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NATURAL DAYLIGHTING IN IRANIAN HOT AND ARID REGION

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Abstract- The rebirth of daylight buildings that are also in harmony with the local nature has been one of the most important issues which might be considered at the forefront of design and planning of the public and private buildings. Electric light can overheat interior spaces even in winter, particularly in hot-arid regions; daylighting can be considered as one of the most effective strategies to reduce the cooling load in buildings. The identification by traditional architects and builders of problems that existed in the use of natural lighting in desert regions will be explored as a living workshop. Many devices and elements have been planned and could be created in order to control the sun's penetration and at the same time to make the best use of daylight. Use of daylighting in building design, particularly in sunny regions, could help in the economic revitalization of existing settlements, in raising prosperity of different socio-economic classes and in environmental sustainability of energy conservation.

Keywords: Natural Daylighting, Energy Conservation, Hot and Arid Region.

I. INTRODUCTION

When providing daylight in hot and arid climates careful consideration must be given to how spaces are lit. Excess heat and light can be problematic when temperatures are well above the human comfort zone for much of the year. Fortunately, traditional architecture in hot and arid regions has organically developed techniques and traditions over the centuries that allows for daylight to be properly and enjoyably utilized in buildings for these regions.

II. CLIMATIC CONSIDERATIONS

Most traditional architecture through time has not had the benefits and shortcuts that prolific post-industrial energy surplus provides. This naturally forces climatic conditions to be taken much more seriously in the design of buildings. These architectures innately take into consideration climate, orientation, location, solar radiation, wind direction and speed, etc. When evaluating traditional architecture, similarities can be seen depending on what type of climate the architecture has come from. Based on this architecture can be divided into four climatic zones consisting of tropic, arid, temperate and cold. Hot and arid climates make up forty percent of the world's land (Figure 1).

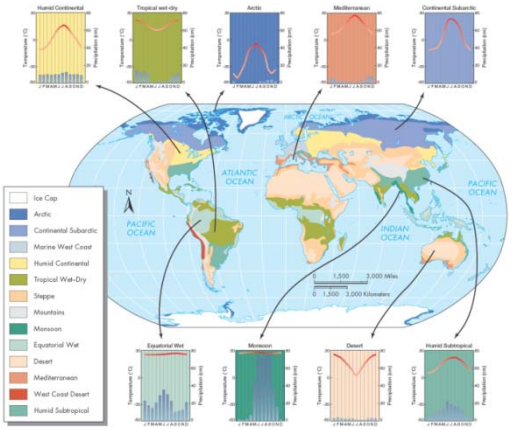

Figure 1. World climatic zones

III. HOT AND ARID CLIMATES

Hot and Arid Climates are a challenging climate to consider when dealing with daylighting. Light is only part of the solar radiation spectrum, there is also heat in the radiation spectrum that will enter a building every time direct sunlight is let in. Any daylight brought into a building needs to be utilized as much as possible so that heat increase is kept to a minimum. Creating openings in buildings can also allow for heat to come in from the surrounding environment. It is important that when openings are created they be best utilized and positioned to allow not only for light to enter the building but ventilation as well. When considering how daylight is obtained in hot and arid climates, one of the largest problems is glare.

Glare is a common issue in desert climates because it easily brought about by bare ground or the light colored facades of buildings, which ironically enough is light colored to assist in reducing too much heat accumulation. There are two types of glare that must be considered: "disability glare, affecting the capacity to see clearly, or discomfort glare, generally experienced as a feeling of discomfort after having been in area where there is any amount of glare for some length of time".

It has been traditionally believed that the few to no windows found in desert climates is due unwanted heat gains, but it has since been discovered that with adequate shade, the actual window size affects indoor temperature very little as long as it is shaded. This leads to the consideration that comprehensive analysis must be considered when analyzing openings in buildings [1].

IV. ARCHITECTURAL CONCEPTS

A. Courtyards

Courtyards are a key component of desert architecture. They allow for an interaction between interior and exterior without exposing a significant amount of the building to the harsher elements. Besides providing security, they are a sheltered oasis, protected on all four sides by the structure but allowing nature to be a part of the architecture (Figures 2 and 3).

