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Passive Techniques Analysis of Residential Buildings for Energy Efficient Modern Residences in Lahore

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Abstract- The forces of globalization have reshaped the world, resulting into the present-day architecture that has lost its relevance with the local climate, culture and social background. Modern architecture all over the world has similar features, materials and form, regardless of the region and has employed energy intensive methods to achieve thermal comfort. The traditional architecture was responsive to climate and region, to achieve thermal comfort in all building typologies in the past. This paper aims to seek the knowledge about the passive strategies for heating and cooling, employed in the residential buildings in past in order to formulate guidelines for designing new houses in Lahore, Pakistan. For this purpose, an extensive study of traditional and modern residential buildings in context of Lahore, Pakistan has been conducted, to analyze form, features, elements, and materials in addition to the active and passive cooling / heating techniques, construction methods of both typologies. The final step is the formulation of guidelines to achieve energy efficiency in residential architecture through the adaptation of passive techniques employed in vernacular architecture in order to provide innovative solutions of the modern times.

Keywords- **:** Energy Efficient Housing, Climate Responsive, Traditional Residential Architecture, Modern Housing, Passive Techniques.

I. INTRODUCTION

Globalization is a worldwide prevalent phenomenon that has a great impact on cultural, social, economic, political, and technological aspects. The field of architecture and urban development are the most effected by the force of globalization. Which led to the standardization of materials, building techniques and architectural features or so-called international style, resulted in lack of traditional and local character [1]. This phenomenon has also challenged our potential to attain a climate responsive architecture, which is evident in residential architecture of Pakistan now a day. Present day dwellings are using energy intensive methods to create comfortable built environment instead of using natural techniques [2]. On the other hand traditional dwellings were responsive to the local climate, surrounding environment, culture and social impacts and an optimum example of sustainable and energy efficient architecture and met the needs of people of its time, although they were not designed as energy efficient structures but through ages it has been explored that they proved as energy efficient buildings [3].

The objective of this research is to investigate the passive heating and cooling techniques adopted in earlier Lahore to devise the strategies to be adopted for the new houses in Lahore in order to attain thermal comfort. So a rounded approach in terms of materials, design strategies, layout and techniques is requisite to achieve a climate responsive solution by taking inspiration from traditional architecture for present residential dwellings, instead of taking into account only certain aspects of indigenous house design.

II. METHODOLOGY

The objective of this research is to formulate guidelines regarding energy efficiency for new houses by reviewing the passive strategies adopted in the old houses of Lahore. To achieve the objective, a three step qualitative approach is adopted. The first step is the identification of new and old houses of Lahore as case studies which can be studied with reference to the energy efficient strategies. The second step is the study and analysis of the data collected from primary sources about the selected old as well as new buildings. This data is further processed and presented in tabular form in the results and is about different variables consisting of some basic energy efficient strategies. After the above mentioned two steps, the final step is the formulation of guidelines regarding energy efficiency which would prove helpful for making modern houses energy efficient. The first two steps would aid to develop guidelines for achieving thermal comfort in the newly designed houses.

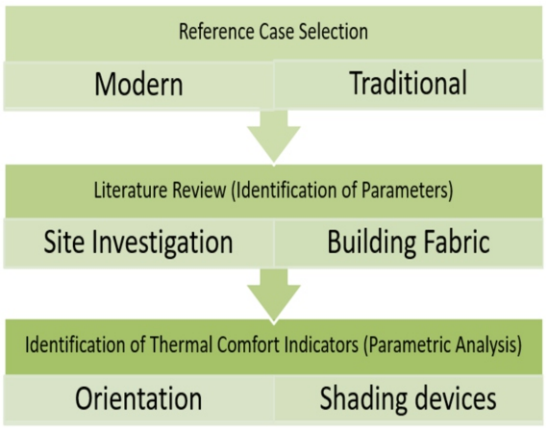

Fig-1: Conceptual Framework for Research phase -1

III. Traditional Residential Architecture of Lahore

Ecological, cultural, social and economic factors were main determinants that shaped indigenous residential architecture [4]. Which resulted climate responsive sustainable architecture along with the great value of esthetics. Residential architecture of walled city of Lahore is a typical example of traditional housing of Lahore, either Ichra was also originally residential area but lately it converted in to commercial area and became central business district of Lahore.

