Assessment of vulnerability of earthen vernacular architecture in the Iberian Peninsula to natural risks. Generation of an analysis tool.

C. Mileto[a], F. Vegas[b], L. García[c] and A. Pérez[d]

[a]PEGASO- REsearch Centre in Architecture Hertiage and Management for the Sustainable Developement, Universitat Politècnica de València, Valencia, Spain; [b]PEGASO- REsearch Centre in Architecture Hertiage and Management for the Sustainable Developement, Universitat Politècnica de València, Valencia, Spain, [c]PEGASO- REsearch Centre in Architecture Hertiage and Management for the Sustainable Developement, Universitat Politècnica de València, Valencia, Spain; [d]PEGASO- REsearch Centre in Architecture Hertiage and Management for the Sustainable Developement, Universitat Politècnica de València, Valencia, Spain

[a]cami2@cpa.upv.es; [b]fvegas@cpa.upv.es; [c]ligarso@upv.es; [d]anprevi@arqt.upv.es

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Earthen architecture is an essential part of the architectural and cultural heritage of the Iberian Peninsula. Both at monumental and vernacular level, this architecture has adapted to the diversity of the territory, the different geographies and climates, the variety of materials available and the cultural diversity which have led to a great wealth of constructive variants of this architecture. The RISK-Terra Project was born in this context, funded by the Spanish Ministry for Science, Innovation and Universities, aiming to contribute to the study of this heritage scientifically researching and analysing the natural, social and anthropic threats to earthen vernacular structures, as well as deterioration mechanisms and transformation dynamics currently observed in this type of architecture in the Iberian Peninsula. The research presented in this text has been carried out within the framework of the RISK-Terra Project, with the main objective of developing an analysis tool for application to any element of traditional architecture or earthen vernacular architecture, assessing the degree of vulnerability to the sudden action or continued presence of natural risks (earthquakes, floods, extreme weather events).

Keywords: earthen architecture, vulnerability, natural risks, Iberian Peninsula

INTRODUCTION

The Iberian Peninsula is a territory with an extensive earthen architectural, monumental and vernacular heritage. The scale of the territory and its heterogeneous geography and climate, the variety of materials available and its cultural diversity are the main factors making up the great wealth of its architecture, urban and rural complexes, and constructive techniques which throughout history have used earth as their main material (rammed earth, adobe, half-timber, cob and its variants). Its value as part of the culture of materials for construction in the Peninsula is beyond question, both for its origin and for the level of conservation of these structures, which are perfectly adapted to the environment (AA.VV., 2011).

However, although this architecture is an essential part of the country’s culture, over the last century it has experienced major abandonment due to changes in the way of life, the depopulation of rural areas or the lack of social recognition. At the same time, the constructive techniques found in these cultural settings have gradually disappeared to be replaced progressively by new standardized techniques, seemingly more long-lasting and advanced. In this context, the conservation of the existing earthen buildings has often used foreign techniques and materials, leading to cultural and constructive deterioration, as well as material, constructive and structural incompatibilities. Currently, this rich and valuable heritage has experienced and continues to experience abandonment and lack of maintenance, as well as unsuitable interventions which not only entail cultural loss, but hinder the resistance and durability of architecture.

The hurdles of disrepute and the lack of knowledge were overcome some time ago, from the late 20th century, when national and international researchers gradually rescued the intrinsic values of heritage and the cultural order of this heritage. Thus, in recent decades interest in the study of earthen architecture has increased progressively, both in terms of the research on traditional constructive techniques and in terms of bioconstruction and the study of the intrinsic properties of these materials for a more sustainable contemporary architecture. Current interest in an environmentally friendly architecture which uses local materials and in which function and simplicity prevail over other factors has led to a renewed gaze to the past. Although the use of earth is nowhere near as prevalent as other contemporary materials it cannot be denied that these initiatives open up new avenues for research and work. Thus, based on the research of these earthen historic structures and an in-depth knowledge of their construction new actions can be proposed for their conservation, to learn from them for a new contemporary architecture.

The RISK-Terra Project was born against this backdrop, aiming to contribute to the study of this heritage, scientifically covering the study and analysis of natural, social and anthropic threats to earthen vernacular structures, as well as the mechanisms for deterioration (erosion, loss of materials and parts, collapse, etc.) and the transformation dynamics (replacement, use of incompatible techniques and materials, etc.), currently observed in this type of architecture in the Iberian Peninsula.

The research presented in this text was carried out as part of the RISK-Terra project. Its main aim was to develop an analysis tool, applicable to any element belonging to traditional or earthen vernacular architecture, in order to evaluate the level of vulnerability to the sudden action or continued presence of natural risks (earthquakes, floods, extreme weather events).

State of the art and objectives

Natural risks have always played a part in the evolution of civilizations, so that their origins and effects have been widely documented. The guide "Riesgos naturales. Guía metodológica para la elaboración de cartografías en España", drawn up by the Spanish Official College of Geologists in 2008 (AA.VV.,2008), provides a clear classification of natural and anthropic risks. We also find extensive documentation of the natural risks of the Iberian Peninsula, obtained from more general documents drafted at European level, including "The Spatial Effects and Management of Natural and Technological Hazards in Europe (ESPON)" published in 2006 (Schmidt-Thomé, 2007) or the more detailed risk maps drawn up by the Spanish Instituto Geográfico Nacional (http://www.ign.es) and the Agência Portuguesa do Ambiente (http://www.apambiente.pt).

Most of these studies, assessing architectural vulnerability, focus especially on seismic risk (Cantarino et al., 2014;Latanda, Beneit, Barbat, 2009; Gonzalez-Drigo et all, 2015). On an international scale, the study of reference on earthen architecture under seismic risk is the project "Seismic Retrofitting Project" by the Getty Conservation Institute, a more recent major study on the structural and seismic behaviour of earthen architecture (Cancino et al., 2014) (Lourenço et al., 2019) (Karanikoloudis, Lourenço, 2018).

