SUSTAINABILITY AND BIOCLIMATIC DESIGN PRINCIPALS IN HOT-DRY AREA OF IRAN

MAHSHID MIKAEILI[1], FARUK SARIHAN[2]

ABSTRACT

Today, buildings worldwide account for up to 40% of total end-use energy. Sustainable architecture is a general term that described environmentally conscious design techniques in architecture and landscape design. The aims of sustainable architecture at producing buildings that adapted to climate, local, cultural and environmental contexts. Sustainable architecture also referred as Green Architecture, Energy Conscious, Eco friendly, Energy Efficient is a design that uses natural building materials that are energy efficient and that make little or no impact on the nature of a site and its resources. Climate has a major effect on the energy consumption in building. Bioclimatic design in vernacular architecure aims to lower energy consumption, based on the understanding of the climatic parameters that influence the energy behavior of a building. It requires knowledge of the relation between the building's envelope and the local environment. Reducing energy consumption, using natural resources and providing comfortable, and sustainable living spaces are the aims of bioclimatic design or climatically responsive sustainable building design (vernacular building) in hot-dry areas of Iran.

Key words: Sustainable Architecture, Bioclimatic Design, Passive Solar Methods, Vernacular Architecture.

1. INTRODUCTION

Buildings worldwide account for up to 40% of total end-use energy. Today, in construction of some modern buildings, using new strategies of sustainable design have a great importance on human living and energy using. In this system climate has a major effect on the performance of the building, and energy consumption. The important responsive of the sustainable building design is reducing energy

[1] PhD. Student. Ankara University, Department of Landscape Architecture, ANKARA
[2] Res. Assist. PhD Student. Ankara University, Department of Landscape Architecture, ANKARA

consumption, using natural resources and providing comfortable and sustainable spaces for living (Serbescu 2009).
According to accumulation of empirical knowledge in vernacular architecture in differnt parts of Iran, using passive design strategies such as solar orientation, natural ventilation, using of thermal inertia and shading are basically techniques of adaptation with environment. Noticeably, during the last decade, the academic interest in the sustainability of vernacular architecture has grown. Unfortunately, around the world, vernacular traditions are seen to be in a state of decline and are frequently looked down upon, abandoned, neglected or actively demolished. Steadily, vernacular architectural methods are replaced by modern architectural methods, international technologies, materials and forms (Oliver 2003, Knapp et al. 2005, Vakili et al. 2006). Interestingly, these vernacular traditions are exactly the ones that are identified as being able to provide valuable lessons in terms of sustainable design. To many academics these represent a sophisticated, advanced and refined nature of vernacular passive cooling, ventilating and heating strategies (Fathy 1986, Kheirabadi 1991, Qobadian 2006).
In a vast country such as Iran with 1,648,000 km^2 width and very different climatic zones, traditional builders have presented a series of logical solutions for human comfort (Tavassoli 2008). Despite of the high diversity in architectural patterns, there are five principles in all historical buildings. These principales are; 1) introversion, 2) avoidance of vanity, 3) self-sufficiency, 4) architecture structure, 5) people oriented (Pirnia 2003).
This study is based on a research program on traditional building techniques that have used in differnt parts of the hot-dry areas of Iran. The study introduced designing strategies and principles in hot-dry climate in traditional housing based on climate responsive design. These issues related to sustainable and bioclimatic design in vernacular buildings. The research examines the various passive methods that are widely adopted by vernacular architecture in historical buildings. These methods explain their operation in details, solar orientation, distances between buildings, natural ventilation, building envelope, thermal inertia and building form that highlighted the main factors of their use that reduces environment effectiveness.

2. SUSTAINABLE ARCHITECTURE

The history of environmental friendly architecture becoming widespread goes back to 1970's. Since then, the words "Green", "Ecological" and "Sustainable" are terms used by environmentalists to indicate modes of practice (Ghani 2012). The transition from "green" to "eco" to "sustainable" in the design field represents a steady broadening of scope in theory and practice, and to a certain extent, an increasingly critical perspective on ecology and design (Madge 1997).
In Architecture there are many ways a building may be "green" and respond to the growing environmental problems of our planet. Green buildings are high quality buildings, they last longer, cost less to operate and maintain and provide greater

occupant satisfaction than standard development (Ghani 2012). A green building is an outcome of a design that focuses on minimizing the use and on increasing the efficiency of resources. The steady depletion of non-renewable resources of energy has forced the search for energy efficient building alternatives as it is the single largest consumer of energy-intensive materials (Vijayalaxmi 2010).