Indigenous residential architecture of Lahore primarily consists of three main aspects; *cultural, environmental and technical.* The *Cultural* aspect of architecture highlighted ideology, faith, behavior patterns Cultural values of inhabitants. The *technical* aspects recommend the techniques used for construction using the indigenous material and local craftsmanship to attain optimum results.

The *Environmental* value indicated climate responsive approach; methods and techniques through design of building elements and features to harness natural energy resources to achieve heating and cooling. The traditional houses unified all above-mentioned values and aspects.

The typical *layout* of residential dwellings was extroverted; a central courtyard surrounded with verandahs and the verandah led to interior rooms [5]. The brick courtyard house had been a substantial element of this region since the very first recorded development of this region; Indus Valley Civilization [6]. A typical form of construction known as haveli was built from two indigenous materials i.e. brick and lime mortar [7].

The characteristics of the courtyard house depend on the environment and the culture of a group of the specific region; For example, courtyards can be used as an indoor garden, or can function as the focal point of the house. Through thousands of years, it was shown a different courtyard dwelling, planning, Sumerian and Pharaonic Egypt registered as the oldest culture in the Middle East, which have the oldest example of the courtyard [8].

Earth was also a popular construction material since the dawn of civilizations because of its thermal insulating properties. Thermal comfort was achieved by the architectural elements like high ceilings, darichas, barsatis, ventilators, massive walls, jalis (screens), verandahs, jharokas (balconies), fountains, plantation, chajjas (overhangs), courtyards and basements [9].

Other strategies included passive techniques such as stack effect achieved through courtyards to improve air quality, protection from excessive heat gains through massive wall ranging from 18”-2' in thickness [10] evaporative cooling achieved by the provision of water bodies in the center of courtyard, cross ventilation and eviction of hot air from interiors through chimneys and ventilators, jalis for introduction of cool air into interiors and chajjas acted as shading device [11].

The above description indicates that traditional dwellings achieved not only high level of esthetics but also provided zero-energy model its passive design strategies alone.

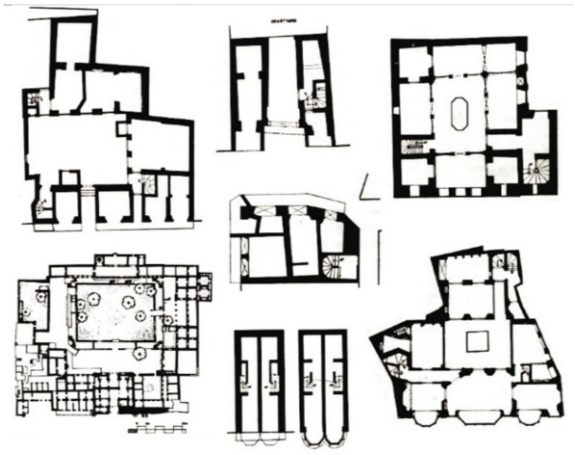

Fig-2: Traditional house typical layouts in the Walled City of Lahore.
(Source: The Walled City of Lahore, publication by PEPAC)

Modern Residential Architecture of Lahore:

Modern housing of Lahore is result of deep influence of international style and westernization in a way that it has lost its relevance with the surrounding environment and climatic conditions. It is quite evident that the building are constructed irrespective of solar orientation, local climate and culture and the predominant feature are extrovert layout, large windows excessive use of concrete and glass [12].

In current scenario there are two popular typologies of housing, detached single family dwelling and the semidetached single-family unit. Row housing is very popular is predominant in modern housing schemes of

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Lahore. The *layout* of house is extroverted surrounded by open spaces, enclosed from all sided by boundary wall giving a sense of complete ownership of the residents. The mandatory spaces of house include a car porch, drawing, living room, and kitchen and bed rooms with attached bathrooms [13].

