

Vernacular Architecture of the San Pedro de Atacama's Ayllu as a Facilitating Mechanism for Sustainable Development in Chile.

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Abstract - The main objective of this study is to explore how the construction of adobe and the Ayllú can be a facilitating mechanism for environmental protection, sustainability and development. The Ayllú de San Pedro de Atacama has been selected as a case study, because: (1) it is a territory with unique vernacular architecture, made up of adobe construction, (2) it has an ancestral tradition in adobe construction, (3) its construction typology is part of its material heritage and is used as a tourist resource, (4) it is located in one of the driest deserts in the world, (5) its adobe construction has allowed to safeguard its identity, sustainability and development community. The methodology is carried out, through a constructive analysis of an Ayllu, together with the analysis of 6 interviews carried out by the Pangea Foundation with key actors to explore the link with environmental protection, sustainability and development, together with a mapping of where The main Ayllu in San Pedro are located and analyze the heritage tourist offer in this regard. It is concluded that adobe construction can be a facilitating mechanism for environmental protection, sustainability and development, as is observed in the case of San Pedro de Atacama.

Keywords: Ayllu, Adobe, SDG 11 y 13, Environmental Sustainability and Development, Environmental protection, San Pedro de Atacama

1. Introduction

To the north of Chile is the city of San Pedro de Atacama, located in Region II-Antofagasta on a high plateau of the Andes mountain range. It is the driest desert area in the world, it has significant variations in temperature, strong winds and high solar radiation [1].

It is a colonial town with narrow streets and houses built in adobe and cactus wood, they stand out both for their architectural value and for their proximity to the archaeological remains and also for their sustainable nature [2].

Since 9,000 BC the link between inhabitants and location has been latent, the occupation of the land is closely linked to the presence of water masses and plant resources throughout the territory, around 200 BC more numerous settlements began to appear where they begin to install adobe houses [3]

San Pedro de Atacama is made up of fourteen ayllus, among them: Coyo, Tulor, Catarpe, Solor and Tambillo. Ayllu is the name by which each family group is designated in an indigenous community of San Pedro de Atacama, it corresponds to an ancestral form of family distribution in agricultural lands and irrigation channels, the production of the Ayllu is wheat, corn, vegetables or fruit trees, however, the largest production is alfalfa, destined for sheep, llamas, horses or donkeys.

Not only the ayllu organization system is identity, but also the construction of their homes in adobe or mud, both clay materials that facilitate environmental protection and sustainable development due to their low impact.



Fig. 1: Location map, comunne of San pedro de Atacama, Own elaboration

2. Theoretical Framework

Ayllu is the name by which each family group is designated in an indigenous community of San Pedro de Atacama, it corresponds to an ancestral form of family distribution in agricultural lands and irrigation channels, the production of the Ayllu is wheat, corn, vegetables or fruit trees, however, the largest production is alfalfa, destined for sheep, llamas, horses or donkeys. San Pedro de Atacama is made up of fourteen ayllus [4], Conde Duque, Yaye, Sequitor, Larache, Solcor, Solor, Cucuter, Beter. Poconche, Coyo, Tulor, Quitar, Catarpe and Tambillo.

Wood and earth are still materials used in construction in northern Chile, both considered sustainable due to their low environmental impact. The adobe, are blocks of earth, specifically a mass of mud with clay and sand sometimes mixed with straw [5]. It is a material that was used in almost all ancient cultures not only for housing, but also for public structures. In San Pedro de Atacama, it is present mainly, due to the energetic properties of this material: they have low thermal conductivity and the heat storage capacity is high, the ability to absorb or reject solar radiation is interesting due to the different colors that have [6], so that, in terms of comfort sensation, the oscillations of the internal temperature and time delay are reduced during the day and there is heat return at night.

Make cities and human settlements inclusive, safe, resilient and sustainable; and promoting sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all are part of the objectives of the United Nations Department of Economic and Social Affairs (SDG). Human settlements appropriate land in different ways, they evolve, transform, adapt, innovate and change according to new demands, this is closely related to factors such as physical and social changes. Compact cities have been shown to use land more efficiently and are better located to provide public goods and basic services at lower cost [7]

Goal 11 focuses on improving the safety and sustainability of cities, which implies guaranteeing access to safe and affordable housing, in addition to improving marginal settlements. It also includes making investments in public transportation, creating green areas and improving urban planning in a way that is productive. To do this, a series of indicators are used, distinguished in point 11.3.2, Proportion of cities that have a structure of direct participation by civil society in urban planning and management and that function regularly and democratically.

