Tradition in Continuity: thermal monitoring in vernacular architecture of farmsteads from northeast Portuguese region of Trás-os-Montes

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ABSTRACT: The study focuses on the identification of a typology of vernacular architecture, characterized by dispersion and isolation on a territory usually associated with concentrated settlements. This paper aims to contribute for understanding how local factors (climate, economy, culture, etc.) influenced vernacular architecture inthe northeast of Portugal by analysing the strategies and building solutions that enable it to cope with climatic adversities. Through *in-situ*monitoring temperatures and relative humidity,is attemptedto show the potential of the case studies in maintaining the indoor air temperatures within the boundariesof comfort even when the externaltemperatures are outside the boundaries.

1 FRAMEWORK AND OBJECTIVES

This paper aims atidentifying and atcharacterizing a typology of vernacular architecture from thenorth-eastern region of Trás-os-Montes, understanding its integration in the territory, the management of local resources and its relation with the city. In the previouslystudied typologies in this region, usually associated to concentrated settlements,the street is the link between the house and the village. This study seeks the exceptional elements like farmsteads, dispersed on the territory. Thus, it is intended to (1) contribute to the knowledge and preservation of these, until now, unprotected architectures,characteristics of local culture and identity, through survey and registration, but also (2) to understand and scientifically validate vernacular solutions and strategies, contributing to the development of contemporary solutions.

The awareness that resources, but also the territory, are not unlimitedhave led to the emergence of new standards and regulationsapplied to buildings: the *Passivhaus* concept, proposing passive solutions that ensure minimum energy consumption for a house, or ZEB models (Zero Energy Buildings), buildings that over a year do not consume more energy than they produce. These trends are the most representative of the discussion in the field of energy efficient buildings, and areabove allbased on the Energy Performance of Buildings Directive(EPBD, 2010) that set that all new buildings must comply with the n-ZEB standard (nearly-zero energy buildings) by 2020.

By their isolation from theestablished infrastructural networks, the typology in study isan especially relevant case studyfor self-sufficient construction,i.e. for interventions that are aimed toreinterpret the integration of design strategies with cultural and geographic environments.These strategies remained viable for hundreds of years and are the result of an experimental evolution of ancient wisdom. It is precisely this character of continued evolution of the vernacular heritage, its flexibility and ability to be adapted to the climate and other environmental factors, that is the focus of this paper.

2 BACKGROUND ON VERNACULAR HERITAGE

Since the late 19th century several researches on vernacular architecture were conducted seeking for the autochthonous characters of the different nations and regions (Ferreira, 2013). In a different cultural context, in the following century, modernisnt architects also loooked for vernacular, searching for values of essentialism, rationality and commitment to human and environment (Llano, 1996).

Similar processes took place in Portugal, with the most significant survey work of *Popular Architecture in Portugal* (Sindicato Nacional dos Arquitectos, 1961) having been published in the late 50's. In this work, the authors recognized that was the "last possible moment to register in all its fullness a world about to disappear". Recognizing the consistency and the ability of traditional architecture in the articulation of geographical, economic and social factors, this work has become a marked influence on Portuguese architects like Fernando Távora or Siza Vieira.

In parallel, the ethnologist Ernesto Veiga de Oliveira undertakes various studies on traditional architecture that culminated in a posthumous publication (Oliveira & Galhano, 1992). Although focused primarily on the ways of living, this work weaves important considerations about the spatial and territorial aspects of dwelling. Emphasizing, as the Survey, the dwellings of rural settlements, it offers a clear systematization of different morphologies in block-house or patio-house, with ground floor or two storey variants, which will be used in this research as reference for the characterization of farmsteads.

More recently, in 1999,the International Council on Monuments and Sites, in the *Charter on the Built Vernacular Heritage*, defines the vernacular heritage as "the fundamental expression of the culture of a community, of its relationship with its territory", that "It is a continuing process including necessary changes and continuous adaptation as a response to social and environmental constraints" (ICOMOS, 1999).

