Comparative study between a proposed architectural prototype and heritage buildings to a hot-arid climate. The case of San Lorenzo de Tarapacá.

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ABSTRACT: On June 13th of 2005 an earthquake destroys most of the town "San Lorenzo de Tarapacá", located in the north of Chile. This one shows a vernacular architecture directly related to a hot-arid climate where it is placed, since adobe is the main building material. However, the poor seismic performance of adobe, the loose of traditional handmade construction, and the poverty that affects the community threats the architectural heritage of San Lorenzo de Tarapacá.

To confront these problems, a group of students of the Pontificia Universidad Católica de Chile develops a strategy for the town reconstruction, considering that the origin of a new constructive system is the internal environmental conditions developed in vernacular architecture for this specific latitude.

This study tries to optimize the thermal performance of a prototype proposed as a reconstructed dwelling. For this purpose, simulations by means of TAS software have been made to study the thermal behavior of a paradigmatic heritage building, obtaining a comfort standard to this zone. Therefore, different solutions will be proposed in comparison with this standard, in terms of thermal comfort, resources economy and construction advantages.

Keywords: thermal comfort, resources economy, Heritage architecture, reconstruction

1. INTRODUCTION

In the north of Chile, at Atacama desert, is located Tarapacá village (69º 30'20), as many towns of the region was affected in 2005 by an 7.5 Richter degree earthquake that destroyed near the 65% of the constructions and that showed a greater problem: the non-existence of national politics of reconstruction for zones whit hereditary value and the obsolescence of traditional constructive methods. With this as starting point, a group of students of the Catholic University of Chile tries to deepen in the challenge of find or generate politics of reconstruction for these zones, that define and respect lines of patrimony to maintain people´s identity and at the same time, constitute systems of habitable reconstruction.

One of the definitions of patrimony presented, besides the architectural formal lines, is the development of constructive design through the generations, responding in a sensible way to the specific climatic needs of this zone, using basic materials.

The reaction of the governmental institutions to this problem does not responds in an elaborated way to this particular town, and follow a systematic method used in all the previous interventions of massive housing.

The Project of Tarapacá consists chiefly in presenting a new constructive system that respect these needs and that deliver similar thermal characteristics. The first problems falls in establishing which is the thermal standard, or which are the temperature levels where habitable comfort is handled. Heritage buildings offers a sensible answer to these demands, it is based on the improvement obtained by test and error during the times. The thermal analysis of these constructions will give us an specific standard to generate a new constructive system. At present the alternatives of construction for the town of Tarapacá are basically 4 that constitute two groups; the traditional, that have had a development in the town by a prolonged time since the antiquity, and those introduced in the last half century. The traditional are the composed adobe of land bricklaying walls of 60 cm. thick, and roof with wood structure, and covered with reed and clay. This is the oldest alternative, dating many of its constructions from the Spanish colony, or of the Peruvians times. In the saltpeter period an abundance of great quality pine allows build in base of wood structure with partitions of cane braided and clay, this receives the name of quincha.

The most modern constructive system includes concrete or clay cooked bricks. Besides, a considerable part of the town has been built with precarious and extremely light materials, as is the case of the emergency dwellings delivered by the government after the earthquakes of 1983 and 2005, expanded with any panel of available wood.

The adobe offers good thermal conditions by its exceptional thermal inertia, Nevertheless, after the last earthquake a 98% of the adobe constructions did suffer damages that compromise its structural stability, or directly collapsed. With this situation as argument, the authorities determined that the adobe cannot be used any more as a structural system.

The quincha had, in general, a good resistance to the earthquake, nevertheless the shortage of wood, and the lower quality of the available one, make questionable the feasibility of his use. The concrete blocks have lower thermal inertia than traditional materials, and therefore they are not a good alternative in habitable constructions. Besides, it constitutes a reason of external dependence. The search of a constructive design that respect the specific thermal needs of the town and at the same time a level of economy and facility of construction, is the purpose of this investigation

2. METHODOLOGY

2.1 Architectural proposal for the reconstruction.

To establish a standard of comfort for this specific zone an old heritage dwelling was analyzed. At present this house is half destroyed by the earthquake, but the architectural analysis and the observation of the constructive tracks, permit its reconstruction digitally (Fig.1). The constructive system of this heritage building is in adobe bricks of 68cm. thick, timber ceiling structure and a roof of cane and clay. It presents three principal spaces, the central as a walkway and two laterals that generate the precincts. This dwelling is one of the oldest of the zone.