Sustainable architecture can be practiced still maintaining efficiency, layouts and cost effectiveness. Construction projects typically consume large amounts of materials, produce tons of waste, and often involve weighing the preservation of buildings that have historical significance against the desire for the development of newer, more modern designs. Sustainable development is one such measure, which presents an approach that can largely contribute to environmental protection (Ghani 2012). However, being sustainable is not just about energy saving, but also about the better use of suitable materials. We have to use materials far more efficiently than we do now. Sustainability also means an increased importance being placed on use of materials, which are renewable, recycled and non-toxic. Public awareness must be generated that such buildings, which incidentally are low cost, are not inferior to conventional concrete buildings. Similarly, using locally sourced materials, materials with a high recycled content and ensuring an envelope design, which does not enhance the operational heating or cooling energy can go a long way in designing energy-efficient buildings (Vijayalaxmi 2010).

Sustainable architecture is a general term that describes environmentally conscious design techniques in the field of architecture. Sustainable architecture is framed by the larger discussion of sustainability and the pressing economic and political issues of our world. In the broad context, sustainable architecture seeks to minimize the negative environmental impact of buildings by enhancing efficiency and moderation in the use of materials, energy, and development space. Today, the idea of sustainability and ecological designs are to ensure that our actions and decisions do not inhibit the opportunities of future generations. This term can be used to describe an energy and ecologically conscious approach to the design of the built environment. The aims of sustainable architecture at producing buildings that is adapted to local, social-economic, cultural and environmental contexts, having in mind the consequences to future generations. In this frame, the important priority must be to minimize energy consumption in buildings in both terms of maintenance and embodied energy, through the use of passive design strategies for reducing the use of energy consuming equipment.

Besides all these measures and approaches, passive strategies such as bioclimatic design offer great ways of energy saving. Bioclimatic design is a design strategy which relates climate control in a building to the analysis of weather data and the requirements for human comfort. Bioclimatic design is also the outcome of such a strategy. Hence the bioclimatic design can be understood as the architectural design using human adaptability and passive climate control as interactive measures of energy efficiency (Bromberek 1995).

Traditional and Vernacular buildings in contrast to Modern buildings constructed in 20th century are more climate-receptive; the climate-responsive architecture originates in the pre-industrial era before the introduction of air-conditioning and electric lighting. Each region of the world employs its own techniques and designs in its buildings that are best suited to that particular region and that encompass the region's cultural patterns (Sharma and Sharma 2013). The essence of bioclimatic design is to create a favorable microclimate both inside the building and outdoors through the application of architectural techniques (Bondars 2013). Bioclimatic design measures are centered primarily on the climate of a specific area as thus; building envelope and orientation, energy source, sun shading devices, passive design, indoor air quality, heating and cooling, landscape (Folaranmi et al. 2013). For effective design and good thermal achievement, Bioclimatic design recommends the following factors to be considered:

- Building orientation: buildings should be inclined on site to face the north-east, south-west approach to allow minimum solar radiation into the buildings

- Window openings: the openings should be wide enough to allow maximum natural ventilation into the indoor space.

- Glazing: solar glasses that are double paneled and well laminated that allow light but reduce heat penetration should be used.

- Natural materials: should be used for construction such as adobe, compressed earth, and wood as they have better thermal inertia than most conventional building materials.

- Renewable energy: these energy sources as solar and wind energy are more energy efficient and do not contribute to CO2 emission which pollutes the environment.

- Landscape: trees should be planted around the houses as they help improve the surrounding air and keeps the environment cool.

- Cross ventilation: houses should be cross ventilated for effective air flow in and out of the building (Folaranmi et al. 2013).

Passive climate control is the climate control achieved as a consequence of the use - exclusive or prevailing- of passive means, that is: means that do not use power (inflows of externally produced energy) to perform the intended tasks (Bromberek 1995).

2.1. Principles of Climatic Responsive Design

The climatic conditions of the central part of Iran share common traits of extremely low annual precipitation and low humidity, restriction of water source, intense daylight and thermal gain from the sun, dynamic seasonal, daily temperature fluctuations, seasonal wind and sand storm.