In the present days, there has been the awareness that the responses for a more sustainable architecture could be found in a thorough look on vernacular architecture, focusing on form and passive systems to optimize the relationship with the environment. In this sense, the research of Fernandes (2012) presents a classification of strategies and solutions identified in various surveys on popular architecture in Portugal, according to the principles of sustainability and climate region.

Other studies, sought to recognize bioclimatic design strategies of Spanish vernacular architecture, enhancing their recovery and integration in contemporary buildings (Cañas& Martín, 2004) and monitoring *in-situ* some of these strategies, by analyzing and comparing the thermal performance of vernacular face to contemporary buildings (Martin et al., 2010).

3 CASE STUDIES DESCRIPTION

Unlike the Terra Quente Transmontana, where the Mediterranean climate promotes the monoculture with greater economic value - especially almond, olive oil and wine - the Terra Fria is characterized by extensive fields of crops and pasture, in a climate of extremes: a very cold winter - usually with air temperatures between 11ºC and -11ºC - and a hot and dry summer, in average between 29.1ºC and 14ºC(IPMA, n.d.). Here, small rural settlements are predominant, based on a livelihood economy, withagriculture and livestock, always in close proximity to the village, which was the subject of previous studies (Sindicato Nacional dos Arquitectos, 1961; Oliveira, 1992).However, the presence of larger agglomerations, where trade and services assumed great relevance, potentiated different ways of occupation of the territory, as scattered small farms that produced essential goods to supply the city or village.

The highest density of these farmsteads is in the surroundings of Bragança, the most important city in the region, where it is possible toidentify 52 farmsteads with a radius of 5 km from the city(Figure 1). However, documents from the early 20th century point to a much higher number, about 100 (Alves, 1938), in many cases unoccupied, in an advanced stage of degradation and others much adulterated.

These farmsteads arise from the balance between the vernacular landscape and political landscape, as defined by Jackson (1984): the political landscape express needs of community relations and can be indifferent to topography and the local culture, the vernacular landscape "is the result of a slow adaptation to the place, the local topography, climate, soil and people" (Jackson,

1984). In relation to the vernacular landscape, settlement is usually along the water lines, predominantly on the slopes(in the quadrants between south and west) in areas that enable agriculture, pastures and woods (Figure 2). Despite this strong relationship with the land, there is also a relationship with the political landscape, particularly marked by paths and access roads to the city (figure 3). The highest concentration of this typologywithin a 5km radius from the city enabled daily access, on foot,to the market, the reason for the existence of these farms, in a symbiotic relationship with the city.

The unique morphological characteristics of each case is a relevant factor, as it allows to show that vernacular architecture more than applying similar local/regional building solutions always developed site-specific ones. Despite this diversity, the typology has in common the characteristics summarized in Table 1:

Figure 1 Farmsteads location within a 5km radius of Bragança

Table 1. Typology characterization and case-studies presentation

Generic Characteristics	Quinta de Campelo	Quinta do Cano
Isolated but close to town	2,2 Km (30 minon foot)	2,2 Km (30 min on foot)
Adaptation to topography	0,80 m	1,50 m
Orientation favouring South	South-East	West
Close to water sources	100 m	Near the house
Kitchen Garden	Yes	Yes
Diversity of crops	Cereal, Vineyard	Vineyard, Orchard, Olive grove
Livestock	Sheep, Cows, Pigs	Chickens, Ducks, Rabbits

The first case study, Quinta de Campelo, has been referenced since 1697 (Alves, 1938), however, the current configuration results from several changes over time. In the last century, this building was submitted to several transformations that significantly changed it, such as the expansion over the courtyard in the 70s. Morphologically integrates what Veiga de Oliveira&Galhano (1992) call a two-storey Patio-House, the most characteristic of this region. The main front is oriented to the southeast and the building envelope consists of schist walls of approximately 70 cm, with clay mortar partly replaced by cement mortars. Pine wood ceilings

create an inhabited attic with the exception of southwest-facing room, just with wood lining. The partition walls are in *tabique* (traditional frame system with wood and clay) and stucco; the main room is separated from the kitchen by a pine wood panel. The original wood window frames were replaced by aluminium windows with double glazing. Due to the implantation in a very low slope zone, cellars and stables, not in use today, are buried only about 80 cm, in direct contact with the soil. The *porta-carral*(oxcart gate),in the northwest courtyard, is protected from the rain by a porch.

