THE VERNACULAR ARCHITECTURE OF MONTESINHO NATURAL PARK: BUILDING TYPOLOGIES AND PASSIVE ENERGY STRATEGIES

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Keywords: Vernacular Architecture, Typology, Passive Energy

Abstract:
The objective of the paper is to understand the most representative typologies of vernacular buildings at the Montesinho National Park (MNP), in the north of Portugal, based on information obtained from field research. The vernacular architecture in rural villages has suffered an important transformation process in recent years due to significant socioeconomic changes, depopulation trends, alterations and adaptation of the existing building to the new living standards, and import of non-local and non-traditional materials, among others. Located on the northeastern border of Portugal with Spain, the climate of "Terra Fria Transmontana" of MNP is cold in the winter coupled with the abundance of rain, while it is hot and dry during the summer period. This paper will present a statistical analysis of the building typologies observed in the selected villages and the potential passive energy strategies identified in the area. The first part details the strategies, criteria and assumptions used in the categorisation process for building typologies. Based on the information collected, the most representative vernacular architecture typologies were identified. The paper describes not only the main construction materials used for vernacular buildings in the region but also the prospective impacts of modern constructions and modifications that took place. Following that, common passive energy strategies in MNP are also discussed in general. Some preliminary illustrations of the typical typologies will also be shown in 3D models. The main findings reveal that Protruding staircase (PS) is the most common typology followed by Slope 2 Storeys (S2S) and 2 Storeys (2S) typologies among the 8 villages surveyed. Lastly, the paper also serves as a first step of a broader research project that aims to understand the energy performance of representative vernacular typologies of rural villages of Portugal in MNP and the attempt in providing retrofitting strategies to improve its thermal comfort while balancing among vernacular building's heritage authenticity and sustainability.

1 INTRODUCTION

With the increasing socio-economic changes, new materials availability and depopulation trends among rural villages, the landscape of the vernacular architecture has undergone inevitable transformations. In order to experience a better living standard, many rural buildings were altered or in some cases, entirely built above ground with non-local and non-traditional materials. The term "common" vernacular buildings that was conceived conventionally, seems to have been adulterated with other influences nowadays and its rural representation diminished [1]. Though each village may encompass their unique identities in certain minor aspects in addition to the rampant buildings modifications, this paper attempts to find the common features in buildings among the villages before standardising them, so as to discover the most representative typologies via highest frequency calculation, amidst the changes.

The photographic and videographic field survey carried out for the vernacular typological study included 8 villages located within Montesinho Natural Park (MNP), namely Guadramil, Aveleda, Rio de Onor, Cova da Lua, Moimenta, Pinheiro Velho, Montouto and Sandim. According to Köppen-Geiger climate classification, this region is categorised as *Csb* (warm-summer Mediterranean climate), in which the summer is warm and dry, and there are 4 or more number of months with average temperature more than 10 °C [2]. The climate of Terra Fria Transmontana (Cold Land of Trás-os-Montes) is continental with abundance of rain, snow and glacial during winter. However, it is stifling hot and dry that usually result in rivers and springs being dried up in the summer [3], and having very cold winter bundled with hot and dry summer [4][5] while generally being portrayed as "harsher winter conditions and milder summers" at the northern region [6]. The lowest daily minimum temperature is -11.6°C while the highest daily maximum temperature is 38.8°C that were recorded in the district of Bragança between 1971 to 2000 [7].

With limited resources available as building materials, builders at rural areas are obliged to design their houses as practical as possible in providing shelter against the local climate [8]. The general Trás-os-montes or the northern traditional vernacular houses are made of stones, with a distinct ground and elevated floors (the ground floor is usually used for agricultural storage and cattle), external balcony and exterior staircases [3]. The cattle are located below dwelling floors mainly to utilise the heat generated by them especially during night time [9]. In general, the local materials at MNP that were utilised for traditional building construction are schist and granite stones, oak and chestnut woods [5].

