INVESTIGATING SUSTAINIBILITY IN HOT AND DRY CLIMATE OF IRANIAN CITIES, THROUGH CENTRAL COURTYARD HOUSES

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ABSTRACT: There are so many buildings in cities that are designed without any attention to solar passive strategies. Although researches have been established to minimize energy consumptions in designing buildings, but there are still too many energy loss in buildings. Continuing of this problem not only it causes crises of energy, but also it is a source of environmental pollution. This research has investigated texture of hot and dry climate of Iranian cities to understand that how traditional texture has created urban comfort in Iranian cities. It could be seen that although hot and dry climate have created difficult conditions for residents in urban texture, but Iranian architects have used several techniques to create desirable spaces in Iranian cities. In this research characteristics of traditional central courtyard houses of Iranian cities in hot-arid climate were investigated. Parameters of central courtyard houses such as orientation, scale, proportion, courtyard components, and materials were compared. As a result of this study, it was demonstrated that traditional Iranian architects have designed buildings with great consideration to solar passive strategy techniques which cause reducing energy consumption. Reducing energy consumption in Iranian architecture has created sustainable architecture through simple method of organization.

KEYWORDS: sustainability, urban texture, central courtyard houses, hot and dry climate.

1- INTRODUCTION

Sustainable is defined as "the creation and responsible management of a healthy built environment based on resource efficient and ecological principles". Sustainably designed buildings aim to lessen their impact on our environment through energy and resource efficiency. It includes the following principles:
- Minimizing non-renewable resource consumption  
- Enhancing the natural environment  
- Eliminating or minimizing the use of toxins

According to the OECD Project, Sustainable buildings can be defined as those buildings that have minimum adverse impacts on the built and natural environment, in terms of the buildings themselves, their immediate surroundings and the broader regional and global settings. Sustainable buildings may be defined as building practices, which strive for integral quality (including economic, social and environmental performance) in a broad way. Thus, the rational use of natural resources and appropriate management of the building stock will contribute to saving scarce resources, reducing energy consumption, and improving environmental quality. The OECD project identified five objectives for sustainable buildings:
1. Resource efficiency;  
2. Energy efficiency (including greenhouse gas emissions reduction);  
3. Pollution prevention (including indoor air quality and noise abatement);  
4. Harmonization with environment;  
5. Integrated and systemic approaches.
Sustainable building involves considering the whole life of buildings, taking environmental quality, functional quality and future values into account. Sustainable building design is therefore the thoughtful integration of architecture with electrical, mechanical and structural engineering resources. In addition to express concern for the traditional aesthetics of massing, orientation, proportion scale, texture, shadow and light, the facility design team needs to be concerned.

Sustainability in any urban development is non-damaging to the environment and which contributes to the city’s ability to sustain its social and economic structures. According to an accepted definition of sustainable development that is taken from the Brunt land report2, the objectives for an agenda of urban design in a regime of sustainable development would emphasize conservation of both the natural and built environments. Principals of sustainable urban design would place priority on the adaptation and re-use of existing building, infrastructure and roads, together with the re-use of recycled building materials and component, where new development is necessary.

1 METHODOLOGY

Observation was the main method of this article. It intends to analyze characteristics of courtyard houses in hot dry regions. Studying the regional climatic solutions in warm and arid, and warm regions of Iran without using fossil fuels shows several adaptations including a wide extent of urban design, houses design, and materials selection according to hard conditions. In the following there will be a short explanation of some adopted methods to reach optimum heat and chill and human heat comfort by creative urban and architectural design for using available natural environmental energy.

2 FINDING AND DISCUSSION

The previous study by Ratti et al (2003) demonstrated that the courtyard configuration showed better response through the calculated environmental variables (surface to volume ratio, shadow density, daylight distribution, sky view factor) than the pavilion types in the specific context of hot-arid climates. “What building forms make the best use of land?” If ‘best’ is interpreted in environmental terms without sacrificing floor space for a given plot of land, then the answer for hot arid climates is the courtyard form.

The combinations of
(i) Larger surface area and high thermal mass,
(ii) Daylight via the courtyard and shallow plan form,
(iii) Narrow spaces for shade and improved thermal comfort despite increased heat island;

Create a context where low energy strategies through the limitation of air conditioning loads are possible. A primary characteristic of this is that courts can create a microclimate in the form of an intermediate environment that will be more quite, clean and more private than the street. The result is that the surrounding interior spaces can interact positively with this improved microclimate(Figure1).

Figure 1 Axonometric courtyard and of two pavilion structures by Ratti et al (2003)
One can speculate that even in temperate and cool climates many of these characteristics of courts will make them the “building forms that make the best use of land”, particularly in an urban context.

