Responsible Design and Delivery of the Constructed Project
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THE ELEMENTS OF NATURAL CONCEPT IN SUSTAINABLE BUILDING SKINS

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Introducing new ideas and solutions that serve environmental functions in sustainable building designs have become an enormous challenge recently, particularly with the current practices of architects and designers in this field. To achieve comfort zone in commercial and residential spaces, the three major aspects that have to be considered are thermal, ventilation and daylight. The proposed project is located in Abu Dhabi, United Arab Emirates, and the main purpose of choosing this location is the hot weather in the U.A.E. Therefore, applying the bio-mimicry design on building skins will react as a solution to improve the indoor thermal comfort in reducing solar heat gain and achieving uniformity in daylight as well as focusing on ventilation in certain seasons, to motivate and enhance the natural ventilation pattern and to reduce the energy consumption as well. This study will mainly focus on developing a building skin that considers locally sourced material such as clay and protect birds' habitat by creating a place for breeding and feeding the birds as well as to integrate plant pots into the skin to reduce pollution. Secondly, combining it with a natural concept strategy that matches the various systems used, to enhance the indoor environment and the indoor comfort needs. The Simulation software, ECOTECT/IES, was used to measure the daylight and thermal performance levels before and after applying the skin concept. The expected findings of this paper may also help in solving part of the existing building envelopes and evaluate their negative impacts in the hot climate region.

Keywords: Thermal comfort, Ventilation, Daylight.

1 INTRODUCTION

Human population is increasing massively; wherever we go, as humans, we completely change the natural habitats of the place we occupy. Studies have shown that the forest has declined by 19% in the last three centuries, the grassland declined by 8%, and cropland increased over 400% (Marzluff 2001). Formerly, buildings were used to perform as a form of housing, making a direct separation between users and their occupied environment. Architecture began to separate from its ordinary characteristics and went outside the box. As much as the designer inspired by nature, and as much as the human needs are reached by doing so, architechs and designers are converting these types of behavioral processes into human-made design solutions (Maglic 2012).Today, the new ideology used is "Biomimicry design" that imitate nature to develop comfortable housings and systems to serve the human needs. The outcome expected from this study is to create a balanced harmony between architecture, human needs, and the environment. This study will mainly focus on the building skin systems that serve the hot climate region. The case study project used in this paper is from Abu Dhabi, United Arab Emirates. The IES and Ecotect

software were used for simulation to extract the thermal and daylight figures. The climate – consult was used to extract climatic data information. On the other hand, the proposed bio-mimic concept will have to achieve the optimum desired comfort zone in residential spaces. Therefore, three main features to be focused on are thermal, daylight and improving the natural ventilation pattern in houses.

2 SELECTED CASE STUDY

The Project is located in Al Raha Garden Abu Dhabi, United Arab Emirates. The main reason of choosing this city is the massive construction development taking place. Masdar city is a real project example of the importance of sustainability to this country (Masdar 2018). The construction materials used in the existing villa block walls are plaster concrete and final finish of paint. UAE Climate data indicates the weather seems hot and humid in summer and the temperature rises to about 48 C° and 90% humidity especially in June - August. The average temperature in summer is 32-36 C° (Figure 1). (Casey 2017)

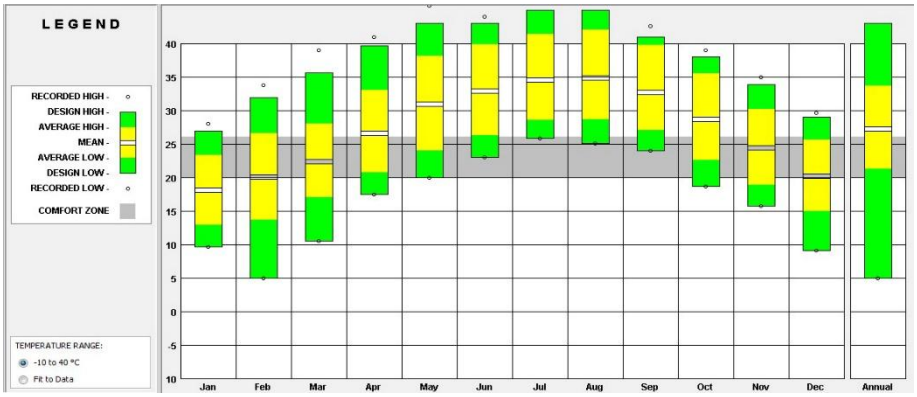

Figure 1. Temperature average. Climate consultant, City of Abu Dhabi, UAE (2016).

