BIOCLIMATIC STRATEGIES OF TRADITIONAL EARTHEN ARCHITECTURE

ABSTRACT

Purpose

The purpose of this paper is to identify and characterise bioclimatic strategies of traditional earthen architecture in a specific territory, the Valencian region of La Serranía. These constructions were built in relation to their surrounding geography or climate through several mechanisms facing the action of solar radiation, water, wind, etc.

Design/methodology/approach

The research methodology is based on a comparative analysis of selected case studies representing the constructions and typologies of traditional earthen heritage in a territory with similar geography and climate, albeit with certain zonal limitations.

Findings

The results show that these constructions built with earth offer a global solution to environmental conditioning factors of the region by 10 strategies formalised at urban, architectural and constructive level, either independently or jointly. Although climate variations affect its behaviour, traditional earthen architecture seeks compactness to reach indoor comfort.

Originality/value

Traditional earthen architecture is a valuable heritage in danger which has been devaluated until several years in this remote region. Therefore, prior knowledge of its bioclimatic strategies and formal constitution is essential to establishing heritage intervention criteria and proposals adapted to its geographical, socio-cultural and socio-economic context.

KEYWORDS

Bioclimatic strategies; earthen architecture; vernacular heritage; architecture and climate; historical housing

ARTICLE CLASSIFICATION

Research paper

1. INTRODUCTION

Variable factors in geography and climate for each region, as well as the cultural diversity and availability of materials, greatly condition the constructive solutions of vernacular architecture, especially earthen architecture, in the Iberian Peninsula. These types of buildings adapt to the conditioning factors imposed by the natural and socio-cultural and economic conditions of a specific area, creating solutions which guarantee occupants’ comfort.

Traditional earthen heritage is a ‘contextualised’ architecture that was built at a specific time within a specific geographical area. In this respect, this architecture is born from the ‘genius loci’, emerging from a place and for a place (Norberg-Schülz, 1981).This is an environmentally, socio-culturally and socio-economically sustainable architecture. It incorporates factors of nature into architectural design so that it can reduce its adverse effects (Achenza and Giovagnorio, 2014). It also takes into consideration the socio-cultural identity of the community (Guillaud, 2014) and optimises the efforts poured into the construction process of a specific region (Correia *et al.*, 2014).

Traditional earthen architecture in the Iberian Peninsula shows the various constructive solutions offered by the different techniques when adapted to the demands of the surroundings. These human creations can blend into nature and take into account the bioclimatic characteristics of the place, while ensuring user comfort, optimising the use of local materials and reducing the potential impact of natural risks. However, it should be noted that this study focuses on bioclimatic architecture, which uses only the resources from the surroundings to guarantee the energy optimisation of the surroundings and the comfort of spaces (Vegas *et al.*, 2014).

Given that the constructive solutions of traditional earthen architecture are conditioned by different factors, information can be obtained on the different constructive solutions based on geography and climate when the rest of demands are limited. Thus, the study of the bioclimatic strategies of traditional earthen architecture is proposed for the region of La Serranía, in the northwest of the province of Valencia, which fits this description.

La Serranía is a large territory in which three distinct climatic sectors can be identified (Pérez Cueva, 1994) within the Mediterranean climatic characteristics of the Comunidad Valenciana. This brings about major differences in the numerous constructive solutions using earth in the region, with abundant wealth and an agricultural economy at the time of construction of this architecture (Rodrigo, 2000).

Four major families are identified among the different earthen constructive techniques in the region of La Serranía. Rammed earth is without a doubt the predominant technique in the region, used both in the north and south (Balaguer, 2017). This study therefore focuses on traditional constructions executed in the many variants of rammed earth in relation to the bioclimatic strategies of this unique regional heritage.

2. REVIEW PROCEDURE

2.1. Aim

This research is based on the hypothesis that traditional architecture answers to the demands of its surroundings, optimising locally available material and economic resources while reflecting the cultural identity of a region. The definition of strategies for the adaptation of traditional architecture to different natural settings is complex unless socio-cultural and socio-economic conditioning factors are limited. It is therefore vital to select a territory which presents the ideal characteristics for the study.

The main aim of this study is to identify and characterise the bioclimatic strategies of traditional earthen architecture in the region of La Serranía. This location presents unique climatic characteristics with slight variations by area to which vernacular construction has adapted through the experience over centuries.

This study specifically aims to define climate characteristics and their interregional variations, as well as analysing representative traditional earthen architecture cases in the region studied. In addition, classification at urban, architectural and technical-constructive level ensures a more precise definition of these bioclimatic strategies.

2.2. Methodology

The research methodology, based on the analysis of representative case studies of traditional earthen architecture in different climate sectors of La Serranía, establishes a classification for its bioclimatic strategies. Four research phases are therefore proposed:

2.2.1. Documentary information collection

Research began with a study of the literature on the region, providing in-depth information on its geography, climate, economy and society and culture. In addition to local and regional publications, the meteorological database of the CEAM Foundation (Mediterranean Centre for Environmental Studies) and AEMET (Spanish Meteorological Agency were consulted. Thus, the variations in climate in the region could be observed and recorded.

In addition, the literature on the mechanisms for architecture to adapt to its location was studied, using other architectural typologies characteristic of Mediterranean regions with similar climate conditions as reference.

2.2.2. Definition of the geography and climate of the region

Based on the information compiled the geographical characteristics and climatic sectors of the territory were established and examined in combination with the values for environmental variables from different parts of the region. This distinction is based on different normalised climate classification systems.

2.2.3. Case study analysis

A series of case studies were selected from the database from a previous research (Balaguer, 2017), including three buildings for each of the climatic sectors identified. These buildings are representative of the traditional earthen constructive solutions in the region and are therefore confined to rammed earth in its many variants. In addition, the architectural typology selected is limited to residential buildings given the need to satisfy the comfort conditions of occupants.

For each case study, information is recorded regarding location, urban site, architectural design and constructive characteristics (Table 1).