Objective 13 establishes "Climate Action" and seeks to provide support to vulnerable regions through actions that go hand in hand with efforts aimed at integrating disaster risk reduction measures into the policies and strategies of the nation.

Environmental sustainability ensures that the depletion of natural resources is avoided to maintain an ecological balance while meeting needs [8]. In the case of San Pedro de Atacama, SDG objectives 11 and 13 are present from the

point of view of housing and construction materials. The use of adobe acts as a facilitator of environmental protection and sustainable development in response to a close relationship between man and the environment, materialized by earth, stone, tar, straw, and chañar and carob wood. Currently, the increase in tourism in the area, added to the absence of regulations that defend the constructive identity of the community, has generated the emergence of new constructions that threaten the heritage of the area. The Navea Family house [9], of the Ayllu Solocor, is located south of the Plaza de San Pedro de Atacama and was built with the adobe technique with blocks of 0.5x0.3x0.1 meters with a wall thickness of 50 centimeters, a reflection of how the surrounding materials can be used at the home level and promoting environmental sustainability, on the other hand and on a macro scale, the Moroccan Pavilion stands out at Expo 2020 in Dubai [10], with 4000m² of rammed earth, Although it is a contemporary work, it acts as a promoter of construction heritage.

Adobe from a sustainable perspective, associated with green architecture, is not exclusive to the northern part of Chile, reaching even beyond the Andean highlands. Examples such as Zethé and Sabina Grande [11], located north and east of Huichapan, Mexico, respectively, are abundant. Both are archaeological sites characterized by semi-arid climates, where adobe has been taken as the main material for the construction of houses for years by the indigenous peoples of the sector, understanding that its use is presented as a viable alternative to the need for housing, through self-construction. Another example would be the town of Renedo de Valdavia [11], belonging to a dry region of Spain where the block of mud is worked with straw as a construction material.

In addition to adobe, the importance of the figure of the community as part of the approach to sustainable development, especially considering existing indigenous communities, also becomes relevant as a factor and actor in the process. In this sense, projects such as Mu Hu Yapu, which means Abundant Seed in the Kunza language [12], where an Atacameño community builds a greenhouse with state funding, demonstrate the importance of working together with the communities not only for their knowledge, but also for the promotion of these, given the clear relationship with the environment and its understanding that ultimately translates into a sustainable way of approaching and working with it, strengthening environmental management and citizen participation within sustainable development processes.

3. Methodology

The research will be carried out mainly through the analysis of secondary sources such as texts and public access interviews carried out by authors related to the study area, mainly from the Pangea Foundation. In addition, support material will be used as constructive analysis of the architecture of the area and the climatic behaviour of the Atacama Desert as a macro area to work on, both with the intention of characterising the vernacular architecture of the place associated with the driest desert in the world. Given that this architectural typology does not belong only to the north of Chile, but to the entire Andean Altiplano area, the research will also be based on studies carried out in similar contexts such as Bolivia.

In the first place, bioclimatic architecture, sustainable development and environmental protection must be defined in relation to vernacular architecture, after characterising it. In this sense, it will be analysed from a descriptive perspective regarding its relationship with its environment, and from a physical perspective, constructively understanding spatial and material decisions in relation to climatic conditions, thermal comfort and habitability.

Understanding the role of ancestral knowledge in the consolidation of this type of architecture, which is reflected in the understanding of a geographic context and how it is responded to given its hostility, the constructive analysis will be complemented with a climatological analysis through the use of software. Computational companies such as AndrewMarsh, to support the relationship between what has been built and its environment to establish it as a model for sustainable development and environmental protection.

Thus, the vernacular architecture of San Pedro de Atacama is proposed as a mechanism to establish models of environmental protection and sustainable development, having adobe as a distinguished material.

4. Results

The urban development of San Pedro de Atacama has always been subject to its geographical and climatic conditions, closely related to the Atacama Desert near the mountain range, which implies dry climates, with low rates of relative humidity, except in cultivated areas and valleys. that allow the entry of humid coastal air. [13] According to the Koppen classification, SPA is classified as a cold arid climate (BWk) [14] having an average annual temperature below 18 ° C. The greatest amount of water falls in the summer months, with drought being one of the main problems in the area in terms of habitability and quality of life. SPA is an oasis within this desert, which allows its development as a settlement.

As part of the Andean Altiplano, it has a cultural wealth from the hand of the native peoples associated with the territory and its history. In this sense, today about 50% of the population of San Pedro de Atacama identifies as part of some original people, mainly Atacameños and Quechuas [2]. Thus, given their legacy and associated vestiges, the town is recognized today as the archaeological capital of Chile.