3 NATURAL CONCEPT

"It may be true that one has to choose between ethics and aesthetics, but whichever one chooses, one will always find the other at the end of the road" (Hagan 2001). Many habitats have been converted into road and buildings due to human activities. This study focused on developing a building skin inspired by birds in nature. The major idea behind this concept is to develop an eco-friendly building skin including small houses for birds inside the skin that protect these species in UAE (Hockin 2017). Two types of the local birds that live permanently in residential and landscape areas were considered, “House Sparrow” and “Little green Bee-eater” (Kshemkalyani 2009). The birds’ wings movement has been studied and matched with the idea of protecting the main building structure by integrating new skin made of solar screen fabric. A modular structure made of clay (terracotta mold) attached to the villa using steel channels and solar screen shades fixed between the clay modular are used to control thermal aspects.

4 EXISTING VILLA ANALYSIS

4.1 Daylight Factor Analysis (Existing Villa)

The percentage of DF was considerably high by 5.5%. This percentage shows the needles of artificial light during daytime, but overheating the space. The current material used is double

glass, as to follow the UAE standard requirements. Double-glazing with an absorbent film that transmits 39% of solar heat and reflects 61% U factor is 0.25 and solar heat gain coefficient is 0.39 (Tamco 2017).

4.2 Hourly Heat Gains/Losses – (LV, GF)

This graph (Figure 2) shows the results of material conductivity and HVAC Loads on the existing structure (Plaster Walls and Double Glass). The conductivity of materials increased drastically in noon to 4:00 P.M and reached 3600w. The HVAC increased gradually from early morning of 7:00 A.M. to reach the peak at 12:30 noon by 6800w.

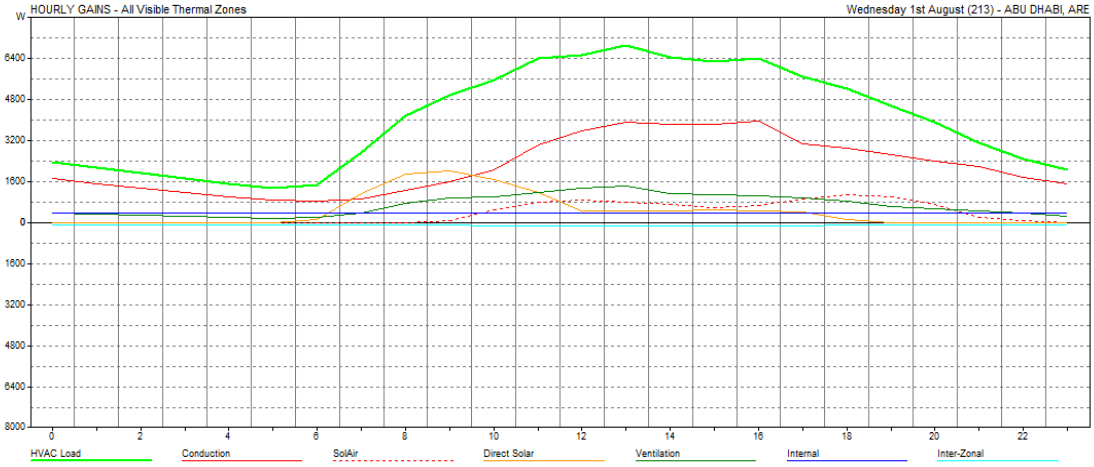

Figure 2. Hourly heat gains/losses (Ecotect 2016).