2.2.4. Classification and description of bioclimatic strategies

After analysing the case studies and considering the climate of the region, the bioclimatic strategies for traditional earthen architecture are defined in terms of adaptation to the demands of the geography and the needs of local residents. The bioclimatic strategies identified are first classified according to the climate element or geographical characteristic they answer to. A second classification describes these strategies and classifies them according to their material form in urban, architectural or constructive terms.

3. RESULTS

The demands imposed by the natural setting have shaped the character of its residents and conditioned the architectural solutions used in La Serranía throughout history, bringing about a wide range of constructive responses to the needs of the society. Adapting traditional architecture to a heterogeneous setting has led to quickly incorporated solutions, both in terms of the area they are in and the changing summer and winter conditions.

3.1. Climate classification of La Serranía

The climate of a given location is the complex combination of different elements, parameters and factor, resulting in a set of meteorological phenomena which characterise the average condition of the atmosphere and its evolution (Neila González and Bedoya Frutos, 1997). The climate is determined by climate factors which make up inalterable characteristics for the location, which result in clear climate elements.

In the specific case of La Serranía, there are characteristic steep crags in most of the region, hence its name in Spanish. There is an overall irregular presence of valleys between mountains, along with the notable presence of large corridors and plateaus suitable for agricultural activity. In orographical terms, La Serranía is located in an area of transition characterised by the contrast between landscape units and continentality. The average altitude of the region is more than 500 metres above sea level, although much of it exceeds 1,000 metres, and with southern regions reaching an altitude around 120 metres. There are barely differences in the latitude of the different areas of the region, located between 39º 35' and 39º 55'. In addition, until a few decades ago, local economy relied mostly on agricultural and livestock activity (Rodrigo, 2000), traces of which can still be seen in a mosaic of fields for cultivation alternating with forest areas and small population nuclei.

Although traditionally limits have been established between Serranía Alta, Serranía Media and the Turia Valley (Rodrigo, 2000) these are not based on the administrative organisation of the territory, but on the distinct geographical characteristics of the region and the position of the Turia river. Although the aim was not to establish climate areas, popular knowledge identified these three regions according to variations in climate.

There is no single classification for climate but rather countless forms of classification based on different criteria (hygrothermal, biogeographical, algebraic, geographical, bioclimatic, etc.) (Neila González, 2004) and this research has followed a system defined by previous specialist studies (Pérez Cueva, 1994). Thus, three climate sectors can be distinguished in the region of La Serranía as a result of the diversification caused by geographical factors: the different levels and compartmentalisation of the relief, the orientation of the relief and the coast, the position of the region and the proximity of the Mediterranean as a thermal levelling agent and source of humidity.

The characteristics of the relief are the cause of significant thermal contrasts, especially in winter, although the orientation of the valleys helps to direct breezes, moderating the summer temperatures and reducing continentality, so that transition in climate inland occurs gradually (Pérez Cueva, 1994).

The climate sectors defined are as follows (Figure 1):

- Climate from the transition zone: Located between the coastal plains, the mountains in the northwest, and the Requena-Utiel plateau, this area shares characteristics with nearby regions. Therefore, in this area of warm summers and moderate winters there is a sharp thermal oscillation (10-12ºC) greater than in coastal areas. Rainfall distribution, with a mean of 550 mm, is heterogeneous.
- Mountain climate of the northwest: The northernmost area of the region includes one of the sectors with the highest rainfall in the Valencian Community, with maximum rainfall in spring and autumn and an annual mean of 650 mm. This is an area of fresh damp summers with higher thermal oscillations (10-14ºC) and colder mean temperatures than other regions due to high altitude and latitude along with its relative distance in relation to maritime masses.
- Climate of the western central sector: The westernmost area of the region is characterised by the high thermal oscillation (12-14ºC) and the coldest mean temperatures due to its continentality and altitude, so that freezing conditions in winter are common. Mean annual rainfall is around 450 mm, distributed throughout the year, except for summer.

Figure 1. Map of climate sectors. Source: L. Balaguer (based on Pérez 1994)

Equally, geographical factors condition the annual wind regime in the region, influenced by the outlines of the Valencian territory. Thus, it is worth noting two alternating seasonal cycles: autumn-winter, with a predominance of westerly winds, and spring-summer, with maximum easterly frequencies. The mean velocity of wind is 2-4m/s, lower than that of coastal regions, so that it is reduced as the flows move inland.

In addition, the direct influence of solar radiation on temperature and the creation of microclimates should be noted. Mean daily averages in solar radiation recorded oscillate between 4.2 and 4.4 kWh/m^2, lower in this northern region than in the centre and south of the Comunidad Valenciana.

3.2. Comparative analysis of case studies

Nine rammed earth residential buildings in different climate sectors of the region were analysed. Traditional earthen construction, representing the wide range of architectural techniques and typologies in the region, are found in different localities, reflecting a series of similarities and differences when comparing major aspects relating to their location within the city, architectural design and constructive characteristics.

In terms of the buildings' location within the urban layout (Table 2) it is observed that residential buildings are located in urban nuclei, terraced or on corners (Balaguer, 2017), making up a dense urban fabric with a predominance of narrow streets under 6 m wide in over 50% of cases. The streets are even narrower (on occasion under 4 m) in urban areas in the primitive nucleus of the location. In addition, urban nuclei are in territories at different levels which establish an orientation of the urban fabric which conditions building façade orientation, generally seeking those facing south, east, or a combination of both. Given this urban context, the height of constructions is increased to four levels in search of radiation to incide on façades, the width of which is thus reduced to 5 m. This way, the resulting plots have a characteristic elongated shape, often overlooking several streets even if there is not always an access on both.

Based on the architectural design (Table 3) in all the residential units hearths take on an essential role as the chimneys rise from the ground floor to the top floor of the building, mostly reserved as an attic space, which is usually open plan with a sloping roof. The façades exposed to solar radiation had a small percentage of openings (3.1– 24.5%), with parallel jambs in 30% of cases, while in the rest of cases at least one of these surfaces is slightly sloping or curved. Given their small size, the openings incorporate lightweight shading elements such as curtains, replaced frequently given their nature.

