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PATHOLOGY IN CRUDE EARTH, RESEARCH ON CONSTRUCTIONS IN THE ECUADORIAN ANDEAN AREA

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ABSTRACT

The dynamism of the construction on land in the Ecuadorian Andean area is reflected in the richness of its discrete formal configuration, site materiality and adaptability to a primary rural landscape, where such construction has been affected by the passage of time, atmospheric agents and periodic lack of maintenance.
The investigation tries to catalog some of the constructive pathologies product of the construction on raw earth in the Ecuadorian Andean area, since the land is the constructive element of easy access and employment, its reduced cost of execution and adaptability allows the construction on raw earth to develop in our geography.
The methodology was based on the application of the SVE method (Systematic Visual Evaluation), together with the systematization of the building diagnosis supported by the site visit, technical sheet, graphic schemes and photographs, where the pathologic status of the real state is described with the particularities of the constructive system applied be this adobe, tapial or bahareque; fifty cases of construction located in rural areas of five provinces of the central highlands of Ecuador where studied.
The results allowed to elaborate a pathological pattern of the building, finding causes and effects as a common factor that allowed to generate common typologies and thus elaborate the guidelines for a better intervention as well as the characteristic of the mixture that allows to delay the damages of the buildings.

Key words: Earth construction, constructive pathology, sustainable vernicle architecture.

1. INTRODUCTION

If the land is the economically accessible natural resource, simple to work; it is practically the element to create this reciprocal transfer of ancestral knowledge of constructive systems based on raw earth creating simple housing solutions or bigger constructions. Efficient and dynamic is this type of construction for demonstrating the thermal inertia as well as the natural hygrometric regulation of space solutions, which determines an economic saving in heating in winter and air conditioning in summer, which we could conceptualize as zero ecological footprint. Opposite to what is described will be its deterioration in the face of atmospheric factors such as wind, water, erosion, disintegration and loss of material, or lack of consolidation of its masonry, determining a number of constructive pathologies.

The Brundtland Commission report in 1987 of the World Commission on Environment and Development (WCED) incorporates the terminology sustainability, referring to "development that meets the needs of the present generation, without compromising the ability of future generations to meet their own needs" [1]. (UNESCO, 2003, p.45) and so the land as raw material contributes to the sustainable development of the people, and, construction with this material would solve the housing shortage of the world population [2] (Fontaine, Anger, 2009). The United Nations Land Conference, 1992 in Rio de Janeiro [3], triggers the call for responsibility and conceptualization of sustainable development protected by improving the living, economic and social conditions of the population, in harmony with the future safeguarding of natural heritage, however, the Organization for Economic Cooperation and Development relates to construction based on raw land as the viable sustainable closed cycle alternative [4] (OECD, 2003).

17% of the places on the list of World Heritage Sites are sites of architecture built on land [5] (Grandreau, Delboy, 2012) and about 30% of the world's population lives in houses made from this material as a foundation, masonry or filler material; without forgetting that in our country there is an important heritage built on raw land; the research is carried out in the Andean rural area of the provinces of Pichincha, Cotopaxi, Tungurahua, Chimborazo and Bolivar, where a large number of traditional constructions based on land are evidenced identifying techniques such as adobe, tapial or bahareque; the universe of the sample was determined by the greatest amount of information of the same, as well as of the seventy-four samples, only fifty were processed. These had as a common element constructive, typological, compositional patterns as well as their accessibility to both the taking and to the verbal transmission of the occupant of the property.

From this architecture of improvised needs or architecture without architects [6] (Rudofsky, 1968, p. 58), Ecuadorian geography feeds and affirms that response to the need of refuge for the people; the basic construction material that each geographic region has and the zonal meteorological characteristics; this is how architecture is produced spontaneously by the people based on an ancestral imaginary response to their essential need for refuge; this is evidenced by the traces of progressive growth of vernacular architecture on land that is scattered throughout our territory, in its four regions it is evidenced from constructions such as the adobe "wall by hand, dried in the sun" [7] (UNDP, 1987), tapial "Earthen wall between boards" [8] (UNDP, 1988) and the bahareque "wall with interwoven wood, reeds or canes" [9] (Minke, 2000).