This type of layout satisfies the needs of users somehow with the social setup of families but minimizing the interaction with the nature, the only form on incorporation of vegetation in built environment is front lawns which deprives the contact of the users with outer natural world. There is lack of Geometry in design of these houses and proportionate system relies on the plot size of house. Due to absence of regional identity these houses lack in association with culture and history of region.

This western housing type became famous in this region the after the arrival of electricity, the internal environment could be made comfortable by the mechanical heating and cooling through the machines only. Having no regard for sun, wind and light, the houses lost their functionality [13]. In the present situation of energy crisis, energy efficient house is essential.

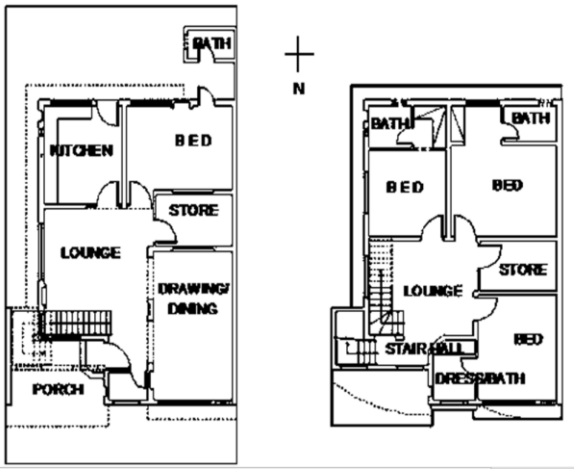

Fig-3: Typical modern house plan
Source: Author

Analysis's of Architectural Elements of Traditional Houses:

An extensive study of traditional residential architecture including haveli Nau Nihal Singh, Lal haveli, haveli of Ranjit Singh, Barud Khanna haveli and common houses located in walled city, and ten marlas & one kanal houses located in modern developed areas of Lahore; Lake City, Bahria town and DHA has be conducted to draw a comparison between the traditional and modern housing typologies. This study leads to explore the spatial organization, form, layout, geometry, architectural elements, material, and construction techniques, heating and cooling techniques of both types.

Fig-4: Haveli Barood Kahana
Source: Walled City of Lahore Authority, WCLA. 2014

Fig-5: Haveli Nau Nihal Singh & Lal Haveli
Source: Walled City of Lahore Authority, WCLA. 2014

IV. Results

Passive strategies are certain techniques used to achieve thermal comfort within the buildings with least or no energy consumption. There are three different strategies of passive techniques used during the building design process, first is before construction or on-site considerations, second involves the design features of building and third are weather skin features.

- *Site Planning Stage:* This includes location, orientation, microclimate modifications and foliage.
- *Architectural Design Stage:* This is very important for Architects and designers as this involves salient features of building design i.e. sun screens, overhangs, shades, volume/ surface ratio, building openings and exposure.
- *Materials and construction Stage*: After Designing and planning of the building comes the fabric of the building i.e. material typology, insulation of walls and roof, finishing/textures, glazing properties [17].