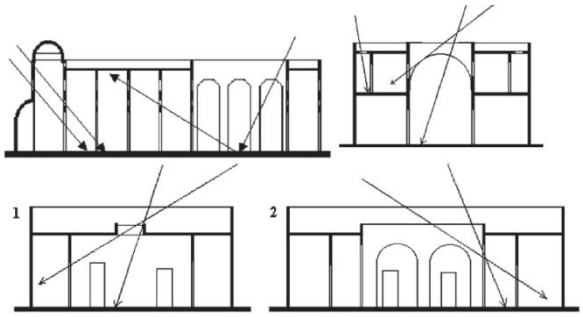

Figure 2. Different kind of courtyards

Figure 3. Courtyard views of houses in central Iran

Roof openings in courtyards are influenced by the severity of the climate. Within hot and arid climates some are hotter than others. When the climate is on the milder side it is typical for the entire area of the courtyard to be uncovered. In more severe climates, the courtyard may be only partially open to the sky further protecting it from the elements. Courtyards and the spaces that sound the periphery can be single height or double. Double height courtyards allow for a deeper recess to store more cool and for stack ventilation to occur more efficiently.

B. Iwans

Often times traditional architecture will have a unique room known as an 'Iwan'. Iwans are spaces within the building where one side is entirely open to the outdoors, typically a courtyard, to allow for privacy and security. This open side of the semi-enclosed rooms allows for light to enter the Iwan and the spaces beyond. Most typically Iwans are located on the south side of courtyards with the open side of the room being to the north. This allows for the Iwan to harness the indirect light of the northern sky without having direct light enter in (Figure 4).

Figure 4. Courtyard and Iwan views of houses in central Iran

C. Windows

Windows are utilized for the primary purposes of daylight, sunlight, ventilation, and views. It is important that windows be ideally designed for the purposes they are needed to serve. Size Windows to the exterior are typically of small size and screened. In hot and arid climates it is important that windows be tailored specifically for their use whether it is ventilation, natural light, or views.

Even within the greater desert environment openings will also vary in size depending on the climate. The more harsh extreme deserts will accommodate even smaller windows then the average desert environment to combat the harsher conditions. As windows are located higher up on a building it can be beneficial for the windows to be smaller since they are more likely to have an unobscured view of the sky and light can enter more readily [2].

D. Deep Reveals and Split Windows

Often times it is beneficial to break windows up into smaller windows with an increasing thickness towards the interior, this allows for even further control of light. By making the window reveal deep and splaying it wide as opens into the room, this allows for glare to be reduced as light will reflecting on reveal and reducing the contrast between window and the interior wall.

E. Colored Panes

Colored panes allowed for a further diffusion of light and privacy in buildings. An example of this can be seen in the Turkish baths where the colored light creates and ambient mood that is further enhanced by its reflection off of the steam vapors (Figure 5).

F. Lattice Work and Screened Openings

Often times in the desert this allows for air and light to enter through at a filtered rate but privacy the privacy is still retained. Lattice work and screens can be constructed out of metal, stucco which is typical of public structure. Lattice work is also often made of wood which is more typically seen in houses (Figure 6).

Figure 5. Colored panes

Figure 6. Adobe window in a public garden in central Iran

One such type of wooden lattice is the 'moucharaby' which is made up of wooden spherical lattice work. The round surfaces allow for light to enter and reflect of the surfaces very softly allowing for light to be reflected softly into the space, as well as ventilation, but privacy is still provided.

V. ADDITIONAL ARCHITECTURAL CONCEPTS

A. Dome Shaped Roofs

Besides having good structural properties the form of dome shaped roofs assists in other elements of the architecture. Many dome roofs have an oculus at the top. This top lighting entering through the dome allows for the direct pool of light to migrate through the space during the day while the dome shape of the roof assists in the reflecting diffused light elsewhere into the space. On the exterior, the form of the domed roof also allows for better circulation and ventilation within in the space. No matter what time of the day or year it is, only a portion of the roof will be exposed to direct sunlight at a ninety degree profile angle at any particular time due to the spherical shape of the roof. With flat roofs due to their simplicity of only a few planes direct exposure of the sun's radiation to a larger portion of the roof perpendicular to the sun's rays at a given point in time is going to occur (Figures 7 and 8) [3].

