Comfort for the poor

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ABSTRACT: Bogotá has problems of squatters, mainly due to migration of people that try to look for better job opportunities and security. These newcomers urbanize in a disorganized way due to their scarce knowledge of construction and to the lack of money.

The designs of housing where these migrants live do not promote comfort. The project is proposing a feasible solution to this problem.

The main purpose of the project is to achieve comfort relying solely on design fundamentals. The most important fundamentals that the project refers to are the material and the form; by modifying them, passive systems could be introduced as part of the design of the houses instead of using complex active systems.

Other important thing considered in the project is the limited amount of economical resources. The project provides a form to keep the cost of the houses low. The location for this project is Bogotá, Colombia, this accounts for another important fact of the project, which is that it takes the advantage of the geographic position of Colombia, which is in the tropical zone. A prototype house of a neighbourhood called "Ciudad Bolivar" was used to base the project.

Conference Topic: 2 Design strategies and tools
Keywords: Comfort, temperature, materials.

INTRODUCTION

Colombia has a problem of violence in this moment due to guerrilla activities. It causes migration of people to urban areas where they expect to find better opportunities of work, security and development.

Bogotá is the most populated city in Colombia [1]; it has around 7 million inhabitants. The majority of its population have a very low salary (about US$150 per month) and the high percentage of unemployment makes people build illegal houses in the surrounding areas of cities in bad conditions; uncomfortable, without services and unsafe.

There are some institutions that are struggling to improve the quality of living of these poor people and trying to legalize their plots. This situation makes possible to develop more comfortable houses with economical materials and low energy consumption.

Ciudad Bolivar is a big neighbourhood of 22,908 m2 and urban area of 1,443 m2 [2]. The population is about 600,400 inhabitants [3] and continues growing everyday.

2. BACKGROUND

2.1 Location

Bogotá is located in the latitude 4, longitude -74.6 and the altitude is 2,555 meters. It is limited by geographic characteristics like mountains (East range) and Bogotá River. Its form is elongated from north to south. It is part of Cundinamarca, geographical division. It is located almost in the centre of Colombia and Cundinamarca.

Bogotá is partly organized radially but combined with a cardinal plan. This means that, the highways are organized almost radial and parallel to the elongated form, but between them there are some streets with different importance, depending on their width, these streets are organized in an orthogonal way shaping the neighbourhoods.

2.2 Climate and vegetation

Bogotá climate is cool, it does not have seasons, and the weather is unpredictable: in the morning could be hot with spectacular sunshine and in the afternoon could be cold and rainy. Its mean temperature range is from 14,2°C to 12°C but it could have extreme temperature ranges from 26°C to -4°C.

IDEAM [4] is in charge of climate measurements in Colombia. It is a governmental institution. Scientists in IDEAM measure solar radiation, temperature, precipitation, humidity, wind and other geographical and environmental data with special technology and equipment; some of these devices are in stations located all around the country.

Bogotá only has one station for solar radiation but about seven for temperature, precipitation, humidity and wind; unfortunately some of these seven are not very accurate due to scarcity of economical resources. But for this work it was taken accurate data: the information of solar radiation is from Airport El Dorado station which is the only station in Bogotá that measures it; and, temperature, precipitation,
humidity and wind data from Universidad Nacional Station.

Sunshine average is 4.41 hours/day with the highest 5.8 in January and the lowest 3.6 in May and July.

Radiation average is 14.28 MJ/m²/day, with the highest 16.91 in February and with the lowest 12.98 in November.

This means that Bogotá although has good radiation during the day, it also has a great amount of rainy and cloudy days.

2.3 Colombian architecture

In Bogotá there are several varieties of architecture. Many of them can be into seven big types: indigenous architecture, colonial architecture, 19th century architecture, republican architecture, transition, modern movements, and current architecture [5].

In Colombia, there are many examples of architecture; people that do not have architectural studies make most of them. Architects have made architecture from only a few centuries.

We have the influence of Spanish architecture due to colonization, the colonial house have the typology of Andalucia houses. During that time, Spain was influenced by Islamic architecture and it was introduced to our country.

Silvia Arango, who researched about the story of architecture in Colombia, divided it in the above 7 groups, but she did not include squatters, maybe because we cannot call squatters architecture and part of the story, but I think it has to be considered as part of our habitat due to the great amount of people that lives in this kind of houses.

2.4 Squatters

These are poor houses due to the migration of people caused by the violence in rural areas, it is difficult to call their constructions “architecture” but it is the cruel reality, houses made with sheets of corrugated iron, and some with plastic that are only enough to cover the people from the rain and wind [6]. The consequences are catastrophic thus people suffer from sickness and terrible conditions of living. Luckily, there are some houses that are made with brick, concrete and materials more durable and stable.

