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Redefined Energy Efficient Strategies to Achieve Thermal Comfort in Contemporary Houses in Lahore, Pakistan

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Abstract- The past few decades have witnessed a visible rise in energy consumption by the residential users. The adverse change can be partially attributed to a modernistic and apathetic approach to house designs which do not adhere to the local realities of climate, topography and orientation. The paper is part from an ongoing Ph.D research on Thermal Optimization of a House through Geometric Modelling in Semiarid climate of Lahore with emphasis on open spaces and openings inside the house design. The paper aims at investigating current strategies and techniques of energy efficiency being implemented by contemporary architects in the modern house designs. A cross-analysis of the residential projects as selected case studies, was carried out to identify the customized parameters, regarding window design, adopted to deal with the semi-arid climate of Lahore. Meanwhile a number of books, journals, magazines, research papers, essays and blogs (both in printed form and online) were consulted regarding the literature review. Detailed analysis showed that architects in Lahore are employing some of the passive principles regarding window design alternatives such as window wall ratio (WWR), window Glass, window orientation and shading devices with the aim of creating houses that correlate with the climatic conditions to develop energy efficient houses. But none of the selected case study showed a deep understanding by the architect, as far as design of windows is concerned. There is still the need to evaluate the buildings with respect to the design of openings/windows at modelling stage to counter the extremes of local climate and to formulate the codes.

Keywords- Energy Efficient, House design, Lahore.

I. INTRODUCTION

House form occupied by the middle-class population of Lahore has evolved drastically in the past 100 years. The evolution can be traced through the transition from the introverted traditional houses of the walled city settlement into the Bungalow style houses of the cantonment area and finally culminating into the contemporary houses of expanding housing societies[1] .The urbanized layout of the old Lahore city was dotted with vernacular houses having central courtyards that depict an introvert tendency. The cityscape witnessed the culmination of colonial bungalows in late 19th century, which were an amalgam of English design in terms of aesthetics and local Indian principles in terms of passive design principles. The houses that emerged after partition in1947 rose from the philosophy of modernism which capitulated on the freedom and power to utilize energy resources in bulk quantities. Houses of current era display an array of stereotype houses which often overlook the passive design principles due to strict building codes of setbacks. Consequently, there has been a sharp increase in the electricity and energy consumption in the residential sector in the past few decadesectors. The city of Lahore, based in a developing country with an unstable energy production, has failed to address this unprecedented demand of energy consumption.

The past century can be termed as the catastrophic age with regard to the ecosystem considering the rapid increase in pollution and depletion of natural resources. Currently, the rate of production and consumption of natural resources is not compatible i.e. it takes 18 months for the earth to regenerate the amount of resources that are being exhausted in 12 months.[2] It is for this reason that a substantial amount of research and development regarding Energy Efficient Building has been carried out in the affluent countries of the West. The phenomenon of Energy Efficient Building is helpful to counter the problems related to energy consumption in developing countries like Pakistan as well.

Energy efficient strategies are the only viable solution that enables us to create buildings, with lesser dependence on mechanical means to provide comfortable living conditions. They tend to produce a customized design which makes optimum use of climatic factors of sunlight, rain and winds of that particular zone. This research paper focuses on the

analysis of passive methods that have been employed in the house building practices in Lahore, to attain energy efficiency. The objective of this research is to analyze the contemporary houses, by renowned architects, with respect to passive design strategies of window alternatives like orientation, Window wall ratio, window glass and shading devices used in Lahore. The houses are evaluated in terms of energy efficiency.

To attain the objective of the study, relevant literature regarding the above-mentioned passive design strategies has been studied and findings in hot climate like that of Lahore have been deduced. Then the designs of contemporary houses have been evaluated according to previous findings from the literature.

II. Research Methodology:

The data collection involved findings of the previous researches. Books, websites, research papers, architectural journals and essays were studied to acquire secondary data on the passive design strategies of window alternatives like window orientation, window size, window glass and window shade.