2 MATERIALS AND METHODS: CATEGORISATION PROCESS FOR BUILDING TYPOLOGIES

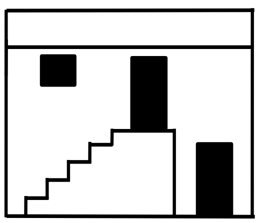
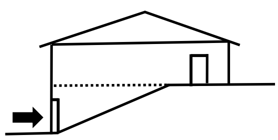
2.1 Basis and Assumptions

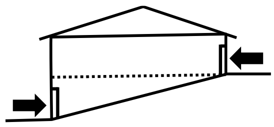
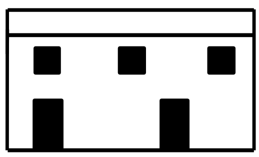
The subject buildings targeted are residential buildings with vernacular features, including buildings that are partially dilapidated, modified buildings and newly built buildings (both with modern or local traditional materials) as long as the prominent typological features are still visible. The survey aimed to survey all buildings of the 8 villages selected, even though some buildings could not be included mainly due the lack of accessibility. In any case, more than 80% of the buildings in each village were evaluated in the present study. Courtyards and agricultural lands attached to the buildings were not considered at this preliminary stage of characterisation. In addition, roof types were not considered as part of the features because there were insufficient information gathered for many vernacular houses. Note that the survey was carried out from the ground.

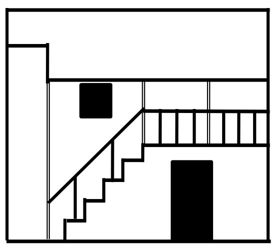
Vernacular buildings revolve and improve over the time, reflecting changes in socio-economic conditions, material availability and construction skills/technologies. This can be seen in bigger building dimensions (e.g., higher ceiling heights), modern built materials and variations of architectural constructions. In terms of modifications, common tendencies observed are increasing the building space to meet the changing lifestyles of the inhabitants and maximise their land plot potential, for example by adding another floor. It is neither the objective of this paper to conduct stratigraphic analysis to reveal various layers of construction changes nor the identification of architectural styles whereupon it derives, as it revolves over the architectural eras or other influencing factors in Portugal. It is important to highlight that the typologies presented were packaged in various dimensions whether in terms of length, height or width. Likewise, it is assumed that the villagers initially construct the traditional buildings to adapt to the local climate and topography, according to local resources availability and socio-economic conditions in resource efficient ways. This includes, for example, the consideration of accessibility when assessing the upper floor of a building, which can be frequently built partially buried on a slope.

An illustrative sketch of some typologies and a brief description are presented in Table 1 as follows:

Table 1 Typology definitions and criteria

S/N	Sketch	Typology	Description
1		Protruding Staircase (**PS**)	a) Exterior staircase to 2nd floor b) Staircase may be sideway (as sketched) or frontal c) 2 storeys d) Upper floor entrance at the same facade/plane with lower floor entrance e) Both upper and lower entrances are facing the main road f) Porch at upper floor entrance is not enclosed and not part of the thermal envelope
2		Slope 2 Storeys Side (**S2SS**)	a) Upper floor entrance is at higher ground elevation and lower floor is at lower ground elevation b) Upper floor entrance not at the same facade/plane with lower floor entrance (or vice versa from the sketch) c) If there is a staircase, it is usually not higher than a floor´s height. The staircase may include a door porch in some cases. d) Usually individual buildings or at the edge of a row of joined buildings

3		Slope 2 Storeys (**S2S**)	(a) Single storey at higher elevation (b) 2 storeys at lower elevation (c) May or may not have staircase for entrance at higher ground elevation. If there is a staircase, it is usually not more than a floor´s height. The staircase may include door porch. (d) Entrances for both elevations are not at the side (e) May or may not have entrance at lower elevation or upper elevation (f) Includes Local and Non-Local materials (g) Usually the buildings are joined (h) May or may not have staircase for entrance at higher ground elevation. If there is a staircase, it is not more than the lower floor´s height (small side steps)
4		2 Storey (**2S**)	(a) 2 storeys (b) Usually there are 1 or 2 doors at lower floor/ elevation at the same facade (c) May include windows at lower floor, but traditional building usually have no windows at lower floor

5		Balcony with Staircase (**BS**)	a) Exterior staircase connected with balcony (Not recessed balcony) b) Staircase may be sideway (as sketched) or frontal c) Roof eave usually extended to cover balcony and may extend to parts/all of staircase d) 2 storeys e) There are cases of staircase sharing and extended balcony to other household(s) f) Usually upper floor entrance at the same facade with lower floor entrance g) Usually lower entrance is below the balcony h) Balcony is not part of thermal envelope and not enclosed i) Balcony length is usually longer ≥ 1 door´s width j) Minor additions using wood materials are expected
6		Shed, Granary, Storage (**SGS**)	a) Shed b) Granary c) Garage d) Storage e) Animal’s shelter