Squatters are predominant in Ciudad Bolivar.

3. PROBLEM

This paper is concerned with a solution to improve the housing of the poor people in Ciudad Bolivar in Bogotá; which is a big neighbourhood of squatters.

Housing is not appropriate designed: its shape, structure, foundations, and materials are not adequate. This lack of design and resources causes cold temperatures at night, hot temperatures at midday, diseases, bad smells and bad quality of life.

The great majority of the houses have a central yard and the other spaces are located surrounding that yard, there are between 4 to 7 people living in 72 square meters.

3.1. Materials of the squatters

Some of the houses are built with perdurable materials (brick, concrete, wood and corrugated iron for the ceiling), some others just have corrugated iron everywhere, in walls, roofs, and concrete slab in the floor. For these purpose, a house with perdurable materials will be used.

The climate in this location is cool but rains frequently, the wind comes from everywhere due to the mountains shape in this place. The soil is dust because of the erosion but it is a good soil for foundations because it is hard stone.

The purpose is to design these houses according to the needs of the people and with economical materials. The design must achieve comfort as much as possible with these few resources.

4. METHODOLOGY

4.1 Specifications

In order to work in this project is necessary to make a list of the things that were done to achieve these objectives:

- Analyse the necessities of the place: people from Ciudad Bolivar need economic houses, but also a good quality of life. It is mainly a social problem but also interdisciplinary and architects and urban designers must care about this problem.

- Chose the architectural problem and look for a solution: orientation of streets and houses is not appropriate in some cases and this work would propose a design that can reach more comfortable housing for the population of Ciudad Bolivar.

A model will be done in DEROB program [7] looking for the best design in order to achieve comfort. The model was changed 5 times; these changes are called “cases” for this work. Every case was modelled in DEROB to see the effects and this paper will show them all.

- Look for economical help to make reality this.

Teach users “how to use the house”: how to save energy, water, take advantage of solar energy, obtain good ventilation and therefore obtain comfort.

5. GENERAL INPUT

It is important to know that Bogotá comfort zone is between 19°C to 24°C.

The date April 15 was chosen because it has the predominant wind direction and has the average data from temperature and relative humidity values [4]. It is not necessary to try more months because Bogotá do not have strong seasons.

5.1. Prototype house design and ventilation behaviour:

Function of the rooms:

I = Living room. 3.5m x 4.5m
II = Kitchen. 3.5m x 2.5m
III = Bathroom. 1.5m x 2.5m
IV = Restroom. 3.5m x 6m
V = Hall. 1.5m x 3.5m
VI = Court yard. 3.5m x 5m. (Open), with shading devices in case 2, and close in case 5
Figure 1: Areas with ventilation problems

5.2. Material data

Table I: Material properties used before and after the changes.

<table>
<thead>
<tr>
<th>Material</th>
<th>Tick</th>
<th>Conduct</th>
<th>Sp. heat</th>
<th>Densit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polystyrene</td>
<td>500</td>
<td>0.033</td>
<td>0.01</td>
<td>40</td>
</tr>
<tr>
<td>Brick</td>
<td>150</td>
<td>0.5</td>
<td>0.2</td>
<td>1300</td>
</tr>
<tr>
<td>Cement mortar</td>
<td>10-15</td>
<td>0.93</td>
<td>0.29</td>
<td>1800</td>
</tr>
<tr>
<td>Gypsum</td>
<td>5</td>
<td>0.22</td>
<td>0.23</td>
<td>900</td>
</tr>
<tr>
<td>Tiles</td>
<td>11</td>
<td>0.9</td>
<td>0.27</td>
<td>2000</td>
</tr>
<tr>
<td>Concrete - wood fiber</td>
<td>150</td>
<td>0.14</td>
<td>0.16</td>
<td>450</td>
</tr>
<tr>
<td>Sand stone</td>
<td>500</td>
<td>1.85</td>
<td>0.2</td>
<td>2350</td>
</tr>
<tr>
<td>Sand</td>
<td>200</td>
<td>0.4</td>
<td>0.24</td>
<td>1700</td>
</tr>
<tr>
<td>Reinforce concrete</td>
<td>150</td>
<td>1.28</td>
<td>0.26</td>
<td>2100</td>
</tr>
<tr>
<td>Corrugated iron sheets</td>
<td>2</td>
<td>60</td>
<td>0.14</td>
<td>7800</td>
</tr>
<tr>
<td>Wood softwood</td>
<td>50</td>
<td>0.14</td>
<td>0.76</td>
<td>550</td>
</tr>
<tr>
<td>Air space at 21°C</td>
<td>230</td>
<td>0.24</td>
<td>2.80</td>
<td>1.201</td>
</tr>
</tbody>
</table>

5.3. Schedules

Activities schedule: People from Ciudad Bolivar get up early, about 4:00 a.m. in the morning, prepare breakfast to eat immediately, and lunch to take to work, and go to work. They rarely come to have lunch, there are some unemployed that stays there all the time but this exercise is working with a project with employed people.

