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Systemic Analysis of Bioclimatic Design of Low-Income State-Led Housing Program "Socio Vivienda" at Guayaquil, Ecuador

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Abstract. A multidisciplinary team of researchers from the University of Guayaquil carried out hygrothermal analysis of single-storey dwellings from state-led program called "SocioVivienda" at Guayaquil, motivated by high indoor temperatures above comfort zone. Based on bioclimatic models obtained, architectural improvements were proposed to dwellings in order to improve habitability and comfort conditions of their householders, being a fundamental tool for designing future housing projects for low-income families. In systemic analysis carried out, thermal characteristics of materials are taken into account together with surfaces colors, the application of passive ventilation techniques, bioclimatic strategies related to building's orientation in relation to the sun, and physical, economic and social characterization in order to approach to its whole reality, as well as the energy simulation carried out with DesignBuilder software.

Keywords: Social inclusion · Concurrent engineering · Participatory design Bioclimatic design · Low-income housing

1 Introduction

Rural-urban migration to cities in Latin America has brought social and economic improvements to the population where indigence fell from 12% to 6% of the population with an increase of 10% points in the last 20 years, which has increased the demand for urban services overcoming the response capacity of national and local governments, which generates informal access to basic services and housing. This is equivalent to about 160 million inhabitants living in low-income settlements that go hand in hand with increasing land value, which decreases the affordability of an increasing number of low-income families to the acquisition of their own homes.

The problem of habitat in Ecuador is related to the issue of poverty as the origin of informal settlements and the demand for basic habitability conditions as a human right. During the 20th century Guayaquil experienced a disorderly growth due to its economic and commercial activity as Ecuador's main port. The development brought as a consequence regional migrations, promoting a growth of the population that has not

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been coupled with the conditions of habitability and urban services, characterized by inequality. This growth has been caused by the illegal appropriation of agricultural or urban lands, public or private properties, by low-income social groups from rural areas or the city, with the purpose of getting their own house [1].

In spite of the actions carried out by the National Government to solve the precarious habitat problem in the country, there are still aspects that have not been sufficiently considered in social housing projects, such as the characteristics and needs of the population to be served, which are related to the theme of integral habitability. Promoters of public and private housing offer solutions that do not correspond to the needs and expectations of the dwellers, where they only consider material's costs as a criterion selection, leaving aside bioclimatic and design criteria [2].

The University, in response to its social commitment, must propose study and research proposals on these housing problems to contribute with residential solutions according to the different human, geographic and historical realities of the popular sectors [3].

There are four parameters that condition the thermal sensation, of which three of them are related to air: temperature, humidity and movement (speed), added to these, the solar radiation. Together form the main elements that affect human indoor termal comfort. The use of computer systems for the analysis of thermal, energy and air flow behavior becomes more important to the extent that the systems are more complex [3–5].

2 Bioclimatic Design Approach

In the bioclimatic analysis of dwellings offered by the "Socio Vivienda" program, aspects such as the orientation of the building in relation to the position of the sun and the inclination of the axis of rotation of the earth were considered. The modeling was done with the DesignBuilder as shown in the Fig. 1.

Another aspect to consider is related to ventilation. On July 17, 2018, latitude −2.135397 and longitude: −79.963843, inside the house no wind speeds were recorded above 0.2 m/s in the anemometer. The modeling with the software showed how the circulation of the air inside each interior space behaves. See Fig. 2.

In the space occupied by the living-dining room and kitchen, there is a sliding window of 0.50 m^2, an immediate exchange is generated between the lower and up-per part of the window and an turbulence effect flow is not perceptible by the dwellers. Wind direction is visualized when modeling the room with the exit door to the open backyard. Temperature changes in the air flows near the building envelope (walls and roof) are also evident. The results of thermal conductivity are shown in the relationship between the outside temperature and the indoor temperature of the dwelling. See Fig. 3.