7		Unidentified (**U**)	(a) Insufficient information for categorisation (i.e. obstructions and inaccessibility, insufficient video graphic/photographic evidences, etc) (b) Combination of several inseparable typologies (c) Individual stylised design renovation, which is not common. It may include vernacular buildings with local traditional materials but uncommon typology (d) Signs of some elements (i.e staircase, balcony, etc), which are incomplete, damaged or taken away (as building materials maybe) (e) 3 Storeys buildings

2.2 Categorisation Process

In order to determine the most representative typology, the process begin with four main categories which are: 2 Storeys, 1 Storey, Unidentified (U) and Shed,Granary,Storage (SGS). This is followed by the soil topographic conditions that frequently shape the buildings´ typology, divided into "Slope" and "No-Slope" cases, as shown in Figure 1. Based on the prominent features of the buildings observed and extracted, e.g., protruding staircase at the facade, the typologies were then grouped and categorised. The main prominent features that are identified and were used to define the vernacular architectural typologies are: Protruding Staircase (PS), Balcony with Staircase (BS), Protruding Side Staircase (PSS), 2 Storeys (2S), 2 Storeys Advanced (2SA), 2 Storeys Narrow (2SN), Slope 2 Storeys (S2S), Slope 2 Storeys Side (S2SS), Slope 2 Storeys Same Entrance (S2SSE), Protruding Balcony (PB), 1 Storey (1S), 1 Storey High (1SH) and Slope Basic (SB). The numbers of modified typologies were not marginal. Therefore, additional typologies were assigned, e.g., Modified Protruding Staircase (MPS), Modified Balcony with Staircase (MBS). Meanwhile, Unidentified (U) and SGS categories are relatively straightforward and their definitions are explained in Table 1, without further sub-categories.

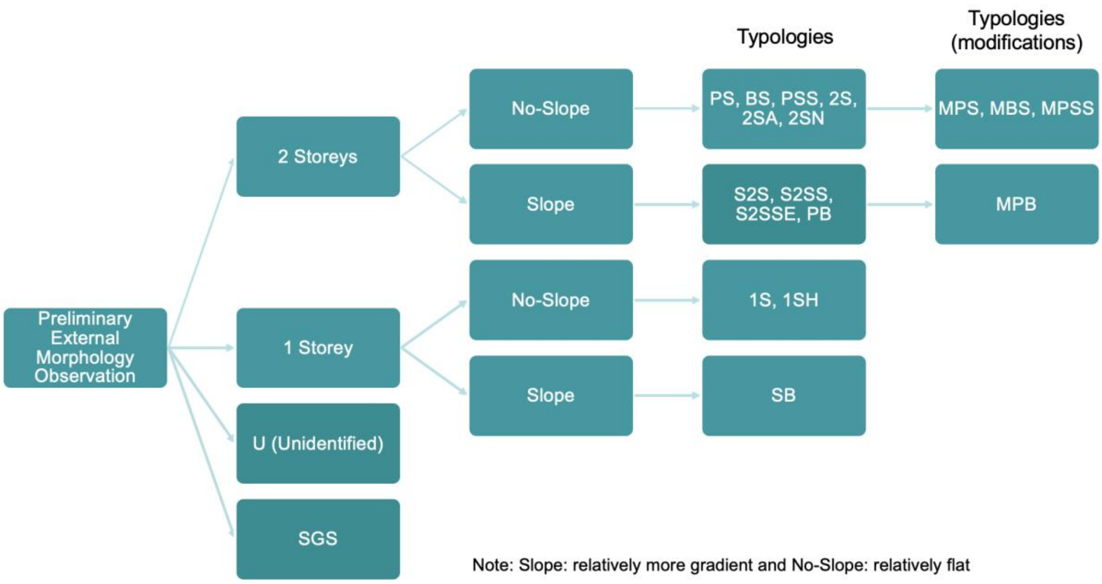


Figure 1 Typology categorisation process

Upon determining the respective percentages of the typologies in each village, the most frequent 3 typologies observed in each village were tagged as Rank 1, 2 and 3. This ranking system per village was selected because each village is unique, partly due to geographical and micro-climates differences. The system avoids overweighting typologies that are predominant in villages with a larger number of buildings, aiming to understand the most common typologies among the 8 villages. The method also screens out SGS and U categories from the analysis. The results were then compared among the villages where the weighted cumulative values were calculated for each typology, by assigning weights of 3, 2 and 1 for Rank 1, 2 and 3 respectively. For example, the weighted cumulative value (WCV) of Protruding Staircase (PS) was calculated as follows, where Quantity (Qty) is the number of a certain rank tabulated across the villages for a particular typology and the overall total weighted rank (OTWR) is calculated as 53.

