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THERMAL COMFORT AND ENERGY EFFICIENCY ANALYSIS OF AFFORDABLE HOUSES IN MERIDA, MEXICO

Teresa E. RAMÍREZ ORTEGÓN[1]*. Alan E. VEGA PASOS[2], Sergio O. Álvarez Romero[3]
*[*1,2,3]Autonomous University of Yucatan (UADY), Faculty of Engineering, Department of Construction, Av. Industrias no contaminantes Apdo. Postal 150 Cordemex, Merida, Mexico; +52 (999)9300550 ext. 1104;*
[2]Email: alan.vega@correo.uady.mx 3Email aromero@correo.uady.mx

Corresponding Author:-
Email:-teresa.ramirez@uady.mx

Abstract:-

Sustainability and climate change are challenges that our generation has to overcome, in order to ensure the future generations a secure environment. In the particular case of Merida, Mexico, thermal comfort is not considered in the design stages of affordable houses. Designing an affordable house for hot and humid climate becomes a challenge when thermal comfort is required without the use of air conditioning. Merida, Mexico is one example of this type of climate, and to choose a home that ensures thermal comfort in the built environment, a few issues were discussed. An energy analysis of a typical affordable home was performed using Autodesk's Building Information Modelling (BIM) software to check where the lack of passive system alternatives or a bioclimatic design is affecting the energy efficiency. This project found that minor changes can make a difference between having a high-energy consumer home or an energy efficient one. Besides air conditioning, it was demonstrated that appliances and lighting might not represent high energy consumption. The main problem is the thermal discomfort inside due to the design, so air conditioning equipment is needed to overcome this issue, representing a high energy demand.

INTRODUCTION

Sustainability has become a goal for every government, every industry, every human being, and in construction that is not the exception. Providing affordable housing is in the agenda of every government in the world mainly in developing countries which use this strategy to reach the goal of achieving social sustainability. However, affordable houses built in the last decades of the 20th century in many countries were not designed to operate efficiently and nowadays, that is believed that the environmental part of sustainability is as important as the social one, new processes of designing, building and operating dwellings have to be considered in every stage of a house's life cycle.

It has to be stated that almost all the energy in the planet comes from the sun (McMullan, 2007), a few factors that have influence on the energy performance of a building are: the site, different climate means different problems and solutions; layout, to harvest as most solar energy and wind as possible to provide natural lighting and ventilation; shape and size; planning; fabric, the materials in the envelope will affect the thermal comfort of the users.

A house that has special design criteria to minimize the operating energy usage taking into account the thermal comfort of the users using passive or active strategies and technologies is considered to be a low energy house (Sartori and Hestnes, 2007). To provide thermal comfort there are two starting issues: the external climate, referring the place where the building is allocated and is governing the heat losses or gains of the house and; the internal climate, meaningful to the control of air, relative humidity and temperature (Chalkley and Cater, 1968). Probably the most important way to provide thermal comfort and be energy efficient is by the use of natural ventilation which contributes to sustainable building with low energy cost, however it is quite a challenge for designers to provide natural ventilation in hot and humid climates where its effectiveness is limited and during some parts of the year thermal comfort can't be achieved by using it. Climate, the users and their comfort, layout, shape, the envelope, the surroundings and the heat gains of the building are the main factors that determine if natural ventilation is feasible (Etheridge, 2012).

The orientation of a house is also important to make it as efficient as possible, this determine the heat gains and losses from the walls. Orientation and location of walls, windows, skylights and openings have massive importance due to the gains induced by the sun, when this is not considered in the design stage normally shading devices that could have been avoided are used (Chalkley and Cater, 1968). The use of shading where needed (considered from the design stages), ventilation, radiant cooling or evaporative cooling are some of the strategies that can be used to provide comfort at low energy cost (Watson and Labs, 1983).

In the whole Latin America sustainable building practices are being promoted nowadays and Mexico has been leader of the region in building efficiency and sustainability aspects (Urban Land Institute, 2009), the INFONAVIT, a government institution which provide subsides to the housing sector, when affordable houses' design considers energy efficiency, passive technologies and sustainability factors.

The city of merida

Climate

Merida is the capital city of the south-eastern Mexican state Yucatan with a population around one million inhabitants it is the largest city in south Mexico. The city is characterized by its low rise architecture, where the skyline is practically flat; the city is located in the middle of a tropical rainforest region, the climate conditions are hot and humid and hot and sub humid for most of the year, summer temperatures overcome 30°C with peak temperatures above 39°C; the lowest temperatures occur in the months of January and February and flow between 10 and 15°C; besides the high temperatures, the level of humidity is almost 100% during the summer and the raining seasons, this has a big effect on the comfort of the people creating a "sense of heat".

