MODEL OF HOUSE DESIGN RESPONSIVE TO HOT-DRY CLIMATE

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ABSTRACT

The presented model here represents one of a series of our applied research, aimed at providing easy and very simple design formulation to be a model for architects to illustrate to them the possibility of linking results of applied research with aesthetic and occupation human needs if adopted in large housing projects to be harmonious with our climate and environment.

This model won a prize of the Iraqi Energy Consultative Committee in a competition for the best environmental design, and in retrospect evaluation after implementation, thermal, economical, and utilization measurements were performed on the model 20 years after its construction. The results were in agreement with initial design expectations, to verify the success of the bases on which the model was designed.

The design style for this model was applied on a 2-storey house, construction area 380 m², land plot area 288 m², with eastern frontage. The house consists of 5 bed-rooms, reception, living area, office, kitchen, store-room, 4 bathrooms, and interior garden, proved that:
1- The internal temperatures for most days of the year were within thermal comfort limits for dry-hot climate areas;
2- During summer days, use of low-load air-conditioning appliances is sufficient to bring the house temperature to thermal comfort limits;
3- Day-time, since sunrise, the house enjoyed good natural lighting for most rooms;
4- With the introduction of more advanced wind catchers than traditional ones, the design provided natural air circulation, to cool people and building day- and night-
time during temperate months, and provided cooling for the night, and early hours of the morning during summer-time;
5- The design facilitated interior space (garden) of temperate temperature during summer and winter, where summer temperature was nearly 13 degrees less than for the outer garden;
6- Electrical power consumption for lighting, heating and cooling about 7500 Kilo-Watt for one year.

Key words: Climatic Design, Sustainable Design, Courtyards, Wind Catchers.

Introduction

Great number of architects talks about traditional buildings and how they provided environment suitable for people daily needs in all aspects, including thermal ones. They declared their views to utilize the heritage vocabulary features in present buildings. The performance of the majority in current designs does not meet users needs, the reason, for what we believe in, is that these features in their old formulation were efficient within man's comfort limits, when fans, conditioners and electricity were not available.

For our conviction, the knowledge of the scientific basics of features enables us to develop these vocabularies, and utilize them in our current designs so as to affect current architecture to become thermally responsive.

From the start of the 70's, we have drawn a research plan to lead us connectively to indicators and bases that help architects in designing environment – responding buildings accordance with man's current comfort levels. After more than 15 years of connected research and studies, a house model was designed and built on 288m$^2$ plot, on which thermal measurements were performed. The results were submitted to a competition organized by the Iraqi Energy Consulting Committee. The design won the competition as the best environmental design in 1992, and was shown three times on Iraq Television during "Science for All" program. During the use of the house, several thermal and usage measurements were performed, and number of houses were designed on the its scientific bases.

After 20 years of the success of experimental experience, new scientific measurement were made, which verified the sound scientific efficiency of the designs used model.
General Description

1- A house built on 288m² plot of pant of dimension (12m × 24m) (Fig. 1).
2- Ground floor area is 180m², and 180m² for first floor. Both floors include 5 bedrooms, visitors’ room, living room, office, a large kitchen and several bathrooms. The house is designed closed to the outside with small windows on the façade while large windows are open onto a courtyard of area about 20m², and has two wind catchers, the area of each is about 3m². The house has, an outside garden and garage of about 60m² (Fig. 2&3),
3- 25cm thick walls were built with Thermo stone blocks, whose thermal insulation is 0.2W/mk⁰ (twice the insulation of ordinary building material), and used structurally as bearing walls.
4- The roofs were built of reinforced concrete 15cm in thickness, covered with waterproofing material layer, 5cm polystyrene, 10cm river sand, and 4cm concrete tiles, (U-value 0.364W/m²k⁰)[1].