WCV = [Rank 1: 4Qty x 3wt] + [Rank 2: 1Qty x 2wt] + [Rank 3: 1Qty x 1wt] = 15 and ranked frequency, WCV/OTWR =15/53 ≈ 28%.

Further details of the highest 3 typologies ranking in each village are shown in Table 2.

Table 2 Top 3 typology ranks in each village

	Sandim	Guadramil	Montouto	Rio de Onor	Cova da Lua	Aveleda	Pinheiro Velho	Moimenta	Weighted Rank (WCV)	(%)
PS	3	1	1			2	1	1	15	28.3
BS		2		1			3		6	11.3
S2S	1	3		2	1				9	17.0
S2SS			2		3		2	3	6	11.3
SB	2						3		3	5.7
PB				3					1	1.9
PSS			2		3			3	4	7.6
2S					2	1		2	7	13.2
1S						3			1	1.9
S2SSE			3						1	1.9
							OTWR	TOTAL	53	

In any case, one of the hurdles in categorising the typologies are the existence of mixed typologies that challenge the grey areas in our initial definitions and grouping. It was observed that there are cases where several buildings are combined under the same household. Traditional buildings that combined 2 typologies were also observed. In addition, modifications which usually entail additions of building volumes were not uncommon, including newly built constructions with modern materials. Table 3 further illustrates some cases of mixed typologies and the criteria adopted to categorise these buildings.

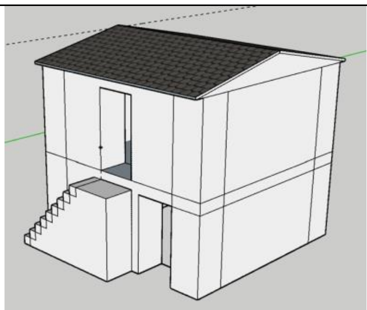
Table 3 Scenarios of mixed typologies and criteria followed for the typological analysis

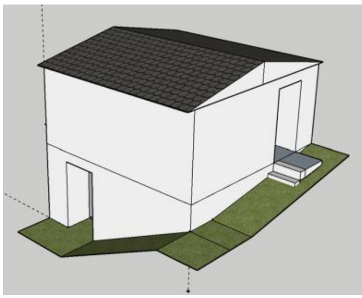
S/N	Scenario Examples	Conditions	Resolution
1	2S + BS ⇨ BS 2S	a) 2 Typologies observed in a household b) Potential distinctive separation into 2 buildings with 1 typology each c) Example: 2 separate buildings combined as one household under same owner	**2 independent buildings were considered**
2	S2S + BS ⇨ BS	a) 2 Typologies observed in a household b) No distinctive separation of Typologies into 2 buildings c) Both typologies share entrance at least of a floor (i.e. ground or 1st floor)	**Typology which is more cost and time effective will be calculated** *Example: BS at lower elevation access to 1st floor is more efficient than access from higher ground elevation (S2S)*
3	S2S + BS + PB ⇨ U	a) 3 or more Typologies observed in a household b) No distinctive separation of typologies into several buildings	**It will be categorised as Unidentified (U)**

2.3 3D models of selected typologies

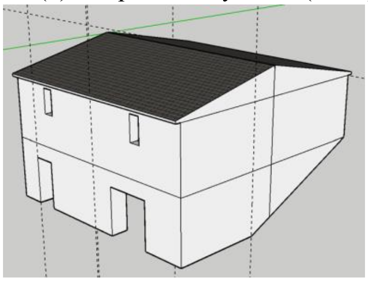
Since the typological analysis involve not only the front facade of the buildings, some common typologies i.e Protruding Staircase (PS), etc, are presented in representative 3D models as shown in Table 4. It also shows photographs of representative buildings from each typology observed on-site.