In general, the assessment of architectural vulnerability to natural and anthropic risks has been studied mostly through the use of analysis matrices which establish a correlation between the state of conservation, the components of buildings and the effects of degradation on them (Ortiz et al, 2014; Galán et al, 2006; Ortiz, Ortiz, 2016). Most of these studies focus primarily on monumental architecture elements in order to provide control and protection strategies for conservation.

In terms of vernacular architecture, development is not yet noticeable in terms of prevention and analysis methods, especially when exclusively considering buildings using earthen constructive systems.

Therefore, in order to develop an analysis tool applicable to this type of architecture an analysis matrix was generated based on the type and form of the characteristics of the constructions, placing these in a five-level scale by degree of susceptibility in relation to the individual risks. These are then contrasted with the risk maps in order to obtain the level of vulnerability.

The final aim of this research is to legitimate the level of resilience of vernacular architecture to natural risks in order to assess their response to the new threats aimed at phenomena provoked or aggravated by climate change, in order to establish guidelines for the adaptation, protection and improvement for its conservation and valorization in modern society.

Natural threats analysed

In the Iberian Peninsula, as highlighted in the Spanish National Plan for Emergency and Risk Management for Cultural Heritage (MECD, 2015), floods and seismic activity are the natural phenomena most frequently causing damage to rural and urban settings.

In the assessment context for the conservation and protection of architecture, it is also necessary to consider the effects derived from climate change. In connection with this, in 2007 the Spanish Ministry for Ecological Transition and Demographic Challenge published the report "El cambio climático en España. Estado de situación" (AA. VV, 2007) warning that the possible scenarios caused by climate change included an alteration of the frequency and intensity of extreme climate events. Later studies (Rodríguez, 2018) describe a variation - quite noticeable in some aspects - of the atmospheric conditions in the Iberian Peninsula. Furthermore, other authors (Rios et al, 2014) and institutions such as IPCC (IPCC, 2012) link the increased frequency and severity of extreme weather events to climate change, considering them risks to society.

In rural settings and small nuclei of population, as well as in large urban nuclei, there is a large number of cases representing earthen built vernacular architectural heritage (AA.VV., 2011; Muñoz, 2014), which could in turn be considered susceptible to exposure to situations of risk caused by the action of the phenomena mentioned.

Therefore, analysis focuses on the capacity for response of the constructions at risk from seismic activity, floods and extreme weather events. A common methodology is used for the individual assessment of these risks.

METHODOLOGY

The assessment of the multiple variables taking part is carried out in two phases. Firstly, obtaining the level of susceptibility by construction and risk and secondly superimposing the case studies onto the risk maps in order to verify the existence and level of vulnerability.

Creation of the analysis tool

The aim of this tool is to establish a correlation between the architectural characteristics and constructive variants of the individual cases in relation to the different risks for analysis. This tool was generated using a matrix in Excel to calculate the susceptibility of the constructions.

Extraction of architectural characteristics and their variants

Given the great richness and variability of the elements which make up this architecture the first step for its assessment was its characterization, taking into account its size and geographical and climatic diversity (Muñoz, 2014; Dipasquale et al, 2011).

Based on an initial sample of 50 case studies homogeneously distributed throughout the Iberian Peninsula, different characteristics of a constructive and material nature were identified, relating to the surroundings, morphology and composition. Based on this classification, analysing each characteristic, variants answering to different conditioning factors were identified and elements which could be grouped were taken into account, seeking to simplify the great diversity of real variants characterizing vernacular architecture (Guerra, 2011).

In terms of the characteristics linked to the surroundings, those considered relevant for the assessment of specific risks included the volumetric characteristics of the adjoining buildings, the position in relation to the urban level and the urban typology.

Among the characteristics linked to morphology and composition efforts have been made to ensure as much data as possible was collected to provide information on the construction and on how far they can be seen as a characteristic element when determining a building's resistance to the action of any of the risks considered.

Characteristics taken into account include the number of floors above ground, the geometrical proportion on the floor plan, occupied surface of the floor plan, percentage of surface occupied by openings in relation to the total surface of the façade, type of roof, type of eave, the presence or absence of vertical protection in addition to the rendering of the constructions on the exterior façades, characteristic bracing between structural elements, and the type and composition of the vertical constructive system.

Specific focus is placed on the characteristic of the composition of the vertical constructive systems, as the study focuses on earthen built architecture, contemplating the different variants found in the Iberian Peninsula. Based on previous projects, such as Terra Europae in Europe and Res-tapia and Sostierra in the Iberian Peninsula (14), a classification system was set up to group constructive systems which use earth as a main component, as rammed earth, adobe and half-timber systems. In addition, these three systems can be found in combination, used as reinforcements or supplements which can lead to a variation in the mechanical and resistance characteristics in relation to the predominant system. Thus, this analysis has observed both the specific type of system and whether it has been combined or supplemented.

The constructive and material characteristics show the most specific characteristics of the construction, such as the materials used in the plinth, rendering, and the specific variant of rammed earth, adobe or half-timber used.