The constant presence of the desert and its landscape, plus the close relationship with the native peoples that inhabit the place, have transformed the town into one of the most coveted tourist destinations in the country, placing it as a focus of development both locally and nationally, a factor that today conditions this process and becomes part of the dynamics of SPA itself.

Understanding the indigenous bases and their permanence in the territory, today the organisation model of the place is based on the Ayllus, or extended family in Quechua. Thus, the land, mainly agricultural, and the irrigation channels associated with it, which are of utmost importance given the general water shortage in the sector, remain under the administration of family organisations generally associated with a current indigenous community [9]. The organisational model also goes hand in hand with a clear understanding of the territory, which is passed from generation to generation to respond in a good way to the needs and demands of inhabiting the desert. One of the answers is the consolidation of a vernacular architecture capable of responding to the habitability needs that temperatures and humidity conditions imply.

This architecture takes the earth as its main material, through the use of adobe or mud, also mixing stone, tar, straw and woods such as chañar and carob [9], all local materials that were adapted to generate a way of living. Thus, the vernacular house of San Pedro is organised through a patio that articulates the interior spaces of the home as the centre of the house. In addition, it usually has vegetation to create an interior microclimate with a certain level of humidity, protected from the wind and with plenty of shade. These types of houses are usually built several centimetres below ground level, some even being staggered, in order to lower the interior temperature. The thickness of the walls allows them to absorb the high temperatures of the day to expel them by convection once it is finished, and thus heat the home on cold desert nights. [15]

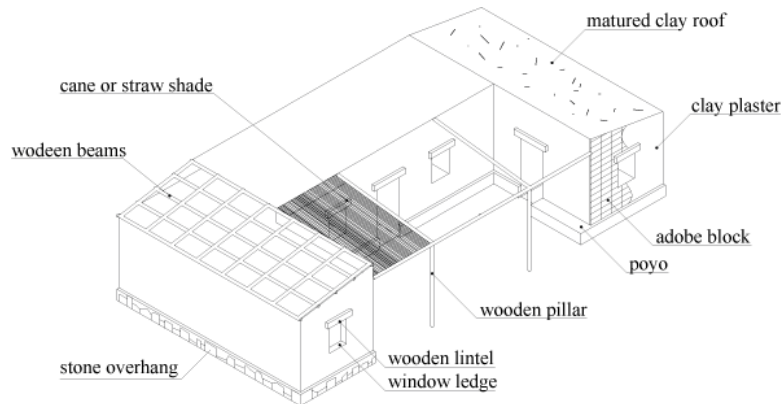


Fig 2: Building material and configuration of an ayllú, own elaboration

For the analysis of passive heating techniques, Calama is chosen as the reference city, since (a) is the closest city to San Pedro de Atacama and (b) have the same Koppen classification of cold arid desert climate (BWk). According to the climatic analysis we are shown that the temperatures oscillate between 5 and 30 degrees Celsius throughout the year. For these values, the Giovanni climate diagram is used, which introduces as a variable the effect of the building itself on the internal environment, the building is interposed between the exterior and interior conditions, proposing passive techniques for its conditioning. According to this table, in the case of SPA, the passive techniques to be used should be mainly those of passive solar heating and internal gain when the climate is not within a comfort range.

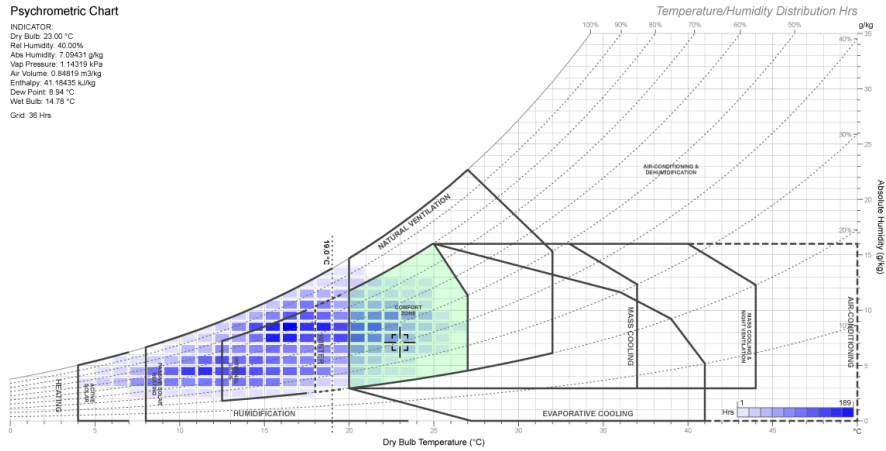


Fig. 3: Givoni chart for passive heating techniques of Calama [16]

From the analysis of the coldest and hottest day of the year 2018 in Calama, we can conclude that the lowest temperatures and with the highest relative humidity fall at night between 01:00 AM and 05:00 AM, while the highest temperatures and with lower relative humidity they occur in the afternoons between 1:00 PM and 5:00 PM.