Figure 2 Typology distribution according to vernacular landscape and Figure 3 Typology distribution according to political landscape

The second case study, Quinta do Cano, has been referenced since 1864 (Alves, 1938) and it is, until nowadays, in a configuration that isvery close to the original as a two-storey Block-House. The few changes suffered in the mid-'50s follow the traditional construction processes, including the division of the interior spaces with partition walls in tabique and exterior coatings with lime mortar.Although located in a valley, the building takes advantage of the slope of the hillside, to locate the wine cellar — approximately buried in 1.50 meters in the east side. The building envelope is composed of approximately 80 cm thick schist walls, and the most exposed façade is oriented to west. The doors and window framesare still in wood; the floor and the wooden structure are in chestnut wood. All compartments have ceilings, creating an uninhabitable attic, except the kitchen, with no ceilingto facilitate smoke evacuation from the fireplace.Vegetation is usedto shade the courtyard and the existence of awater tank next to the house, helps promotingevaporative cooling in the hot season.

4 ON SITE THERMAL MONITORING

4.1 *Methodology*

Retrieving the methodology of Martín et al. (2010),were monitored in-situ the strategies identified in the vernacular architecture of Terra Fria Transmontana in order to scientifically validate

these solutions, that still lack a quantitative assessment, but also to identify common weaknesses in these constructions.

The monitoring conducted in the two buildings focusedon the registration of the temperature and humidity with sensors Klimalogg Pro TFA, with an accuracy of ± 1 ◦ C for the air temperature and ± 3% relative humidity, at intervals of 15 minutes and for periods of 15 days in the hot season.

Monitoring in Quinta de Campelo took place fromJully 14th to 28th of 2013 and the temperature and humidity sensors were placed in the porch of the Northwest courtyard and next to the Southeast façade -, and in four indoor locationsthat are the most relevant in the daily life of the inhabitants: Southeast room, Southwest room, kitchen and cellar, as noted in plans and sections of Figure 5.