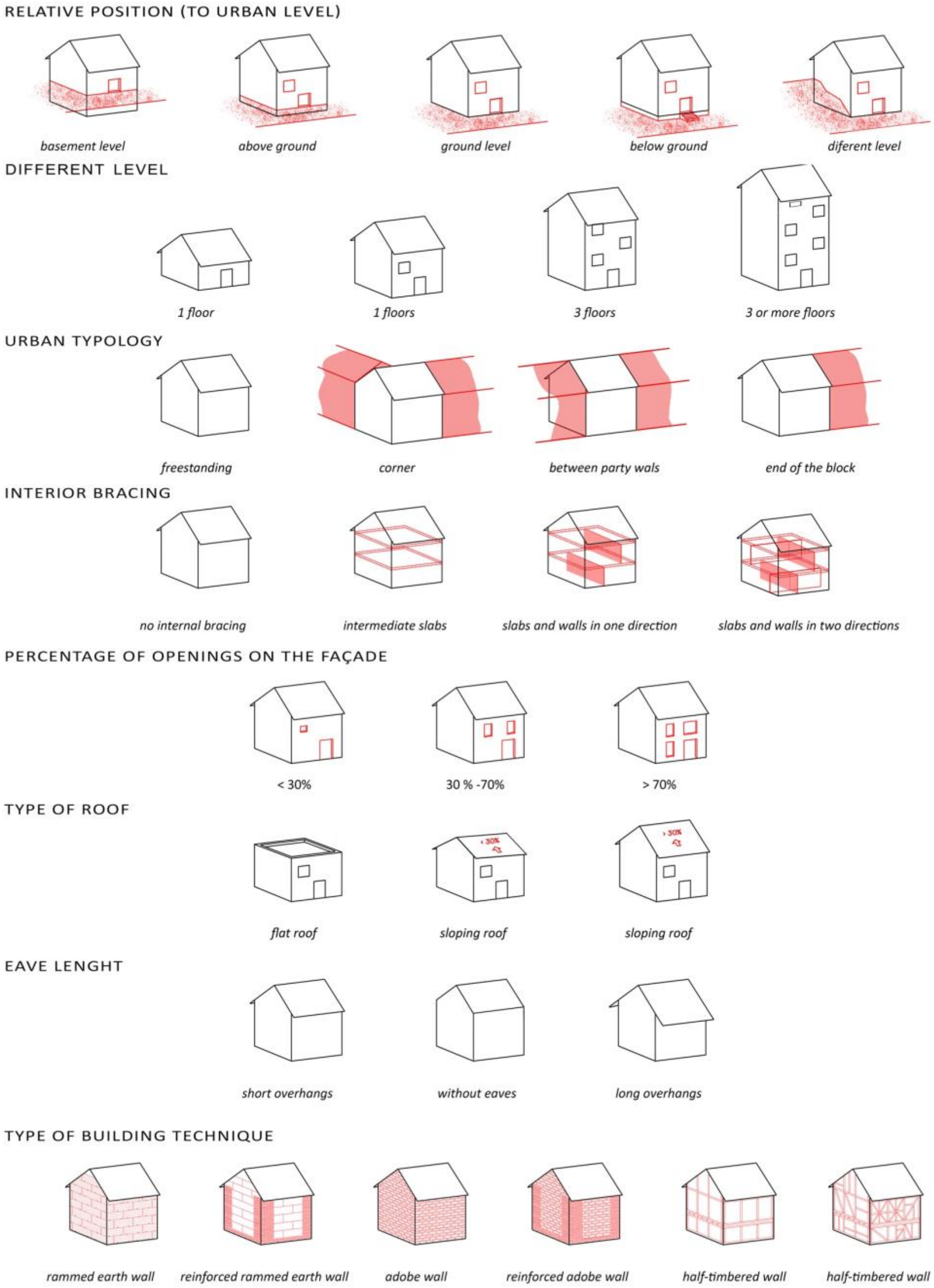

Figure 1. Schematic examples of the characteristics analysed

Assessment of risk of architectural characteristics

The second step of this study phase proposed the assessment of each characteristic and its corresponding variants in relation to each of the independent risks. The aim was to define whether or not each characteristic and its particularities affect the susceptibility of the complex to risk situations in each of the cases analysed, acting also as a conditioning factor for the rest of characteristics to some degree.

The aim was to carry out a very specific quantitative evaluation by risk and case study, requiring consultation with experts and their assessment of earthen built architecture in the analysis of natural risks. To do so the DELPHI method (Astigarraga, 2002; Reguant-Álvarez, Torrado-Fonseca, 2016) used a questionnaire completed by 43 experts in different fields (architects, technical architects, engineers, restoration experts, etc.) with different levels of experience.

Each expert assessed the individual characteristics for each type of risk on a scale of 0 to 10, with 0 representing nil influence on general structural behaviour. In order to calculate and assess the mean value to be considered in each case the Chauvenet Criterion (Taylor, 2014) was used to obtain a standard deviation of 2. In parallel, as well as the mean value, the number of responses with nil value was considered in order to rule out any characteristics whose limited relevance meant they were classed as non-influential for the purposes of calculating the susceptibility matrix.

Table 1 shows the results analysed as the mean depending on the level of experience of the experts surveyed.

	SEISMIC ACTIVITY				*FLOOD*				*WEATHER EVENTS*			
	G 1	G 2	G 3	% of nil values	G 1	G 2	G 3	% of nil values	G 1	G 2	G 3	% of nil values
Adjoining buildings	5.77	6.00	7.10	18%	2.48	1.38	3.08	72%	4.62	5.14	6.00	34%
Urban condition	6.23	5.22	6.00	14%	7.90	8.67	7.25	2%	6.71	6.57	5.70	16%
Urban typology	7.41	6.89	8.56	7%	3.52	3.78	4.58	41%	5.70	5.50	7.11	20%
Geometrical proportion	6.95	6.38	5.90	9%	2.05	1.33	2.91	70%	3.75	2.71	4.00	54%
Type of roof	6.10	5.22	5.00	20%	3.38	2.22	1.91	54%	6.55	7.86	8.44	16%
Occupied surface	4.71	5.14	4.10	35%	2.33	2.22	3.67	39%	3.78	4.00	3.80	58%
Percentage of openings	7.95	8.13	8.10	10%	2.81	2.44	4.73	63%	4.81	7.14	5.70	28%
Eave length	3.62	3.56	3.36	60%	3.71	3.22	2.42	60%	5.71	8.17	8.56	18%
Additional protection	3.95	5.88	2.22	58%	4.81	4.89	5.00	34%	6.57	8.00	7.10	18%
Number of floors	9.15	9.13	8.45	4%	4.10	4.33	4.08	41%	5.60	5.83	5.89	23%
Interior bracing	9.40	9.11	9.00	2%	2.86	2.89	1.91	66%	5.10	3.14	2.00	52%
Existence of plinth	5.90	4.29	4.64	29%	6.38	7.89	6.09	20%	5.75	6.86	6.00	25%
Rendering	3.10	4.29	3.00	63%	4.90	5.11	4.58	38%	6.11	8.00	7.38	16%
Type of technique	8.70	8.50	8.60	9%	6.29	6.13	6.50	18%	6.14	7.00	7.40	20%