Figure 7. Dome shaped roofs are a part of natural cooling and ventilation systems in hot arid climates

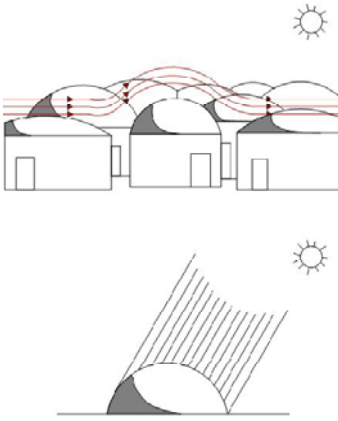

Figure 8. Openings on the dome shaped roofs are ventilation and daylighting elements

B. High Ceilings and Double Height Spaces

High ceilings in public spaces allow for large openings, to courtyards and other exterior conditions allowing for maximum sunlight to enter. These large openings also give sunlight an opportunity to reflect off of the ground and deeper into the space. This can be clearly demonstrated as many Iwans are double height (Figure 9).

Figure 9. High Ceilings views of houses in central Iran

C. Semi-Enclosed Spaces

Similar to courtyards semi-enclosed spaces allow accessibility to the outdoors and light but provide partial protection from the elements which is especially necessary in hot and arid climates.

D. Double Walls

Double walls are walls that allow for more efficient insulation in hot and arid climates. One wall takes the brute of the direct sun, while the wall that actually encloses the house is able to be protected and remain cooler. Typically windows are not located on double walls as they are typically facing south on the exterior towards the harshest direction of the sun.

E. Muqarnas

Muqarnas which are typically seen in mosques are more than just a beautiful decorative feature. They are also a structural system that allows for a lightened load of dome structures. In addition to the structural properties, the varying angles of Muqarnas allow for a filtered diffraction of daylight into the space below (Figures 10 and 11).

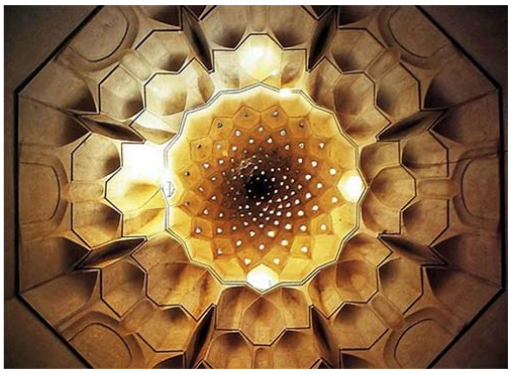

Figure 10. The Muqarnas diffuse sunlight inside the building and create an ornamental and delightful luminous environment

Figure 11. Muqarnas views of houses in central Iran

VI. BUILDING TYPOLOGIES

A. Domestic Structures Courtyards within Houses

In many traditional desert architecture houses courtyards exist in the center of the home. Upon entering a home traditionally the courtyard is the only space that is directly accessible to the exterior. This also gives the opportunity to extend a view to beyond the outside of the house if so desired. One of the most important principles of the desert home is that all rooms and are orientated towards the courtyard. Besides being the social heart of the home, this allows for air circulation, ventilation and light to effectively enter the home.

B. Open Connection to the Interior

It is important that the connection of courtyards to the interior is established through openings that blur the line between indoor and outdoor. This encourages the interaction and full benefit of the courtyard to the occupants of the building. It is also important that there be more than one access point to the courtyard otherwise the courtyard does not serve as an access point to other parts of the house [4].

C. Oasis Space

Within the courtyard there is very often a pool of water that is not only a refreshing oasis but provides evaporative cooling and reflective light into the house. Courtyards also have vegetation which contributes to further evapo-transpiration and filtering of sunlight. These spaces since already protected provide an ideal place to create a micro-climate in the harsh climate of hot and arid regions [5].

D. Space Occupancy

Within homes space is occupied reflective of the orientation. If space occupancy is static the most occupied spaces will be in the southeast to receive morning light before the day becomes too warm. Other times depending on season spaces will be occupied depending on the time of year. In the winter the north part of the home is occupied to allow for more light to enter the space from the south via the courtyard and other openings. In the summer occupancy exists in the south, where the wall is much thicker on the exterior to the periphery of the building and direct sunlight is not able to enter the space through the courtyard.

E. Public Structure

Traditional public structure in desert climates includes a number of building typologies, including streets, Inns, mosques, and baths. Each of these has various forms that accommodate the desert environment effectively and allow for natural daylighting to be used. Each typology has its own needs and various levels of privacy that must be considered.

F. Streets

Streets tend to be narrow with single or double height buildings on either side. They can be partially covered or fully covered, sometimes by second stories of structures above. This allows for daylight to enter the street spaces, but keep the daylight to a minimum as desert can be harsh (Figure 12) [6].