5 THE PROPOSED MODULAR SKIN DESIGN AND DEVELOPMENT

The developed modular structure is made of clay mold strips divided into pieces, 1m length by 55 cm width (Terracotta Tiles). Each clay tile is erected directly to steel columns that are attached to the building concrete structure vertically with horizontal rails (Figure 3). The structure is creating a double skin façade with the original building structure. In the north façade side, the developed modular (square shape) consists of pot channels in order to grow plants. The roots of the self – climbing vines are placed inside a pot for simple irrigation system by pouring water directly into the pot, and the climbing vines will attach itself to any close rough surface (Figure 3). This will help on feeding the birds as well as a warm place for breeding and creating their nests inside a small opening shaped in the modular. On the other hand, in the south façade, the modular consist of greenery channels that are connected by automated solar fabric louvers to enhance thermal comfort level and control the sunlight and daylight penetration to the original building. (Shen and Tzempelikos 2012). Additionally, this system was made to enhance natural ventilation during cold seasons to improve indoor air quality. This system will give the design flexibility to change and adapt with various weather conditions along the year.

5.1 Exterior Solar Shade

5.1.1 *Solar screen fabric*

Unique PVC-coated solar screen fabrics block up to 97% of the heat without creating a closed in feeling. In addition to superior durability and minimal maintenance, the fabric's 4% openness

provides excellent outward visibility. It is a composition of polyester and vinyl polyester (Insolroll 2016).

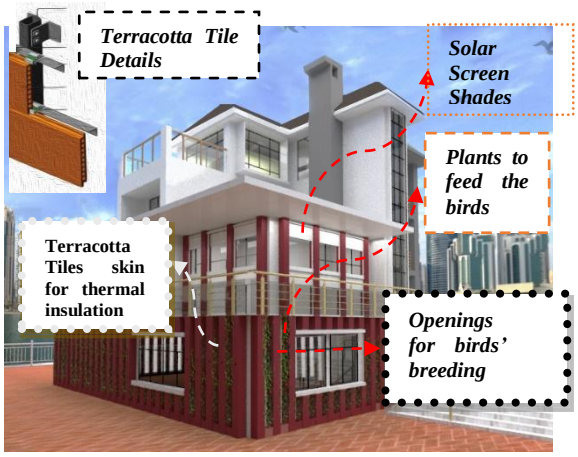

Figure 3. Developed skin.

6 RESULT OF THE APPLIED SOLUTIONS

6.1 Daylight Analysis Pattern (Terracotta Skin & Solar Shades Fabric: Living Room, GF)

The daylight level and daylight factor have been improved significantly after applying the screen shades to the opening in ground floor level.

6.2 Thermal Analysis (Terracotta Tile and Solar Shades Fabric – Living Room, GF)

Figure 4 shows the hourly heat gain/losses of the living room space, while after applying the solar shades screen the conductivity reduced by less than 3200w and the HVAC load decreased to 4900w in August during the peak time 12:00 – 1:00 P.M.

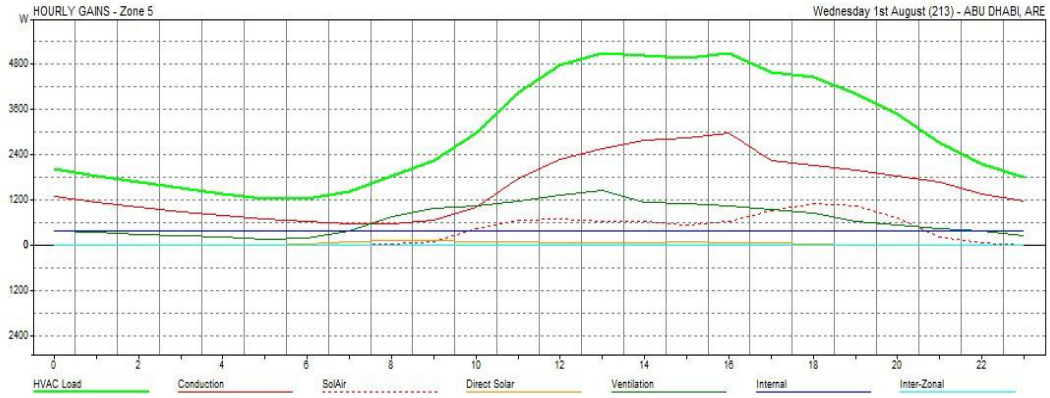

Figure 4. Solar shades screen (hourly heat gains/losses) – Living room, GF (Ecotect 2016).

