Architectural Enclosures as a Contribution to Thermal Comfort in Social Housing

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Abstract:- This article presents the optimal system to contribute to the thermal comfort in social housing built in a warm climate regime in Ecuador, taking as a case study the city of Azogues, through the comparative analysis of scientific information of two systems of architectural enclosure, to maintain the thermal balance inside the building; because the houses that are built in extreme climates are characterized by being of social interest and are inhabited with profound problems of thermal comfort. The methodology used for the analysis of the content of the research is qualitative. The main theoretical-methodological contribution of the research lies in the contribution to the fulfillment of an important aspect of public policy in a specific area of the country. Based on this, it could be extrapolated to other cities with social interest housing.

Keywords:- *Architectural Enclosure; Thermal Balance; Social Housing.*

I. INTRODUCTION

The resulting construction in Ecuador is characterized by the "lack of designs adjusted to the climatic, industrial and environmental characteristics" [1]. Housing built in extreme climates are characterized by being of social interest and are inhabited with "serious comfort problems and require large energy consumptions for thermal conditioning" [1]. The city of Azogues, province of Cañar, of warm temperate thermal regime, and presents high concentration of social interest housing in its urban and rural parishes. However, the situation that affects thermal comfort at the national level is repeated.

In this context, the relevance of analyzing the appropriate materials to achieve an architecture adapted to the environmental setting of each area becomes important. To this end, it is important to understand the building envelope. According to [2], building envelope systems should offer an adequate number of alternatives to adapt the building skin to different climatic zones and orientations according to contemporary comfort criteria. If the building is considered as an integrated system to which certain technologies are incorporated to improve the "thermal" quality, the whole system reacts, resulting in energy savings, which generate a decrease in operating costs and the amortization of the investment originated by its implementation [3].

There are several envelope systems to achieve thermal comfort in dwellings. Thermal comfort is defined by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) as the point of equilibrium between the psychic and physiological sensations of the human being and his immediate environment, in which objective and subjective variables are involved between the human body and its context [4]. Nowadays it is possible to find several thermal insulation methods to achieve thermal comfort. The most common, applied to housing constructions, are: lamb's wool, use of vegetable fibers, biomass, prefabricated panels, containers with water as insulation, green walls, vertical gardens, among others.

For the analysis of a sustainable way to achieve thermal comfort, two types of thermal insulation in houses will be analyzed. The first method is vertical gardens on the facades as thermal insulation; and the second is the construction of panels that will serve as water containers. The latter serves both as thermal insulation and as a heater; in addition, it offers the possibility of reusing the stored water to reduce consumption in the house. The analysis focuses on these two methods due to the ease and feasibility of adapting to any type of construction, the possibility of obtaining construction materials in the environment, skilled labor and energy use properties.

Vallejo & Yépez [5], present the results of their research on the construction of vertical gardens as thermal insulation based on plants of certain characteristics used in two types of gardens. For the basic garden with only one type of plants, ferns, scientific name (Nephrolepsis exaltata) was used and for the conventional garden four types of plants, ferns, mala madre or tape, scientific name (Chlorophytum comosum), Ivy (Hedera helix) and St. George's sword or mother-in-law's tongue, (Sansevieria triifasciata), these plants were placed in a cabin and compared with another cabin without plants to see the contribution in the thermo-hygrometric comfort and then to find the relationship of the vertical garden with the thermo-hygrometric comfort.

For their part, vertical gardens are the most widely used. A vertical wall, which can be installed both inside and outside the building, provides environmental and energy benefits, increases thermal insulation in the wall where it is installed and reduces the necessary ventilation by acting as an air biofilter. For the association of plants in the vertical garden prototype, four species were used: Fern (Nephrolepis exaltata), Ribbons (Chlorophytum comosum), Ivy (Hedera hélix) and St. George's Sword (Sansevieria trifasciata), these plants are recommended by NASA as they purify the air inside buildings.

Jiménez [6] presents a proposal for a modular, assemblable, flexible and mobile vertical garden model, this element he names as a sustainable urban wild organic urban wall (MOUSS), which serves as an active thermal control unit in buildings.

On the other hand, according to [7], current buildings are not in balance in relation to thermal energy, buildings gain heat due to the way they are oriented, therefore they need high energy consumption to be balanced, for this reason it is necessary to install equipment that helps to reach a thermal comfort inside the facilities. The author proposes a thermal insulation system that can be used to heat or maintain thermal comfort inside a building. According to the invention, containers are built near the surrounding surfaces of a room, these containers are filled with a fluid inside which will serve as heat transport and then be reused.