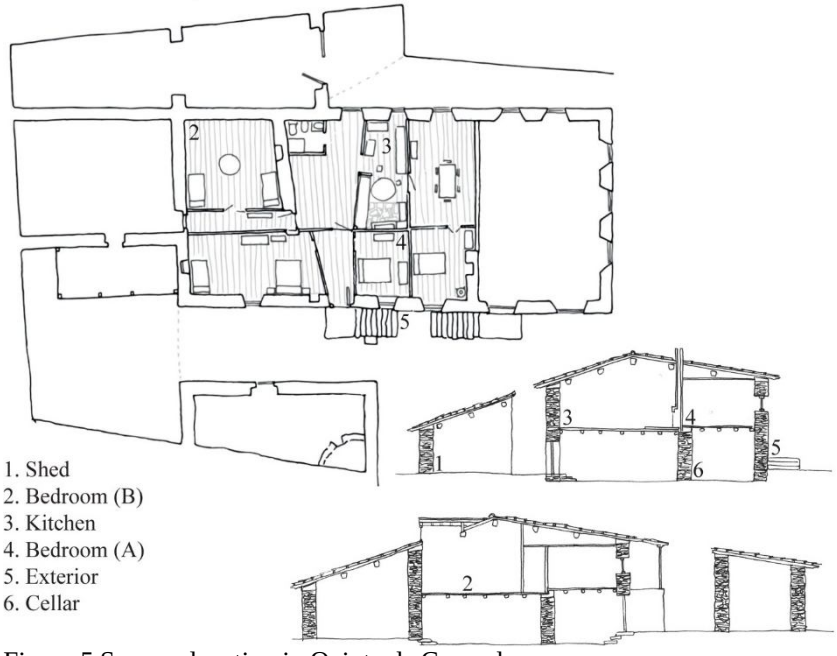

Figure 5 Sensors location in Quinta de Campelo

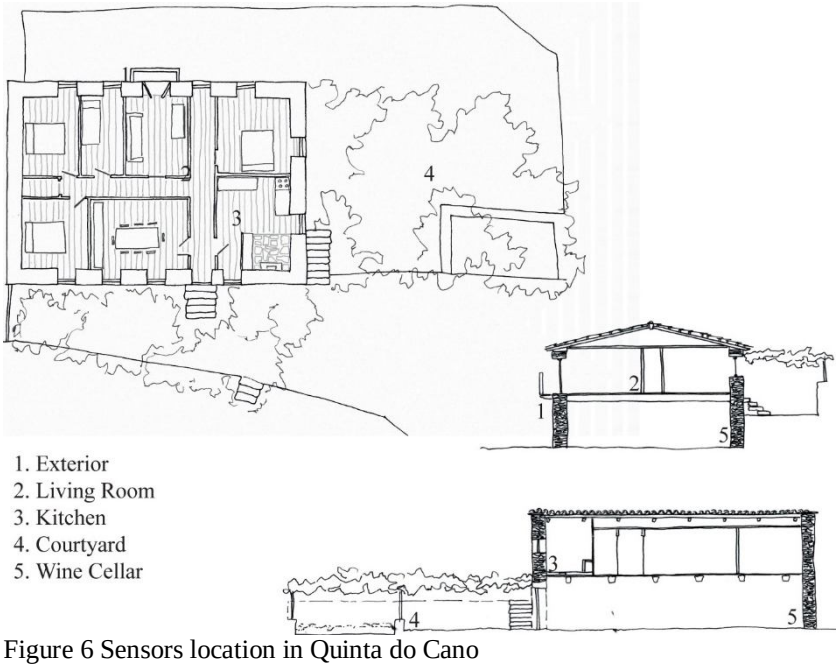

Figure 6 Sensors location in Quinta do Cano

Monitoring in Quinta the Cano took place between July 25th and August 8th of 2013 and the temperature and humidity sensors were placed in the Northeast courtyard and West façade -,

and three interior locations: the West living room, kitchen and cellar, as noted in plans and sections of Figure 6.

4.2 *Analysis Of Results*

In Quinta de Campelo, the building has been permanently inhabited for thirty-two.The survey to the inhabitants allowed to conclude that the Southwest room is only occasional used, and that the Southeast bedroom is usually occupied between 9.30 pm and 7.00am; the window is open to ventilate the compartment throughout the morning. The kitchen, social area of the house is usually occupied in the periods between 10.30 am and between 1.00 pm and 7.00 pm and 9.30 pm; the window remains open throughout the night time, as shown in Table 3.

Table 3.Campelo Farmstead – house daily use description

	Period of Use	Natural Ventilation
Kitchen	[10.30 am – 1.00 pm] [7.00 pm – 9.30 pm]	[9. 30 pm – 7.00 am]
Southeast Bedroom	[9.30 pm –7.00 am]	[9.00 am – 12.00 am]
Southwest Room	Ocasional	

Air temperature profiles recorded in the several building spaces/rooms allowed to realize the effect of spaces occupation (Figure 10). In compartments oriented to the west, the maximum temperatures are reached at the end of the day, when there is direct solar radiation. However, the maximum temperature in the kitchen is maintained in a longer period, between 6.30 pm and 8.30 pm, coinciding with the period of use at dinner time.The room West (B) presentsboth the highest temperatures and highest temperature range (Table 4). These resultsare related with the effect of the Sun later in the day and the composition of the roof, with no attic, that facilitates heat lossduring the night. In the Southeast bedroom (A), thermal amplitudes are smaller, with minimum temperatures during the morning, between 8.30 am and 10.30 am, when the window is open to ventilate the compartment.Although the building envelope of this compartment is exposed to solar radiation during the morning, this is only reflected on the interior temperature at the end of the day. The cellar has almost constant values, with an air temperature around 21ºC, and a high relative humidity of about 70%, as shown in Figure 11.