In terms of construction (Table 4) it is observed that the outer walls of the buildings (both façade and partition) are load-bearing with a mean thickness of 40-55 cm, up to 10 cm less on the top floor of the building. These walls are supported by masonry plinths which are as high as the ground floor in over 75% of cases. The rammed earth walls were originally limewashed to protect the surface from the elements, although they now generally use cement mortar and a white plastic paint finish for the purposes of decoration. In addition, all the housing units are finished off with traditional curved tile roofs.

3.3. Bioclimatic characteristics of traditional earthen architecture in the region of La Serranía

Based on the results of the comparative analysis of the case studies and the climatic characteristics of the region up to 10 bioclimatic strategies can be identified which determine the non-variants of traditional earthen architecture in the region of La Serranía. These strategies can be grouped, in general, into four types depending on the climate element or geographical characteristic: resource availability, action of solar radiation, action of water or action of wind (Table 5).

Equally, the bioclimatic strategies of traditional earthen architecture in the region take material form through several solutions on three different formalisation scales, which correspond to the characteristics analysed in case studies (Table 6). As some of the solutions adopted are the result of the simultaneous implementation of several strategies their correlation is clear for the purposes of defining an overall response to the geographical and climatic characteristics of the region.

3.3.1. Strategies aimed at optimising resource availability (S1)

Despite the wealth of natural resources in the region, traditional architecture is characterised by the optimisation of means and the efficient use of local materials. While it is relatively easy to transport materials and access population nuclei through waterways and the orography of the territory in which the settlements are located, a choice is made to economise on the constructive process. Thus, stone, earth or wood are raw materials frequently used in the constructive solutions of traditional architecture. At urban level, the buildings are usually terraced, grouped into forming compact nuclei, thus reducing the efforts and costs of execution.

3.3.2. Strategies aimed at monitoring the action of solar radiation (S2 – S6)

Solar radiation is an essential climate factor for determining the main climate parameters (Neila González and Bedoya Frutos, 1997), so that monitoring its incidence is vital to adapting the constructions to a specific geographical context. The region of La Serranía enjoys a significant number of hours of sunlight a year, with radiation levels which make it possible to reduce the energy dependency of buildings through different solutions.

The strategies aimed at controlling the action of solar radiation include two subgroups: external action strategies (S2 – S3) and internal action strategies (S4 – S6). While the former identify the degree of solar radiation, either capturing or offering protection, the latter regulate the thermal energy resulting from solar incidence.

The orientation of housing units is conditioned by the directionality of the urban fabric, whose axes are based on the orography of the terrain and solar trajectory. Thus, housing façades are built preferably facing south in order to capture as much solar radiation as possible to accumulate it in the constructive elements exposed. Solar radiation also benefits from the form and measurements of the openings in the walls (Figure 2). These elements frequently present a splayed shape, with sloping jambs or curves that adapt to the angle of incidence of solar radiation entering the building, thus minimising the shade projected by elements that are set back.

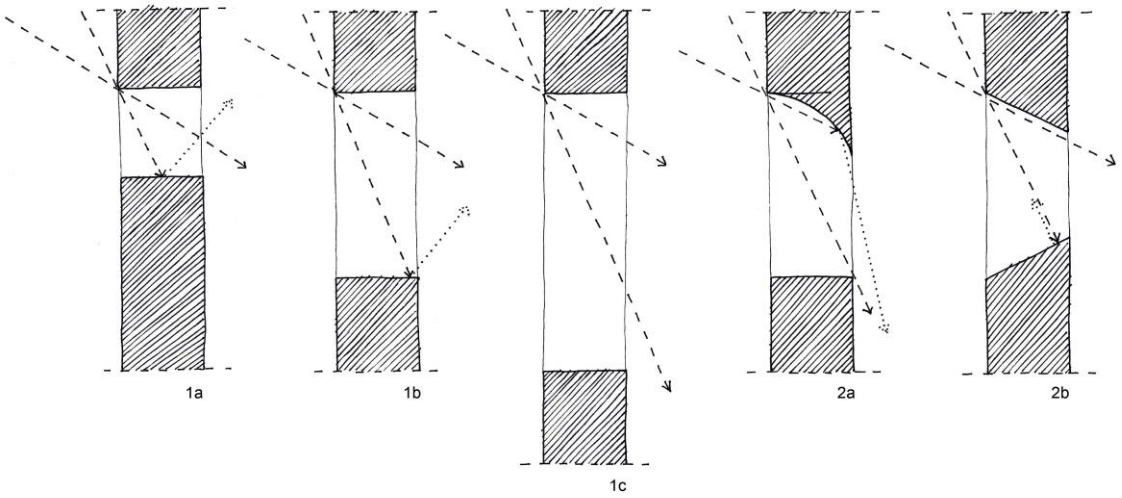


Figure 2. Influence of different types of openings on solar radiation entering the building. The angle of incidence of the solar rays depends on the form and measurements of the openings. As in summer the radiation enters mainly by reflection, the sloped (2b) or parallel (1b, 1c) shape of the jambs facilitates the entrance in winter. Source: L. Balaguer

However, this capture of solar radiation which is so beneficial in winter has negative effects in summer. Given the impossibility of substantially modifying housing from an architectural and constructive urban perspective, traditional constructions use formal solar protection devices in different ways. As buildings are distributed in compact groups they represent fixed shading elements for the narrow streets and the lower stories of the façade (Figure 3). The architectural design of buildings reduced the number of façade openings to the bare minimum to guarantee acceptable health conditions thus preventing an excess of solar radiation from entering the building (Figure 4). This characteristic further supports the concept of compactness formalised on an urban scale. Additionally the traditional architecture sometimes used white limewash both inside and out, thus reflecting solar radiation and reducing the thermal energy produced by its accumulation in the walls (Serra, 2009).