G. Mosques

Mosques are one of the primary religious structures that are very common throughout hot and arid regions. They serve multiple functions besides religion they also

function as a place for education, social meetings, funerals, etc. Mosques utilize courtyards, which are their primary provider of daylight surrounded by Iwans and large openings, and high ceilings allowing for maximum penetration of daylight from the courtyard. Mosques additionally utilize deeply recessed screened windows to add light to the interior (Figure 13).

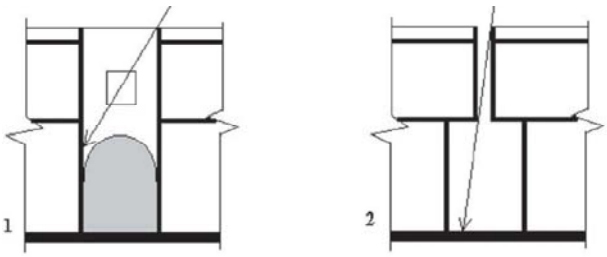

Figure 12. Different structures to provide more shadow in the public streets in hot arid climate

Figure 13. Mosque and lighting views in central Iran

H. Schools

Schools are also often based around the courtyard concept. Typically there courtyards are taller than they are wide. Some school courtyards are surrounded by iwans. This provides a semi-enclosed comfortable space for students to work on their studies (Figure 14).

Figure 13: Aga Bozorg school and mosque in central Iran

I. Baths and Hospitals

Baths and hospitals utilize many techniques already discussed such as courtyards and small openings to allow for natural daylight. This is of particular importance in these structures as even in history daylight is considered a key component to health.

VII. CONCLUSIONS

1. Modern Architecture: Modern Architecture takes on the opposite form than traditional architecture. The building faces out with windows on all four sides to the exterior of the space. All windows are much larger in size. Square footage of buildings is much greater, and many times the architecture is completely indifferent to solar orientation. The difference between interior and exterior is distinct there is no blurring of boundaries as typical modern buildings in hot and arid climates are cooled by HVAC systems that perform best in a closed system.

2. Modern Urban Conditions: In modern day Phoenix streets are the exact opposite of traditional streets. They are wide, surrounding buildings are low, providing no shade to the street at anytime. There is no form brought to the street by the surrounding architecture, which prevents any opportunity of natural ventilation constructs to be formed. Daylight is in complete excess, there is no need for daylight to exist anywhere near the quantities it does, especially if the street is designed for pedestrian use. Finally the streets are paved with black asphalt, the most absorbent color in the spectrum, allowing for the highest absorptance of heat possible. Implementing any part of the traditional street, decreased width, higher sides, or higher Albedo would each bring about great change to the modern street.

3. Quality vs. Quantity of Light: The quantity of light that is provided to these traditional houses spaces is less than the amount of light that is typically utilized in internal spaces today. But it is the quality of light, the consideration that natural light is thoughtfully brought into the space without a significant increase in temperature, not so much light that is produces glare that is considered worthy of study [7].

Many of the traditional spaces, especially the spaces in the home are not adequately lighted to modern standards. This is especially the case since some modern tasks are more arduous and requiring a higher level of light. Quantity and size of windows would also not pass many modern day codes, in particular providing a window in every bedroom of adequate size to escape out of in emergency. It is important that the techniques and methods used to bring the daylight in be considered but the plan of traditional building not necessarily be identically replicated.

4. Application of Traditional Principles: Application of traditional principles can be applied in individual elements or greater wholes. Whether applied piecemeal or holistically all can be of benefit. For the health of building occupants even in desert climates it is important to be exposed to daylight as opposed to artificial light. The important recognition of traditional principles is that they fully embrace and respect the conditions of the surrounding environment as it was impossible to be ignored without cheap energy in the past. Harnessing indirect, making sure windows are located to minimize direct sun, filtering light before it enters the space; these are all simple concepts that designers can apply once they are familiar with them and their value.

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BIOGRAPHY

Bahram Ahmadkhani Maleki was born in Tabriz, Iran, 1980. He received the B.Sc. and the M.Sc. degrees from University of Shahid Beheshti, Tehran, Iran. Currently, he is a full time Academic Staff of Seraj Higher Education Institute, Tabriz, Iran. His research interests are in the area of sustainable energy in architecture, green energy and green architecture. He has published more than 30 papers in international journals and conference proceedings.