In the Ecuadorian territory, this development is evident by simple access to the raw material input of the construction, generating spatial responses to its worldview, culture, ethnicity and localized resource. Highlight that in our study area, the central highlands of the country, the compositional physical properties of the land; clay, sand and silt [10] (FAO, 2014) in addition to plant fiber allows for better consolidation and vertical load support, the thermal inertia that land masonry possess allows heat and solar rays to fall into the walls of earth are transmitted envelopingly over the perimeter of the space, consolidating thermal comfort. [11] (LARA, 2018).

2. METHODOLOGY

The method to follow in this investigation uses this reciprocal transfer of ancestral knowledge of building systems as the main source of the occupants of the property that was evidenced by being part of the visit to the property; after this, the SVE (Systematic Visual Evaluation) method was used, which requires having a dynamic protocol that starts with the on-site visit of the seventy-four inspections, here the same technical variables described in the file were used where the constructive system is differentiated, the existing pathological process, cause - effect - solution and schemes of affectations; after this, the data collected was systematized, at the time of validating, tabulating and weighing the quality of the specimens it was determined that fifty witnesses met the technical protocols to be weighted; comment that the introspections to the buildings were with NDT trials (Non Destructive Testing) thus avoiding any kind of damage to the building and that the sample part of the study is contaminated.

3. RESULTS AND DISCUSSION

3.1 Study by constructive process

The ancestral constructive knowledge of masonry on land is shown in the fifty samples processed. Figure 1 describes and locates all of them; 18 samples are Adobe-based constructions, 17 Tapial samples and 15 Bahareque samples, displaced in the Andean geography.

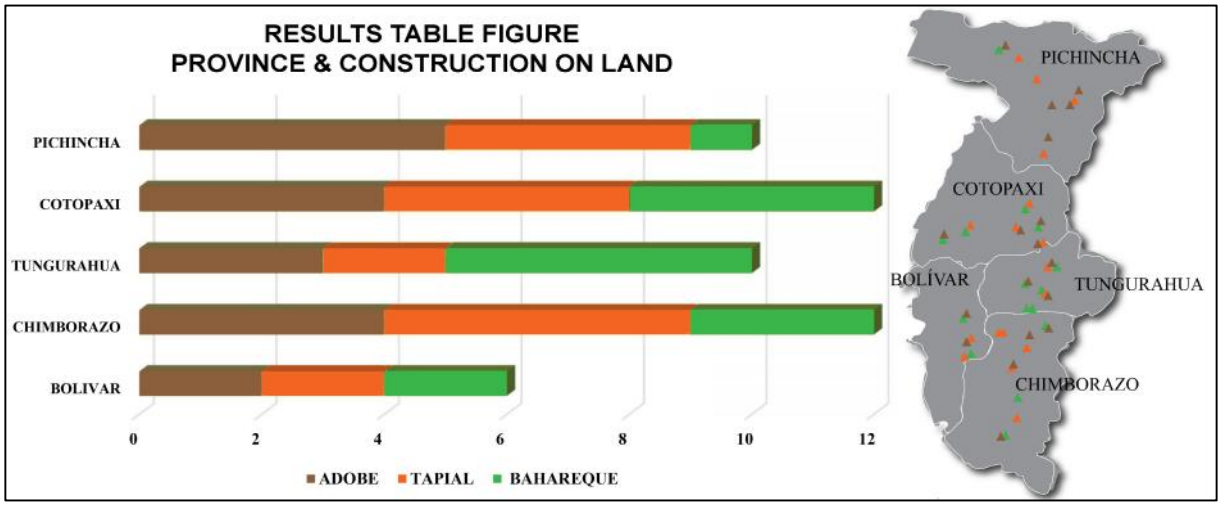

Figure 1: Results table figure Province & Construction on land

The existing geomaterial in the Andean area studied stands out for the diversity of climatic floors and ecosystems: from the foothills of the western plain, Andean moors - glaciers and Amazonian river plains; however this is the basis of any of these three constructive applications in raw earth, the constant of the elements is its composition and balance that in addition to clay, sand, silts, are the fibrous organic materials accessible from the area that in its vast majority are reduced to straw or animal manure, and natural binders such as "substances such as blood, sugar, milk casein and even egg albumin" [12] (CABRERA, 2000); take into account that these earth masonry used as cladding or thin surface plasters "chocoto" or lime, this last one as a formal induction of the Hispanic conquest that chose to "whitewash the interior and exterior walls of the houses" [13] (BOADA et al. 1993).