The Housing Sector

The growth and urban development of the city of Merida has been at the same time organized and disorganized, it is said because in the north of the city where the residences and most of the services are allocated there haven't been and strict and serious adherence to the urban development plan; however, in the low-income areas (where the affordable houses normally are) there has been a strategic approach and the city grows more organized. A good example of this strategic approach is the good results that zones in the city like Caucel city (west side of the city) or Kanasin (east side of the city) where socially everything is within a walking distance, all services and needs can be found there, those areas showed a better economic growth that other places where affordable houses are allocated but were built without a proper urban development planning.

Affordable Housing Situation

According to the INFONAVIT, the state of Yucatan, where the city of Merida is, has had an offer of 25,635 affordable houses from July 2013 to June 2015, and only 8,049 of them were sold; this means that in July 2015 there were more than 17,500 affordable houses to sell in the state, most of them in Merida or its surroundings. (INFONAVIT, 2015)

This data means that there are more houses than people that actually want to buy them. Even when the INFONAVIT has been applying several "environmentally friendly" programmes like "green mortgage" (which motivates construction firms to include eco-friendly technologies like solar water boilers or insulation) there haven't been much attention in social or climate design, most of these affordable houses have a height of 2.4 meters from floor to ceiling resulting in hot indoor

temperatures and, when the tenants can afford it, use of air conditioning devices which use the majority of electricity for those houses.

In a whole development point of view, there isn't specific regulation applied to provide a "sustainable development" in one project. There is existing regulation to provide green space and places for social interaction, however, many times it is not there due to the lack of supervision by the authorities or lack of interest.
The good thing is that the INFONAVIT motivates to build sustainable houses and real state developments providing more subsides for those projects that take sustainability into account in the design stage and include all services in one place and provide energy efficient homes.

Methodology
To create an understanding of the situation of affordable houses in the city of Merida, Mexico an analysis of where they are, the typical dimensions, the number of people living in them, the features in design, among others, will be made. Other characteristics that will be analysed are the services and facilities located in the nearby of the areas where the affordable houses are.

By selecting a typical house, a rough conceptual energy analysis will be made, using Autodesk's Building Information Modelling (BIM) software, which has demonstrated that is an effective tool to make comparisons rather than perfect energy analysis which is not the main objective of these research; the analysis will take into account the materials of the fabric and how the environment is affecting the indoor energy performance.

Adding little changes in design and using bioclimatic design elements, proposals of new affordable houses will be made, making the costless or cost-effective for both, the builder and the tenants.
Analysing the possible results of these changes in design in energy and comfort terms, conclusions will be made comparing the advantages of costless alternatives in construction and design which can bring more comfort and a better energy performance that can result in money savings for the tenants that are assumed to be low income people.

Analysis of affordable houses in merida
Energy Analysis
In order to perform a conceptual energy analysis, an affordable house allocated in the west side of the city of Merida was selected. The layout of the house is two bedrooms, living room, kitchen and a bathroom in a one-floor building, perimeter walls are found in the North, South and West facades.
The main materials used to build for the walls and slabs are lightweight concrete blocks and cement mortars, there isn't thermal insulation and the windows are single paned clear windows representing around 10% of the walls of the house.
The surroundings of this particular house are identical houses in neighbouring properties having no affectation on the energy performance of the studied house. The pavement roads and the concrete sidewalks increase the heat island effect and add heat to the environment resulting in the use of more air conditioning.