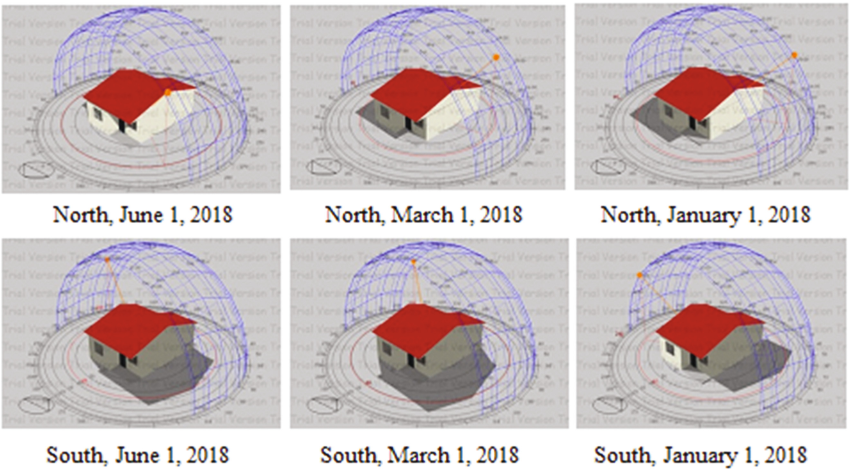

Fig. 1. Modeling of homes with the Design Builder.

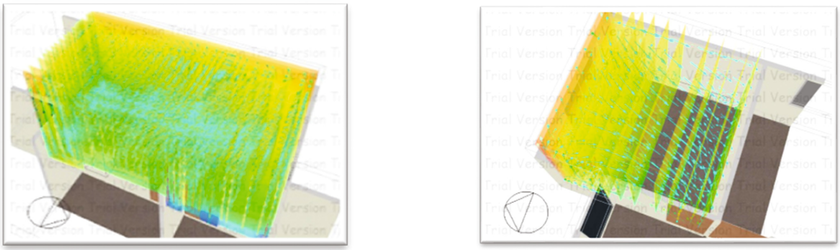

Fig. 2. Modeling of the air flows on each indoor space. Living-dining room and kitchen (*left*) and bedroom (*right*).

Fig. 3. On the x-axis (*hours of the day*) and on the y-axis (*temperature values*) recorded at indoor spaces of the dwelling.

3 Analysis and Discussion

It is important to establish bioclimatic criterion by understanding the climate and requirements for the project [7]. In this way, cooling requirement are defined, through the strategies of natural ventilation and the blocking of solar radiation to avoid overheating the interior of the dwelling through the energy absorbed by the roof and the facades respectively. As a tactic, shading with eaves of the main and posterior facades are projected, as well as heat gain decrease through the roof. Another important aspect related to sun protection is the indirect gain through the walls and specially through metal roofs that creates a scenario with heat flows into the building that are not adequate. It is vital to understand the thermal behavior of colors and textures of building materials, which requires elements and finishes with high albedo and low absorption [8], especially on the roof and terrace area. Dwellings oriented east-west receive direct solar radiation throughout the year on their facades and the roof or facades facing north and south, receives direct solar radiation for six months each. This is the reason to use eaves, and control colors, textures and voids on facades.

Thermal behavior of steel roofs can be improved by using bright white paints, or with their original finish that reflects the radiation very well, thus decreasing its absorptivity from 0.78 (a rusted sheet) to 0.25, expecting a reduction of almost 9 °C on the material's surface. When using a new polished roof, the incident radiation is reflected from 25 to 30%. [9]. In the case of hot-humid climates, there is recommended maximum transmittances of 1.1 W/m2 °C [10] but in the case of zinc sheets, values of 5.8 W/m2 °C are present. This is why the insulation towards the interior, prevents discomfort due to the radiant temperature generated by the transfer of heat through this metalic roof. To work the cover, it is recommended to finish with light or bright colors, better if they are new zinc plates [11]. Inside place the insulation fixed by straps and leaving a ventilated air chamber with EPS of 15 kg/m^3 and 50 mm [12].

4 Conclusion

The use of systems for bioclimatic modeling is necessary to support the decision-making process. The systemic approach and the bioclimatic strategies allow evaluating the proposals of housing design in order to improve the quality of life of people regardless of their socioeconomic status. This is where bioclimatic architecture delivers its contributions and solutions, including the dwellers in their design processes from the beginning of a housing project. These processes allow projecting appropriate architectural responses to the relationships between habitat and housing. Understanding the thermal behavior of building materials is vital, as the skin or building envelope of a project directly affects the human indoor thermal comfort. Designs in hot and humid climates should give preference to projects based on natural cross ventilation within their architectural spaces, accompanying them with coherent responses of materials and building systems to the climate, as well as sun control and shading devices.

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