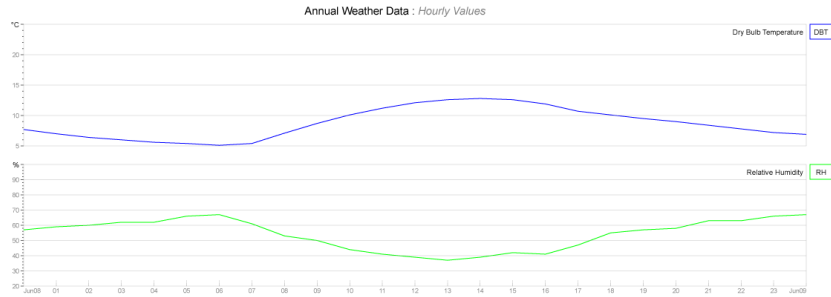


Fig. 4: Temperature and Relative Humidity in Calama 11th of June 2018 [17]

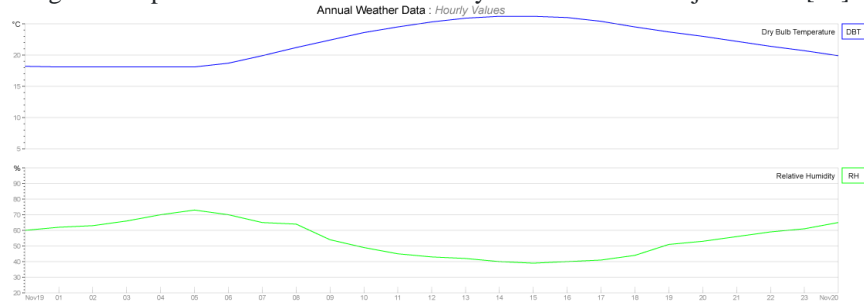


Fig. 5: Temperature and Relative Humidity in Calama November 19th 2018 [17]

To characterise the thermal profile of the Atacama ayllu, the U-value of the walls must be considered and compared with the construction standards to seek compliance. [18]

Although according to the thermal zoning proposal by the regulatory plan, SPA has a flexible minimum thermal transmittance (U) of $3.0 \text{ W / m}^2 \text{ K}$ while the ceilings one of $0.6 \text{ W / m}^2 \text{ K}$. [19] The low thermal conductivity of brick and adobe whose values are 0.45 and 0.80 W / mK respectively, on a summer day these values can vary from 0.2 to 0.16 W / mK , variation in the temperature gradient that contributes directly to heat flow through the wall. [20]. The large thermal mass allows the external temperature cycle to be smoothed so that relatively small internal temperature fluctuations are observed. [20] With this, SPA adobe houses allow adequate thermal comfort. Thanks to its low transmittance, we maintain a cool environment during the day thanks to the fact that it does not allow the direct transfer of desert temperatures and a warm environment at night, since part of the heat of the day is retained in the adobe.

The exposed architectural character adds to the tourist attractions of SPA from the point of view of the object, as a resource. In this sense, thinking about the development of the sector, the role of tourism activity is recognized to enhance

these processes from both cultural and economic perspectives, but also recognizes a duality regarding its implementation. On the one hand, tourism attracts investment that in the long run allows local development due to the economic benefits and visibility abroad, but on the other hand, its implementation without a regulatory model begins to dent the cultural dynamics of the sector, which is reflected in constructions outside the vernacular typology that do not respect the global image of the people, programmatic implementations that do not consider desert conditions, therefore respond to these with invasive external agents and mainly acculturation processes on the part of indigenous peoples given the influence of external entities and the lack of a sustainable development model with cultural perspectives that helps to promote its heritage [2].

In this sense, and understanding that tourism as a factor can no longer be eradicated from the town, it is necessary to establish a sustainable development model based on this that allows promoting the associated cultural heritage without predating, and without going any further, the potentiality of this for SPA hand in hand with vernacular architecture, given the reasons exposed, mainly climatic. Said model would take the ancestral knowledge and the human-geography relationship, which finally translates into an understanding of the territory, to take them to the field of tourism, not as a resource to be exploited, but as raw material. In a way, the establishment of the vernacular is proposed as a constructive typology to develop tourism, where hostels, bars and shops, nowadays alien to this model, are inserted in it as part of its attractiveness. Thus, not only does it respond to a geographical context that may be hostile due to its weather conditions, but also tourism and heritage are considered from a symbiotic relationship that serves to develop economic activity but at the same time promotes the knowledge of the sector, also influencing in the dynamics of the indigenous peoples of the sector, given their role as carriers of knowledge, therefore they become key pieces for their development since the consolidation of these constructive models at present and their promotion as knowledge towards the future.