Ahmed S. Muñaisen, Mohamed B Gadi (2005) identified the Effect of courtyard proportions on solar heat gain and energy requirement. The effect of changing the courtyard’s proportions on the solar heat gain and consequently on the required energy to achieve comfort was examined through varying ratios R1 and R2 and observing the result at different times. The ratio R1 is taken as the ratio of the courtyard’s floor perimeters P to the form’s height H (P/H); it indicates the depth of the form. It ranges between 1 and 10 in one degree steps. Ratio R2; which indicates the elongation of the form, is the ratio of the rectangular courtyard width W to its length L (W/L).

A building with an internal courtyard with R1 of 1 and R2 of 0.1 is found as the optimum. It indicates that the percentage of increase in the energy requirement becomes greater with having the courtyard form shallower and less elongated. Generally, with having the form shallower, more radiation enters the courtyard and less self-shading is produced. The difference tends to be smaller as R1 increases due to increasing the collected solar radiation. Although the received irradiation increases when the form becomes shallower, the heat loss increases and the heating load as well. The annual required total energy increases as the courtyard elongation increases. The effect of the shaded area on increasing the energy demand becomes slightly less as the courtyard’s plan approaches a square. It ranges between 5.6% at R2 of 0.1 and 2.5% at R2 of 1. Generally, the more elongated the courtyard building the closer to the minimum the annual energy consumption. For the purpose of reducing the cooling load in summer and heating load in winter, deeper courtyard forms were the most preferable. (Figure 2).

Nowadays, the image of ideal living is based on other role models. The detached residential house represents a longing for autonomy and privacy. In consideration of this trend, the courtyard house, characterized by its introverted nature, could experience a renaissance. The courtyard as a secluded open space is the central element that is also utilized to provide daylight and ventilation. The courtyard type carries potential to solve many of the problems currently related to housing. First of all, this type allows for very dense urban developments since it can be linked to other units on three sides. As a consequence, the courtyard house type requires very little surface area, resulting in many energy advantages. Moreover, the courtyard can be used as an "energy garden" that comprises glazed surfaces in combination with storage walls oriented towards the sun, thereby realizing energy gains and creating transparent living spaces.

The quality of adding onto this house type on three sides also allows for linking different units with each other so that growing or shrinking modules can be realized with minimal constructional effort. One prerequisite is that these modifications have been structurally provided for in the floor plan. This means that circulation and layout are designed such that several rooms can be joined to a unit by simply creating a wall opening or by cutting off a small hallway. This degree of flexibility entails turning away from the ideal of a self-contained dwelling in favor of open structures that are no longer bound to property lines since existing building regulations as well as static ownership structures with title registrations often hinder building across more than one lot. Technical solutions for preventive fire protection and billing of...
energy consumption have long been available. The key factors are proper proportions and orientation of the courtyard, because in extreme cases this typological element is the only source of daylight. Therefore, it is mandatory to examine whether sufficient daylight enters the building. This should be done by calculating the angle of incidence of sunlight during all seasons, particularly when working with multi-storey buildings. With regard to the different angles of incidence in the morning, at noon and in the evening, a rectangular shape on an east-west oriented longitudinal axis has proven to be advantageous. Orientation and building heights within the urban context are important as well. The intimate character of the courtyards can be enhanced to match the growing demand for privacy. The possibility to include more than one courtyard allows for a differentiation of courtyards solely providing daylight, recreational courtyards with green areas, "energy yards", and access yards, each affording different degrees of openness. When considering all of the qualities the courtyard house type offers, this type seems to be an extremely viable concept for future applications. The variants presented in the following are to highlight its potential for development and encourage architecture to create new variants.

**Characteristics of hot-dry Climate in central plateau of Iran**

This Climate consist of the most parts of the central Iranian plateau, receives almost no rain for at least six month of the year, hence it is very dry and hot. In this climate the summer is very hot – arid and the winter is very cold and hard. In this area, sky in the most of months of year is without cloud and the weather hasn’t nay humidity. Thus temperature is very variety in the past has presented a series of logical solutions for human comfort. A principle for the existence of building is the need for better environmental conditions. “Early men built houses to keep out the elements – rain, wind, sun and snow. Their purpose was to produce an environment favorable to their comfort and even to their survival” (Fathy, 1986). This attribute draw a connection between the architecture and the climate and demonstrates a physical and architectural characteristic in a particular region. Urban texture in this climate has these factors: (Figure 3)

1- Urban texture is very concentrative
2- City spaces are surrounded completely
3- Narrow alley without any regulation. Sometimes covered by arch
4- Building contact to each other (wall to wall)
5- Building have been located for using sunray and wind

![Image](image_url)

**Figure 3 Textures of Kerman & Yazd**
Main characteristics of building form in central plateau region are:

1. Buildings have central yard, all space are opened toward to the central yard.
2. Buildings have underground, portico and wind tower.
3. Floor of yard and floor of ground floor is made lower than floor of alley.
4. Rooms have high height.
5. Roof is made of arch and dome.
6. Walls are thick.

