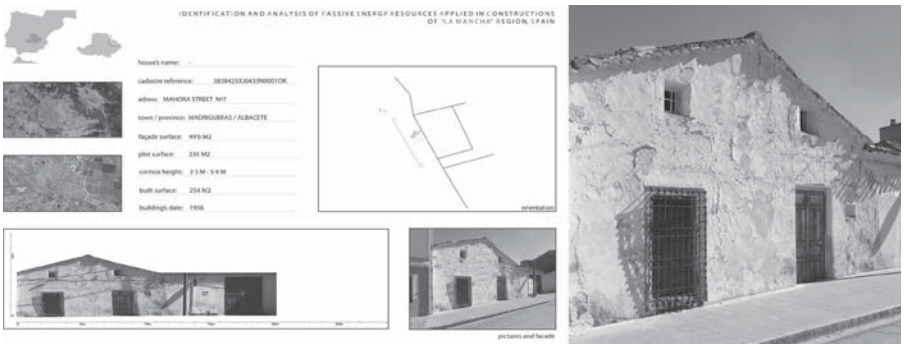

Figure 4. Case-study example: Territorial and municipal data of a vernacular construction located in Madrigueras (Authors).

tion, chamber with average ventilation, skirting based on bricks and curved tiles). The purpose of establishing these two scenarios has been to compare and contrast the energy efficiency of the vernacular solution with other models (Table 1).

Similarly, we proceeded with the study of the wall, where different thicknesses have been considered. We compared the energy performance of the thickness of the original wall (60 cm) built with the rammed earth or masonry techniques, with others of different thicknesses (10, 100, 200 cm). In this comparison we have also used a conventional contemporary wall solution (two ceramic sheets plus thermal insulation).

As for the wall/opening ratio we established different analysis models. On the one hand, we carried out the study of the envelope with the original wall/opening ratio (Figs 6–7), and on the other we modeled the building envelope using different wall/opening ratios (1 and 90%). To summarize, the results show that, in the case of the chamber, varying the height results in a negligible reduction of global CO_2 emissions from the construction, nor the use of contemporary solutions based on industrial thermal insulation and ceramic or concrete materials does substantially improve the situation.

Changing the thickness of the wall or the wall/opening ratio yields similar results. Increasing the thickness of the wall relative to the vernacular solution results in a very modest reduction of global emissions of CO_2 Kg CO_2/m^2. The same happens

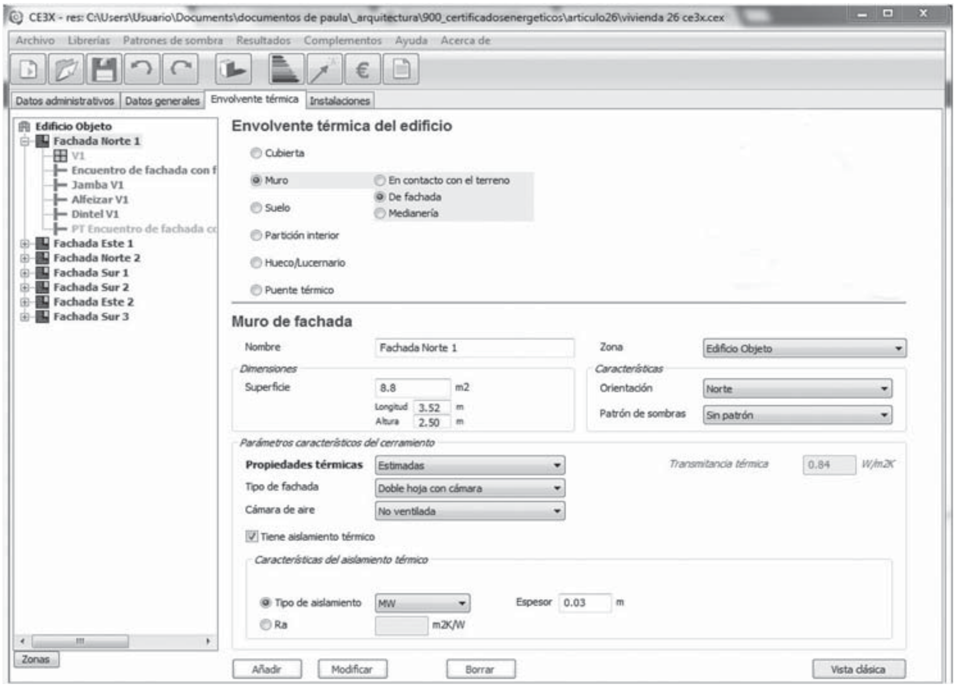

Figure 5. CE3X tool data process example (Authors).

Table 1. Two detached examples about ventilation chamber measures and proportional emissions of CO_2 Kg CO_2/m^2. Actual survey data compared with contrasting scenarios (Authors).