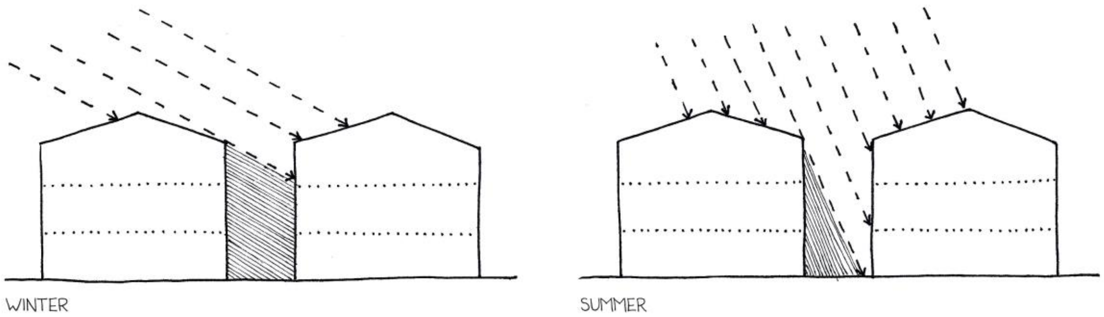


Figure 3. Effect of urban compactness on facades' solar protection. Source: L. Balaguer

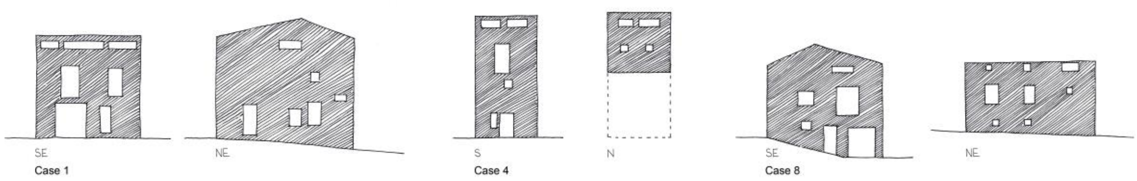


Figure 4. Presence of openings on facades. South-faced fronts have more openings to increase energy gains in winter but considering the effects of solar radiation in summer. North-faced ones reduce the number and size of the openings as solar radiation doesn't fall upon the surfaces with this orientation. Source: L. Balaguer

The thermal insulation of housing units plays a key role in the strategies proposed for adaptation to the climatic context, with its notable daily and seasonal thermal oscillation. This strategy is implemented at different levels, always seeking massive compact architectural and constructive solutions. Thus, housing units are terraced, making up compact nuclei which combine to counter the elements. Lower down the thick earthen walls (40-55 cm) act as barriers, with high mass and thermal inertia reducing the incidence of variable atmospheric conditions, thus generating more regular energy flows than enclosures without inertia and reducing the oscillation of indoor temperatures compared to outdoor ones (Serra, 2009)(Figures 5 & 6).However, an architectural solution is proposed that moves away from the compactness, designing a space which occupies the entire surface of the top storey of the building ventilating and reducing exterior-interior thermal oscillation. The attic thus acts as a thermal filter by minimising variations in temperature compared to external conditions in the spaces lower down (Matoses, 2015).

In addition, the severe climate conditions require a series of architectural and constructive devices aimed at preserving as much thermal energy as possible. The compactness of the building counters the external actions (Carlos *et al.*, 2014), so that the low number of openings favouring solar protection of the indoor spaces help to conserve the thermal energy captured by the rammed earth walls. The division of traditional housing into different small spaces minimised heat losses and allows user comfort temperature to be reached quickly (Matoses, 2015). In terms of construction, the thick walls with high thermal inertia contribute to the conservation of thermal energy by reducing the effects of temperature changes (Serra, 2009) (Figures 5 & 6). However, it should be noted that the thermal insulation capacity of earth is conditioned by a series of characteristics (thermal conductivity, specific heat, etc.) (Minke, 2013).

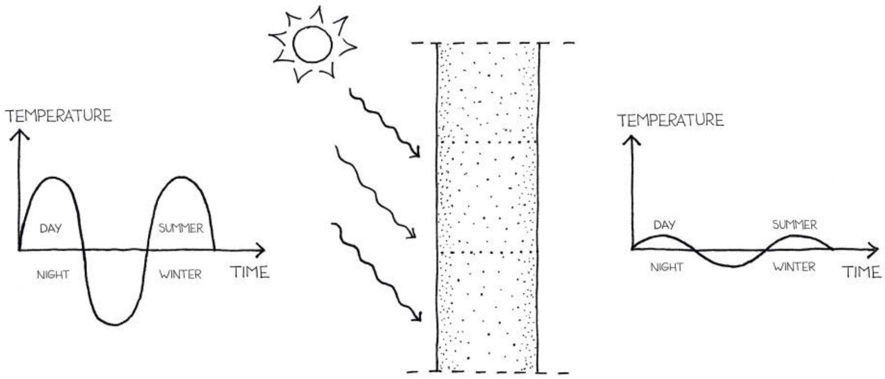


Figure 5. Reduction of thermal oscillation. Thanks to its thermal properties, rammed earth walls reduce temperature's variations between day and night in inner spaces, as well as between longer periods of time. Source: L. Balaguer

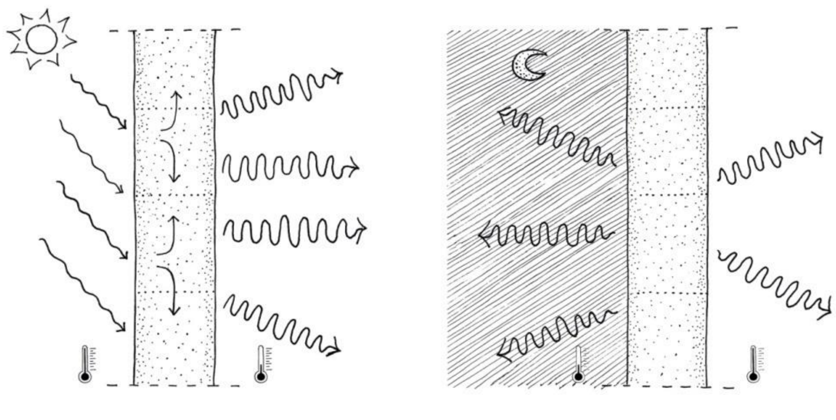


Figure 6. Thermal behaviour of rammed earth walls. The wall accumulates thermal energy during the day and this is partially transferred to inner spaces. As the atmospheric temperature decreases at night, the stored energy is transmitted to the outside, although to a lesser extent to the inside. Source: L. Balaguer