In the design of traditional houses in the hot and dry area in Iran, there are several precautions taken to mitigate the temperature extremes. Houses are surrounded by high walls and isolated from the street. During the day, external walls of houses usually provide shady areas in narrow streets and especially in courtyards. By means of thick and heavy walls, a cooler environment in summer and a warmer environment in winter can be provided easily.

As a whole, the city structure resembles a battlement fully enclosed from all directions which prevents the invasion of enemies from any side. In fact, it is for both defense purposes and to prevent high velocity winds and sand storms from penetrating into the town. For that reason, the appearance of the inside of the city is completely different from the outside, and the air inside is more static than outside the city. The main streets in the town face the direction of the prevailing wind. Of course, the streets are narrower than streets built for other purposes (in other regions). Surely if the streets were not narrow more sand would have been blown into the streets from the desert and ferocious winds would have penetrated into the city districts. Meanwhile the compact nature of the buildings prevents very high temperatures to develop by exposure to the sun.

In a hot and dry climate, the most preferred house plan is one with a courtyard (Figure 5). In order to minimize the area affected by the solar radiation, compact forms are chosen. By arranging those forms with courtyards, shady areas can be obtained. In courtyards, with the help of water and plants for evaporative cooling, the floor temperature can be minimized by the high walls surrounding the courtyard, shady areas can be obtained and the open areas can be used during the day. Channels for water poured out from the pool are important elements for cooling. Water is often spread by channels to the floors of the courtyard and evaporative cooling from the surface of the courtyard floors which are made of porous stone contributes to that effect. Courtyards are always on the ground floor and have different forms depending on the landscape of the house.

Sustainability and energy efficiency are greatly affected by a building's skin. The amount of surface area, material choice and insulation strategies are key elements in buildings located in this region. The buildings are built in special forms and architects tried to minimize the ratio of outdoor surfaces of buildings to the space required instead for habitation.

Due to very hot temperatures, the building materials absorb heat from the sun and make it available later when the sun goes down. In other words, this energy is retained in the walls about 8 hours and the other
parts of the building envelope and is gradually transferred to the inner compartments. Such a quality provides leads to two alternatives in cold and warm seasons (Figure 6).

Use of vernacular materials such as brick and adobe is always one of the concerns in the architecture. As an illustration, they used to use excavated foundation soil in order to make bricks. There are many examples like this which are incorporated in today’s architectural concepts for sustainable building design. Vernacular material selection, compatibility, embodied energy, application of passive energy and design environmental strategies in waste and technology management concerning the impacts in the environment are all concepts that are part of sustainable building design.

In the hot and dry climatic areas in Iran, in examples of traditional architecture, to benefit from the time lag of temperatures in the building envelope, materials with greater thermal mass have been chosen. These kinds of thermally massed envelope details are very convenient for continental climates, where the summers are very severe with high swings in daily temperature variations. This big thermal mass will slow down the heat transfer through the envelope and thus higher day-time temperatures will be reached indoors although outdoor air temperature is much lower and consequently more stable indoor thermal conditions will be provided. On the other hand this thermal mass, which has higher surface temperature on outer side will rapidly lose heating energy to the atmosphere via radiation at night to start the next day from a cooler level (Yılmaz 2004). When observing traditional examples, it can be seen that the transparency ratio of the building envelope is chosen as low as possible and the opaque parts of building envelope were constructed by the materials with a high heat capacity as thick as possible. The high heat capacity of the opaque component provides a high time lag for the transmission of the outside temperature to the internal area while the low transparency ratio minimizes the direct solar radiation gained through the windows (Holman 1976). By means of the high heat capacity of the building envelope, the effect of the outside temperature is minimized and a cooler internal area can be obtained during the day (Figure 7). Therefore, calcareous rock, stone, mud and the combinations of those materials are always preferred in this climate (Yılmaz, 2004). Calcareous rock, which is a sort of porous limestone, is an especially better insulator against cold and warm air and regulates the humidity of the living place. In this climate other precautions against the solar radiation are:
- Minimization of the area and the number of windows;
- Construction of windows at a high level to block floor radiation;
- Minimization of the absorption of heat by facades by choosing white or light paint colors;
- Providing natural ventilation especially at night;

Figure 6 Typical plans

Figure 7 Sect ion-elevation
- constructing a part of the house below grade, which is always cooler than the ambient outside temperature in summer (Rapoport 1969).