Table 4.Quinta de Campelo – Summary of registered temperatures and relative humidity

	Temperature (ºC)				Relative Humidity (%)	
	MAX	MIN	Range	Average	MAX	MIN
Exterior	32.2	14.1	11.3	23.5	80	17
Shed	29.2	16.9	5.6	24.2	73	26
Cellar	22.1	20.3	0.2	21.4	73	67
Kitchen	29	20.4	4.5	25.2	66	28
Bedroom (A)	28.5	20.3	3.6	25.3	59	28
Bedroom (B)	29.8	20.5	4.7	25.9	62	31

The indoor minimum temperature peak has a time lag of 4 hours, comparing with the outside; the time lag between the maximum indoor and outdoor peak is, on average, 3 hours. On days when the temperature ranges are identical, the difference between inside and outside is lower.Neverthelesswhen the outside temperature fluctuations are larger, this gap may correspond to more than 10 hours, with the maximum and minimum temperatures in the interior to reflect outside temperature decreases from the previous day, probably due to the thermal inertia of the thick schist walls of the building.

Quinta do Cano, is only sporadicallyusedand therefore the use has no significant effect records. Since solar exposure is predominantly West, due to the need to adapt to the topography, the maximum temperatures are reached usually in the late afternoon, between 6.00 pm and 7.30 pm. Exception is made for the Northeast courtyard that, by its more protected solar orientation,

reaches higher temperatures between 3.00 pm and 4.00 pm (Figure 12). In addition to solar orientation, the use of vegetation for shading and the presence of the water tank allow evaporative cooling(as demonstrated by the relative humidity values (Figure 13)), which makes this outdoor space more comfortable on the hot summer days. Compared with theoutdoorspaces without cooling strategies, the courtyard has on averagea temperature range 3°C lower than the exterior temperatures and a maximum temperature 5°C lower.

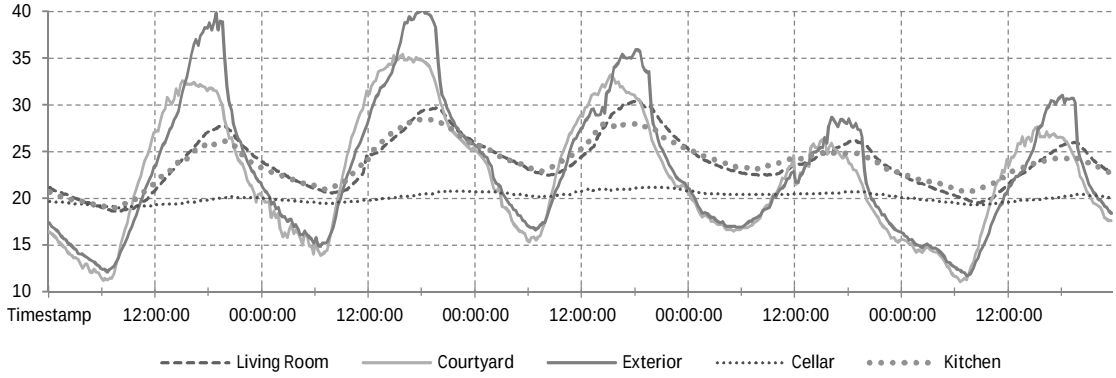

Figure 7 – Quinta de Campelo – indoor and outdoor air temperature profiles between 20th and 25th July