Table 1. Results of the assessment of the characteristics by risk depending on the level of professional experience of survey respondents. (G1: experts with over 20 years' experience in the field; G2: experts with between 10 and 20 years' experience; G3: experts with less than 10 years' experience)

The characteristics considered most important in the case of susceptibility to seismic action are: the number of floors (mean: 8.9), interior bracing (mean: 9.1), percentage of openings on façades (mean: 8.1) and type of constructive technique (mean: 8.4). In the case of susceptibility to floods, the characteristics considered most important are: position in relation to the urban level (mean: 7.9), the plinth (mean: 6.8) and type of constructive technique (mean: 6.3). As regards the intervention of extreme weather events the most important characteristics are the type of roof and eave length (mean: 7.5), the additional protection and type of rendering (mean: 7.2) and the type of constructive technique (mean: 6.8). These result in the quantitative assessment by characteristic and variable (Table 2) used to develop the assessment system for the level of global susceptibility.

The variants of each characteristic are assessed on a scale of 1 to 5 where 1 is considered a favourable response, where the damage caused by the risk intervention is minor or non-existent, and 5 is the response where the damage caused is more likely to contribute to the collapse of the construction.

CHARACTERISTICS		SEISMIC ACTION		FLOOD		EXTREME WEATHER EVENTS			CHARACTERISTICS		SEISMIC ACTION		FLOOD		EXTREME WEATHER EVENTS	
Urban condition		0.6		0.8		0.7			Constructive technique		0.9		0.6		0.7	
	Basement		5		5		5			Rammed earth		1		1		1
	Below ground		4		4		4			Adobe		3		4		5
	Ground level		3		3		3			Half-timber		5		5		3
	Above ground		1		1		1									
	Several levels		3		3		3		Characterization of constructive system		0.9		0.6		0.7	
										Homogeneous rammed earth		1		1		1
Number of floors		0.9		0.4		0.6				Supplemented rammed earth		5		3		3
	1		1		1		1			Mixed rammed earth		3		5		5
	2-3		3		3		3			Homogeneous adobe		5		5		5
	4-5		5		5		5			Supplemented adobe		3		3		3
										Mixed adobe		1		1		1
Geometrical proportion		0.7								Simple half-timber		5		5		5
	a x a		1							Complex half-timber		1		1		1
	a x 2a		3													
	a x 3a or higher		5						Vertical protection				0.5		0.7	
										Yes				1		1
Occupied surface		0.5		0.4						No				5		5
	0-50		1		5											
	50-150		3		3				Plinth		0.5		0.7		0.6	
	>150		5		1					No plinth		5		5		5
										Masonry		3		3		3

Building type		0.7		0.4		0.6				Ashlar		1		1		1
	freestanding		5		5		5			Ceramic brick		2		2		2
	End of block		4		4		4									
	On a corner		3		3		3		Type of wall		0.9		0.6		0.7	
	Between party walls		1		1		1		Rammed earth	Simple		5		5		5
										Reinforced with lime		4		4		3
Adjoining buildings		0.7				0.5				Reinforced with lime and masonry		4		4		3
	2 build. with > o = height		1				1			Formwork masonry		5		5		5
	1 build. with > height and 1with = height		1				2			Interlocked with timber		1		4		3
	1 build. < height and 1 = height		3				3			Lime concrete		2		1		1
	2 build. with < height		5				4			Gypsum		2		3		3
	non existent		5				5			Limecrusted		2		3		2
										Brick-faced		2		2		2
Interior bracing		0.9								Stone-faced		2		2		2
	Floor+wall 2D		1							With gypsum joints		3		4		4
	floor+wall 1D		2							With gypsum brenca supplements		3		4		4
	Floors and ceilings		3							With lime joints		3		3		4
	No bracing		5													
									Adobe	Earth joints		5		5		5
Percentage of openings		0.8				0.6				Lime joints		4		4		3
	<30%		1				1			Reed in joints		1		4		3
	30%<x<70%		3				3			Bricks in joints		3		2		1
	>70%		5				5			Stone in joints		3		2		1
										Wood in joints		3		3		3
Type of roof		0.6				0.7										
	Flat		1				5		Half-timber	Rubble infill		5		4		2
	sloping>30%		5				1			Monolithic infill		3		3		1
	sloping<30%		3				3			wattle-and-daub or reed		2		5		5
										Wooden screens		1		2		2
Type of eave						0.7				Wooden boards		3		2		3
	no eave						5			Stone slabs		5		1		4
	Short overhang						3									
	Significant overhang						1		Renderings				0.5		0.7	
										No rendering				5		5
										Earth				4		4
										Earth and lime				2		2
										Earth with fibres				3		3
										Lime				1		1
										Gypsum				3		3

Table 2. Quantitative evaluation by risk for individual characteristics and their variables for calculating the susceptibility index.

Development of the calculation system. Generation of the assessment matrix.

The basic development of the matrix to determine the index of susceptibility is found in the Leopold matrix (Leopold et al, 1971), relating effects and causes. In this case, instead of relating degradation mechanisms with the origin and evolution of the deterioration a relationship is established between the constructive systems used and their response to possible deterioration.

The matrix is divided into three parts, one for each risk analysed. All the characteristics and specific variants for each case study, as related to their overall degree of influence, are entered into the rows. The level of influence of each specific variant is multiplied by the level of importance of the characteristic, and the result is added to the rest of variables. The result is divided by the number of characteristics catalogued to provide an index in absolute values. This last step is completed taking into consideration that as this is mostly residential vernacular architecture it is not always possible to introduce all the data contemplated in the analysis. Therefore, as a deviation of data could provide irregular and hence erroneous results, the final result is corrected based on the number of data compiled.

In addition, dependent characteristics, which jointly influence the response of the building to a specific risk, were also taken into account. This is the case of the analysis of building typology and the characteristics of adjoining buildings in the event of seismic action, or in the event of flooding, the surface occupied by the number of floors of the building (Stephenson, DÁyala, 2014; AA.VV, 2009).