The conservation of the thermal energy produced by the solar radiation captured is sometimes insufficient for reaching indoor comfort temperature in winter. As a result, in traditional dwellings fires with chimneys are frequently found, providing additional heating indoors. These elements cover the height of the building and are placed at the centre of the floor plan, adjoining one of the partition walls. Their position in the kitchen makes this space central to users' every day activities (Carlos *et al.*, 2014) and takes on a certain symbolism in the socio-cultural context in which this architecture was occupied (Flores, 1973). Equally, it ensures the transmission of heat produced to the nearby rooms, most frequently used by the residents (Carlos *et al.*, 2014) (Figure 7). A notable source of heat energy in the building which should be noted is that produced by humans through body homeostasis processes (Serra, 2009), either from the residents or their animals. The heat generated by the numerous livestock animals, housed in the stable of the lower level of the building, rises up (Sebastián, 2015).

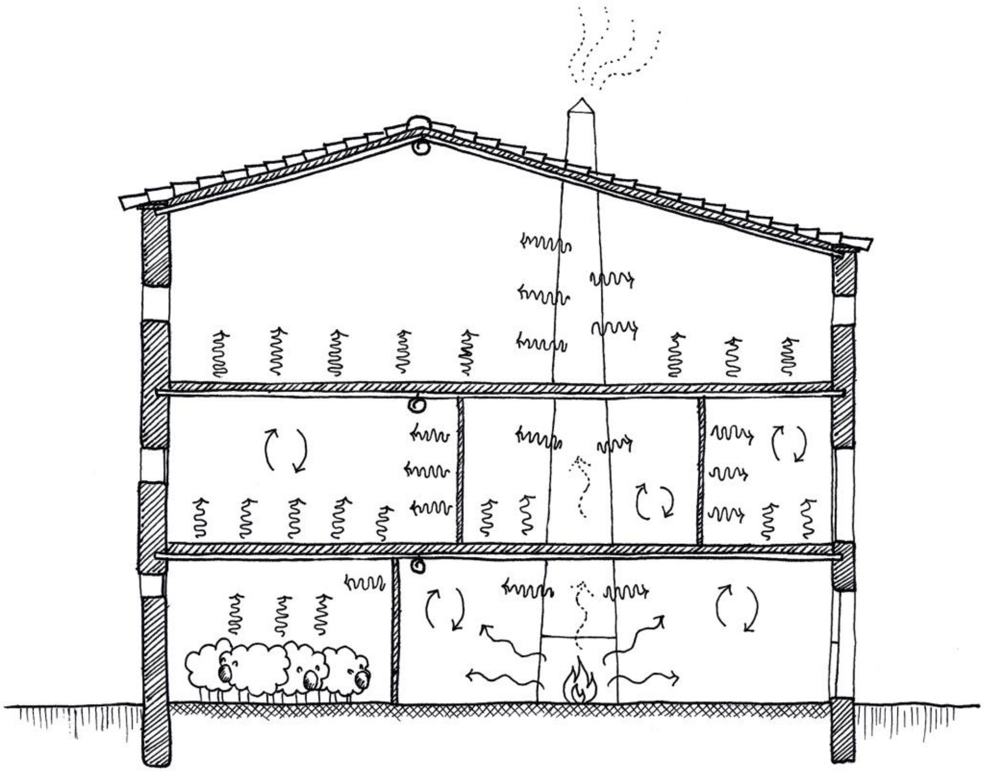


Figure 7. Production of interior heat. The thermal energy produced by the chimney and animals is transmitted through the rooms of the house. The architectural and constructive features of the building allow to conserve this energy. Source: L. Balaguer

3.3.3. Strategies aimed at controlling the action of water (S7 – S8)

Rammed earth walls can resist for centuries providing their base and crowning are suitably protected from water (Mileto *et al.*, 2014) to prevent possible degradation phenomena which could compromise the integrity of the building.

The erosion caused by water is one of the main agents of degradation for any construction, but especially for exposed constructive elements. Despite the limited rainfall in the region, La Serranía experiences periods of heavy rain which traditional architecture overcomes by placing sloping or hipped roofs close to 30 degrees depending on their position within the city (Matoses, 2015), using the orography of the terrain to limit the exposure of buildings and allow water to run off as much as possible. It is also common to find wide eaves extending these roofs (Figure 8) in order to prevent the water from running down the surface of the walls and contributing to their erosion. The shape and position of the constructive solution of the roofs, with curved Arab tiles, make it easier for water to run off.

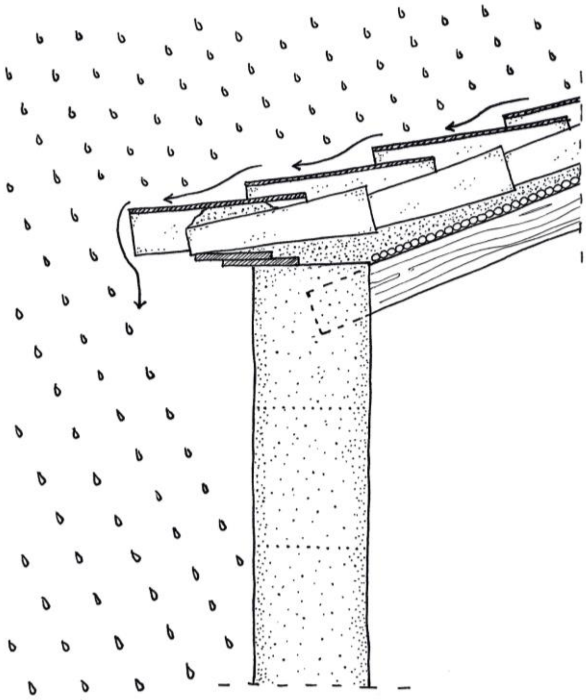


Figure 8. Protection from the rain through sloping roof and wide eaves. Source: L. Balaguer