Their jobs are not professional: house cleaning, take care children, construction workers, flower workers, etc.

5.4. Formulas used for ventilation:

- For cross ventilation (formula taken from Puppo [8].)
  \[ \text{ACH} = \frac{A \times W \times \sin \text{angle}}{V} \]
  \( A = \text{Area of the opening} \)
  \( W = \text{Wind speed} \)
  \( \text{Angle} = \text{wind angle incidence in the volume} \)
  \( V = \text{Volume of the room} \)

- It was also used ASHRAE [9] formula for Stack effect in case 5
  \[ Q = C_p A \left( \frac{\sqrt{T_2 - T_1}}{(T_2 - T_1)^2} \right) \]
  \( \epsilon = A_1 / A_2, \quad A = A_1 + A_2 \)
  where \( C_p \) is the discharge coefficient

5.5. Wind specifications:

The minimum wind that comes into a room is between 1 and 2 ACH because windows and doors are not well sealed.

Wind direction comes perpendicular to the facade because wind from SE is predominant with 1.9 m/s. Nevertheless, this data was taken from 10 meters from the ground floor, were wind speed is higher, and it is necessary less speed because the height of the house is just 2.5 mts. Then it was calculated like this:

\[ \text{If} \quad 10 \text{ mts are} 1.9 \]
\[ \text{Then} \quad 2.5 \text{ what is?} \]

Solution: \[ \frac{2.5 \times 1.9}{10} = 0.47 \]

that is about 0.5. Value for wind speed used.

As it can be seen in the project, volume I is the only that have cross ventilation in the base case. The formula \( Q=0.025AV \) [9] was used for volumes II, III and IV, but ACH result was too low that cannot be possible. Taking into consideration that the reality is that people really feel air movement in the yard and the second formula does not give the real data. Therefore, the formula used was the one of Puppo’s [8].

5.6. INTERNAL LOADS (w). [9]

Data taken from Ashrae:

- 1 Person: standing 152, cooking 170, sleeping 75
- Refrigerator: 780
- Light: 100
- Hot plate: 3800
- TV: 100
- Hi-Fi:125
- \( W = \text{Power} = 1 \text{ J/s} \)

When volumes are with activity inside:

<table>
<thead>
<tr>
<th>Volume</th>
<th>Generators</th>
<th>Total W</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>4 people, 2 light bulbs, refrigerator</td>
<td>1100</td>
</tr>
<tr>
<td>II</td>
<td>1 person, 1 hot plate, 1 light</td>
<td>2270</td>
</tr>
</tbody>
</table>
5.7. Conventions:
- ACH = Air change per hour
- Temp = Indoor temperature
- Out_temp = Outside temperature
- Op_temp = Operative temperature, what is reflected to our body from all the elements that surround us and what we really feel. The target of this exercise is to obtain this data in the comfort zone.

<table>
<thead>
<tr>
<th>bulb</th>
<th>Temp</th>
<th>Out_temp</th>
<th>Op_temp</th>
</tr>
</thead>
<tbody>
<tr>
<td>III 1 person, 1 light bulb</td>
<td>225</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV (people wake up) 5 people, TV, Hi-fi, 2 light bulbs</td>
<td>1000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV (people sleeping) 5 people</td>
<td>375</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In the charts the vertical coordinate indicates temperature in centigrades (begins with 5 and ends with 25, the difference between horizontal lines are 2°C). Horizontal coordinate indicates hour (From 1 to 23)

6. CASES

6.1. Base Case:
This case has the prototype conditions of a relatively normal house for the inhabitants of Ciudad Bolivar in materials and geometry (See figure 1). One of the biggest problems that this model has is the cold during the night and in the morning, and hot during the afternoon; the corrugated iron roof worsens these problems because high U-value and thermal capacity.

In the base case, it was assumed that people left the doors of the kitchen and the bathroom open during the night. It is also considering that the doors of rooms III and IV can be open during the day.

The wind velocity in the courtyard could not be 0.5 because it is surrounded by volumes, and then it was taken only 15% of 0.5 m/s for this space.

As you can see in the figure 1, there is a problem of ventilation in the orange areas.