Therefore, the index of susceptibility for the three risks is calculated as follows:

$$SI_x = \frac{\sum(ch_x \times va_x)}{\sum ch_x}$$

where:

SI_x: susceptibility index by risk

ch_x: level of influence of characteristics by risk

va_x: degree of response offered by a characteristic depending on which variant is in each of the risks.

After applying the calculation system to the case studies we obtained a risk index value for earthquakes, floods and extreme weather conditions. This value provides the level of susceptibility to which it is compared on a five-level scale where the levels of susceptibility are classified as low, medium-low, medium, medium-high and high.

As the relevance of the characteristics is not homogeneous for the different risks the level scale is adapted for each risk considering a hypothetical case with the least favourable sum, and so the level with the highest susceptibility, while the least susceptible is a hypothetical case with the most favourable characteristics. This results in three susceptibility scales based on these ranges, one for each risk.

Cases assessed

After developing the analysis tool the following phase was to use it to evaluate cases. 258 case studies with locations homogeneously distributed throughout the Iberian Peninsula were entered, producing a typological map drawn up in parallel. The case studies were selected based on the main characteristic to be assessed, the main constructive system had to be based on earthen constructive systems: rammed earth, adobe and half-timber.

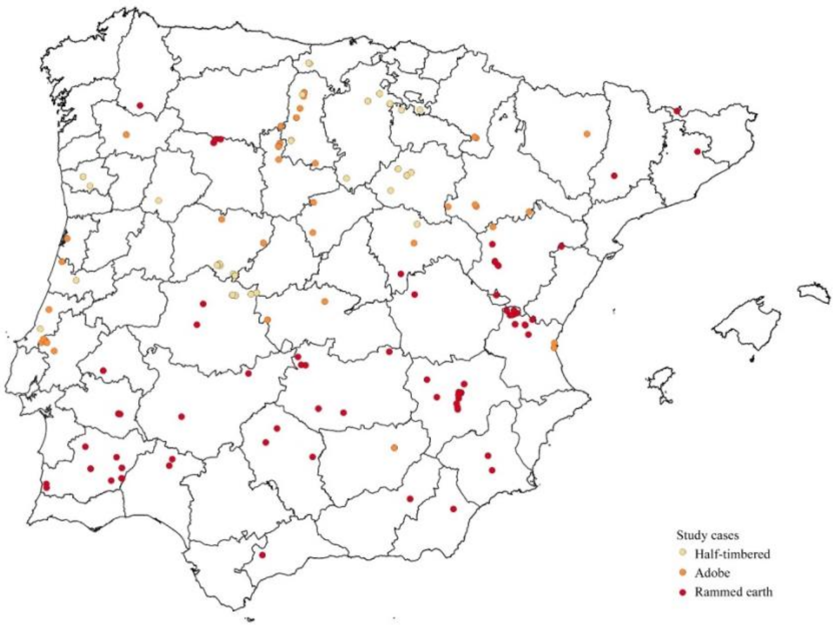

Figure 2. Map of case studies by constructive typology.

Generation of the database –GIS system application

The vulnerability analysis is based on the presence of risk. In order to analyse the vulnerability of the constructions it is necessary to compare the susceptibility index of individual case studies with their geographical position, the characteristics of their surroundings and the risk antecedents. To do so the use of a Geographic Information System (GIS) is used to cross-reference the database of case studies mentioned earlier with the risk maps available.

The bases of the risk maps were obtained, in the case of seismic and flood risk, from the national atlases drawn up by the Instituto Geográfico Nacional Español (20)(21) and the Sistema Nacional de Información de Ambiente SNIAmb de Portugal (22). The seismic risk map corresponds to the assessment of seismic risk considering the maximum acceleration of the terrain and the acceleration of gravity. The flood risk map considered for the analysis was drawn up considering a 100-year return period, as most of the constructions assessed are assumed to have a longer useful life cycle.

The analysis of extreme weather events is more complex as these phenomena differ in origin and characteristics and can be extreme winds, convective phenomena, extreme rainfall, etc.(Rios et al, 2014; Sanz, Galán, 2020). In this case variations in rainfall are considered for the risk assessment, based on the maps provided by the Atlas Climático Ibérico (AA.VV, 2011) and the projected scenarios for climate change (26).

Generation of risk influence and vulnerability analysis maps

Based on the import to the Qgis application (27) of georeferenced data obtained from the analysis matrix in Excel and the geographical risk maps, we can assess the superimposition of the different levels of susceptibility of each case with risk areas.

This superimposition shows the cases found in at risk situations, making it possible to identify their typology as well as using the analysis tool generated to ascertain the extent of any existing vulnerability.