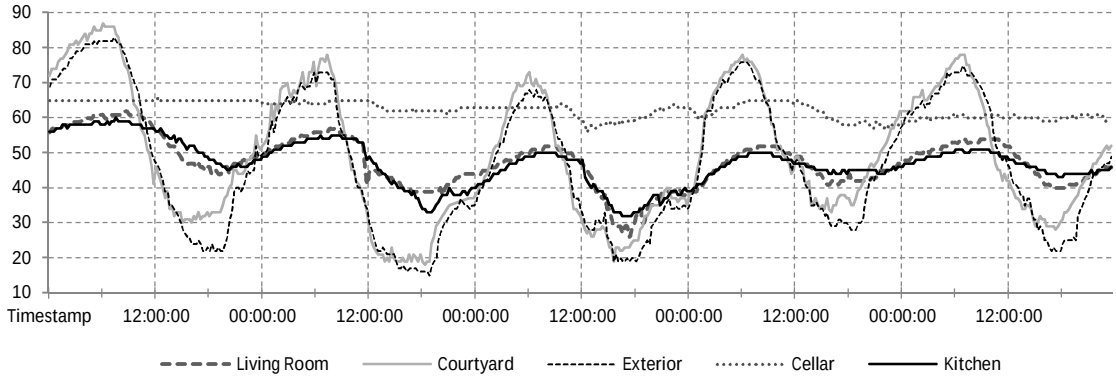

Figure 8 – Quinta de Campelo – indoor and outdoor relative humidity profiles between 20th and 25th July

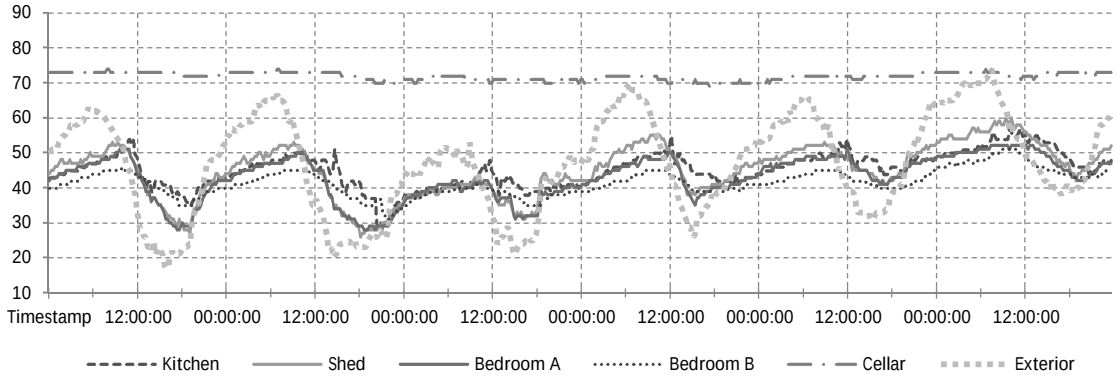

Figure 9 – Quinta do Cano – indoor and outdoor air temperature profiles between 30th July and 3th August

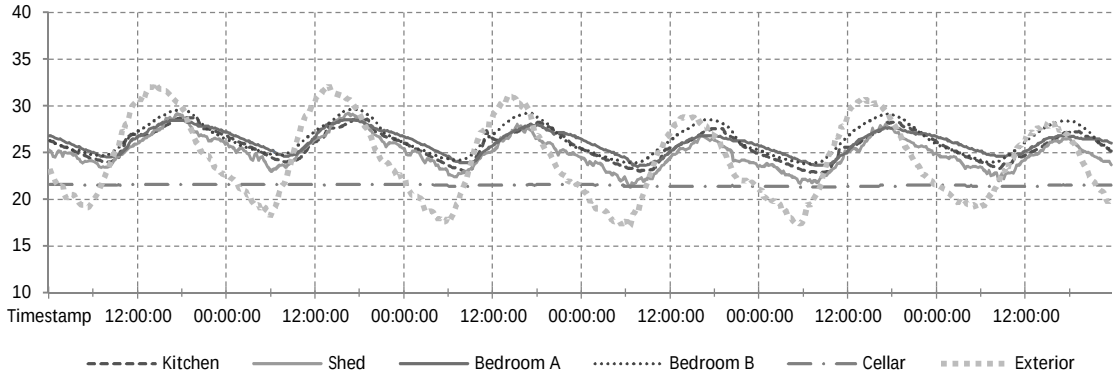

Figure 10 – Quinta do Cano – indoor and outdoor relative humidity profiles between 30th July and 3th August

The cellar, although more buried at East than the samespace in Quinta de Campelo, hashigher temperature variation and lower relative humidity valuesbecause of the building'sorientation that is completely exposed to direct solar radiation during the hottest hours of the day.