Broad line Environmental Vocabulary of Designs

1- Benefiting from the concept of adjacent in heritage houses, construction was adopted in our model to be on the outer perimeter of the land plot, to be adjacent to the neighboring ones, which will shield the outer walls from exposure to solar energy and outer hot air. on this basis the house wall will be considered as if it is an inner wall within the unit compound and the houses group as if it is one house, one shields the other from three directions. Thermal conduction along the houses’ ground floors will result in thermal equilibrium [2].

2- Use of courtyard, 75% of its ground is laid by porous bricks making the floor a cold pool.

Since the courtyard in to vertical section contains protrusions (Fig 3) the walls will be shadowed summer time. The incident sun rays on balcony tiles, which shadow the ground floor of the space will force the hot air above the pathways move within the area between the first floor and the air above making the temperature at the near side of the floor inside to remain at low temperature.

3- The courtyard walls in all directions are elevated to ceiling level (fig.3) which makes air motion within the courtyard weak. The courtyard then maintains low temperature day time, when wind catchers and windows are kept closed.

4- The use of creeping plants and low –condensed indoor plants (fig.4), effectively shadowed the walls from sun rays, keeping walls temperature near the plant's temperature, which lower than that of human body. The adoption of low concentration
planting reduces the relative humidity below 40%, resulting in comfortable state. (No water fountains were used to elevate the relative humidity).

5-Adoption of large wind catchers above the house ceiling connected to rooms overlooking the inner garden or connected to windows overlooking the outer garden results in bringing air of lower dust and heat percentage than coming from the road, whose temperature is higher due to its contact with black roads of high heat storage and heat – storing outer walls, with the air – borne dust raised by cars, especially in dry hot weather, where streets are force of rising dust. The air coming from large wind catchers means that the high pressure of the incoming air column from the wind catchers will cause air motion that will yield a feeling of an effective temperature lower than that of true reading of the thermometer [3]. Also if its path on exit is through windows overlooking the outer garden, it will force the outer hot air in the street out of the house.

6-Adoption of Sun breaker made of bricks (fig. 5) as part of the architectural facade of the building has shading efficiency greater than 80% summer time and shading efficiency 30% winter time, this will result in low summer thermal load, and raise natural heating winter time.

7-Placing the windows at the inner edges of the walls thickness to raise their thermal performance [4] and air – capture efficiency, whenever air pressure is positive on the windows and increase evacuation when the window serves negative pressure.

8-Use of insulating building materials, with Time lag between 17 to 12 hours (Thermo-stone Walls) [1], which helps in effecting night – time air cooling of air coming from wind catchers. The cooling is for inner building shell when heat reaches it after 12 hours.

Figure 1 : Façade of the model design – Baghdad - Iraq
9-Use of small external windows, at 10% of floor area or 24% of the outer wall area shadowed by sun and rain protection projections as to the windows overlooking the inner garden, and glazed areas shadowed by sun and rain protection projection, which represent 87% to 55% of vertical walls.
10-Good winter sun was provided for rooms overlooking the exterior via vertical windows enabling sun rays entry to 15m inside the house (Fig 6). As to summer, the sun rays enter to less than 1m inside, and for short periods. The winter sun was made to reach the west – facing rooms on ground floor and overloading the courtyard by the property of reflecting sun rays from 10mm glass in the first – floor. Although this Sunning is not sufficient it provides the inhabitant with feeling of warmth, and the pleasure of enjoying the sight of winter sun. The percentage of rays entering was 20% of its original energy.

**Visual Aspects**

Normally it is said that environment – compliant buildings are poor aesthetically. On this basis, attention to visual vocabulary of the model was given, including optical illusion in enlarging the space area and feeling of openness. The inner spaces were to be connected with the inner garden by large windows, effecting illumination of inner of about 1:15 of the illumination of inner garden. Such percentage gives the observer feeling of visual comfort, with no stress to connect the inner space with garden as if it is one part of it (fig.7). Therefore, whenever one enters a space of spaces overlooking inner garden adds the garden area to that of the room, giving the feeling that the building area is much bigger than the true area. However, if we use big windows in the spaces overlooking the exterior, it would give smallness to these rooms, because they create optical rebound for the eye as a result of quantity if intense light coming from the outer space, which causes a feeling of withdrawing the wall containing the window to the inside which causes a feeling of shortening the length of room (since the outside rays even in the winter is greater 100 times that of illumination of room illumination) [5 ].