These are the results:

It can be seen that the outside temperature has comfort zone from 12 to 17 hours, just 5 hours, and the operative temperature, which is what we really feel, is more or less parallel to the outside temperature. The purpose is to increase 12°C in the morning to gain comfort in the house.

6.2. Case 2:
The court yard was cover with a shading screen to protect from the cold, and to produce lower ACH.
These are the results compared with the base case:

| Volume 1: A little increase, between 0.5 to 2°C. | Volume 3: Few improvements, between 0.1 to 0.8°C |
| Volume 4: It shows a great increase at night due to activities also, but still it is very cold in the morning. |

Conclusions:
This case still do not reach the comfort, therefore shading screen improves but not enough.

6.3. Case 3:
Changing corrugated iron for slabs of concrete with wood aggregated.
These are the results compared with the base case:

| Volume 1: Is hotter in the morning but at noon is colder. It is interesting to see that the line is getting straight. There are differences of temperature between -1.5 and 4.3. |
Volume 2: It increases between 0.5 and 2.1. The opt_temp is reaching comfort only for 1 hour, from the hours 21 to 22.

Volume 3: there are differences in temperature between -0.7 and 1.8 higher in the morning and lower in the afternoon. In this room is normal these situation because is very small and its door is open all the time and tend to keep the out_temp.

Volume 4: It is optimal the behaviour; increase and decrease when is needed. However, it is still cold in the morning.

Conclusion:
Change the roof to concrete – aggregated wood slab, improves a lot comfort and gives an optimal op_temp.

Temperature increase or decrease when is necessary, against outside uncomfortable climate.

6.4. Case 4
It was compared with case 3.
A door was placed between the courtyard and the volume I.
The temperature decreases between -0.2 and -0.3. This case is not relevant for the study.

6.5. Case 5
It was compared with case 3.
Covering the court yard with a semi-transparent sheet of fibreglass and create a stack ventilation in volumes 2, 3 and 4 to provide cross ventilation and try to eliminate the corners that are not well ventilated (See figure 1). The stack ventilation was designed with double wall with a cavity between, and a long horizontal grille of 1.00 x 0.30 mts that could be closed near to the floor (see figure 2).

Figure 2: Ventilation system used in case 5 to avoid bad smells and cause cross ventilation.

Covering courtyard with semi-transparent roof and eliminating shading devises in the courtyard. The purpose of the shading devises was to provide protection to the doors against the rain and worked as circulation halls but in this case they are not needed.

The new volume VI (close), that before was the courtyard (open), works as a Green House. Radiation can penetrate and heat the air that goes into volumes II, III and IV and rise the temperature to reach comfort. The stack effect warms the volumes and at the same time improves the ventilation problems. The double wall acts as a chimney in the common wall back to the Kitchen, bathroom and bedroom, taking out the cold air and keeping the hot air inside.

The ventilation input in this case works different as other cases because there is not ventilation coming into this space directly as before. Therefore, it was necessary to use two charts for ventilation: Forced ventilation (l/s) for stack effect produced for the cavity and Schedule chart with Infiltration ACH (m3/h) for cross ventilation between volumes.

To use the stack ventilation formula is required to assume some temperature in the green house, like 22°C against 7°C from outside, to have exaggerated temperatures (to have accurate data it is necessary to measure it).

There is also a problem with the calculation in Volume I because this green house effect causes some hot air coming into it and making some kind of conflict with the air coming from outside.

Another change made in this case was the material absorbance of the wall in the bathroom but the temperature did not change the result.

The problem with forced ventilation chart in DEROB is that it does not give you the possibility to input schedules and thus the results will be approximated. For this purpose; it would be better to do further research in AIOLOS (special program for ventilation).

Results:
amount of cloth that people can wear, of 1.3 or 1.5 and therefore they can feel comfort.

The project improves between 4 and 8°C in the morning, when is the coldest time and smaller improvements in the afternoon when is the warmest time. This behaviour makes the best reaction in highland climate.

CONCLUSION

The best case to solve temperature and ventilation at the same time in this house is with case 5 solution.

It is better to change the roof of these houses with concrete and houses must be oriented in south west direction to have perpendicular wind direction and enough solar radiation, light and heat, it also depends of the function of the building. The streets must be located parallel to the common walls of the houses to have better urban ventilation in this area.

Concrete could be more expensive than corrugated iron but compared with cost in the future would be cheaper because if people want to build other floor, that they usually do, they can save money because the roof for the first floor could be also the floor for the second floor.

It is also important to create a green environment in this neighbourhood because it can help to stop erosion in this area and provide shadow and a better urban environment.

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