The Prototype presented by Grupo Tarapacá where built in a new constructive system that intends to answer the needs of housing comfort, seismic resistance and respect town´s heritage condition (Fig.1). The prototype’s program is an office-library developed for the neighborhood council - for reasons of property was not built a personal dwelling - located to some 100 mts of the center of the town. The prototype was built during February with the collaboration of the local community and utilizing constructive techniques and north traditional materials, to achieve an approach with the inhabitants and its traditions, an adequate adaptation to the zone climate (wide thermal oscillation, characterized by high and low temperatures, strong solar radiation, null cloudiness)

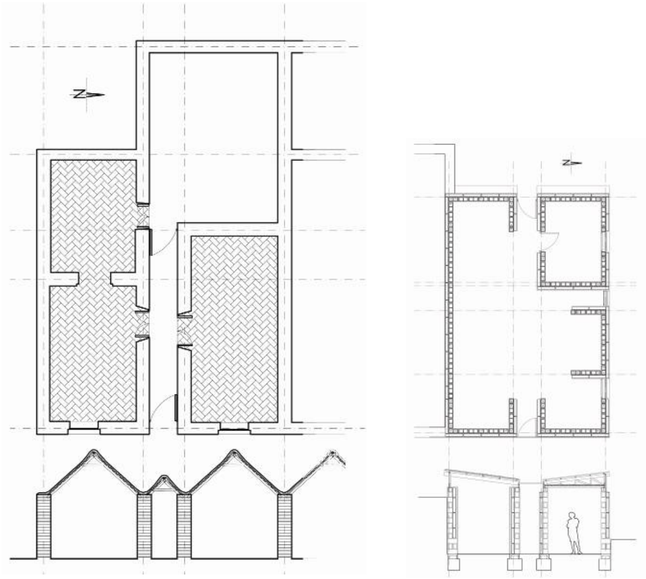

Figure 1: Digital reconstruction of the heritage building (left). Plans of the prototype (right).

The constructive system was developed in concrete blocks bricklaying (19x19x39 cm.) Reinforced with steel bars 12, Covered with recycled adobe blocks positioned as tambourine and semidetached to the wall by earth adhesive mortar. Along this a hexagonal netting galvanized was arranged (1 x 0.6 mts.) in all its perimeter.

The netting is strained in horizontal way through screws anchored to the structural concrete blocks wall in the spaces of doors and windows and through the foundations. At the same time, the netting is anchored by wires of steel galvanized nº 16 already arranged symmetrically inbetween bricklayings, this wires besides maintain canes of bamboo that act as vertical reinforcement, permitting a load distribution. All this envelope is covered with a 5cm thick clay stucco and revoked with a lime and cement painting as exterior termination, achieving a wall of 38 cm. of thickness with a high thermal inertia.

The roof was carried out with a pine wood structure to achieve a ceiling aired where the inside ceiling is held by canes and a clay layer. In the outside roofing is made of zinc plates.

The thermal behavior analysis of the proposed prototype was compared with the heritage architecture standard. This procedure was intended to generate constructive solutions, searching for alternatives to improve the dwelling prototype, reaching the thermal standard.
In the aim of promote a "doing knowledge" installed in the local community, emphasis is focused on construction technics more than in a particular architectural project.

2.2 Methodology of thermal modeling.

The heritage dwelling's thermal modeling intends to give reliable results of a specific thermal comfort range. The variables tested in series of simulations where the incidence of thermal mass in temperature stabilization, the relation of air volume and thermal loads, the incidence of ventilation on the inside and the ventilated roof as radiation shield and heat diffusor.

This study was carried out through the TAS software (www.edsl.net) born in England and of common use as consultancy tool for the professional environmental development. This software uses series of modules which are placed in a 3d modeler, as a thermal-energy analysis. A simulator of climatic control, and even one 2d CFD module (computational fluid dynamics). In terms of tools for environmental analysis, TAS has been catalogued as one of the most advanced, compared with other of smaller level (which are very used in the architectural design due to an easy results obtaining and friendly interface.). TAS accuracy is based great number of variables, and that determines results. [4]

The traditional dwelling of Tarapacá, is constituted by materials whose features like U values are unknown. This is the case of the cane and reed used in ceilings. Cane was considered as a hollow wooden piece, and was modeled as two wooden layers wit an air cavity. It was determined by series of simulations that the small measures differences on this material where irrelevant in the results.