Composition of architectural components and spaces create dynamically urban areas. In these regions cities illustrated integration of homogeneous and centralized structures that compressed for creating close correlation between components. Vernacular architecture in these areas has demonstrated by sustainable architecture components that suggested various solutions which are adapted with environments potentials, natural ventilation, as a certain parameter for cooling and sense of comfort. The buildings are constructed according to the specific climatic conditions and differ with those built in other climates. Central Iranian vernacular buildings are commonly equipped with thick and high walls, vernacular materials, wind-catcher, central courtyards, water pools and vegetation, basements, loggias and separate seasonal rooms. All these features together form a vernacular passive cooling system that modifies to some extent the impact of the hostile outdoor environment.

Due to lack of access to modem heating and cooling equipment's in ancient times the architects were obliged to rely on natural energies to render the inside condition of the buildings pleasant. By this way, without any mechanical methods and just by utilizing environmental energies such as wind, solar energies and architectural elements such as shape of roofs (using dome and arched roofs instead of flat roofs), walls (using huge and thicken walls), materials (includes mud, mud brick ,stone, brick, mortar, lime and rarely wood), multistory yards or garden puddle (Persian: Godal Baghcheh) in the yard of houses for increasing the contact of building surface with earth, window, wind-catcher (Persian: Badgir) have been provided comfortable condition for occupants. Furthermore, the urban morphology in hot-dry regions is the cause of condensed and concentrated urban texture in which the main arteries are facing the desired wind and opposing undesired one. Many of these vernacular cooling strategies in central Iran are said to have remained relevant to local cultural needs and to work in harmony with the natural environment because they are based on low and local use of energy and resources (Afshar et al. 1975, Heidari 2006). Because of this relevance, it is frequently claimed that there are many lessons to be learned from them in terms of creating a contemporary sustainable design and construction (McMurry et al. 2000, Qobadian 2006).

Through evaluating traditional architecture, designers have taken advantages of difficulties of areas and presented the most suitable settlements designs for each climatic region based on this three scales; macro, medium, and micro scale. This classification is on base urban designing scale, house designing scale and architectural elements designing scale in a house. Basic principles of macro climate responsive are in the urban designing scale. This principal include; Site and orientation of the building, distance between buildings, enclosed urban environment and using organic designing method for creating narrow and irregular streets.

***Site and orientation of the building*:** The most important design parameters in urban designing scale that affecting indoor thermal comfort and energy conservation in building are site and orientation of the building. These parameters depend on topography as a basic parameter, climate, sun radiation and wind direction. Commonly, in these areas houses are situated according to the slope of a city hill.

Effectiveness element in determination of building orientation in this terrain is daily or annual prevailing wind. Generally, in different places buildings oriented in northeast-southwest, north-south and northwest-southeast direction (Pirnia 2003).

Distance between buildings: These areas demonstrated compact urban context. Houses are surrounded by high walls and isolated from the ways. During the day, external high walls of houses usually provide shady areas in narrow streets and especially in central courtyards. By means of thick and heavy walls, a cooler environment in summer and a warmer environment in winter can be provided easily. The walls are structurally independent together that provided thermal protection from the intense desert sun. The exposed surfaces to direct sunlight can be reduced by up to 50% when neighboring walls are constructed closely together (Qobadian 2006).

Enclosed urban environment: The city structure resembles a battlement fully enclosed from all directions. 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 (Fig. 1).

Narrow and irregular streets: The main streets in the town face are in the prevailing wind direction. Of course, the streets are narrower than streets built in other regions. Surely if the streets were not narrow more sand would have been blown into the streets from the desert and harsh 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. Houses are formed around courtyards and have thick walls and a minimum of openings. They are built close to each other, protecting one another from solar radiation and sandstorms. Narrow ways of 2-3 m are shaded by the high walls of the surrounding houses and allows any air movement to be accelerated. In some area, as a static solution against tall walls bending and creation shady pedestrian, between two tall walls were built vaulted canopies (Sabat) along the pedestrian way (Pirnia 2003, Qobadian 2006), (Fig. 2).

Figure 1, 2. Narrow and irregular streets. Sabat inside narrow way

Fundamentally, medium climate responsive design principal are in the scale of the buildings designing form, construction material and material Self-Efficiency, building coverage and thermo-physical properties of the building envelope in the hot-arid area of Iran.

Building form: Central courtyard was known as an eternal pattern and common typology of houses in these areas. Especially in the hot-dry climate, the central courtyard and pool are the main space of a house. Pool of water and plants in central courtyards create a pleasure micro-climate area by evaporating and creating cooling. The temperature of the courtyard's floor has minimized by the high walls that surrounded the courtyard and created a shady area. Some buildings have constructed multi-stories courtyards "Garden Puddle" (Godal Baghcheh) for benefiting from natural cooling of the earth (Qobadian 2006),(Fig. 3, 4).