The climate of Lahore is studied to have a better understanding of energy efficient methodologies useful in the specific climatic conditions. The prominent architects of Lahore who have been consistently active in the professional as well as academic domain are listed. The names of listed architects are Nabeel Wali, Aqrab Rana, Obaid Ghayyor, Kamil Khan Mumtaz, Ghulam Dastgir, Faisal Rasool, Faiz Qureshi and Wasif Ali. Among the above-mentioned names, four architects are selected on the basis of designing houses particularly with the embedded Lahore's climatic conditions. The design of a house from each selected architect is taken as a case study. The four different house designs named as A, B, C and D are presented in the form of drawings and photographs. Then these case studies are evaluated on the basis of the conclusions drawn from the previous researches. The data is presented in tabular from. Evaluation and discussion is done on the basis of the design features regarding window variants which are in accordance with the parameters set by the previous researches. Also the site visits of the selected case studies expounded a better understanding of what the architects intended to achieve through the energy efficient methods incorporated in the designs and what was the additional impact after the design implementation.

Climate of Lahore:

The Lahore falls in the Semi-Arid Zone according to BSh according to Koppen Geiger Classification of climates. The climate of Lahore is characterized by cold dry winters, hot and humid summers and low rainfall.[3]. A temperature chart of Lahore is shown in the fig below.

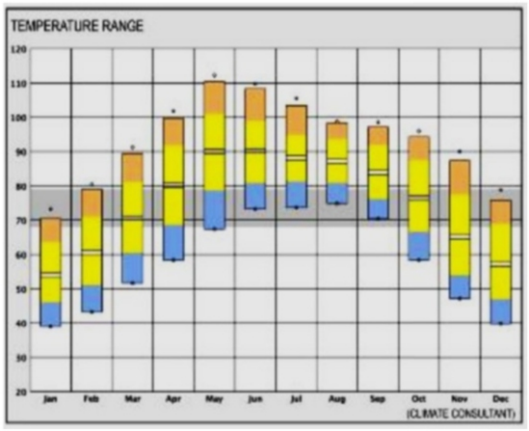


FIG.1 Annual Temperature Chart of Lahore (Orange color showing the Average High Temperature, Yellow showing the Mean Temperature and Blue showing the Average Low Temperature in °F month wise) SOURCE: [4]

Window Orientation:

In the hot climates, orientation of a building has a profound impact on the energy consumption of a building. In hot climates like that of Lahore, west orientations causes the highest amount of energy consumption 26% more than south orientation. The most desire able orientation in such climates is North South [5]. It means that most of the surface area of the external envelope must face the two orientations i.e North and South. And more windows must be oriented on North and South orientations. Another study conducted to find the optimal orientation for better energy consumption suggested that South is best for winter heating and North is best for summer cooling [6]. A study conducted to find the optimal orientation in relation to building form again suggested that the best suited orientation for all rectangular forms of buildings is North South and is responsible for least energy consumption.[7]

Window Wall Ratio:

Window Wall Ratio (WWR) is defined as the area of the external wall to the area of the opening. WWR is an important factor in determining the thermal conditions inside the building [8]. The installation of an optimum size of the window can reduce 40% of energy consumption. The optimum size of window ranges from 10-50% for all types of facades on all orientations[7]. Heat gain and heat loss through the window design affect the indoor comfort level. Window Size (WWR) is an important factor in determining the indoor comfort level especially in hot climates like that of Lahore. A study conducted to conclude an optimum size of window in hot climate of Ghana suggested a range between 10% to 40% [9].

A study conducted to achieve a desire able size of window in the climate of Lahore also observed that there is a gradual decrease in heat gain by a decrease in the size of the window [8].

Window Glass:
Glass occupies a comparatively larger part of window design and is responsible for admitting huge amount of solar radiation inside the building thereby increasing the cooling load of the building [10]. The properties of glass material is determined by attributes like U-Value, thermal transmittance, Visible Light Transmittance (VLT) (VLT) and Solar Heat Gain Co efficient (SHGC). The energy consumption in a room decreases with the use of the glass material with low U-Value. This study was conducted in hot climate of Gaza strip[11]. The windows with smaller area (WWR) can be used to attain higher energy savings with the use of glass with high VLT value (clear glass). |On the other hand, windows with large WWR are beneficial with the combination of high-performance glass with low U-Value and SHGC. This research was done for the hot and humid climate of Malaysia [12].