Table-1: Comparative analysis between tradition and modern dwelling of Lahore

No	Architectural Features	Traditional Houses of Lahore	Modern House in Lahore	Comparative Analysis
1	***Spatial configuration***	Introverted planning with more open spaces, courtyards, balcony's and verandahs in the center of the houses and havelis. These have always kept the houses cool without any aided active cooling techniques or means e.g Barood khana Haveli, Haveli Nau Nihal Singh Lahore etc	Extroverted planning with open spaces/lawns/courtyards around/outside the constructed house found in the small foot prints like 10 marlas and 1 kanal houses whereas internal courtyards in 2+ kanals. Now this is observed being practiced in the small houses as well.	Introverted planning with verandah and balconies play a vital role in the cross ventilation of the houses semi-arid climate houses as it can decrease the operational cost of the building with a ventilation gain of to about 8.9 % and 6.7% in the new houses of LDA and DHA respectively. **Source**: *Madeh Ilyas, Samar Shaheen , Ishrat Hameed Alvi, comparative analysis of LDA and DHA houseson Ecotech for Energy consumption with and without courtyard, B-AE Thesis uet(2016)* [14].
2	***Windows and shading devices***	Small, big all sized windows, ventilators have been used in the havelis and houses opening mostly inside the corridors then outside. shade in form of chajjas, jharokas and balconies.	Standardization of window sizes have been done. Large windows used mostly of (6'x8' or 8'x8') used in bed rooms and lounge, ventilators are skipped, no proper shading only decorative devices. No verandahs and balconies are used in houses. Similarly, no internal terraces. Similarly, window planning is not crucially done. More focus on aesthesis.	Fenestration and shading devices play vital role in managing the heating load. The heat load decrease with the decrease in window size and vice versa. The heat gain is maximum with the largest window on the south side i-e up to 320 MJ / m2-yr. And it is lowest on the North side i- e up to 120 MJ / m2-yr. The descending order of impact of different orientations on heat gain is South, East, West and North respectively. **Source:** *M Rashid, AM Malik, T Ahmad, "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, 2016* [15].
3	***Wall thickness***	Thick walls ranging from 18"-3'	9" thick walls.	Walls with 13" thickness can provide an insulation bed.
4	***Ventilation***	Stack ventilation. Due to central courtyard these traditional houses and havelis were cool in summers.	Mechanical ventilation. Due to the design the dependency on mechanical means is a lot more on the active means.	Stack ventilation is natural and more effective. Warm air escapes through the ventilator and cool air enters through the windows. **Source:** *Qureshi, R. Ahmed (2015). The Traditional Courtyard House of Lahore: An Analysis with Respect to Deep Beauty & Sustainability (M. Arch, Kansas State University Manhattan)* [13].
5	***Orientation***	Orientations observed according to solar path as the land was readily available in Lahore then. And mostly houses were constructed on larger plots outside walled city and ichra like model town etc.	Irrespective of solar path. Majority of the houses are laid out as per the devices housing schemes that have fixed orientations without any planned schemes and the architects and the owners are deemed to follow that that eventually effects the designs.	N-S in a better orientation yet east west needs properly planned shading devices. Rooms on these orientations are not feasible for round the year activities. North and east need 31% more thermal load then southern lounges. **Source:** *A.Khan, S.Arif, K. Alamgir, 'Comparison of Buildings Thermal Loads against Building Orientations for Sustainable Housing in Pakistan", Mehran university Research Journal of Engineering and Technology, Volume 31, No.3, July 2012,(ISSN0254-7821)* [16].
6	***landscape***	Minimum due to land area.	Outside lawn. Foliage screening around exposed areas.	Landscape aids in the energy efficient house design. No foliage screen present

The traditional houses were designed and planned by taking into account, all above levels of passive design strategies. These passive design strategies were archived by the *form*, *spatial organization* and architectural *elements* of the buildings [18].

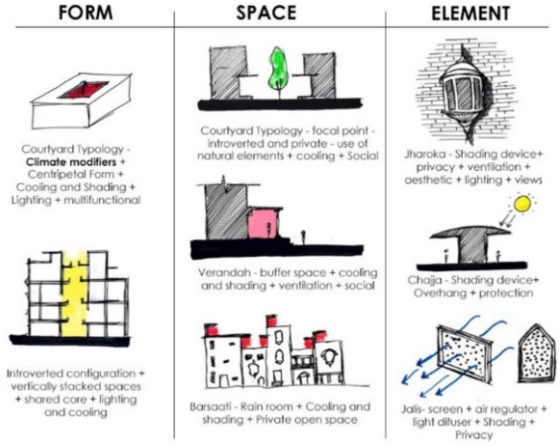

Fig-6: Different aspects of traditional housing, source: Zara Shafique - Understanding Traditional Domestic Buildings in Pakistan"- Lessons for contemporary design, Pg 43 [18]

Induced ventilation: Induced ventilation was achieved through three techniques; courtyards, air vents and wind towers.