Table 4 Typologies of vernacular buildings: 3D Models and representative buildings observed on-site

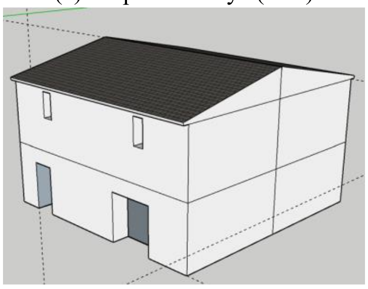
3D Models	Examples
 (a) Protruding Staircase (PS)	



(b) Slope 2 Storeys Side (S2SS)



(c) Slope 2 Storeys (S2S)



(d) 2 Storeys (2S)

3 RESULTS AND DISCUSSIONS

From the 1212 total numbers of buildings surveyed and accounted in this study, the results were compiled and presented in Figure 2. The Protruding Staircase (PS) scored the highest ranked frequency with approximately 28% (WCV/OTWR: 15/53) among 8 villages while Slope 2 Storeys (S2S) with 17% and 2 Storeys (2S) with 13%. Therefore, Protruding Staircase (PS) and Slope 2 Storeys (S2S) are the other two most frequent typologies among the 8 villages surveyed.

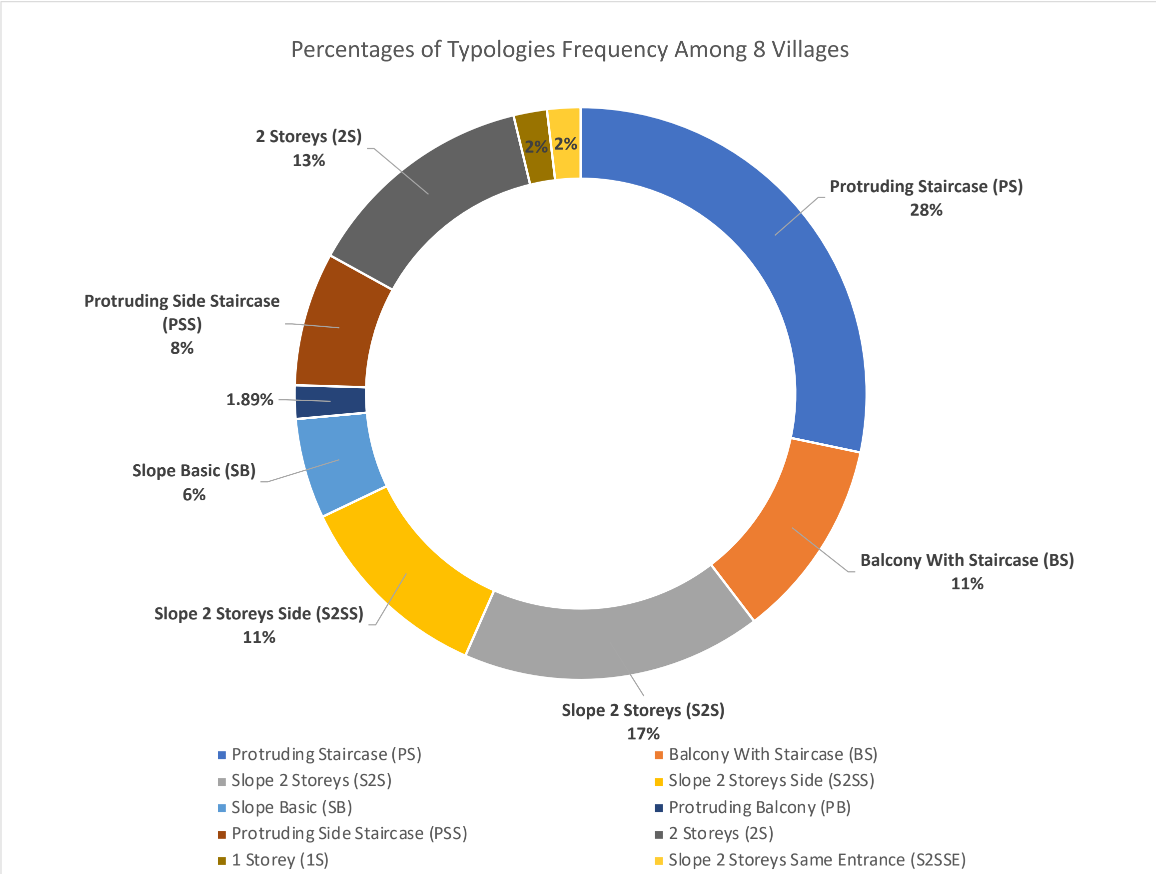


Figure 2 Percentages of typologies frequency among 8 villages in MNP

Among the most common typologies observed are the buildings with 2 storeys. In this case, a fundamental aspect is to understand the accessibility to the upper floors, e.g., through a staircase or the slope of the terrain. Other important features are the connection between lower and upper floors´entrances relative to the buildings´wall facades/planes. For example, in S2S typology, the lower and upper floor entrances are at wall facades/planes opposite to each other while in S2SS, the entrances are at wall facades/planes orthogonal to each other. As such, staircase(s), whether external or internal of a building, may be an indicator that differentiate some typologies. Hence, the idea is not to micro-cluster every architectural variation but rather, to extract certain prominent features common among the 8 villages, which allows to group them accordingly into the typologies, as presented in Figure 1. It is expected that the buildings, although grouped under the same typology, show differences in terms of dimensions, number of openings and entrances, and sizes, etc.

The purpose of the category of typology Unidentified (U) is to reflect the level of inhomogeneity relative to the typological criteria assigned in this study in each village. The highest buildings inhomogeneity were found in the village of Aveleda and Cova da Lua ranging between 31% to 35% in each village, while Rio de Onor, Guadramil and Montouto were calculated in the range of 15% to 18% at the lower ends of heterogeneity.

3.1 Potential impact of modern construction and modifications

Most of the buildings that are still occupied have usually undergone some modifications or are newly built. In fact, approximately 3% from the total accounted buildings (Total 1212 buildings in 8 villages used in the calculation) consist of modified typologies (MPS, MBS and MPSS), where the building´s initial volume is extended occupying the porch/balcony of the upper floor and affect the thermal envelope´s initial structure. Since this study is based on external morphology observation as the preliminary stage without further detailed analysis e.g., hygrothermal validation, etc, the following Table 5 shows some modern construction modifications and their potential impacts to energy performances and thermal comforts to the buildings.