Window Shade:
Window Shade is a very important parameter of window design and shading the window is desired when a building acquires excess heat in summers. Shading is first tier approach to sustainable cooling. [4]

III. Results and Findings

The details of the case studies are presented in the Table 1.

Table 1: House Projects by selected Architects

HOUSE	ARCHITECTS	SOFTWARE APPLICATION	HOUSE PROJECTS	YEAR OF CONSTRUCTION
A	**Sideworks Pvt Ltd** (Aqrab Rana)	Yes	Obaid House	2019
B	**Wali And Associates** (Nabeelwali)	No	Architect's own House	1995
C	**Kamil Khan Mumtaz** (Associates)	No	Bina Jawad House	2015
D	**Ghayyoor Obaid** (Architects)	No	Architect's own House	2004

The plans and pictures of selected case studies are given below with a brief discussion on the energy efficient strategies employed by the architects in the designs.

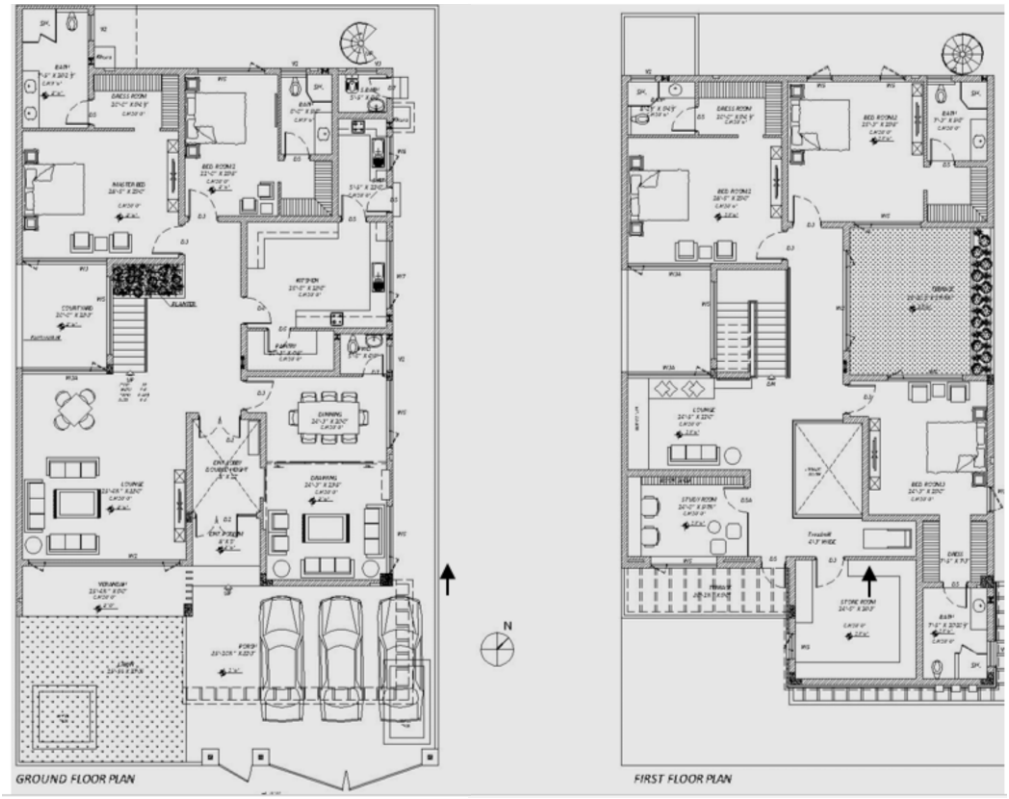
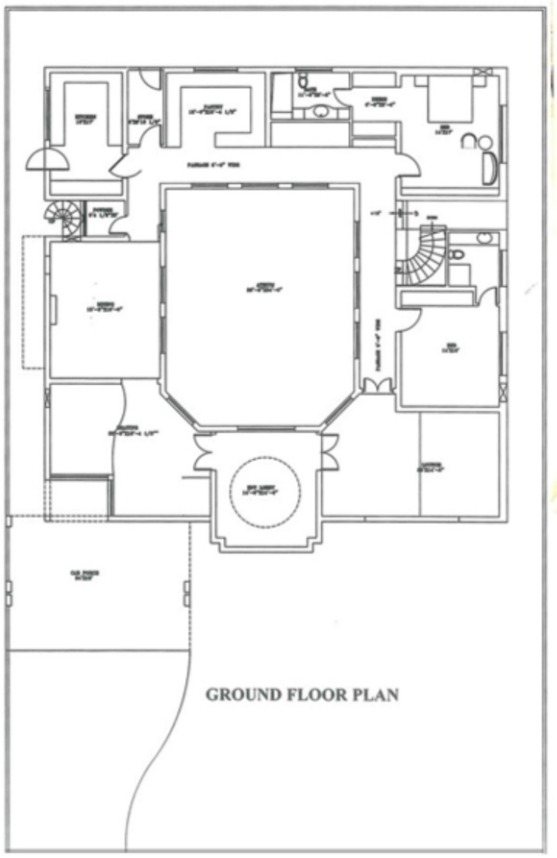