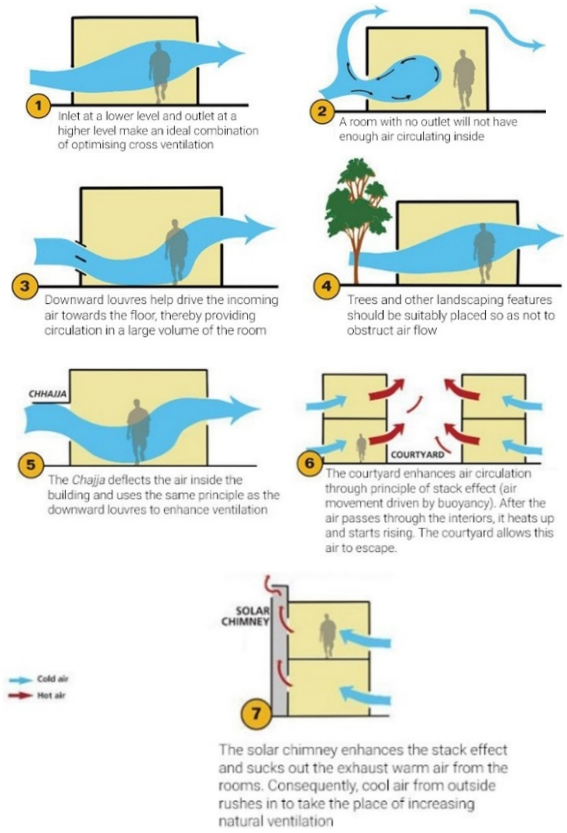

Fig-7: The ventilation process source: Zara Shafique - Understanding Traditional Domestic Buildings in Pakistan"- Lessons for contemporary design, Pg 63 [18]

Courtyard (central open space inside the house) is the oldest known, form of dwelling, acts as microclimate modifier of microclimate, when certain variables are taken in to account such as the orientation, attach volume and ventilation [19].

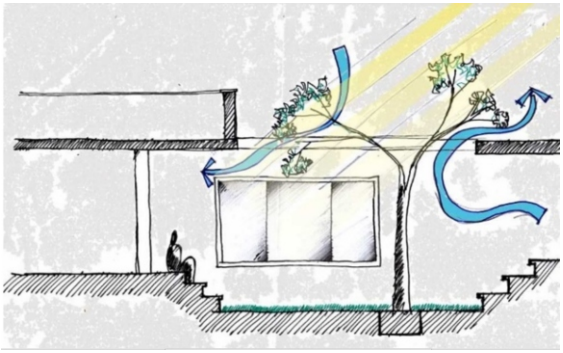

Fig-8: Concept sketch of courtyard as climate modifier, using air, vegetation and sun

Building layout plays a significant value in the orientation of courtyard, hence the solar path, performance of shading devices, solar heat gains and wind direction, all these factors have Impact on microclimate [20]. Direct guidance suitable orientation of courtyard in building helps to achieve the thermal comfort, however if the solar angle and direction of wind are not suitable, can cause thermal discomfort.
Courtyard form employs technique of stack effect for natural movement of air and ventilation. Due to stack effect cool air enters in the room and hot air raises and escape through open to sky courtyards. It also allows diffuse light to penetrate inside. Air vents allow the hot air to escape from the rooms thus creating the natural follow of air through interior spaces. Wind towers or wind chimneys are means of erudite process of air distribution throughout the house and collection of hot air and ejecting it through built spaces.

Shadings
Purpose of shading was to reduce direct solar radiations and heat gains that was achieved with the design elements such as chajas and jharokas.
Shade forms of these features obstruct solar radiations to directly enter inside the rooms, instead allow diffuse light and radiations to penetrate.

Evaporative Cooling
It was found that the internal courtyard with a water feature, tent and water sprinkling during hot sunny hours cause significant cooling effect within the interior of building surrounded with the courtyard.

A central water feature provided in courtyard worked as sprinkler which moist the air, cool it down and improve air quality. Moisture particles of the water absorb heat from the surroundings and evaporate, hence dissipating energy of surrounding heat from surroundings and evaporate, hence dissipating energy of surrounding environment which lowers the temperature and create Environment. Which as a result lowers the temperature and create cooling effect?