6.3 Daylight Factor Analysis (Developed Skin – Living Room, GF)

Table 1 demonstrates summary results of daylight factor percentages after adding the proposed skin to the structure. Results have shown improvement and balance in daylight factor with an

average of 2.5%. This indicates that thermal level has been improved. However, in a certain time of the day, supplementary artificial light is needed to improve the space lighting (Chou 2004).

Table 1. Daylight factor summary in Living room (Solar Shades and Terracotta Skin) IES 2017.

Surface	Parameter	Values			Uniformity (Min./Ave.)	Diversity (Min./Max.)
		Min.	Ave.	Max.		
Working plane 1 Reflectance=0% Transmittance=100% Grid size=0.30 m Area=13.380 m² Margin-0.30 m	Daylight factor	0.5 %	2.5 %	8.3 %	0.17	0.07
	Daylight illuminance	87.33 lux	577.02 lux	2089.99 lux	0.17	0.07

7 DISCUSSION

Table 2 indicates the final summary results of the studied structure obtained from IES software (The original skin structure vs. the proposed Terracotta modular with solar screen shades). The development of the modular terracotta structure with plant pots and solar screen shades has shown a better improvement to the villa structure in most of the studied factors. Firstly, the daylight factor results in the proposed skin are 2.5% in comparison to the main skin of 5.5%. This percentage of the proposed skin will reduce thermal heat gain and balance DF level. However, artificial light is needed during the day. Secondly, the CO2 concentration in each skin was studied, and results have shown improvement in the clay tile with an average of 360PPM in comparison to the existing skin 455 PPM.

Table 2. Daylight factor and Thermal MWH Analysis comparison (IES 2017).

Residential Villa	Daylight Factor Diffuse Living Room	CO_2 Concentration PPM Living Room	Total Carbon Emission (CE) (Kg O_2)	Cooling load KW Living Room	Total Energy Consumption Yearly
Original Structure Plaster Brick wall + Double Glazing window	5.5 % (Mean Value)	455 PPM (Mean Value)	45,571 $KgCO_2$	0.9 KW (Mean Value)	69.3 MWH
Proposed Skin Terracotta Skin + Solar Screen Shades	2.5 % (Mean Value)	360 PPM (Mean Value)	35,792 $KgCO_2$	0.48 KW (Mean Value)	1.5 MWH

Consequently, the improved space will contribute to reducing the CO2 concentration level and improve the air quality value. Corresponding to the previous result, the total carbon emission value has also been enhanced in the solar screen shades skin. While it is essential to use mineral fibers to have better control in CO2 concentration levels.

Additionally, the usage of plants between the clay structures skins has contributed slightly to the reduction of the total CO2 emission. The third column indicated the cooling loads in each skin. In the proposed skin, the result shows better cooling load with 0.4 KW (mean value) difference than the original skin. Finally, the annual total energy consumption has improved. This result demonstrates a reasonable reduction using the Terracotta tiles. Therefore, if this

solution is applied to the full villa's compound, a significant energy efficiency level will be achieved annually. Accordingly, a better sustainable built environment value will be added to the project.

8 CONCLUSION

This study discussed the development of eco-friendly skin that improves building consumption regarding energy loads, daylight factor and natural ventilation. Moreover, create a safe place for birds to regenerate without the need of destroying their natural habitat to build our cities. The proposed skin is made of Terracotta Tiles (steel structure, light in weight) with integrated solar screen shades. A comparative study has been conducted on IES and ECOTECT software to compare between the original structure (Plaster bricks with double glazing – following the UAE standard requirements) of the villa and the proposed modular skin. The developed skin showed a better result in achieving the desired goals of this study that mainly focused on thermal aspect, natural ventilation (to improve IAQ) and daylight control.

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