Pertanika J. Soc. Sci. & Hum. 22 (4): 1033 - 1043 (2014)

PERTANIKA JOURNALS

SOCIAL SCIENCES & HUMANITIES

Journal homepage: http://www.pertanika.upm.edu.my/

Geometry and Proportion of Traditional Houses in Hot-Arid Region, Iran

Nabavi, F.[1]*, Yahaya, A.[1] and Goh, A. T.[2]

[1]Department of Architecture, Faculty of Built Environment, University of Malaya, 50603 Kuala Lumpur, Malaysia
[2]A T GOH Architect, Dataran Sunway, Kota Damansara, 47810 Petaling Jaya, Selangor, Malaysia

ABSTRACT

The majority of Iranian traditional houses, especially those in the hot-arid region, are best known for their courtyards. In these inward-looking houses, all of the main spaces are shaped around a central open space, which corresponds to the local context and culture. Iranian traditional architecture adhered to certain principles, which are detectable in traditional buildings such as inward-looking, human's scale, modular design, geometry and specific proportion systems. This paper aims to extend analysis of proportion and geometrical principles used in traditional houses, especially the Iranian golden ratio and modularization and their role in creating harmony between culture, built-form and the environment, with special focus on courtyards, main rooms and openings. Thirty courtyard houses in hot-arid region of Iran were selected as case study. The research employs qualitative method, which involves archival documents from Iran's Cultural Heritage Organization, technical visits, on-site documentation and design analysis. This research reveals significant golden rules and modularization are adopted in the design of traditional houses, which is applicable in contemporary house design.

Keywords: Geometry, modular, proportion, traditional courtyard houses

ARTICLE INFO

Article history:
Received: 30 May 2013
Accepted: 30 May 2014

E-mail addresses:
nabavi.faezeh@gmail.com (Nabavi, F.),
yahaya@um.edu.my (Yahaya, A.),
gohaitee@gmail.com (Goh, A. T.)
* Corresponding author

INTRODUCTION

It has long been recognized by scholars that geometry plays a significant role in the traditional architecture of Iran (Ardalan, Bakhtiar, & Haider, 1973; El-Said, El-Bouri, Critchlow, & Damlūji, 1993). Since the 1930s, in Soviet Central Asia, the subject of proportion has been studied with great

ISSN: 0128-7702

interest by scholars such as Ratiia (1950), Wilber (1955), Golombek and Mankovskaia (1985), Rempel and Voronina (1990), and Herdeg and Doshi (1990). The precise understanding of geometry and its relevant terms have enabled Iranian architecture to present more durable, stable forms which are based on circle, square or rectangular geometrical characteristics. The uses of these geometrical aspects, proportions and measurement have helped architects to develop a set of modular design concept (Vakili-Ardebili & Boussabaine, 2006).

According to the 10th century philosopher, Abu Nasr al- Farabi, the fundamental of architecture were derived from mathematical science. Furthermore, the basic science of architecture was the knowledge of *hiyal*. This term is difficult to translate without making any reference to Farabi's discussion of the sciences, from which *hiyal* emerged from. Literally, *hiyal* means "skill, art, cunning", concerning the ingenious and artistic manipulation of geometric forms (Golombek, Wilber, & Allen, 1988). Thus, geometry was the foundation of an architect's training.

There is evidence to suggest that classical Greek architecture utilized a system of geometric proportion, which was probably derived from the intermediary of Euclid's treatise on geometry (Hartshorne, 2000). It was then adopted by the Arabs, and further developed during the Islamic Era. Early Arabic treatises on mathematics paid special attention to the needs of the architect, and it is primarily in these works that the aesthetics of architecture were discussed (Golombek *et al*., 1988). While there is nothing comparable to Vitruvius's treatise on architecture, there are texts dealing with geometry for the architect, geometric designs for craftsmen, and comments throughout general texts on mathematics that are relatable to architectural practice (Golombek *et al*., 1988).

The geometrical basis of Iranian design is apparent in many facets of the architecture: in the proportion of spatial design, in the creation of three- dimensional geometric objects and in two- dimensional surface decoration. Any system of proportion works toward creating a unity of design that renders the product aesthetically pleasing. It has been stressed by many writers that no particular set of proportions is innately preferred by the human psyche. Experiments attempting to prove the contrary, such as those undertaken to elucidate the properties of the "golden section", have at best been inconclusive. The popularity of the "golden section" is related to its flexibility. The Islamic system of proportion, which utilizes irrational numbers, is based on the geometrical proportion of the square, the double square, the equilateral triangle and the pentagon (El-Said *et al*., 1993).

It should also be pointed out that the same methods for developing geometric designs were also used in determining the proportions of a room, its length, width and height. Proportion is one of the determinant criteria in architecture for the perception of harmony. Grütter (1987) said "Harmony is the discipline and regularity which exists between components of phenomena".