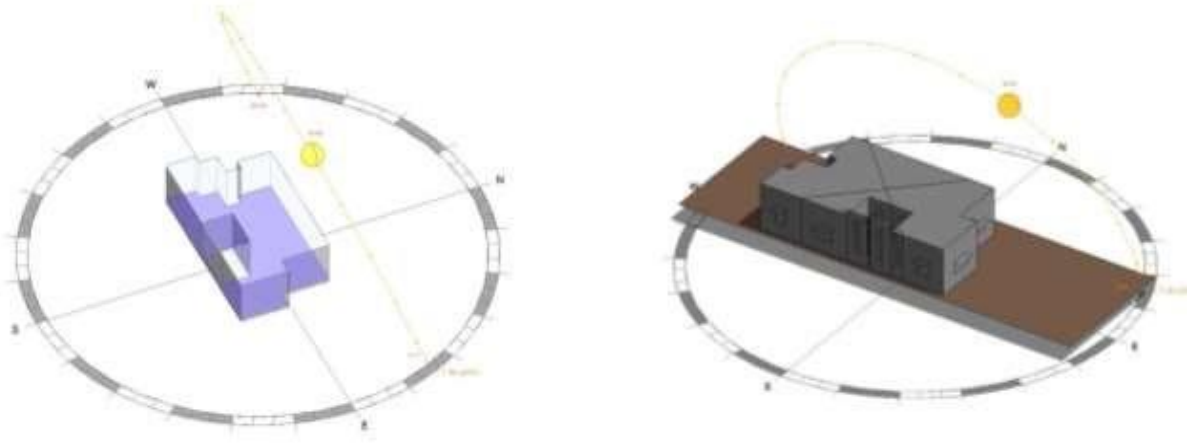

Image. Conceptual energy model for the original house

Results and proposals
Energy Results
After having performed a conceptual energy analysis of an affordable house in the west side of the city, the results were very clear it is necessary to have an air conditioning system in order to bring thermal comfort to the tenants.

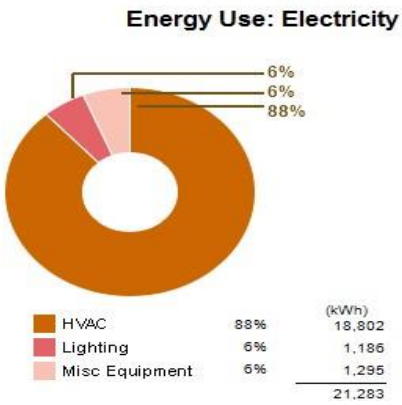

Image. Original house energy results

As can be seen from image if the system is to be used every single time that the climate conditions do not provide comfort, the energy load of the air conditioning system covers 88% of the total load, however, a regular family living in an affordable house in Mexico doesn't have the economic resources to maintain an air conditioning system running almost all the time, sometimes they can only use the system when is absolutely necessary, this, if they have an air conditioning unit, which most of the time they don't. It is quite remarkable the need to change the way we build, and maybe not by changing materials, but changing the design conditions and to consider a climate design including vegetation and natural insulation.

Proposals

As stated in the previous section, a new design was proposed, using local vegetation, trees that are normally allocated on-site and the only thing that contractors must do is to leave them where they already are, a low level of insulation considering a layer of waterproof paint or better, a simple green roof that has already been used in some buildings in the city, like the one allocated in Engineering faculty of the Autonomous University of Yucatan (Ordoñez-Lopez, et.al.).

In the new conceptual design there were no changes in construction materials or glazing location and percentage. Image shows the models.

Image. Climatic design and conceptual model

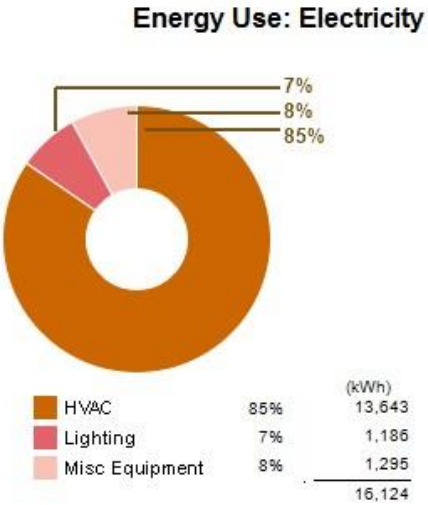

Image. Climatic design energy results

The results from image are conclusive, even when the HVAC load didn't decrease much in percentage (88% on the original house vs 85% in the modified one) the total amount of the kWh used by the house decreased in more than five thousand, this means that the air conditioning system will be necessary 27.5% less than the original house, and that thermal

comfort will be achieved during more time without using active systems, in a place where there might not be the possibilities to afford an air conditioning system a change like this can make the difference between enjoying a place that should be used with that purpose and simply do not have a comfortable life at home.

Conclusions

The results are clear: minor changes can make the difference, instead of building developments of 500 or more houses only considering accommodation of as many houses as possible, a change in design that optimizes the energy performance only by changing the orientation of every house will bring benefits for every tenant. Locating trees and vegetation next to the south or west facades of the houses is a way to take advantage of the environmental design which is a good idea considering that regularly trees are being tore down at the first stages of construction, only by leaving those trees in the places that are going to be needed make a free indoor environment modifier.

Builders and realtors don't consider thermal comfort, or, at least they don't make trade-offs with that, because they tend to think that it is costlier, almost never break the status quo, because it wouldn't make the business affordable to pay more. Government agencies must be stricter to make the housing developers more aware of energy saving policies and supervise both design and construction to provide better comfort, indoor air quality and make the houses use less energy to prevent the depletion of fossil fuels and make the heat island effect in the city reduce.

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