5. Conclusion

From this characterization of the Atacameño ayllu we can say that the construction in mud and adobe configures a unique ancestral knowledge and tradition, born as the response of an ancient community to an arid context that located them. This vernacular way of doing architecture draws the attention of technicians and professionals when responding from their ancient heritage to energy problems that afflict our current technological society. However, it is essential to develop measures for the conservation and respect for the communities that make up SPA, transcending material logics in order to protect worldviews related to the indigenous communities of the environment. According to objective 11 of the SDG, the inclusiveness, security, resilience and sustainability of human settlements are pursued, to which phenomena such as globalization and deregulated tourism can cause the loss or dilution of an exposed culture.

The conscious development of the adobe technique within today's society, gives architecture a field of sustainable construction, with zero emissions and with materials extracted from the same environment. Along with this, the physical properties of the material make it possible to dispense with active heating or insulation techniques, representing significant energy savings in the event that this type of architecture becomes overcrowded.

References

- [1] REPORTE ANUAL DE LA EVOLUCIÓN DEL CLIMA EN CHILE, en línea.
- [2] Ilustre Municipalidad de San Pedro de Atacama 2017 *Plan de Desarrollo Comunal*
- [3] L Núñez, *The Nature of Village expansion during the late formative period in the Atacama Basin*, 1992
- [4] Portal turístico de San Pedro de Atacama Chile, *Ayllu* en línea [Último acceso: 07-01-2022] <https://www.sanpedrochile.com/activity/ayllus/>
- [5] B Aguilar, *Construir con adobe: fundamentos, reparación de daños y diseño contemporáneo*, 2008
- [6] M Palme, J Guerra, S Alfaro *Earth of the Andes Comparing techniques and materials used in houses in San Pedro de Atacama*. 2012
- [7] ONU-Hábitat, Indicador ODS 11.3.1 *Módulo de capacitación: Eficiencia del uso de la tierra. Programa de las Naciones Unidas para el Asentamiento Humano (ONU-Hábitat)*, Nairobi. 2019
- [8] Agliardi E, Agliardi R, *Financing environmentally-sustainable projects with green bonds*, 2018
- [9] Serrano M, *Levantamiento Arquitectónico y la Cultura Constructiva de la Arquitectura Vernácula*. 2017
- [10] D. Stouhi, *4000 m2 de tierra apisonada: El Pabellón de Marruecos para la Expo 2020 Dubai* [Último acceso: 07-01-2022] <https://www.plataformaarquitectura.cl/cl/965607/4000-m2-de-tierra-apisonada-el-pabellon-de-marruecos-para-la-expo-2020-dubai>

- [11] Gómez F, Mileto C, Vegas F, García L. *Procesos patológicos en muros de adobe: panorama general de los mecanismos de degradación del adobe en la arquitectura tradicional española*". En: *Arquitectura en tierra. Historia y Renovación*. Congreso de arquitectura en tierra en Cuenca y Villagarcía de Campos. Universidad de Valladolid. 2016. Pp. 169-180
- [12] Ministerio del Medio Ambiente *Desde San Pedro de Atacama Subsecretario del Medio Ambiente invita a la ciudadanía a postular al Fondo de Protección Ambiental 2022*
- [13] C. Juliá *Características Climáticas de la Región de Atacama* 2008
- [14] Climate-Data, Retrieved from <https://es.climate-data.org/america-del-sur/chile/ii-region-de-antofagasta/san-pedro-de-atacama-21732/>, 2022
- [15] J Salinas *Arquitectura del Desierto: Revalorización de la arquitectura autóctona del norte de Chile desde un análisis climático*. 2009
- [16] A. Marsh, *Psychometric Chart* <http://andrewmarsh.com/software/psychro-chart-web/>
- [17] A. Marsh, *Data View 2D* <http://andrewmarsh.com/software/data-view2d-web/>
- [18] S. Goodhew *Sustainable earth walls to meet the building regulations*. 2017.
- [19] Ministerio de vivienda y el urbanismo, *Estándares de construcción sustentable para viviendas*. 2018.
- [20] A. Holguino *Confort térmico en una habitación de adobe con sistema de almacenamiento de calor en los andes del Perú*, 2018