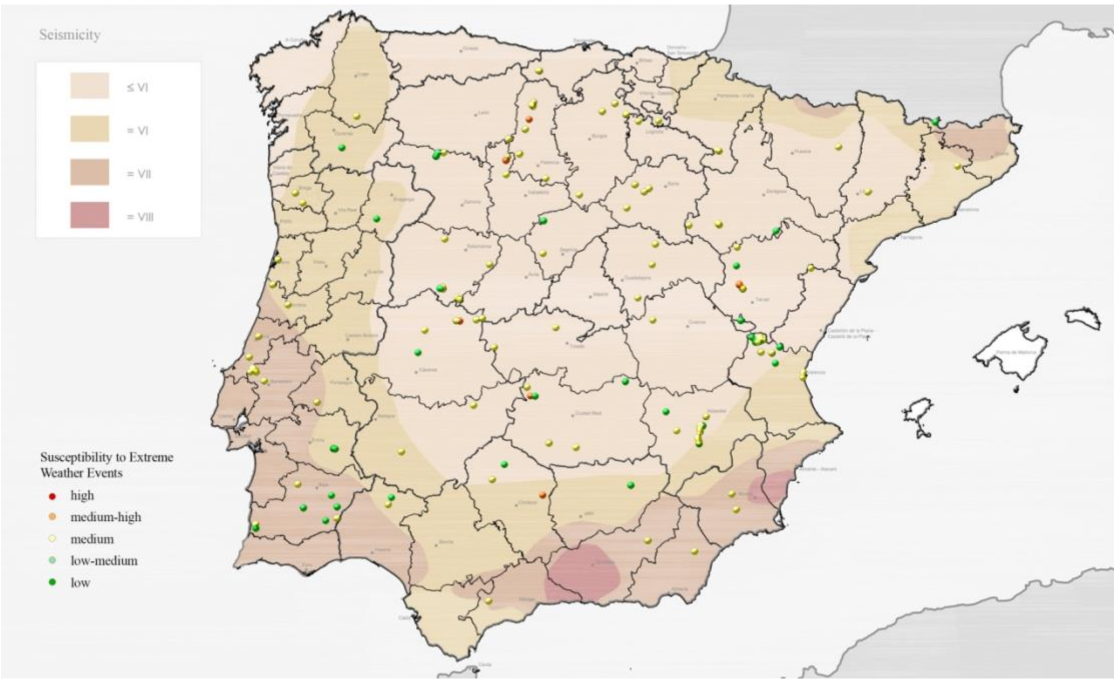

Figure 3. Seismic risk map, intensity analysis, identifying the susceptibility index of case studies. Source: Atlas Nacional de España. Instituto Geográfico Nacional. Ministerio de Fomento and European Seismological Commission.

Figure 4. Risk map for fluvial and marine flooding, identifying the susceptibility index of case studies. Source: Instituto Geográfico Nacional. Atlas Nacional de España.

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Figure 5. Risk map for rainfall intensity (annual mean rainfall (1971-2000), identifying the susceptibility index of case studies. Source: Atlas Climático Ibérico. Atlas Nacional de España. Ministerio de Medio Ambiente y Medio Rural y Marino, Gobierno de España

ANALYSIS OF RESULTS

Typological and constructive analysis

The database used for the analysis consisted of a total of 258 buildings belonging to earthen built vernacular architecture: 46% of cases in rammed earth, 26% in adobe, and 29% in half-timber, while 59% of the total were homogeneous constructions, that is to say, they used the constructive system without supplements or reinforcements in other materials or techniques.

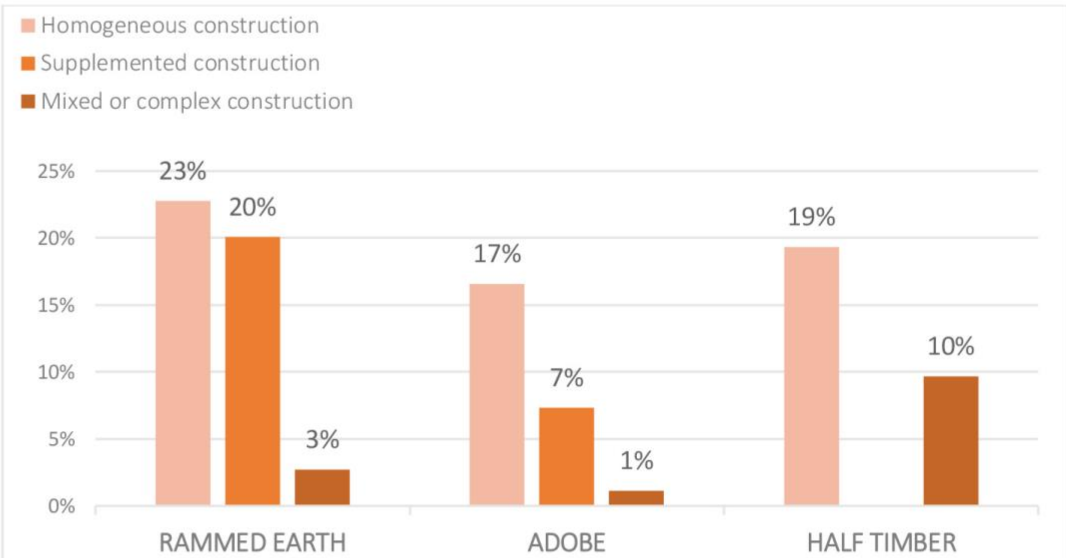

Figure 6. Classification of case studies analysed by constructive technique.

A general analysis of the architectural characteristics clearly shows a predominance of buildings between one and three floors high (96%), with regularly proportioned floor plans, roughly square (83%), built directly on ground level (65%), with very few instances of irregular urban terrain (15%). It is also worth noting how few flat roofs were recorded (2%), and the characteristics of the mostly blind façades, with less than 30% of openings (69%).