The main objective of the research was to identify the optimal system to provide thermal comfort in social housing built in warm temperate climate regime, through the comparative analysis of scientific information of two envelope systems, to maintain the thermal balance inside the building. In order to achieve this objective, the following was carried out: (i) analysis of the pertinence of use of the envelope with green walls, by reviewing scientifically proven information, to characterize it in the climatic floor of Azogues; (ii) inquiry on the pertinence of use of the envelope with water containers, by reviewing scientifically proven information, to characterize it in the environment of Azogues; and finally, (iii) the characteristics of the two types of envelopes were systematized, by comparing their construction systems, to stipulate the pertinence of use in Azogues.

The methods analyzed: i) experimental construction of vertical gardens and their relationship with thermo-hygrometric comfort in closed environments; ii) sustainable urban wild organic wall; and iii) thermal energy system to heat or maintain thermal balance inside buildings or parts of buildings, share the property of providing architectural spaces with sustainable thermal insulation by treating them as efficiently as possible. In addition to this, they share the characteristic that they can be adapted to any type of construction and environment. These methods focus on improving the quality of life of their occupants, with comfortable spaces.

The difference between these methods is the way they are applied as a housing envelope. In the case of vertical gardens and organic walls, plant barriers are used to provide thermal insulation to the place where it has been designated, unlike the thermal energy system to heat or maintain the thermal balance inside buildings that uses chambers with fluid inside. This system also contributes to heat and maintain the thermal comfort inside a space, and presents the alternative of reusing this fluid (water) inside the house.

In addition, the contribution to the thermal comfort of the house within the framework of a sustainable building also depends on the construction management policy. In this context, the project manager must develop strategies that allow the progress of the processes according to the established planning, the success of the project depends on quality, time and cost factors [8]. This can be achieved from the determination of a "Base Case", as pointed out by the Technological Development Corporation of Chile (2015), who assure that "it is the description of the situation at the start date of the project with respect to the standard of architecture design, comfort and consumption of energy resources, water, etc." (p. 44). The idea is that this case is the basis for obtaining the best administrative option to guide the sustainability objectives of the project.

II. METHOD

The results shown below are derived from a correlational analysis, with a quantitative approach. The idea was to compare proven scientific studies on the use and application of envelopes as thermal insulators in buildings in order to contribute to thermal comfort within the housing units, thus determining which system will be the optimal one to use in social housing in Azogues. This correlational study evaluated the degree of relationship between two variables, being able to include several evaluation plans of this nature in a single investigation. The samples of this study were social housing in the Chavay sector of the city of Azogues, taken under a non-probabilistic design. It was analyzed qualitatively which of the studied envelopes is the optimal to apply in the locality, thus providing alternatives for a better quality of life for the occupants of these social housing, the content analysis provided the tools to carry out the description of the main characteristics of the envelopes related in this research, and finally compare between the detailed information to establish which of the envelopes is suitable for the reality of the climatic floor of the city of Azogues.

III. ANALYSIS

Azogues is located in the province of Cañar at an altitude of 2770 meters above sea level. This city is located within the inter-Andean zone of Ecuador, the climatic type of greatest coverage is sub humid temperate cold with small water deficit, in these parts highlight areas with climatic characteristics of type D and B'3 according to National Institute of Environment and Hydrology, which is the case of Azogues that has a warm temperate dry climate with no excess of water in rainy seasons and water deficiency that exceeds six months, at risk of desertification.

The analysis of each envelope was carried out according to the construction system of each one. The feasibility of building the envelope in social housing is what allowed identifying the optimal envelope to be recommended for the implementation of the public policy. In this sense, the detail of the two envelope systems is presented below.

A. Green wall envelope for low-income housing in warm-temperate climate

The presence of gardens on landscaped facades could decisively improve the polluted climate of cities: the air would be purified, dust swirls would be considerably reduced, and temperature variations and humidity percentages would decrease. The plant mass provided by the green envelope façade creates an air cushion that provides thermal insulation.

It also provides shade to the facade and absorbs part of the incident solar energy in the process of photosynthesis [9].

There are 8 types of green envelope facades, according to their construction system and their utility: i) pre-vegetated cistern roofs, ii) opaque facades, gabions, iii) vegetated panels in a metal box, iv) vegetated panels in draining cells, v) greenhouse vegetated facade, vi) sliding vegetated panel [1]. For this case, the "Greenhouse vegetal façade", which provides thermal comfort to the house, was analyzed. This type of envelope is composed of a construction system that allows hygienic ventilation, thermal ventilation and solar protection. Likewise, the incorporation of vegetal elements to the façade envelope offers a variable thermal response according to the external climatic conditions, constituting a key system in the optimization of the comfort qualities of the building [10].

The envelope system consists of a façade enclosure conceived as an extra-flat greenhouse that includes a plant subsystem [10]. Fig. 1 shows the envelope constructed in the typical social housing.

Fig. 1. Façades with green architectural envelope in a social housing type

Fig. 1 shows two options for a green envelope façade. The choice of the appropriate façade for the placement of the envelope has to do with the climatic analysis from which the sunlighting of each façade is derived. In this context, the green envelope system can be adapted to 2 different facades in the house, which shows the versatility of use of this system.