Fig1. House A (a) Ground Floor Plan, (b) First Floor Plan,

(c) South East Elevation

The analytical study reveals that architect has considered the orientation factor while designing the house. The washrooms and storage spaces are placed on east and west orientations and given smaller windows which are high level as well. The architect however did not use high performance glass material in the windows. The size of the windows have not been worked out and windows are devoid of shading devices as well. Architect tried to decrease the heat gain but unable to consider the admittance of appropriate amount of natural light inside the building as suggested in section of Window wall Ratio.



(a)

(b)

(c)

(d)

Fig2. House B (a) Ground Floor Plan, (b) First Floor Plan, (c) South Elevation, (d) Courtyard

House B depicts a central courtyard as the design nucleus (Fig.2). It is covered with fine metal gauze which acts as mosquito netting. Moreover it accelerates the evacuation of warm from the inside which is replaced by fresh air. Fiber glass canopy on half of the metal gauze provides shelter from the rain to the residents who can enjoy the weather while retaining the sanctity of their privacy. The central court, which induces sunlight, fresh air, bird's sounds and rain in the house, is a part of the design strategy to deal with the distinct weather conditions in Lahore. It also acts as a climatic barrier by protecting the internal living spaces from radiated heat. (Fig 3)

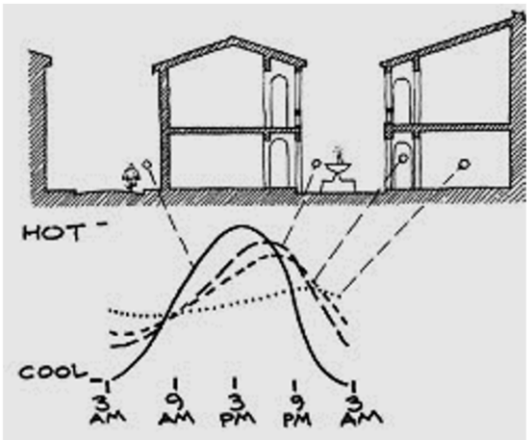
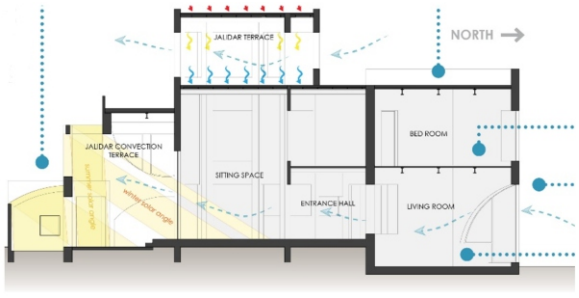


Fig 3 The hot-weather daily temperature fluctuates most in the street, least in the rooms surrounding a courtyard. (Source: Reynold, 2002)

The analytical study showed that architect tried to incorporate the energy efficient strategies like internal courtyard and also have given shades (Fig2 (c)) which looks aesthetically pleasing as well. The windows are devoid of high performance glass. The design is devoid of ample number of windows on the exterior side. However the there are ample number of windows in the Ground Floor Plan which are opening in the central courtyard.