Table 5 Some modifications and potential impacts

	Modifications	Description	Potential Impact(s)
1		Modifications or newly built buildings that increase space or volume	(a) Increase of building volume will require more internal heat gain in order to maintain thermal comfort (b) Usually, the space at staircase built-up are modified (or newly built building) to increase the building volume either at 1st floor and/or lower floor (c) Render the extended roof eave to be anachronistic
2		3 Storeys Buildings	(a) Causes shadow on neighbouring buildings and reduce sun exposures (b) Hindrance to wind and reduce night breeze (mountain wind) especially during summer (hot weather) (c) Observed in approximately 1.49% of total buildings calculated
3		Concrete	(a) Thermal mass capacity reduced with the usage of concrete materials (b) Permeability reduced

3.2 Potential common Passive Energy Strategies Observed

With scarce resources and limited technology, the local villagers had been in the past adapted to the environment conditions by constructing buildings with elements that serve several purposes, utilising local materials efficiently. The thick stone masonry wall, for example, serves not only as the main structural component but also to provide thermal moderation capacity between building´s indoor and external environment. Amongst others, the traditional vernacular buildings are, in general, conceived with some passive energy strategies. Furthermore, buildings for occupation that were built on the slope, as found for instance, in Slope 2 Storeys (S2S), Slope 2 Storeys Side (S2SS), or Slope Basic (SB) typologies, showed the double-edged sword solution for higher exposure to sun radiation besides able to reserve more fertile lands at lower grounds (relatively less slope lands) for agricultural purposes. Table 6 shows some passive energy strategies frequently observed in traditional vernacular buildings in Montesinho Natural Park (MNP).

Table 6 Passive energy strategies frequently observed

	Examples	Description	Passive Energy Strategies
1	 	Extended Roof Eave (for BS)	(a) Enable excessive sun radiation to be blocked during summer (b) Enable shelter from rain water entering the upper floor of the building
2	 	Thick Wall (Thermal Mass)	(a) Thick masonry wall for dual purposes: structural and thermal (b) High thermal mass in the stones able to absorb the heat in day time and reduce the heat transmittance rate during summer (c) High thermal capacity also enables internal heat gains and day time sun radiance to be absorbed and moderate internal temperature fluctuation especially at night
3	 	Small Windows/ Small Openings	(a) Small openings reduce infiltration rate of internal heat gain out of the building during winter (b) Enable more wall surfaces exposed to the sun (c) Lower openings ratio also results to higher wall surface area that serve as thermal mass capacitance (d) Observed in approximately 10.40% of total buildings calculated