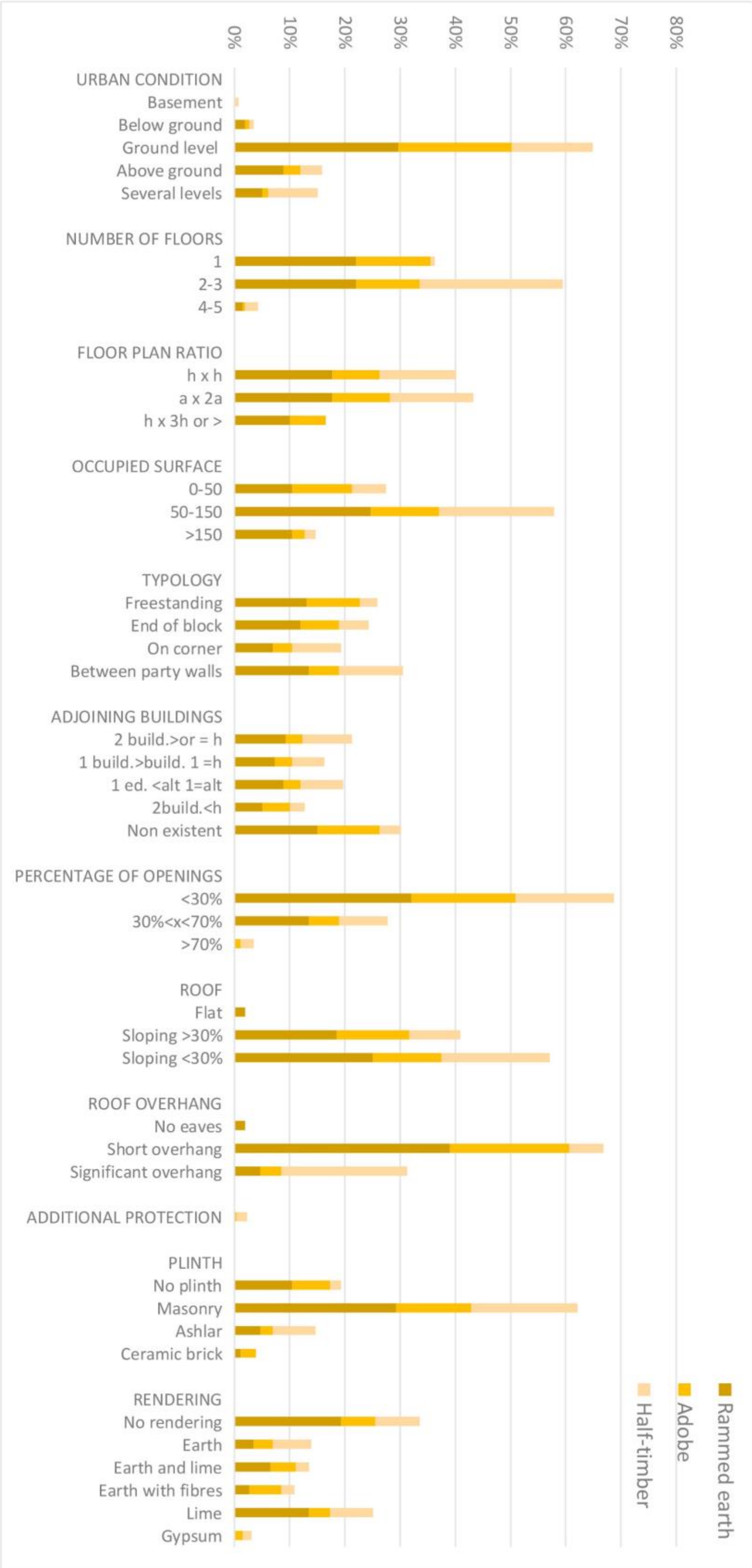

Figure 7. Typological characterization. Analysis of architectural characteristics depending on constructive systems used.

Analysis of the level of susceptibility associated with typology

A specific analysis was carried out of the level of susceptibility associated with the typology for each risk considered. Overall, none of these risks shows a high percentage of cases on the thresholds of maximum risk, while the percentage of cases evaluated with a level of minimum susceptibility is practically zero.

The susceptibility of constructions to vulnerability to seismic action, according to the analysis carried out, is mostly at the low and medium-low thresholds. Most of the cases built with half-timber systems and adobe walls with a medium level of susceptibility and the cases with rammed earth as their main system mostly fall within the categories of medium-low and medium risk.

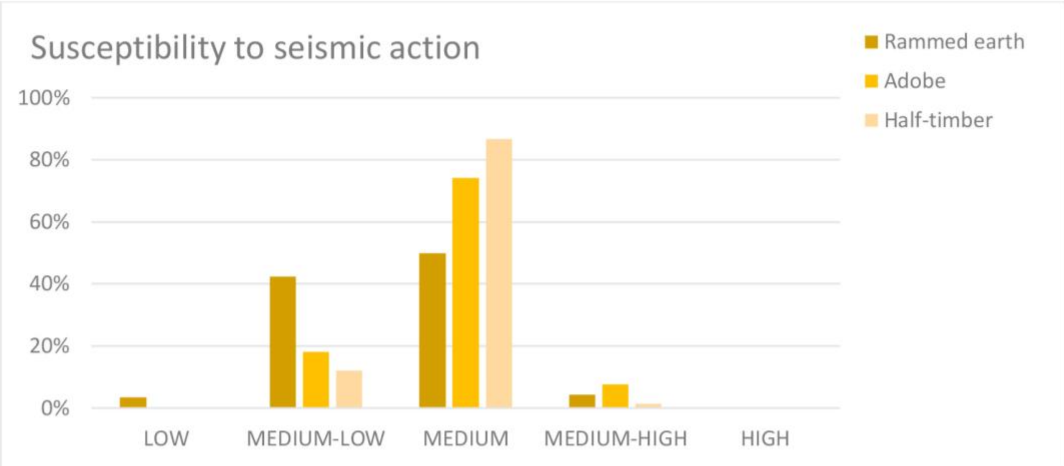

Figure 8. Evaluation of the level of susceptibility in the event of seismic action.

Against the flood risk, the data analysed show that the level of susceptibility for most cases is medium and medium-low, with adobe systems showing the highest percentage with a high level of susceptibility.

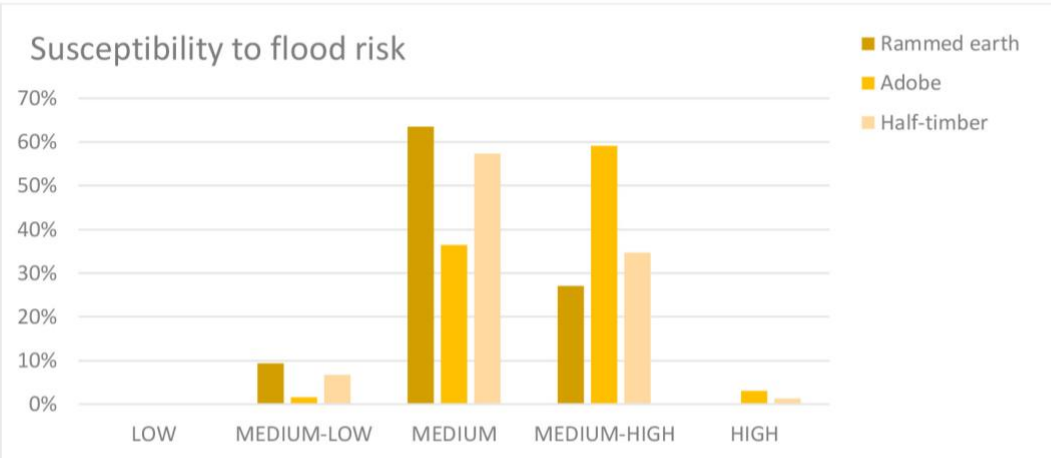

Figure 9. Assessment of the level of susceptibility to flood risk

The results obtained for the risk of intervention in extreme weather conditions are considerably more homogeneous, as over 70% of the cases for the three constructive techniques display a medium level of susceptibility.