Case-Study	Ventilation chamber measures (height)	Heating demand KWh/m2 year	Cooling demand KWh/m2 year	Heating emissions Kg CO2/m2 year	Cooling emissions Kg CO2/m2 year	Global emissions Kg CO2/m2 year
Casas de Juan Nuñez II	**actual survey**					
	2 m	196.1	17.1	75	6.5	**86.2**
	contrasting scenarios					
	0 m	353.8	32.6	135.4	12.4	152.5
	1m	201.7	16.8	77.2	6.4	88.3
	4 m	191.3	17.3	73.2	6.6	84.5
	10 m	187.8	17.5	71.8	6.7	83.2
	PUR thermal insulation	213.3	17.9	81.6	6.8	93.1
Ledaña I	**actual survey**					
	1 m	119.5	7.5	46.7	2.9	**53.4**
	contrasting scenarios					
	0 m	307.6	9	117.7	3.4	125.9
	2 m	112	8.8	42.9	3.4	51
	4 m	105.7	9.7	40.4	3.7	48.9
	10 m	101	9.6	38.6	3.7	47.1
	PUR thermal insulation	132.9	9.2	50.8	3.5	59.1

Table 2. Two detached examples about wall's section measures and proportional emissions of CO_2 Kg CO_2/m^2. Actual survey data compared with contrasting scenarios (Authors).

Case-Study	Wall section (thickness)	Demanda Calefacción KW.h/m2 año	Demanda Refrigeración KW.h/m2 año	Emisiones Calefacción Kg CO2/m2 año	Emisiones Refrigeración Kg CO2/m2 año	Global emissions Kg CO2/m2 year
Cenizate	**actual survey**					
	Stone Masonry Wall 60 cm	68.3	11.2	26.2	4.3	**35.1**
	contrasting scenarios					
	Stone Masonry Wall 10 cm	94.4	9.6	36.1	3.7	44.4
	Stone Masonry Wall 100 cm	62.1	11.3	23.8	4.3	32.7
	Stone Masonry Wall 200 cm	56.4	10.7	21.6	4.1	30.4
	Wall cavity 37 cm	69.2	11.2	26.5	4.3	35.4
Casas Juan Nuñez I	**actual survey**					
	Stone Masonry Wall 40 cm	187.8	17.5	71.8	6.7	**83.2**
	contrasting scenarios					
	Stone Masonry Wall 10 cm	250.1	18.6	95.7	7.1	107.5
	Stone Masonry Wall 100 cm	155.4	13.6	59.5	5.2	69.3
	Stone Masonry Wall 200 cm	140.6	9.7	53.8	3.7	62.2
	Wall cavity 37 cm	110.1	13	42.1	5	51.8

Figures 6 and 7. Case study in Navas de Jorquera (stone masonry wall) y Motilleja (rammed earth building) (Authors).

when implementing a contemporary construction solution in the wall (it should also be noted that this involves a considerable increase of raw material—Table 2).

Therefore, with regard to global emissions, alternative models to the vernacular solution do not provide substantially improved results. With regard to the wall/opening ratio, an increase in the openings' size increases the global emissions of the construction, while reducing the openings impacts negatively on the habitability of the interior spaces. In all cases, as seen above, the values of global emissions of CO_2 Kg CO_2/m^2 per year produced by vernacular solutions are much lower than those achieved after modifying some of the initial parameters.

3 CONCLUSIONS

The interest La Mancha's architecture has aroused in different and well known authors (inter alia Fisac, Caro Baroja, Neila, Feduchi, Jerez García) and it is justified considering the intriguing results provided by the parameterization of some of its key construction features.

Beyond their undeniable anthropological, cultural, and heritage interest, La Mancha's vernacular constructions hold within their walls an ancient wisdom of environmental adaptation and assimilation of influences from different cultural contexts. (See Tables 1 and 2 for details).

The initial validation these authors have reported, intuitively or qualitatively, on the resources identified in La Mancha's dwellings (wall thickness, orientation, color of the walls, size of the openings) has been demonstrated after a rigorous and quantitative analysis such as the one presented here.

Strategies such as the natural ventilation upper chamber present in virtually any La Mancha's construction are clearly justified when considering the results and comparisons indicated above.

The same applies to the choice of thickness and materials employed in the execution of the building envelope. In this case the solution used in these vernacular constructions achieves an efficient energy performance, exceeding current conventional solutions in all instances.

However, the present study must be validated, verified and improved by following alternative avenues of research, as well as increasing the number of constructions analyzed. The material and immaterial loss in La Mancha's architecture has been irreparable. Few constructions remain in an actual state of conservation, but studies such as this would justify the recovery and restoration they deserve.

This is why the interest towards the conservation of these dwelling structures should not only consist of favorable interest relative to their cultural and artistic value; but also, we should be interested about their technological value based on their highly efficient energy benefits which can be applied, without quixotic risks, to new residential buildings both at home or "*Somewhere in la Mancha, in a place whose name I do not care to remember*" (M. Cervantes).

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