4 CONCLUSION

The categorisation process is based on defining prominent vernacular features observed among the rural buildings of different villages in MNP as the fundamental methodology to estimate the most frequent typologies in the natural park. Ranking system and mixed typologies remedies were used to address potential overweighting typologies in certain villages and some grey areas respectively. As a result, the most frequent typology observed in the 8 villages analysed in the Montesinho Natural Park is the Protruding Staircase (PS). From the process itself, it can be deduced that many newly built buildings with modern materials still maintain the past influence(s) or "DNA" of traditional vernacular constructions. The observations are consistent with (Goncalves et al, 2019)´s description that the rural buildings, in parish of Cernache do Bonjardim, at central region of Portugal, are more utilitarian than ornamental [1]. The traditional village buildings in MNP, in general, are leaning more towards being pragmatic and resource efficient. The main typologies identified seem to be also greatly influenced by the topographic conditions of the ground, e.g., taking advantage of the terrain slopes. It is not new that better understandings on the traditional solutions in vernacular buildings are speculated to be beneficial for our buildings' adaptations to the local climates in terms of passive energy strategies and sustainability. However, the "homeostasis" approach in rural traditional constructions adopted by the ancestors that are balanced and efficient towards external environment adaptations, is in fact timeless and should serve as an inspiration to further explore to expand the potential solutions (i.e. passive energy strategies) encompassing a much broader view, not only focusing on the building itself as a separate case, but also its dynamic correlations with the surrounding environment(s) and human activities, whether as an individual building or cluster(s) of building(s).

ACKNOWLEDGMENTS

This work was supported by the Portuguese Foundation for Science and Technology (FCT) under Grant with the reference MTS/BRB/0086/2020

REFERENCES

[1] M. M. Goncalves, S. Pareti, V. Valdebenito, L. Rudolph, M. Teresa Perez Cano, and S. Rosendahl, "From stone masonry to emigrant's mansions. Changes in vernacular architecture in central Portugal," *IOP Conf Ser Mater Sci Eng*, vol. 603, no. 2, p. 022064, Sep. 2019, doi: 10.1088/1757-899X/603/2/022064.

[2] H. E. Beck, N. E. Zimmermann, T. R. McVicar, N. Vergopolan, A. Berg, and E. F. Wood, "Present and future Köppen-Geiger climate classification maps at 1-km resolution," *Scientific Data 2018 5:1*, vol. 5, no. 1, pp. 1–12, Oct. 2018, doi: 10.1038/sdata.2018.214.

[3] E. V. de Oliveira and F. Galhano, *Arquitectura Tradicional Portuguesa*, 5th ed. Lisboa: Publicações Dom Quixote, 2003.

[4] J. Gonçalves, R. Mateus, J. Fernandes, and T. Ferreira, "Tradition in Continuity: thermal monitoring in vernacular architecture of farmsteads from northeast Portuguese region of Trás-os-Montes," in *PORTUGAL SB13 CONTRIBUTION OF SUSTAINABLE BUILDING TO MEET EU 20-20-20 TARGETS*, L. Bragança, M. Pinheiro, and R. Mateus, Eds., Guimarães, 2013, pp. 259–267.

[5] F. M. Silva, C. Sousa, and H. Albuquerque, “Analytical Model for the Development Strategy of a Low-Density Territory: The Montesinho Natural Park,” *Sustainability (Switzerland)*, vol. 14, no. 7, Apr. 2022, doi: 10.3390/su14074373.

[6] J. Fernandes, C. Pimenta, R. Mateus, S. M. Silva, and L. Bragança, “Contribution of Portuguese vernacular building strategies to indoor thermal comfort and occupants’ perception,” *Buildings*, vol. 5, no. 4, pp. 1242–1264, 2015, doi: 10.3390/buildings5041242.

[7] IPMA, “Normais Climatológicas (1971-2000),” *Portuguese Institute of the Sea and the Atmosphere*. https://www.ipma.pt/bin/file.data/climate-normal/cn_71-00_BRAGANCA.pdf (accessed Apr. 21, 2023).

[8] H. Coch, “Chapter 4 — Bioclimatism in vernacular architecture,” in *Renewable and Sustainable Energy Reviews*, Elsevier Science, 1998, pp. 67–87.

[9] A. da M. Antunes *et al.*, *Arquitectura Popular em Portugal*, 3rd ed., vol. 1. Lisboa: Associação dos Arquitectos Portugueses, 1988.