The variation of the technique allowed the research to be nourished by this empirical knowledge, so it puts it at a crossroads: I don't know if it was the construction per se first, that Darío Donoso's definition of adobe “mass of mud that was usually mixed with cut straw, molded in the form of brick, of a wooden mold, air dried ”[14] by the evidence in situ studied; rescue the transition of the collaborative construction process “co-housing architecture” [15] (JARVIS, 2015) that is more evident with the

construction with tapial “each of the pieces of wall built at once based on kneaded and rammed earth between two tapestries Walls built based on these pieces or wall"[16] (PANIAGUA, 2005), where it forced the community work to be an important part of the individual and collective growth of the community; or beyond where the bahareque solved that spatial division between interior and exterior with its “frames or walls of carpentry with right feet, souls, virotillos, etc. Filling the gaps that remains of bricks locked with mixture or plaster. ” [17] (MALDONADO Y VELA, 2002)

3.2 Study case by pathological process

Of the fifty tabulated samples, the results of the investigation determined that 82% encounter a degenerative pathological process, where physical pathologies are the most frequent lesions with 50% of the sampling, and the capillary moisture produces the greater involvement in buildings with 27% of the entire universe studied, this is described in Figure 2.

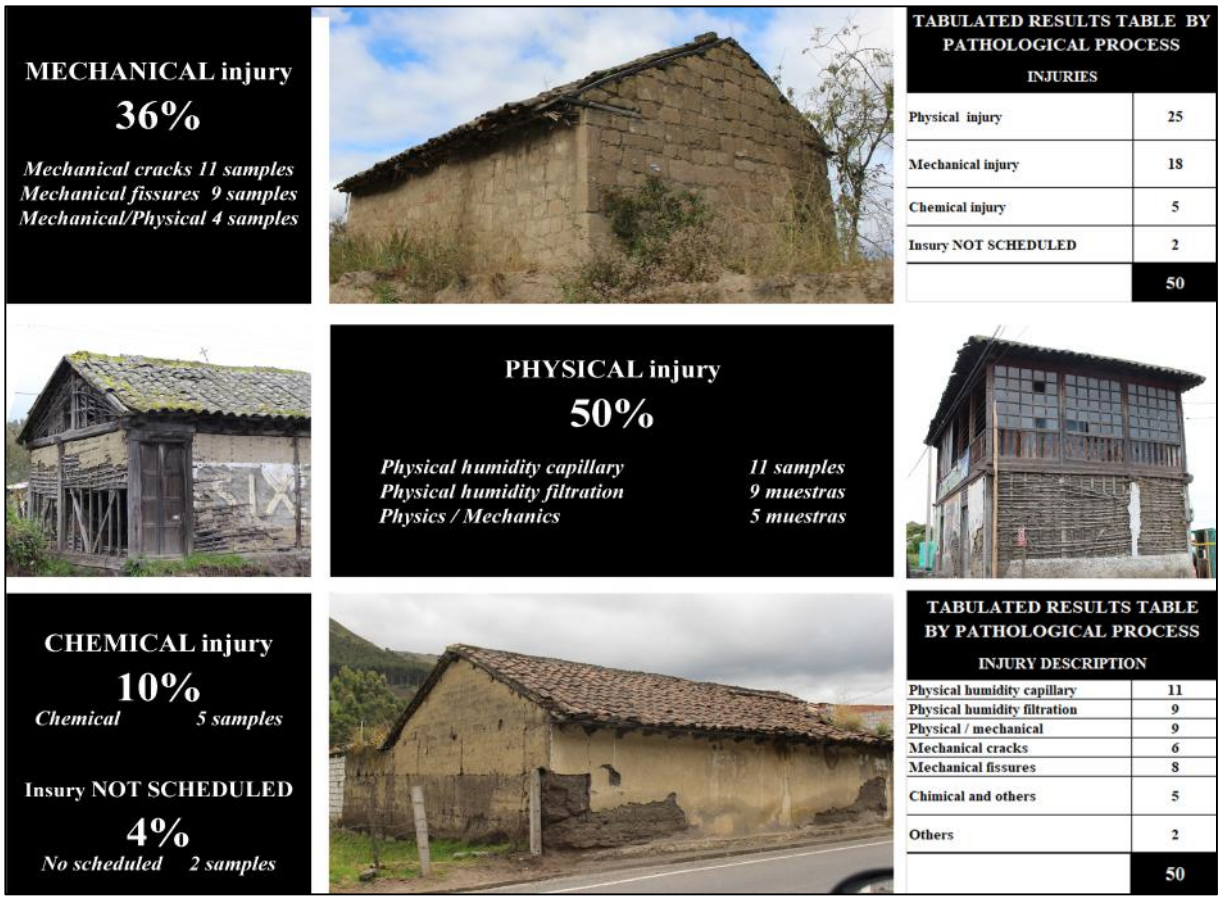

Figure 2: Results of the Pathological Process in the case studies

The constant physical injuries that were evidenced in the buildings studied were in a higher percentage the humidity by capillarity and humidity by filtration, with respect to the capillarity we can note that the lack of conception in the integral design that allows them to isolate the housing of its adjoining as orchards and crops would avoid capillarity in the lower stone chains and saturation or excess water in the lower parts of the walls. Poorly sized eaves or lack thereof force that the upper