*Figure 4 :* Creeping plants shading courtyard walls
Figure 5: Fine Asparagus plants

Figure 6: Winter sun patch in visitors room
Advanced Design Vocabulary Implemented in the Design

Wind Catchers

Wind catchers in heritage architecture are air passages in the residence walls whose horizontal cross-section is not greater than $20\text{cm} \times 100\text{cm}$, ending in an opening inside the rooms, for which the mason gives his best to beatify it. The air duct cross-section area does not exceed, at best, $0.2\text{m}^2$, whose majority were around $0.1\text{m}^2$. Due to the narrow opening, the mason around cannot plane and polish its inner walls, consequently it become a haven for ants and insects, and the wandering of rats between houses in view of its darkness. The majority of house wall are damp due to the influence of ground water, which cools the passing air through the wind catchers slightly as a result of evaporation (this what the author has experienced in 1950). The quantity of air delivered was very small, for which it was finally closed after the author's father bought an electric fan.
The principle of air exchange is considered the best hygienic treatments, and the principle of obtaining air motion is considered an important principle that signals the person of temperature reduction despite higher than comfort limits [6], what is called "Effective Temperature", which varies in feeling with velocity increase of air passing over the living bodies. On this basis, our understanding made us think of the importance of adopting natural ventilation, and the development of this vocabulary. We have innovated a new type wind catchers whose cross-section area is not less than 2m², two sides of which are 3 meters higher than house roof, which face the common Baghdad air.

This wind catchers opens on rooms overlooking the inner garden or outer garden, which cause the air to impinge on the two high walls to drop into the wind catchers. Also; its impact on the two high walls causes negative pressure behind the walls, that is above the inner garden which increase the speed of air motion inside the rooms as a result of difference in height in the air column inside the wind catchers and inner garden, which is lower by 3 meters, and due to the development low pressure above the garden as a result of its impact on the wind catchers wall (Figure 9).

The speed of the air coming through the windows overlooking the wind catchers, whose area is 0.5m², increases the speed of air flow inside the spaces to the extent that a person sleeping in a bedroom is compelled to place cover on the body. No air cooling equipment were used during the last 20 years in the main bedroom, but were forced to install air – cooling equipment during the last three years because of the dusty climate occurring in Iraq during the last 3 years as a result of gross rain shortage which prevented us from using the wind catchers on some days.

The Courtyard

The inner courtyard or past inner garden used to be passage, about which room doors and their inner walls overlooked it.

The hot and cold, rain and dust whenever they occur used to affect the rooms overlooking and individuals moving about inside house. When European architecture was transported, that was publicized by architects graduated from European countries, people departed from the inner – courtyard – based designs completely.

Our convention that inner courtyard is a delight to the eye and sound social connection, we have developed the courtyard to as to be used as isolated of climatic changer, a beautiful vision connector, family gathering site, and an air – exchange center.

We know the provision of clean natural air replacing of the fumigation of inner spaces, even on lower sunning, which people like to reduce during the summer in dry hot climates.
Then development then came by glazing one of the main walls overlooking the interior to the level of ceiling to retain the feeling of openness and visual comfort (Figure 10). It is of importance to mention here, it is not permitted to cover the courtyard with glass ceiling, because it becomes a thermal store and causing lower air motion, thus stopping the function of wind catchers.