The action of water in rammed earth walls can show up as rising damp, and therefore a strategy for action is defined to prevent the appearance of a pathological process at the foundations. Given that the continuous action of damp in this part of the wall can lead to a loss of section of the wall, affecting its stability, the regional traditional architecture places a masonry plinth at the base of the construction to minimise or prevents rising damp (Mileto *et al.*, 2014) (Figure 9).In traditional residential architecture the height of this plinth varies, although in most cases it is as high as the ground storey. It should also be noted that when used as a material for finishing interior walls earth regulates the humidity in indoor spaces of the dwelling (Neila González, 2004) thus ensuring the hygrothermal comfort of users.

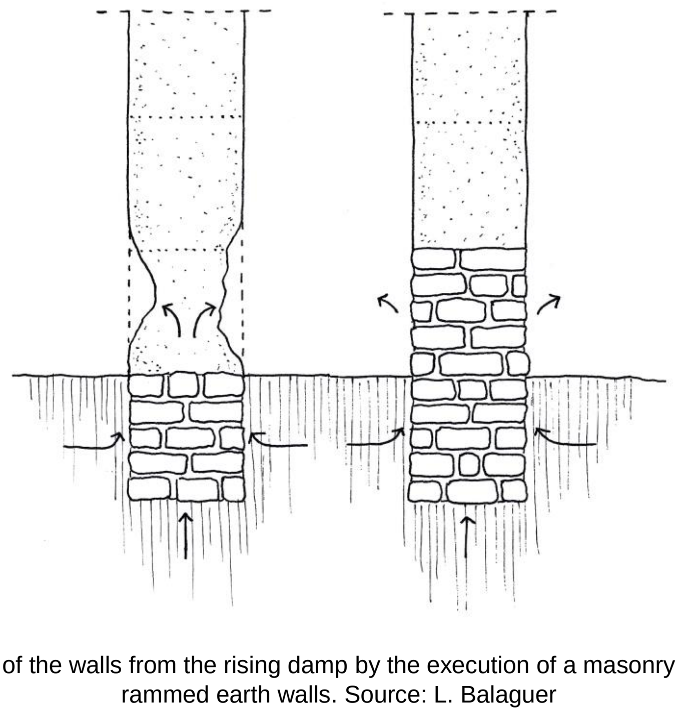


Figure 9. Protection of the walls from the rising damp by the execution of a masonry plinth at the base of rammed earth walls. Source: L. Balaguer

3.3.4. Strategies aimed at controlling the action of wind (S9 – S10)

The action of wind directly and indirectly affects the indoor atmosphere of buildings. Wind affects the microclimate of these constructions, affecting building enclosures and increasing heat loss outwards from the surfaces on which it incides, before finally entering openings and cracks and generating movements and indoor air renovation (Serra, 2009). Based on this situation and the wind patterns in the region, traditional architecture proposes two strategies. While the first aims to offer protection from the wind in order to prevent adverse effects on the interior conditions of the buildings, the second focuses on using these patterns to change these conditions when necessary.

Traditional earthen architecture is inserted into the city attempting to block the passage of effects which are considered negative, thus resorting adapting protection to the orography of the territory (Serra, 2009) and the suitable orientation of the urban fabric. The characteristic compactness of traditional population nuclei ensures their protection from the adverse effects of the wind. In terms of construction it is worth noting that large masonry elements are often placed on the ceramic perimeter tiles of the roofs in order to prevent these from becoming dislodged by strong gusts of wind.

Nevertheless, the action of wind that is suitably directed can help to achieve optimum comfort conditions inside the dwellings, so that the urban layout of historic nuclei is adapted to pleasant breezes. In order to ensure a suitable ventilation of the dwelling, traditional architecture carefully places openings in relation to the pressures predicted on the enclosures as well as the distribution of interior spaces (Serra, 2009). Beneficial cross-ventilation in summer occurs when openings on façades communicate with exterior spaces in different radiant conditions or different conditions of wind exposure, generating 8-20 ACH, in the case of slight exterior wind (Serra, 2009). Moreover, the ventilation of the attic encourages wind's function acting as a thermal filter for minimising temperature variations in the lower spaces of the dwelling (Figure 10).