sills of the walls are exposed to leaks, constant splashes and that initial consolidation of the wall is lost, and a process of sequential erosion begins as a result of the “wetting of plasters by effects of rain and abrupt drying by thermal variation” [18] (MALDONADO Y VELA, 1999) causing the separation of the building element from earth.

Regarding the most frequent mechanical pathologies, there is the settlement of the land due to the lack of leveling and compaction of the same at the beginning of the construction, which added to this there is a random distribution of the full and empty spaces that weakens the monolithic consolidation of the earthworks [19] (ANDRADE, 1996), forcing the appearance of cracks and fissures that on a greater or lesser scale will separate the material and vary the structural composition of the walls; without forgetting that the construction on land has great resistance to compression but little resistance to traction, cutting and bending; and, that it has little surface resistance and that any impact deteriorates it and is evidenced as erosion.

Regarding the most common chemical pathologies on the studied buildings, there is the presence of microorganisms and xylophages that attack the elements of wood or organic fibers, breaking up and separating the construction element, without taking into account that the binders that were most used in this transfer Ancestral construction knowledge was limited to farm animal manure or the aforementioned paragraphs.

3.2 Analysis and results of the sample

Sampling for physical, mechanical and chemical characterization was carried out in the fragments of soil masonry using methodologically NDT (Non Destructive Testing) tests, those sample fragments averaged 13.46gr., more information is clarified in Figure 3; it will be necessary to consider that the total of the fifty tabulated samples were not processed but there was a selection of the raw material of the specimens by constructive system that was analyzed in the laboratory besides than the limitation of the cost of the laboratory for its election.