**Figure 9**: Air distribution by using wind catchers

**Figure 10**: Glazing one wall overlooking the interior
Thermal Measurements

In order to integrate the design from thermal point of view, several treatments were adopted, such as by contact with adjacent houses, use of Thermo-stone walls, ceiling isolations, use of wind catchers to cool rooms and inner shell of the house at night, adoption of the principle of inner courtyard stepped in its vertical section, use of porous materials for flooring, adoption of creeping plants in the inner courtyard and non – dense plants, and use of sun protectors on the outer openings. Consequently, this resulted in temperature inside it, as indicated in the August data (where August is considered in Iraq as the highest temperatures), as seen in Table (1). Fig (11) indicates near or within human-comfort limits for hot dry places, which changes sensibly to an effective temperature (lower temperatures when motion of incoming air from wind catchers occurs or even use ceiling fans). In August 2008 thermal measurements showed that monthly average, maximum, minimum and range are almost similar to those taken in August 1988.

![Figure 11: Comparison between courtyard air temperature and ambient air temperature on 27th of August](image-url)
Table 1: Showing average Air Temperature during August 1988 for different spaces outside and inside the house, knowing that one (250 Watt) evaporative air cooler were used in each floor.

<table>
<thead>
<tr>
<th>Space</th>
<th>ROOF</th>
<th>EXTERNAL GARDEN</th>
<th>COURT YARD</th>
<th>BEDROOM GROUND FLOOR</th>
<th>VISITORS ROOM</th>
<th>LIVING ROOM</th>
<th>BEDROOM FIRST FLOOR</th>
<th>OFFICE FIRST FLOOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature Max. °C</td>
<td>43.0</td>
<td>43.0</td>
<td>30.5</td>
<td>28.0</td>
<td>28.0</td>
<td>28.0</td>
<td>30.5</td>
<td>31.0</td>
</tr>
<tr>
<td>Temperature Min. °C</td>
<td>30.0</td>
<td>30.0</td>
<td>27.0</td>
<td>22.0</td>
<td>22.0</td>
<td>22.0</td>
<td>25.0</td>
<td>25.0</td>
</tr>
</tbody>
</table>

This in its entirety proved how sound the design is in being responsive to climate. The other thing proving that the design model is responsive to the climate is the electricity bills for the two years (from 17-7-1988 to 21-6-1990) amounted to 15000 KW (Figure 12), which means the building was not dependent in its cooling and heating on high electric power.

What can prove the success of realizing thermally-comfortable buildings by using of developed heritage vocabulary as in our model and the adoption of corrective treatments, is in the excellent growth of indoor plants in the inner garden (Fig.4&5), especially the fine Asparagus, the height of which reached 7 meters. It is conclude from the aforementioned, it is possible to adopt and utilize developed heritage vocabulary, the adoption of natural treatments, and utilizing visual environmental vocabulary to realize climate – responsive and beautiful designs.

![Figure 12](image)

**Figure 12**: The amount of electricity (from 17-7-1988 to 21-6-1990) 15000KW

**Conclusion**

Attached houses and inward looking design strategy provide protection from high summer solar energy, and work together with the use of thermal insulation block walls (Thermo stone) in lowering air temperature and decreasing the daily temperature oscillation inside house spaces.

The use of large and improved wind catchers in conjunction with courtyard reduces the need for reliance on air cooling and air moving-equipments day and night for long
periods of the year, and achieving the benefit of cooling buildings' inner skin and human body during moderate summer nights. Moreover, wind catchers help in achieving excellent natural ventilation, keeping air in the building fresh and make living conditions inside healthier, even in the occurrence of lack of insolation.

The integrated gathering of climatic and architectural design vocabulary and the use of plants, with the use of some improved heritage vocabulary could assist designers in reducing dependency on polluted energy and make the house nearly self dependent on creating comfortable environment.

Openness of rooms with moderate lighting intensity inner garden has a great psychological effect on increasing room sizes visually, feeling of openness, and providing relaxing and comfortable place for family.

References