The description of the construction system is shown in Fig. 2, where each layer represents:

- Inner layer: Two-leaf sliding window (1420 x 1410 mm) with metal carpentry and double glazing (14 mm thick) with air chamber (12 mm thick).
- Intermediate layer: Simple lattice of 5 mm thick aluminum louvers, attached to an aluminum frame.
- External vegetation layer. Vertical plant system consisting of a metal planter (1.50 x 0.50 x 0.40 m) with automatic irrigation system by immersion and timer control, helicoidal steel wiring to support plant species and metal frame with metal bolt assemblies.

Fig. 2. Extrusion of elements that composes the façade with architectural envelope with water containers.

A hydroponic substrate is placed in the intermediate layer, which is retained by a felt in which the plants are introduced through holes no larger than 3 mm in diameter. The irrigation system is drip irrigation, interspersed between the layers.

B. Envelope with water containers for low-income housing in warm-temperate climates

The envelope with water containers allows balancing the thermal comfort in a building. The heat gained in the facades where the envelope is placed is equivalent to the solar energy it receives. In this sense, as with the green envelope, the capacity to guarantee thermal comfort in social housing depends on the climatic analysis that makes it possible to deduce the best façade option for installing the envelope system.

According to [7] in terms of thermal energy, there are “heat gaining” and “heat losing” surfaces in any building. The first ones are usually perimeter structures (wall, roof), occasionally Surfaces surrounding internal heat Sources. These areas take the local heat gains. Heat losing Surfaces are the ones which have no actual heat gain, therefore they are colder. In this respect, the facades of social housing, according to their orientation in the city of Azogues, can present two facades to gain heat. The ratio between heat gaining and losing Surfaces always depends on the actual heat gain and the geometry of the building [7]. Therefore, this type of envelope can be used for houses up to 90 m2 in area. This complicates its use for social housing of 100 m2 located in some segments of the city.

Fig. 3. Architectural envelope system with water containers.

Fig. 3 illustrates the envelope system with water containers. In the case of the patent described in this section [7], the invention must first be understood as a thermal energy system made for a small house where there are also closed rooms without windows. Which characterizes the social housing models in Ecuador, and in the area of analysis.

In such a scenario, as can be seen in more detail in Fig. 3, next to the surrounding surface of the façade, and before the interior walls of the same façade, there are attached plastic plate containers. The containers vary in size and their surface area is approximately the same as the surrounding surfaces, apart from the space required for their mounting, respectively.

The facade surface can be made of any material, as long as it does not exceed 15 cm in width, in order not to restrict the principle of heat gain. The connecting elements along the entire facade are also fused to the plastic using any bonding material (such as welding, gluing, heat expansion elements, etc.). The diameter of the connecting elements and the connecting elbow should be as large as possible to ensure an effective flow.

After connecting all joint elements, the internal volume of the containers can be filled with fluid. Since in the event of heating in buildings the heat transfer medium is normally water, in the case of the system entered here the fluid filling of the containers is water as well, and in the further introduction the fluid in general can be referred to as water.

In this system the thermal comfort is not kept when the facade stops receiving solar irradiation [7]. In other words, thermal comfort is maintained during the hours of solar reception during the day. In the case of the social housing in Azogues, thermal comfort would be preserved until 18h35 min of each day.

IV. RESULTS

A. Optimum envelope for low-income housing in warm-temperate climates

From the analysis detailed in point III, it can be deduced that the optimal envelope option for social housing in Azogues is the green wall type. This is due to the following issues:

- Green wall type envelopes do not have a limit of m2 of construction area to provide heat gain in the house.
- This type of envelope does not restrict the hours of heat it contributes to thermal comfort. Therefore, it ensures that the heat gain is uniform.
- The way of construction of these envelopes does not require prefabricated elements, which incur high climatic costs. The more so in the maintenance of the same.

V. CONCLUSIONS

The benefits of architectural envelopes can be extrapolated to any type of building. As indicated, there are no barriers in terms of minimum façade dimensions for their application. In this context, the construction of social housing can gain quality and warmth from the constructive point of view.

Currently, there is a wide variety of envelope systems that account for the growth of this construction practice to ensure thermal comfort in buildings. However, the envelope types presented in this article represent the most appropriate options to be installed in low-income housing.

The green wall envelope construction system allows social housing to gain thermal comfort and a more aesthetic façade. It is worth noting that the architectural designs of this type of housing do not follow aesthetic criteria over functional and economic ones. Thus, the option of a green wall as an architectural envelope for these dwellings contributes to their ornamentation.

However, although this article focuses on the analysis of two types of envelopes, the possibility of incorporating other types of architectural envelopes built from plant material is left open. In addition, it would be useful to inquire about other variables that result from the placement of these systems, such as acoustics, wind, and so forth.

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