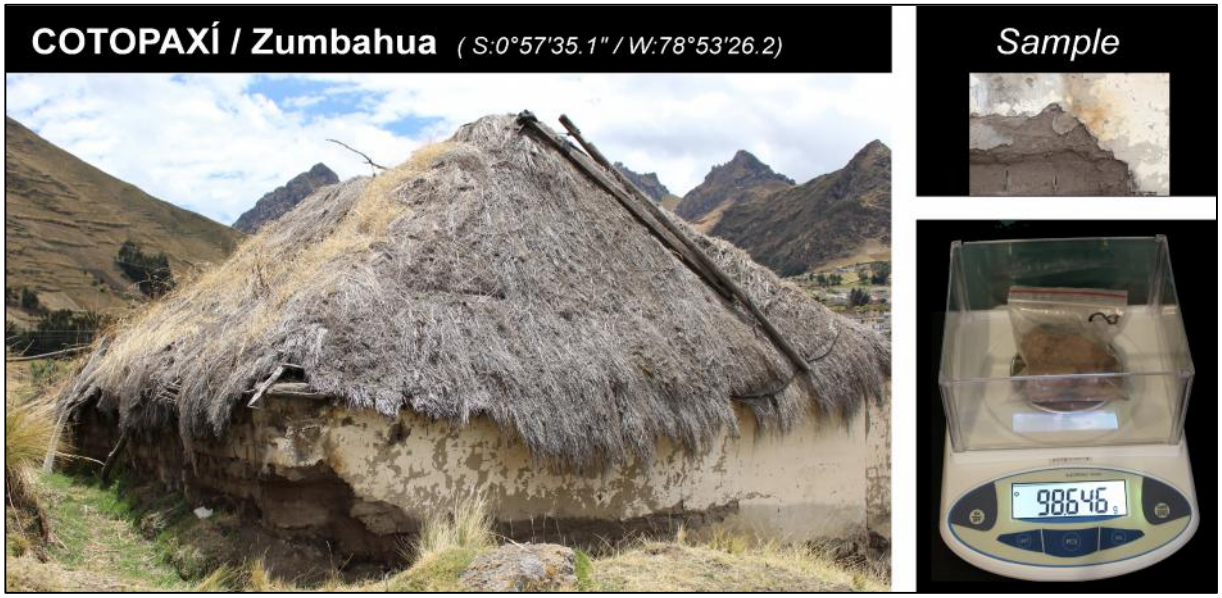

Figure 3: Samples and analysis results

Respecting the protocols established for the main results (average) of the physical characteristics of the analyzed samples, they determined their granulometric composition, specific weight, moisture content, breaking limits - resistance and the organic material in its composition. The mechanical compression tests of the fragments prepared in sheet of the unaltered samples as evidenced in Table 1. With respect to chemical tests, the objective was the determination of the chemical elements existing in the samples and their structure material; an atomic absorption spectrophotometry method was used. [20] (CELY, 2001).

Table 1: Characteristics of the analyzed samples

PHYSICAL CHARACTERISTICS		TABULATED RESULTS OF SAMPLES		
		ADOBE	TAPIAL	BAHAREQUE
Moisture content		3,35%	3,35%	3,25%
Organic material content		4,75%	4,69%	5,51%
Specific weight		Physical characteristics	14,89 gr	8,97 gr
Ph		5.5	5.6	5,5
Consistency limit	LL *(Liquid limit)*	45,51%	41,98%	34,18%
	LP *(Plastic limit)*	26,26%	25,33%	18,51%
	IP (Plastic index)	18,95%	19,26%	18,26%
Granolumetric Composition	Gravel	11,15%	10,89%	7,03%
	Clays	18,47%	17,96%	49,97%
	Slime	73,12%	72,05%	45,45%
Soil composition	SUCS (Unified Soil Classification System)	CL - Organic Clays and Limosas Clays of low plasticity	CL - Organic Clays and Limosas Clays of low plasticity	CL - Inorganic clays of low to medium plasticity, silty clays and lean clays
	AASHTO (American Associattion of State Highway Officials)	A-6 Clay floor	A-5 Muddy soil	A-2-7 Clay silt sand

MECHANICAL CHARACTERISTICS	TABULATED RESULTS OF SAMPLES		
	ADOBE	TAPIAL	BAHAREQUE
Simple compressive strength	3,04 Mpa	2,27 Mpa	2,08 Mpa
Flexural Strength - Breaking Module	0,41 Mpa	Fragment	Fragment

CHEMICAL CHARACTERISTICS		TABULATED RESULTS OF SAMPLES		
		ADOBE	TAPIAL	BAHAREQUE
Composition by chemical element	Al - Aluminum	15,88%	13,56%	17,52%
	Ca - Calcium	2,55%	3,03%	4,26%
	Fe - Iron	4,75%	5,12%	3,95%
	K - Potassium	2,83%	6,84%	4,12%
	Mg - Magnesium	2,10%	3,66%	2,89%
	Na - Sodium	0,57%	0,84%	1,02%
	Si - Silicon	65,90%	63,15%	74,01%

4. CONCLUSIONS

A good intervention begins when all the documented arguments of the raw earth architecture that we are going to study are gathered, starting from the location to the particularities of the building, without forgetting to establish a program of periodic maintenance of the built building. [21] (LARA, 2018)

The Ecuadorian construction code does not analyze the peculiarities of construction on land, and cites the Chilean Standard, which considers construction on land and establishes criteria that maintain and increase structural capacity with the sole objective of resisting the forces of static and seismic design of these structures. [22] (INN NCh 3332, 2013)

The physical determinations of the samples determined that the levels of natural humidity are low, more than possible due to the type of unalterable sample used by the study, as well as the historical chronology of when the building was constructed and the atmospheric and erosion factors characteristic of area.

The samples studied show that the composition of fine soils and organic elements is superior to the data indicated by the sources of consultation and documentation of ancestral techniques, keeping in the acceptable ranges for consolidation of the evaluated piece.

La naturaleza química de las muestras determina un contenido predominante de aluminio y sílice, los demás elementos como el calcio, hierro, potasio, magnesio y sodio ocupan índices permisibles de la muestra, destacar que estos son elementos químicos propios de la naturaleza geológica de la muestra, no existe análisis alguno de ensayos sobre construcciones en tierra para hacer comparaciones o generar patrones.