Other materials as clay, whose ranks of values are very extensive, makes necessary to get information experimentally. To obtain an idea of the U value of the loam, was used the relation between specific weight and U value (Fig.2) established by some authors [1 and 2]

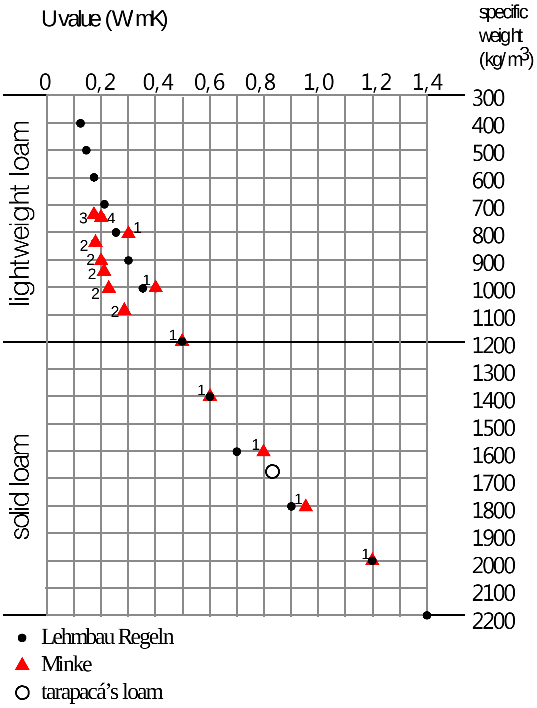

Figure 2: Relation between specific weight and U value, to obtain the loam data.

The technologies of thermal analysis depend on files of certain climates. Those files commonly do not exist for small towns like Tarapacá, that does not even appear in weather websites. The way in which we manage to surpass this technological

constraint was by generating a climate file from the Calama's file (285 km south of Tarapacá and 2200 m. over sea level) For this was developed a formula (Fig.3) The formula moves all the temperatures above zero, adding "tmin", Enlarging the thermal rank from the average temperature "md" with the term "a" (a>1), and establishing the maximum temperature

$$T_p = \frac{\sqrt[a]{(T+t\min)} * (T+t\min)}{\sqrt[a]{md} * b}$$

Figure 3: Formula developed to obtain a climate file for Tarapacá, from the climate file of Calama.

with the factor "b". "T" is the hourly temperature, and "Tp" is the resultant temperature. This formula was obtained from the temperatures measured in situ by group Tarapacá [3], and calculating the way to obtain those results from the Calama's climate file.

The final result graphic (Fig.4) provide us the climate file necessary to proceed with this investigation.

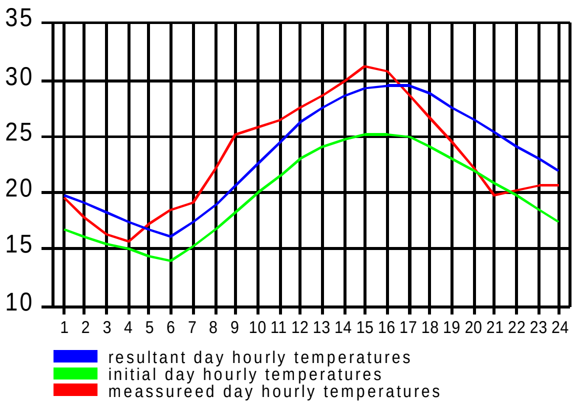

Figure 4: Variations in the curve in the climate file, example day.

2.3 Analisys of the heritage building and the improvement of the prototype.

From this point, the investigation continues now able to get the performance of the traditional dwelling in the specific climate of Tarapacá. The first analysis made with TAS was to measure the behavior of this building during one year, this analysis gave us the inside temperatures. Those temperatures are the base to establishing the thermal comfort where the prototype performance should be handled. The background graphic (Fig.5) shows a gradient, where de darkest color indicates the most common temperature, and the lightest one, shows the rare temperatures, more distant to de average temperature, and closer to the inside temperature limits, in 10% intervals.

The measurement obtained shows that the average temperature is Cº18.7, and de limits of maximum and minimal temperatures are Cº29.2 and Cº11.6 respectively. This indicate a open range of posibilities, because de variation between the max T, and de min T is Cº17.6, therefore, the best result will be the one more stable and closer to the average temperature, for the improvement of the prototype. In the constructive variations to the firs model proposed by Grupo Tarapacá, are considered other 7 options, inside a rank of economy (due to the reconstruction will be in economic housing by the government) and known structural resistance.

This variations are basically changes in how they are grouped, the dimensions of these components, and the percentage of participation in the final solution.