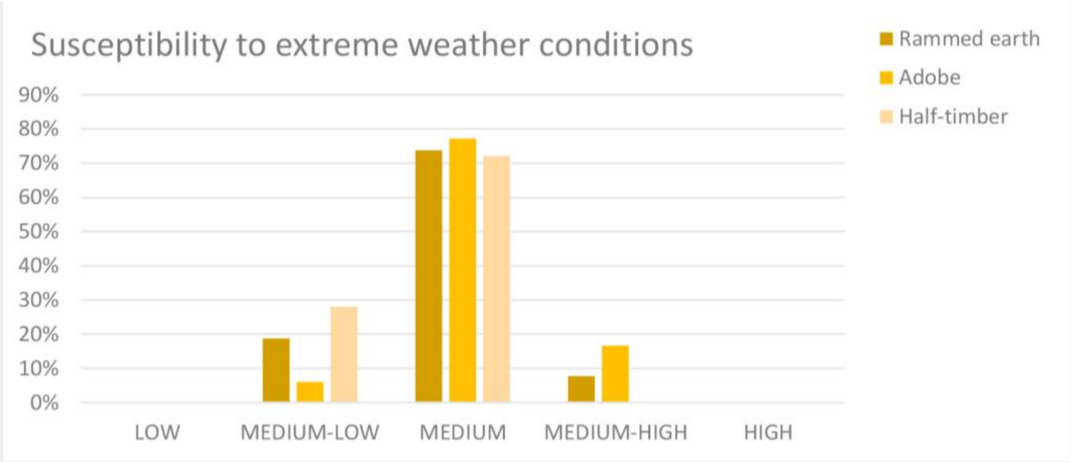

Figure 10. Evaluation of the level of susceptibility to extreme weather conditions.

Comparison of susceptibility and vulnerability

The analysis of vulnerability can be extracted based on the GIS system generated and the superimposition of the cases analysed on the risk maps.

The values of susceptibility are mostly found at a medium level so that it can be stated that architecture generally adapts, insofar as possible, to the risk situations arising in its surroundings.

In a situation of seismic risk it is observed that 70% of cases assessed display a medium-level of susceptibility. However, only 8% of these are in a situation of possible exposure to risk, with a level VII seismic intensity.

The situation is different in possible situations of flood risk. 40% of cases display a medium-high level of susceptibility, while 52% report a medium level of susceptibility. This risk is identified in more specific locations always linked to river and coastal settings, so that the possible surface exposed is smaller. It should be noted that the total surface of the Iberian Peninsula affected by this is considerably smaller than the total surface subject to seismic risk. Therefore, the result with the highest level of general susceptibility is explained by the fact that the susceptible surface is much smaller, and therefore the intervention and need to adapt to this risk is also lower. After the superimposition it can be seen that 2% of cases analysed is at risk, all displaying medium and medium-low vulnerability values.

In terms of the probability of the risk of extreme weather conditions it is also seen that the majority of cases displays a medium level of susceptibility. Analysis of the rainfall intensity shows that the cases defined with the highest levels of susceptibility are in the lower-risk areas.

In view of the typological response of constructions where the number of cases in situations of vulnerability is notably low it is worth noting the resilience of architecture which, in function of the adverse conditions it must face in its life cycle it adopts specific sets of characteristics, which can be clearly seen on typological mappings.

This analysis of constructions should be further expanded taking into consideration its state of conservation and the type of damage or alteration factors which could potentially affect it. This second analysis can help clarify the response, especially as regards constructions in situations of vulnerability following the action of the risk, with a view to establishing the guidelines for intervention for prevention.

CONCLUSION

This research work makes it possible to extract a series of general reflections and avenues of work that should be followed up on in the near future.

The analysis carried out with the methodology proposed shows that in general terms, earthen vernacular architecture, built with the available resources and materials, is gradually adapted with minor variations and adjustments to the specific needs and particularities of each geographical situation. Thus, depending on the case, these variations and adaptations lessen the vulnerability of this architecture to natural risks. Following this analysis, all three risks studied showed only a small percentage of cases (less than 10% in each case) displaying vulnerability. This methodology also includes a second phase of analysis taking into account other factors which influence the level of susceptibility of this architecture to risk, such as the state of conservation of each individual case, given that the response to risk is very different in cases where the structures are well maintained and in good operation, compared to structures with degradation problems and major structural damage, which will almost certainly be more susceptible to these risks.

In addition, the RISK-Terra research Project contemplates other threats affecting earthen architecture (monumental and vernacular), not only natural ones, but also social and anthropic. Social risk is also a major threat to this architecture, socioeconomic factors (depopulation due to migration and lack of employment; development or urban areas; development linked to tourism, etc.) and socio-cultural factors (social discredit, lack of valorization, abandonment due to ways of life, etc.), as well as anthropic threats (neglect, lack of maintenance, lack of protection and cataloguing, etc.), which require a parallel line of research to that presented in this text.

In addition, research is being carried out following three progressive approaches: the territorial scale of the Iberian Peninsula, the intermediate scale of regions, settlements and complexes, and the detailed scale of architecture and the constructive element. The work presented here shows the results obtained in the first scale, the territorial one, which should be contrasted and complemented with the results of the analysis of other scales.

Thus, the cross-referencing of these risks on different scales of approach will provide a general picture of the current vulnerability of this architecture, part of the built heritage of the Iberian Peninsula, at material as well as cultural and ethnographic levels.

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