Fig4. House C Ground Floor Plan, South Elevation

The evaluation study reveals that House C has a site with large area as compared to other selected case studies. The encircled area in the Ground Floor plan is the house plan. (Fig.4). The architect designed the building with traditional planning having a courtyard and verandas facing west and south orientations. Verandahs also act as shades or buffer zones in hot climate. The elevation reveals the arcaded passageways around the building and Jali fjail feature in the exterior wall. Plan shows the number of small windows on all sides. West orientation which is the most challenging one has a courtyard covered on other sides with building. This kind of planning represents the traditional layout of old havelis of Lahore.



(a)

(b)

Fig 5. House D (a) Section, (b) Top; Front Elevation, Bottom; Jalidar Terrace

Analytical study reveals that architect has introduced an innovative kind of shading which he termed as Jalidar Terrace on South to protect the house from harsh summer sun on South and west. The two bedrooms are facing North side to experience the maximum comfortable conditions in the hot climate. There are terraces and verandahs around the building throughout which is a vernacular approach to achieve thermal comfort.

The evaluation data is presented in Table 1.

Sr. No.	House	Area sq.ft	Orientation	Window Wall Ratio WWR	Window Glass	Window Shade
1	A	5445 (1 Kanal)	yes	yes	No	No
2	B	10890 (2 Kanal)	No	yes	No	yes
3	C	13612 (2.5 Kanal)	yes	No	No	yes
4	D	13896(4 Kanal)	yes	No	No	yes

The above mentioned table shows the four different strategies (Orientation, window wall ratio, window glass and window shade) being considered in the selected case studies by writing Yes and No. Yes shows the orientation is considered while designing while No shows that orientation factor is not considered. Analytical study showed a variety of results in the above mentioned case studies. Architects tried to employ the design parameters of window but were unable to fully incorporate the window design strategy. House A showed the consideration of orientation and window size (WWR) but lacked the use of high performance glass and shading devices. The window sizes are not calculated according to sun angles. House B and C showed a larger foot print area with bigger site. The architects have taken advantage of the large sites and introduced a central courtyard technique and vernadahs on south and west sides. House b showed a courtyard and all the windows are opening in it, not considering the orientation factor. Central courtyard can help to minimize the solar gains but can only be given in buildings with larger foot print area. House B has incorporated traditional chajjas which can act as shades well. The sizes of windows are also small in House B but these are not calculated according to sun angle in overheated period of the Lahore. There is no use of high performance glass in any selected case studies which can be effective in reducing heat gains. House C is a unique project as it is a part of a farm house development and the house occupied more area than even house B. Vernada is given on all side and a huge courtyard is also given in center. The House C is a complete representation of traditional design and represents the vernacular architecture of Lahore. This design cannot be included in the discussion fully as it cannot be implemented in designing modern houses having sites of 1 kanal and 10 marlas. Again there is no consideration of window sizes and use of high performance glass. House D is using an innovative kind of shade on south and west but lacked the consideration of window size and window glass.

Conventional houses always relied on natural ventilation for the comfortable interior spaces while the houses of today are inseparable from the cooling produced by air conditioners. Air conditioning is a life changing reality in today's lifestyle and there's no substitute for it. Air conditioners were introduced in Pakistan in early 1970s and they soon became popular and instigated a demand curve [1] It shifted the paradigms of living and human comfort. Consequently, there was a shift from the traditional mode of natural ventilation of the houses. R. Aqrab and his team have a realistic approach towards air-conditioning; they deem it as a necessity. On average, a house constructed on a 1 kanal plot, requires 22-25 tons of air-conditioning on the whole. There is no substitute for air conditioning. They strive to create a nice building envelope with lesser tons of air-conditioning required. The architect G. Obaid also admitted the role of air conditioners in the current lifestyles. He stresses that design is related to lifestyle. The architect is supposed to create atmosphere for the residents according to their lifestyle and preferences. He has to enrich it with the design.[13].