Figure 3, 4. Central courtyard, pool and plants. Garden puddle (multistory yard)

Central courtyard, not only is the natural environment, but also it creates introspective relationship between spaces (Memarian 1998, Qobadian 2006). Compact forms are chosen by designer as a best solution to minimize solar radiation that affected the areas. Structure of the central courtyard both in shape (geometry and design elements), and also in the methods (materials and technology), heavily used the feature of indigenous and local empowerment (Pirnia 2003, Qobadian 2006). Various design of plants and pools in the central courtyard with trees that need little water, such as pomegranate, grape, fig and pistachio, that not only it provide the fruits and vegetables, but also it reduces air dryness (Dehghan et al., 2011).

Building envelope: Sustainability and energy efficiency are greatly affected by skin of building. The buildings are built in cubic forms and architects tried to minimize the ratio of outdoor surfaces of buildings (Memarian 1998). Cubic forms help buildings to have a lower exposure to hot weather factors than the other building forms. In 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. Using white or light color in facades is a way to minimize heat absorption

and maximize sun light reflection from the building's surfaces (Qobadian et al. 2006), (Fig. 5).

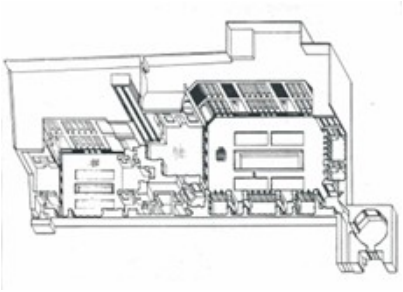

Figure 5. Cubic form of building and multi-central courtyards

Self-Efficiency in materials: Use of the local and vernacular materials such as brick and adobe to reduce energy expenditure is a wise decision since it will also reduce the initial embodied energy as well as cost. They have used the soil of excavating of foundation or multistory courtyards in order to make bricks. Due to very hot temperatures, the building materials absorb heat from the sun and make it available later when the sun goes down. 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 (Qobadian et al. 2006).

Optical and thermo-physical properties of the building envelope: 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 (Holman 1976, Memarian 1998). Therefore, calcareous rock, stone, mud and the combinations of those materials are always preferred in this climate (Memarian 1998).

The basic of micro climate responsive principals are in the scale of the building elements like loggia, porch, seasonal rooms, designing form, wind catcher, window and canopy, isolation and module of building that have been used in these areas.

Module Construction: This unit (module) is a base for other measurements in construction. All elements of traditional buildings used to be built based on this unit and specific proportions in the building system, especially the proportion of windows to surface of the rooms. This system of measurement allowed architects to use specific geometries of buildings and obtain the advantages of structural resistance found to be suitable (Qobadian 2006).

Eyvan and Revak: Loggia (Eyvan) and porch (Revak) are semi-open areas are used to create shady and cool living spaces during the day. Eyvan is three side closed place in front of the rooms and usually are oriented to the south. Especially, south

and east oriented Eyvans are very cool and provide shady places during summer. Revak is another semi-open colonnade arranged in the courtyard always provides shady areas in front of the house and were built in the west (Memarian 1998, Qobadian 2006). (Fig 6, 7).

Figure 6, 7. Eyvan and courtyard, Revak

Seasonal rooms: Rooms and other gathering spaces facing north and are used during hot summer days. These often open onto the courtyard with a small platform (Eyvan). The Eyvan faces the north onto the courtyard which often holds vegetation and water. Winter's siting rooms in south side of buildings is essential where maximum exposure to natural daylight is desired as temperatures may fall to –16 ºC during the winter months at night.

Wind catcher (Badgir): Wind catcher was a common specific feature of architecture found in the majority of warm regions (Fig. 8).

Figure 8. Central courtyard and view of a wind catcher

Wind catcher is like a chimney whose end is underground and the top is elevated above a specific height on the roof. At the upper outlet many small openers or ducts may be set according wind direction. The height of wind catcher, the number of openers and the location of the wind catcher depends on the wind direction and wind force. The wind catcher operates with the change of air temperature and the difference in density of the air inside and outside the channel. The difference of density of the air impels a positive or negative pressure of air which causes the air to flow either to the bottom or to the top (Mikaeili and Memluk 2012), (Fig. 9).