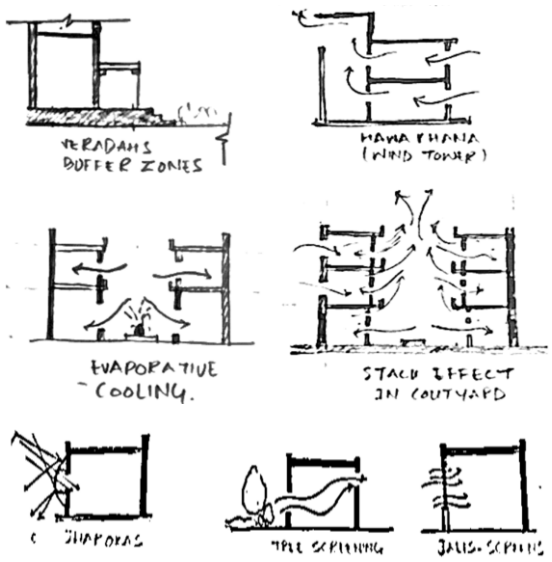

Fig-9: The concept of evaporative cooling used with the central courtyard. Source: Author

Insulation
Thermal insulation is provided to maintain comfortable internal temperature within the internal spaces. Heat transfers from outside to inside of building through building fabric; external walls and roof. In traditional buildings insulation was done with the use of thick massive walls (3' thick outer walls), concealed from outer side and clay which was a famous material in subcontinent provided best insulation properties.

Tree Screening
Placement of natural elements within a courtyard would create environmental benefits. For instance, Safarzadeh & Bahadori [21] found that trees, shrubs and flower plants (as a garden elements) within a courtyard can significantly affect the thermal comfort as they provide shaded area with the wall of the courtyard was tree shading or screening. Vegetation around the openings cooled the penetrating air and oxygenate it. On the other hand, the shadow created by trees keep the building fabric cool in summers. The choice of deciduous and ever green trees was made according to the need of place, in order to let the sun heat and light enter in winters but obstruct in summers.

V. DISCUSSIONS

According to World Watch Institute data, buildings are responsible for the annual consumption of

40% of the world's energy. Energy consumption of buildings can be reduced significantly in every stage of a building life cycle [22] [23]. The primary measure to start from is to design an energy efficient house is the spatial form and typology of house designs. Instead of extroverted form and open spaces around the building, the building exposure should be minimized. The house sharing its walls with the adjacent house and open spaces inside the house in form of courtyard. The second most significant measure is the use of material. Clay or mud plaster was the most popular material in subcontinent, should be used instead of excessive use of concrete. This s not a unique or inapplicable solution it has been implemented in well developed countries like Australia, candida and England recently. Excessive use of glass should be discouraged.

- The regard to orientation is a primary factor to make a house environment responsive. Thus, respect should be given to orientation of sun and wind direction.
- The passive heating and cooling techniques to achieve thermal comfort should be accommodated in design features and form of house rather than relying on mechanical resources only.
- Decorative and design elements such as verandahs, jharokas, chajas, barsatis should be revived in technical and design aspects.
- Courtyard, wind tower and ventilators should be the features of house design for natural ventilation.

VI. Conclusions

The employment of passive design strategies for heating and cooling purposes in the past provided energy efficient residential architecture in Lahore. The incorporation of materials like clay and plaster in addition to spatial configuration and layouts further supported the effectiveness of passive techniques. There are other aided variables proved to work with the passive design techniques architects can employ like landscape, water bodies, site selection, orientation of the house, courtyards, rooms layouts, fenestration, shading devices etc as deduced from traditional houses resources. These energy efficient variables have been used in the old and traditional houses differently and have always proven in the maximization of thermal comfort. Guidelines for using these variables will be customized in the further research to achieve energy efficient housing regarding design and material, living within the limitations of current scenario in the newly constructed houses and even to make certain interventions in the already constructed ones. The adaptation of these variables can improve the heating and cooling loads of the modern houses to achieve thermal comfort in the present scenario.

VII. Acknowledgment

This work is part of a PhD research at the University of Management and Technology by the researcher under the title "*Thermal optimization of a house through geometric remodeling in the semi-arid climatic in the context of Lahore"* for which I am grateful to my colleagues Ayesha Ahmed and Memoona Rashid for their continuous support.

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