In Quinta do Cano, as registeredin the Quinta de Campelo, time lag between the maximum outdoor and indoortemperature peak is of about3 hours; and in the minimum temperature peakis just 2 hours. The air temperature fluctuations are much lower inside than outside, keeping the inside of the dwelling with an average of22.6ºC, even in periods in which outdoor temperature reached up to 40ºC(Table 5).

Table 5.Quinta do Cano – Summary of registered temperatures and relative humidity

	Temperature (ºC)				Relative humidity (%)	
	MAX	MIN	Range	Average	MAX	MIN
Exterior	40.3	10.8	17.8	21.0	89	15
Courtyard	35.4	10.1	14.5	20.3	90	18
Cellar	23.8	18.6	1.1	20.2	66	52
Kitchen	28.6	18.4	3.9	22.9	66	52
Living Room	30.4	18.0	5.9	22.3	64	26

With an average indoor temperature within 23.8°C on hot summer days, the case studies have shown an adequate response through the summer season, mainly due: to the large inertia of the externalschist stoneswalls;to the implemented shadingstrategies;and the evaporative cooling and earth-cooling.

5 CONCLUSIONS

The work carried out until the moment identified a typology of vernacular architecture of the north-eastern region of Portugal that was barely studied until now. In this paper two case studies were identified and characterized (Quinta de Campelo and Quinta do Cano). The study covers their relation with the city and with the surrounding environment and concluded that there is a wise balance between political and vernacular landscape and that these constructions have a thermal behavior that is appropriate to the hot summer in this region. This analysis will be further developed both in on-going monitoring that is being carried out in other case studies and by heating season monitoring.

REFERENCES

Alves, F. M. 1938. *Memórias Arqueológico-Históricas do Distrito de Bragança*. Porto: EmpresaGuedes

Cañas, I., &Martín, S. 2004. Recovery of Spanish vernacular construction as a model of bioclimatic archi-

tecture.*BuildingandEnvironment, 39*(12), 1477–1495. doi:10.1016/j.buildenv.2004.04.007

EPBD, 2010. *Directiva 2010/31/UE do Parlamento Europeu e do Conselho de 19 de maio de 2010 relativa ao desempenho energético dos edifícios (reformulação)*, Estrasburgo.

Fernandes, J. 2012. *O contributo da Arquitectura Vernacular Portuguesa para a Sustentabilidade dos Edifícios*. Guimarães: Universidade do Minho.

Ferreira, T. 2013. Alfredo de Andrade's (1838-1915) Surveyson Vernacular ArchitectureacrossItalyand Portugal. *To andFro: Modernismand Vernacular Architecture*. Porto: Centro de Estudos Arnaldo Araújo

ICOMOS.1999. *Charter on built vernacular heritage.*12th General Assembly in México. Mexico: ICOMOS

IPMA. (n.d.). *Normais Climatológicas - 1981-2010 (provisórias) - Bragança.* RetrievedSeptember 23, 2013, from http://www.ipma.pt/pt/oclima/normais.clima/1981-2010/003/

Jackson, J. B. 1984. *Discovering the Vernacular Landscape*. New Haven: Yale Univeristy Press.

Llano, P. d. 1996. *Razón e Construcción - Arquitectura Popular en Galicia.* ColexioOficial de Arquitectos de Galicia.

Martín, S, Mazarrón, F. &Cañas, I. 2010.Study of thermal environment inside rural houses of Navapalos (Spain): The advantages of reuse buildings of high thermal inertia. *ConstructionandBuildingMaterials, 24* (5), 666-676

Oliveira, E. V. & Galhano, F. 1992. *Arquitectura Tradicional Portuguesa.* Lisboa: Publicações Dom Quixote.

Sindicato Nacional dos Arquitectos. 1961. *Arquitectura Popular em Portugal*. (F. K. Amaral, Ed.) Lisboa: Sindicato Nacional dos Arquitectos.