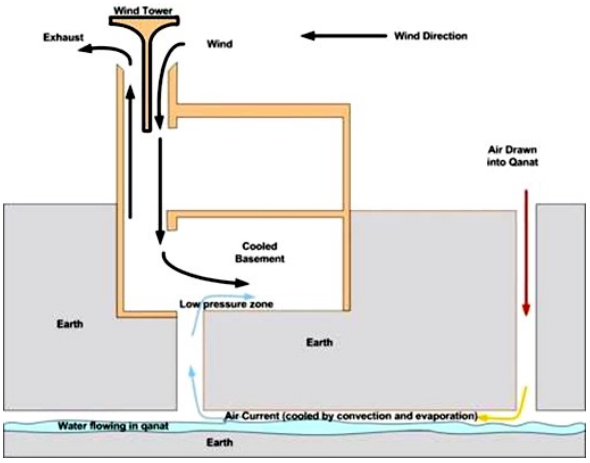

Figure 9. Function of the wind catcher during day and night

The wind catcher operates in response to the condition of the wind and sun radiation in the region. The inside and outside walls absorb a lot of temperature during daytime. As a result they cause a balance of temperature at night and give the attracted warmth to the cold night air. The light warm air inside the wind catcher ascends and is sucked away at the upper elevation. Finally, in a windless environment or waterless house, a wind catcher functions as a stack effect aggregator of hot air. It creates a pressure gradient which allows less dense hot air to travel upwards and escape out the top. This is also compounded significantly by the day-night cycle mentioned above, trapping cool air below. The temperature in such an environment can't drop below the nightly low temperature. The light warm air inside the wind catcher ascends and is sucked by upper elevations. As a result cool air flows from windows and doors into the house and continues all the night (Mikaeili and Memluk 2012).

If wind blows at night, the air will circulates on the opposite direction in the wind catcher. In other words the cold air is sucked into the house. Of course, in such a condition the cold air flowing from the air trap duct which has been heated during the day time will warm the inlet air a little. Nevertheless air circulation again refreshes the inside temperature. During daytime the wind catcher acts contrary to a

chimney. In other words the upper parts of the air trap has been cooled the night before and upon contacting the walls of the air trap the warm air cools down and moves towards the bottom and eventually circulates into the house and exits from doors and windows. The flow of air during daytime accelerates the ventilation process (Mikaeili and Memluk 2012).

Window and canopy: Traditional windows "Orsi" not only an aesthetic factor in building but also is a passive solar factor (Fig. 10). Orsi is reticular window with small color glasses in red, golden, green-blue, violet and brown colors that been used in living and guest rooms. The structure of this windows, instead rotating around the hinge, windows pendant move to above. These wooden windows were built from walnut and red willow wood. The first aim of windows with color glasses is controlling sun radiation influx to inside the house. Because colored glasses have made from different material with distinct refractive index, the secondly creates perception of privacy (Fig. 10). Canopy is another climatic design element for controlling intensity of light inside the houses (Memarian 1998, Pirnia 2003). Canopies stand around the windows in horizontal and vertical form with depth 10-15 cm and made of brick or stucco (Fig 11).


Figure 10, 11. Orsi Windows in a massive wall. Canopy views.

Isolation: Creating an empty space between roof and ceiling created an air for controlling temperature. Ceiling was constructed in vault structure with vernacular material mud and brick, but from the outside the roof is flat. This diversity creates a good isolation in building (Fig. 12).

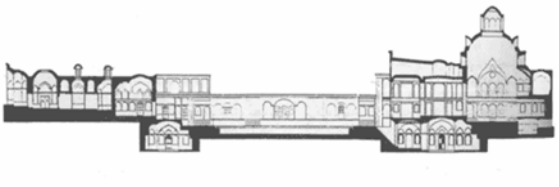

Figure12. The function of multistory roof and isolation

4. CONCLUSION

In this paper attempt was made to suggest a method for achieving of the sustainable architectural design based on vernacular architectural principals. Climate responsive design principals in hot-dry area of Iran were classified in three levels. In the first level, distance between buildings, enclosed urban environment and narrow and irregular streets were considered as macro strategies. Review and development of these traditional urban patterns should be considered in hot and dry cities. Medium scale strategies cover building form, building envelop, self-efficiency in materials and optical and thermo physical properties of building envelop in this paper. Sustainable architecture force us to re-think what we do and synchronize traditional methods of construction and the use of domestic materials. Finally, micro scale strategies demonstrate some more relevant architectural design methods which are the same as contemporary passive systems. The central courtyard must be capable of creating secure in houses or sustainable buildings in the Iranian culture. We present relations between central courtyard and sustainable architecture, and it concluded that the central courtyard is the best strategy to achieve sustainable and economic buildings. The building techniques of the hot arid climatic zones, developed over a long history of construction, have progressed to promote passive climatic conditioning to protect inhabitants from their harsh environments. Those ideas and techniques of city planning, building form, and constructions methods offer great insight to the contemporary designer of Middle Eastern desert architecture.