The chemical nature of the samples determines a predominant content of aluminum and silica, the other elements such as calcium, iron, potassium, magnesium and sodium occupy allowable indices of the sample, note that these are chemical elements of the geological nature of the sample , there is no analysis of tests on land construction to make comparisons or generate patterns.

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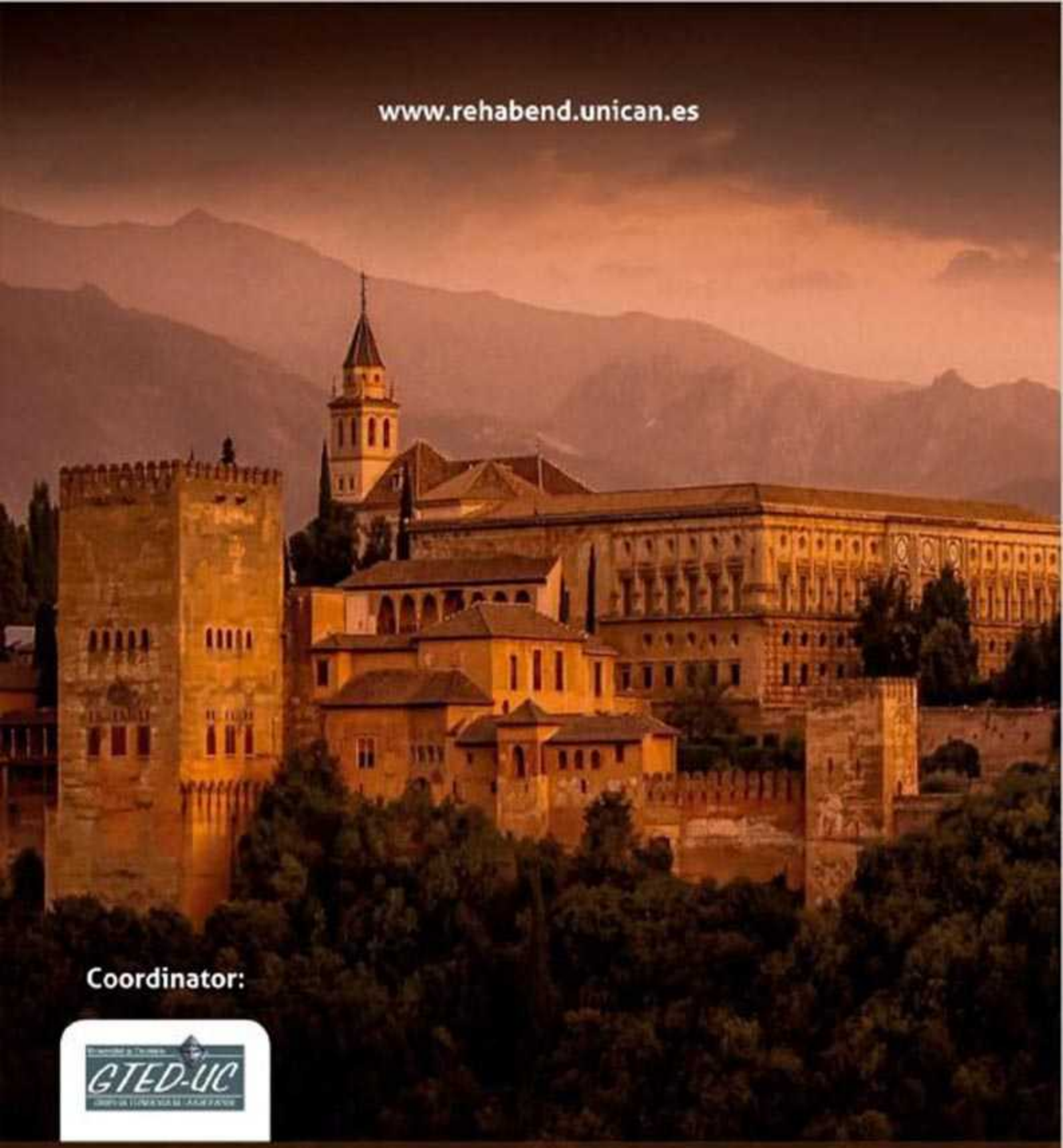

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