3. RESULTS

Five different alternatives in a fully passive ambient where tested (Fig.6), beginning with the prototype developed by Grupo Tarapacá, which was tested in first place, to compare its behavior. The results show that it was inside de new thermal comfort given by the hereditary house, but in the pick hot day, the inside was overheated (Cº31.2). The second alternative was to split the materials and measure the possibility of each material separately, to understand which one had more influences in this results. The tests were made to the same prototype, but only with concrete blocks in first place. The results showed and even higher overheating (Cº33.1) . Then was tested the variation with a 30cm thick of adobe. The results were better than the spected, the thermal oscillation was among the Cº26.5 and the Cº17.4. The third variation tested was the same last model, but with 45cm thick of adobe, looking for the influence of this component in the ecuation.

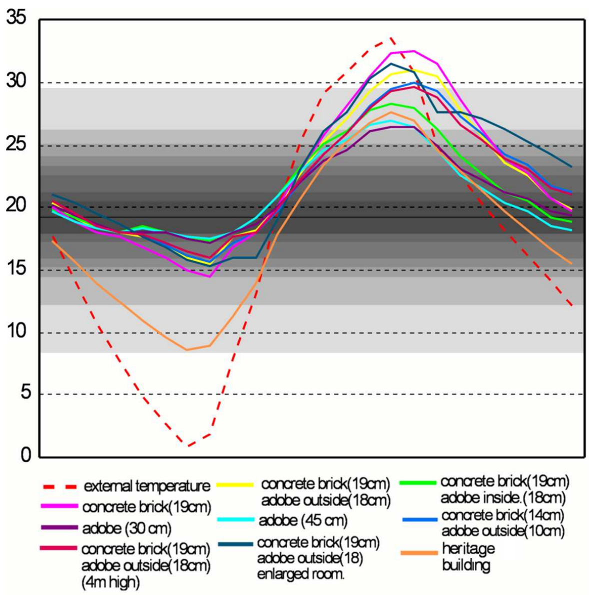

Figure 6: Shows the behavior of different constructive options, over the thermal comfort obtained from the hereditary building.

It showed that de thermal inertia and the less air volume in the inside have a negative response, more mass, more thermal inertia, more overheating (compared with the 30cm thick) but inside the thermal comfort was under de limits. This two last options were developed to find the influence of each material, but they were inapplicable, because in Chile the adobe is not accepted as an structural material after the 2005 earthquake.

Other variation was to make thinner the two materials, (14cm in concrete blocks, 10cm in adobe) to see if this had some influence with the two combined materials. The result showed a better behavior in the thermal control, relative to the use of both materials (Cº31 – Cº15.4). Other test was to increase the inside air volume, trying to establish the influence of this parameter, enlarging the height of the precinct. The behavior was even better that the last one, and the influence of the air volume in the thermal control was showed, as an alternative. The last idea was to see how de direct contact with the sun light does influence in the results. The adobe skin was now in the inside of the building with an outside skin of concrete blocks. This was the best results taken from a combined material's model. The comparison of these results shows that, in the concrete blocks the heat is transfered more quickly, and de adobe have de thermal inertia to liberate this difference of temperature when is necessary, without the overheating caused by de direct exposition to the sun

The thermal comfort of this variation was inside de Cº28.3-Cº18 rank. This result give us the option to make a minimal change in the economy of de resources, the use of the available materials and no major changes in the structure integrity but with a greater improvement. There is no need to make other variation than change the order of the components.

4. CONCLUSIONS

The traditional roofing of tarapaca's dwellings can be optimized by the adding of a cover that generates a ventilates external roof. The exessive air volume of traditional rooms appears as a possible cause of exessive cooling by night. Too much ventilation annules the effect of thermal mass as overheating buffer. If the air changes are more quickly than the heat absorption on the mass, external temperature prevails on the inside. Ventilation shut be controlled but no eliminated at all. The best results where around 0,3 air changes per hour. Overheating control is in direct relation with thermal mass, this way the best results in both heat and cool peaks where shown by a 30 centimeters thick adobe wall. With a 45cm thick wall the maximum temperatures begin raising together with the occupancy, this is caused for the reduction of the air volume. The tendency is confirmed by a 68 cm wall, in which lowest temperatures are even lower than in the 30 cm wall. Possibly this is due to a heat absorption of the walls during the night.

The direct exposition to the sun light can have negative effects in smaller precincts, even if the material used have a great thermal inertia, as the adobe does.

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