REFERENCES

- Afshar, F., Cain, J.N., 1975. Indigenous Building and the Third World. Architectural Design. 4(April), p-p. 207-218.
- Bondars, E. 2013. Implementing Bioclimatic Design in Sustainable Architectural Practice. Architecture and Urban Planning, doi: 10.7250/aup.2013.011.
- Bromberek, Z. 1995. Passive climate control for tourist facilities in the coastal tropics (Far North Queensland).
- Fathy, H., 1986. Natural Energy and Vernacular Architecture: Principles and Examples with Reference to Hot Arid Climates. The University of Chicago Press: London.
- Folaranmi, A.O., Philip, A., Stephen, O., Amina, B., 2013. Bioclimatic Design Principle a Solution to Thermal Discomfort in Minna Residences, Niger State Nigeria. Journal of Environment and Earth Science, ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online).
- Ghani, F. 2012. Issues in Sustainable Architecture and Possible Solutions. International Journal of Civil & Environmental Engineering. IJCEE-IJENS Vol: 12 No: 01.
- Heidari, S., 2006. New life, Old Structure Comfort and Energy Use in Buildings. Proceeding of a Conference. Windsor. UK, 27–30 April. http://www.nceub.org.uk.
- Holman, J.P., 1976. Heat transfer. 4th Ed. New York: McGraw Hill Book Co.
- Kheirabadi, M., 1991. Iranian Cities: Formation and Development", University of Texas Press: Austin, Texas.
- Knapp, R.G., Lo, K., 2005. House, Home and Family: Living and Being Chinese. University of Hawai'i Press: Honolulu. HI.
- Madge, P. 1997. Ecological Design: A New Critique. Design Issues, Vol. 13, No. 2, a Critical Condition: Design and Its Criticism, Summer, pp. 44-54.
- McMurry, S., Adams, A., 2000. People, Power, Places. University of Tennessee. Press: Knoxville, TN.
- Memarian, Gh. 1998. Introduction to House typology in Iran, Courtyard Houses. Tahran University of Sciences and Technology.
- Mikaeili M., Memluk, Y., 2012. Badgir: Design with Nature, a traditional Architectural and Climatic Element in Hot Dry Region of Iran. ICONARCH-I. 15-17 November, Konya.
- Moule, E., Dittmar, H. and Polyzoides, S. 2008. Canons of Sustainable Architecture and Urbanism.
- Oliver, P., 2003. Dwellings: The vernacular House World Wide. Phaidon. London.
- Pirnia, M. K., 2003. Edited by: Gh. Memarian. The style of Iranian architecture.
- Qobadian, V. 2006. A Survey on the Climatic Design of the Iranian Traditional Buildings. Tehran University. Tehran.
- Qobadian, V., Feyz, M., 2006. Climatic Design: Principles of Energy Usage in Buildings, Tehran University, Tehran.
- Serbescu, A. 2009. On change and adaptation: Rural Inhabitation During the Romanian Post-Socialist Transition. Traditional Dwellings and Settlements Review. 21(1), p-p. 37-50.

- Sharma, S., Sharma, P. 2013. Traditional and Vernacular buildings are Ecological Sensitive, Climate Responsive Designs- Study of Himachal Pradesh. International Journal of Chemical, Environmental & Biological Sciences (IJCEBS) Volume 1, Issue 4 (2013). ISSN 2320-4079; EISSN 2320–4087.
- Tavassoli, M., 2008. Climatic Design of Buildings. Tehran.
- Vakili A., Boussabaine, A.H., 2006. Quality Concept in Persian Precedent Architecture: A Lesson in Eco-Building Design. PLEA. 23th. Conference on Passive and Low Energy Architecture. Geneva. Switzerland.
-Vijayalaxmi, J. 2010. Towards sustainable architecture: a case with Greentainer. Local Environment, Vol. 15, No. 3, March, p-p. 245–259.