Due to lack of access to modern heating and cooling equipment in ancient times the architects were obliged to rely on natural energies to render the inside condition of the buildings pleasant. Providing zero condition is one of their architecture solution for making comfort situation. By this way, without any mechanical methods and just by utilizing environmental energies such as wind, solar energies and architecture elements such as shape of roofs (Using dome & arched roofs instead of flat roofs), walls (using huge and thicken walls), materials (includes mud, mud brick, stone, brick, mortar, lime and wood) in house yard (Increase of contact surface of building with Earth), window, wind-tower comfort condition have been provided for occupants. The urban form of traditional city is the highly centralized or inward looking by a deep courtyard. Certainly, the orientation and relation to the environment has been of high importance in the planning of city. The particular climatic problems caused the people of the hot, arid zone to find solutions through their settlements architecture. The houses are arranged around a courtyard. The built spaces around this court have been designed to maximize its passive potential to warm the house in winter when sun angles have the maximum penetration into the winter room. There is sometimes a distinction between the rooms occupied in the summer and the ones occupied in the winter. The summer rooms face north away from the sun and in the winter they face south and have glass doors that allow the low winter sun to penetrate. The high radiation and temperature in the summer, diurnal variation of temperature, seasonal variations from dry, hot summer to cold, dry winter, low humidity, limited water supplies and the dusty winds are the most important factors in forming the urban texture (Figure 8).

Figure 8 A view of courtyard

The plan of the house is geometrical and nearly symmetrical. The major rooms are facing southwest and southeast, the optimum orientation for this kind of climate. For effective solar gain window openings are in walls with an orientation within 15-45 degrees west of south with a southern orientation being the optimum position. The best state of buildings is taking the least heat in summer as much as holding the heat in winter. The courtyard where consist the plants and trees compatible to desert environment and a water pool, makes a microclimate for having the comfort conditions in this hot region. By the wind catcher, the air is conducted into the interior spaces and on water surface at the centre of the courtyards and the plants gets enough coolness in the afternoon. Not only do the wind catchers act as the principal elements for using the clean energy, also the spaces arrangement helps to maximize using this renewable energy. Using the materials like clay and mud brick with the low thermal capacity and the thick walls are a current solution for insulating the building against the temperature variations. The architects have used the massive form of the building, with rubble filled spaces in walls and roofs and shade walls and roofs to not only ensure that the sun never fell on, for instance, a thinner part of the roof, or inside rooms in summer with angled walls, but also they used the curve of the domes and vaults to minimize solar gain into the room below and speed up heat loss from the room through ventilated cupolas (Figure 9).

Figure 9 Section -elevation
The habitants according to the space functions and their climatic conditions in the different seasons choose how spend their time: in the hot and dry summer’s days, almost the underground spaces and the space in the shadow (north-east, south-east), are being used for running away from this heat. These underground spaces have cooler more pleasant temperature rather than their upper counterparts. In the winter’s days, the living rooms face south toward the low winter sun providing the conditions for the reduction in need of fossil energy. On the other hand, at the cool summer’s nights of the desert, the habitats could spend their time on the roofs and under the clean sky full of the stars without any need of the air conditioners.

The traditional courtyard house is an advanced structure. The open-air interior courtyard performs an important function as a modifier of climate in hot, arid areas. The courtyard allows for outdoor activities with protection from wind and sun. The courtyard also serves as an air-well into which the cool, night air can sink. And the plain, thick-walled street facade of the house, with few or no windows, is designed to withstand severe elements like hot winds and sand.

3 RESULT

On the “hot-arid” regions the city is more open to the environment, organized through the “courtyard typology” that become the central “core” of building as a perfect and efficient thermal mechanisms having the function of protection from “sand storm” and open to sun, wind and water gains. The compact city became a more various design of closed and open spaces. Sun shading, wind ventilation and water features are the main characteristics. Is not a purpose to go back to traditional way of living, but the collection of a big repertory and attentive lecture of the past rules and concepts, still available for our modern architecture and urban design, can address us to the new city development design. Taking this Iranian architectural language as climate relationships model, the researchers will find the guide lines for the energetic and bioclimatic reconstruction, of the City of today and the continuity for the shape for the City of tomorrow as Renzo Piano presented “If You ask me how will be the future sustainable City” I will answer: I hope that she will be similar to the “City of the Past”“

REFERENCES