IV. Conclusions

A number of architects are trying to develop and formulate energy efficient strategies but there is much more to be done yet in this direction. There are various researches on different aspects focusing more on the orientation of the house and materials in separate contexts yet there is very less attempt in the designing of an energy Efficient House for this climate. This research attempt to understand the strategies adopted by the practicing Architects in Lahore who have done a few projects in this regard. The paper is part from an ongoing Ph.D research on Thermal Optimization of a House through Geometric Modelling in

Semiarid climate of Lahore with emphasis on open spaces and openings inside the house design. This research was followed by an attempt to understand the "Reconnaissance of the Passive Techniques of Traditional Residential Architecture to Achieve Energy Efficient Modern Houses in Lahore" done to bridge between the old design strategy and spatial designing to make the traditional house in Lahore more thermally comfortable for the occupants. This paper sheds light on the analytical study of the energy efficient techniques regarding window design implemented in contemporary architecture of Lahore. However, there is not a single architect who is designing windows with a full consideration of reducing heat gain in summer and working on all parameters of window design. Also there were very less new houses and projects attempted here due to client's needs and requirements. For the samples of old traditional houses majority of the houses in Lahore are havelis and mansions with variant sizes and data availability. Due to this reliability on the available data is very limited. There is a need to calculate and work out these window design alternatives and employ these techniques to develop policy guidelines so that these can be used in future to design energy efficient houses in Lahore.

V. Acknowledgment

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References

[1] R.Khalid,M. S. Blank, M. (2018). Evolving houses, demanding practices: A case of rising electricity consumption of the middle class in Pakistan. *Building and Environment*, *143*(July), 293–305. https://doi.org/10.1016/j.buildenv.2018.07.010

[2] M. Wackernagel, (1990) *Ecological Footprint NETWORK-ADVANCING THE SCIENCE OF TECHNOLOGY*, *University of British Columbia*. Available at: https://www.footprintnetwork.org/our-work/ecological-footprint/.

[3] R. Haider, A. Yasar, A.B.Tabinda (2017) 'Urban emission patterns at a semi-arid site in lahore, pakistan', *Polish Journal of Environmental Studies*, 26(1), pp. 59–68. doi: 10.15244/pjoes/64284.

[4] M. Rashid, A. Jalil, S. Gulzar, A.M.Malik (2019). The Efficacy of Shading Design in Commercial Buildings in The Semi-arid Climate of Lahore ; Focusing on The Geometry of Horizontal Shade. *Technical Journal Uet Taxila*, *24*(2), 1–10.

[5] R.E.Ashmawy, N.Y. Azmy,(2018). Buildings Orientation and its Impact on the Energy Consumption. *The Academic Research Community Publication*, *2*(3), 35. https://doi.org/ 10.21625/archive.v2i3.344

[6] A. Eljojo. (2017). Effect of Windows Size, Position and Orientation on the Amount of Energy Needed for Winter Heating and Summer Cooling. Journal of Engineering Research and Technology, 1(1), 0-8. https://doi.org/10.13140/RG.2.2.32424.47361

[7] C. Koranteng, E. Abaitey (2010). The Effects of Form and Orientation on Energy Performance of Residential Buildings in Ghana. Journal of Science and Technology (Ghana), 30(1), 71-81. https://doi.org/10.4314/just.v30i1.53940

[8] M. Rashid, T. Ahmad, A.M. Malik, M. Z. Ashraf. (2016). 6. Effects of Orientation and Glazing Material on Heat Gain in Semi-Arid Climate.pdf. Technical Journal Uet Taxila, 21(IV).

[9] C, Koranteng, J.N.Essel, (2015). Passive Analysis of the Effect of Window Size and Position on Indoor Comfort for Residential Rooms in Kumasi, Ghana. Iarjset, 2(10), 114-115. https://doi.org/10.17148/iarjset.2015.21024

[10] M. Rashid, A.M.Malik, T. Ahmad (2016). Effect of Window Wall Ratio (WWR) on Heat Gain in Commercial Buildings in The Climate of Lahore. International Journal of Research in Chemical, Metallurgical and Civil Engineering, 3(1). https://doi.org/10.15242/ijrcmce.ae05160317

[11] A.S.Muhaisen, H.R.Dabboor (2015). Studying the Impact of Orientation, Size, and Glass Material of Windows on Heating and Cooling Energy Demand of the Gaza Strip Buildings. Journal of Architecture and Planning, 27(1), 1-15.

[12] AL-Ashwal, N. T., A.S. Hassan, (2017). The Impact of Window to Wall Ratio (WWR) and Glazing Type on Energy Consumption in Air-Conditioned Office Buildings. International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies, 8(3), 197-207.

[13] F. Haroon, (2019). Interview on Energy Efficient House Designs-interview with Ghayyoor Obaid dated june 2018.