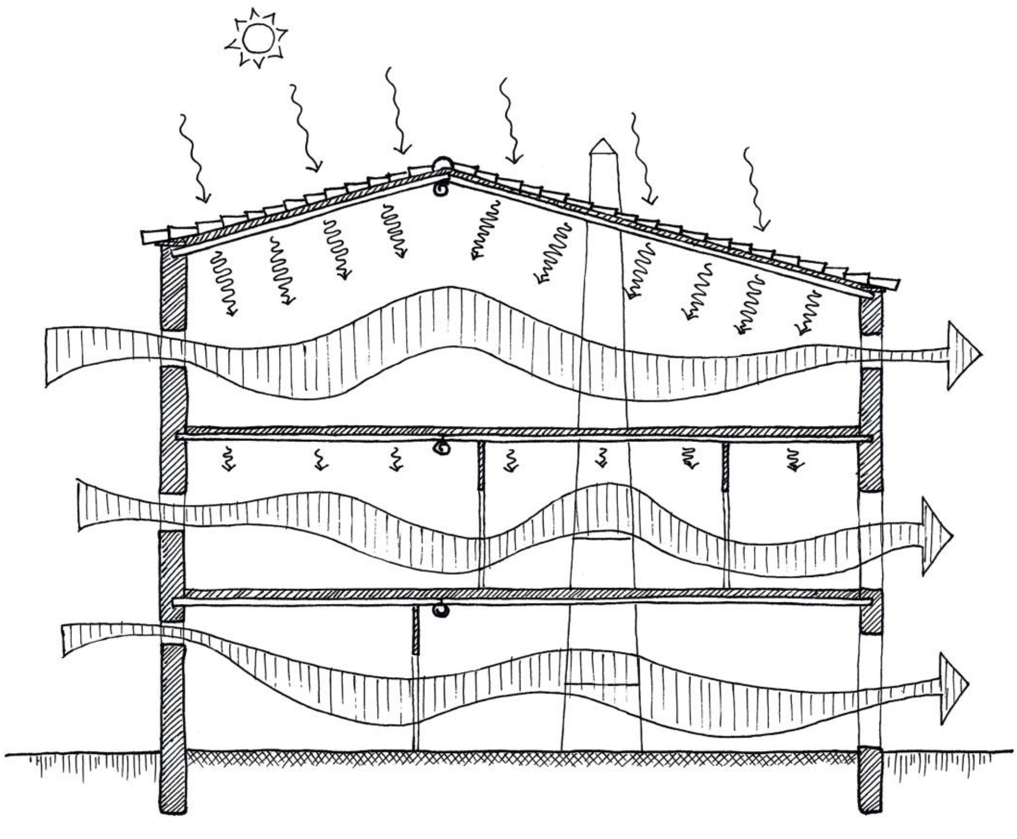


Figure 10. Cross-ventilation of the building. The action of wind through openings minimises the temperature variations and help to achieve the optimum comfort indoors. Source: L. Balaguer

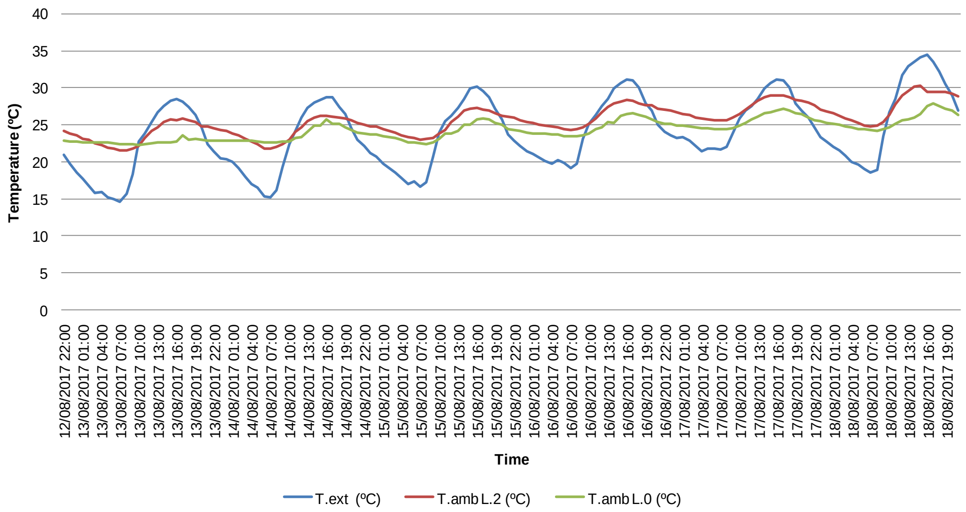
4. DISCUSSION

Despite the three distinct climate sectors in La Serranía, traditional earthen architecture presents no significant variations in bioclimatic strategies at urban, architectural and constructive level. However, a difference is observed in the measurements of openings, with a subsequent increase or reduction in size on façades. A preference is observed for placing openings on south- or east-facing façades avoiding openings on north-facing walls.

The solutions used in traditional earthen architecture to ensure suitable adaptation to the local climate are more complex than in other climates due to the variations between winter and summer conditions and the fact that resolving the former can have a negative effect on indoor thermal conditions in summer and vice versa (Serra, 2009).

In order to guarantee comfort conditions in winter, this architecture favours compact buildings which reduce energy losses and favour gains due to the southeast to southwest orientation of façades; the insulation of enclosures given their high thermal mass and inertia; and suitable ventilation provided by the renovation of indoor air, guaranteeing a healthy atmosphere while limiting the penetration of cold air (Serra, 2009). However, the solutions used to reach comfort conditions in summer provide cross-ventilation of interior spaces to guarantee health and thermal comfort of occupants, preventing the introduction of exterior warm air (Serra, 2009); the use of solar protection on openings based on their measurement and shape; and suitable thermal insulation resulting from thermal mass and inertia of thick earthen walls which minimise the variations between interior and exterior conditions.

In this respect it is worth noting the studies on thermal oscillation in some buildings, examined in a wider ongoing research. The temperature data from the dataloggers in place show the numerical difference between the exterior and interior temperature changes in the building at different times of year. In general, the oscillation of indoor temperature is a third of that of outdoor temperature (Graph 1).



Graph 1. Thermal oscillation of the exterior and interior of a traditional earthen dwelling (Case 4). Over the course of a week (12-18 August 2017) a lower thermal oscillation was observed inside the building (5º gradient) than outside (15º gradient). Both exterior and interior temperatures follow an upward trend, with a maximum of around 4º. Source: L. Balaguer.

Adapting traditional earthen architecture to the climate conditions of the region does not only require an efficient urban, architectural and constructive approach. It also requires correct use by occupants, who must be aware of the bioclimatic behaviour of their dwellings to meet suitable winter and summer comfort conditions, and optimise energy consumption. However, changes in standards of comfort and ways of life compared to the original context in which this architecture was built have resulted in a decisive modification of the way in which it is used, prompting interventions which theoretically aimed to improve living conditions.

Although in recent decades the field of architecture has edged closer to the search for sustainability as a new paradigm (Vegas *et al.*, 2014), focusing on geographical and bioclimatic factors to reduce the energy consumption of buildings, history shows that this is not a recent concern, but one which has been detected from the origins of architecture and was already widely studied in the mid-20th century (Olgyay *et al.*, 2015). Traditional architecture has developed a series of strategies to adapt to environmental conditions, always taking into account socio-cultural and socio-economic contexts, and it must therefore be considered an invaluable point of reference for contemporary architecture. In addition, knowledge of bioclimatic strategies plays a key role in proposing interventions in this heritage.

5. CONCLUSIONS

Traditional earthen architecture is a vast heritage by anonymous builders who, aware of the constructive techniques and geographical and climatic demands of the location, produced architectural solutions which were suitably adapted to the environmental, socio-cultural and socio-economic context. In the case of the region of La Serranía, the features of the territory have entailed the materialisation of a series of bioclimatic strategies in traditional earthen architecture in response to the action of different geographical and climatic conditioning factors: availability of resources and action of solar radiation, winter or wind. Traditional earthen architecture proposes a series of strategies aimed at controlling the effects of these, avoiding the most adverse while favouring those which improve indoor comfort conditions. These strategies materialise as different solutions at urban, architectural and constructive level so that their simultaneous implementation provides an overall response to the environmental setting. In bioclimatic terms, the traditional earthen architecture in La Serranía characteristically seeks compactness to ensure hygrothermal conditions suitable for their occupants and regulated through the ventilation of interior spaces, the evacuation of water in different physical states and the thermal damping caused by the high thermal mass and inertia of earthen walls with few perforations and suitable orientation. However, given the current variations between winter and summer conditions, the use of certain strategies is not always beneficial, making it crucial to identify the bioclimatic behaviour of buildings to ensure suitable indoor comfort conditions at different times of year and optimise the energy consumption of the buildings.

ACKOWLEDGEMENTS

The authors wish to thank the residents of the towns and villages of La Serranía for their collaboration throughout the data collection process.

This work was supported by the Spanish Ministry of Science and Innovation as part of the research project “Restoration and rehabilitation of traditional earthen architecture in the Iberian Peninsula. Guidelines and tools for a sustainable intervention”

REFERENCES

Achenza, M. and Giovagnorio, I. (2014), “Environmental sustainability in vernacular architecture” in Correia, M., Dipasquale, L. and Mecca, S. (Ed.), *Versus, Heritage for tomorrow: Vernacular Knowledge for Sustainable Architecture*, Firenze University Press, Firenze, pp. 41-47.

Balaguer, L. (2017), *La arquitectura tradicional de tierra en la comarca de La Serranía: Análisis tipológico y constructivo*, Master Thesis, Universitat Politècnica de València, Valencia.

Carlos, G., Correia, M., Gomes, F. and Rocha, S. (2014), “Compact houses” in Correia, M., Dipasquale, L. and Mecca, S. (Ed.), *Versus, Heritage for tomorrow: Vernacular Knowledge for Sustainable Architecture*, Firenze University Press, Firenze, pp. 165-171.

Correia, M., Juvanec, B., Mileto, C., Vegas, F., Gomes, F., Alcindor, M. and Lima, A. (2014), “Socio-economic sustainability in vernacular architecture” in Correia, M., Dipasquale, L. and Mecca, S. (Ed.), *Versus, Heritage for tomorrow: Vernacular Knowledge for Sustainable Architecture*, Firenze University Press, Firenze, pp. 57-63.

Flores, C. (1973), *Arquitectura popular española*, Ediciones Aguilar, Madrid.

Guillaud, H. (2014), “Socio-cultural sustainability in vernacular architecture” in Correia, M., Dipasquale, L. and Mecca, S. (Ed.), *Versus, Heritage for tomorrow: Vernacular Knowledge for Sustainable Architecture*, Firenze University Press, Firenze, pp. 49-55.

Matoses, I. (2015), “La vivienda tradicional en La Serranía, equilibrio del acervo como respuesta al habitar” in *Arquitectura tradicional y patrimonio de la Serranía Valenciana*, *proceedings of the conference in Alpuente, Spain, 2015*, General de Ediciones de Arquitectura, Valencia, pp. 24-33.

Mileto, C., García-Soriano, L. and Vegas, F. (2014), “Los fenómenos de degradación más comunes en las fábricas de tapia” in Mileto, C. and Vegas, F. (Ed.), *La restauración de la tapia en la Península Ibérica. Criterios, técnicas, resultados y perspectivas*, TC Cuadernos/General de Ediciones de Arquitectura, Valencia, pp. 52-59.

Minke, G. (2013), *Building with earth: design and technology of a sustainable architecture*, Birkhäuser, Basel.

Neila González, F. J. (2004), *Arquitectura bioclimática en un entorno sostenible*, Munilla-Lería, Madrid.

Neila González, F. J. and Bedoya Frutos, C. (1997), *Técnicas arquitectónicas y constructivas de acondicionamiento ambiental*, Munilla-Lería, Madrid.

Norberg-Schülz, C. (1981), *Genius loci: paysage, ambiance, architecture*. Mardaga, Bruxelles.

Olgyay, V., Frontado, J. and Clavet, L. (2015), *Arquitectura y clima: manual de diseño bioclimático para arquitectos y urbanistas*, Gustavo Gili, Barcelona.

Pérez Cueva, A. J. (1994), *Atlas climático de la Comunidad Valenciana (1961-1990)*, Conselleria d’Obres Públiques, Urbanisme i Transports, Valencia.

Rodrigo, C. (2000), *La Serranía: análisis geográfico comarcal*, Centro de Estudios La Serranía, Valencia.

Sebastián, V. (2015), “Arquitectura popular y vida tradicional en Chulilla” in *Arquitectura tradicional y patrimonio de la Serranía Valenciana*, *proceedings of the conference in Alpuente, Spain, 2015*, General de Ediciones de Arquitectura, Valencia, pp. 270-275.

Serra, R. (2009), *Arquitectura y climas*, Gustavo Gili, Barcelona.

Vegas, F., Mileto, C., Guimaraens, G. and Navalón, V. (2014), “Defining sustainable architecture” in Correia, M., Dipasquale, L. and Mecca, S. (Ed.), *Versus, Heritage for tomorrow: Vernacular Knowledge for Sustainable Architecture*, Firenze University Press, Firenze, pp. 35-39.