Vitruvius and Morgan (1960) said "when we call a building beautiful, it means that the proportion among the components is based on specific rules". Le Corbusier (1931) said "Geometry is the language of man and rhythms are at the very root of human activities".

The emphasis of the Iranian architecture is on beauty and harmony. Proportion and module in components can be observed in many parts of buildings with the aims to reduce the sizes of the components and for the ease of construction in terms of building and matching different components.

TRADITIONAL HOUSES IN HOT-ARID REGION

Diverse climate in Iran has led to different architectural styles and construction in different areas. Hot-arid region includes most parts of Iran and famous cities such as Isfahan, Yazd and Kashan (see Fig.2). In this climate, summer is very hot and arid, while winter is very cold, with less rain and snow (Moosavi, 2011; Zarkesh, Moradchelleh, & Khnlari, 2012).

In the hot-arid region in Iran, traditional building designs, especially house design for all intents and purposes, have solved the climatic situations (Qobadian, 2006). Most traditional houses are introverted with all spaces being arranged around an open, rectangular courtyard (see Fig.1) forming a link between various areas of the house (Pirnia, 2005, 2007; Shabani, Tahir, Shabankareh, Arjmandi, & Mazaheri, 2011). This geometry imposes a corresponding hierarchy to its different spaces. Courtyard house type is commonly found in hot-arid climate regions in many historical cities in the Middle East (Bekleyen & Dalkiliç, 2011). In Iran, courtyard houses are the most prominent house type (Bemanian & Moradchelleh, 2011; Moradi & Akhtarkavan, 2008).

Courtyard becomes one of the determining and organizing factors in traditional building design in hot-arid regions (Qobadian, 2006). The central courtyard is a significant element of traditional Iranian houses where the important spaces were formed. A courtyard is commonly made up

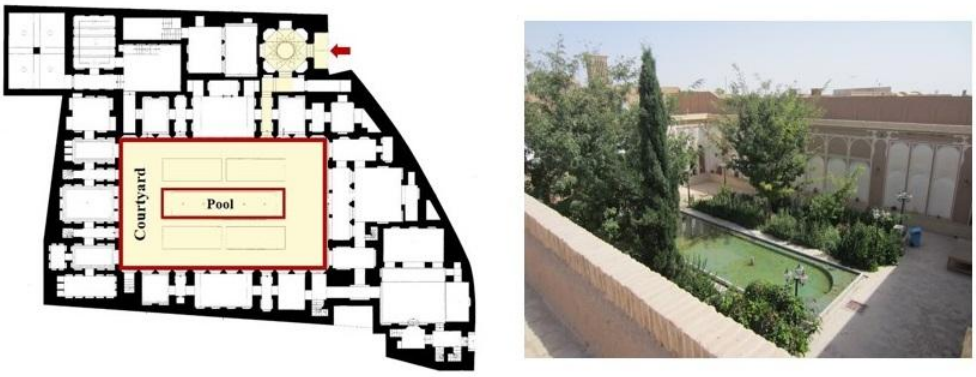

Fig.1: A Typical Traditional Courtyard House, hot- arid region of Iran

of a central pool, small gardens around the pool, and the water pathways, which differ in shapes and sizes due to differing weathers and environments.

The idea of garden and courtyard complements the hot-arid plateau of Iran, and remains as the representation of the concept of paradise during the Islamic era (Belakehal, Tabet Aoul, & Bennadji, 2004). A courtyard can provide security, privacy and comfort to its users within the house. It functions as the core of the house: spatially, socially and environmentally (Ratti, Raydan, & Steemers, 2003).

This study aims to examine the geometric patterns in traditional house plans and sectional elevations in order to conclude a comprehensive utilization of proportion and harmony in the Iranian architecture. It is hoped that via this study, prominent and salient points can be adopted into the contemporary houses in Iran. This is because contemporary houses in Iran are mostly poor in design, proportion and applications and are often described with terms such as "rootless, poor, unhealthy and materialistic" (Barati, 2003; Talischi & Ansari, 2000).

METHODOLOGY

The study employs qualitative method of several steps: (1) Archival research at Cultural Heritage Organization of Iran; (2) Technical visits to several case study houses within hot-arid region (see Fig.2); (3) On-site documentation; and (4) Design analysis.

Archival research from the Cultural Heritage Organization in Iran has helped to identify thirty traditional courtyard houses in the hot-arid region of Iran. All the thirty traditional houses selected were registered in Cultural Heritage Organization in Iran as heritage buildings, built during Qajarian era between 1850-1880 AD and have remained authentic in term of their built form. During that era, housing was the most prominent point in the Iranian architecture (Pirnia, 2005; Soltanzadeh, 2005), and

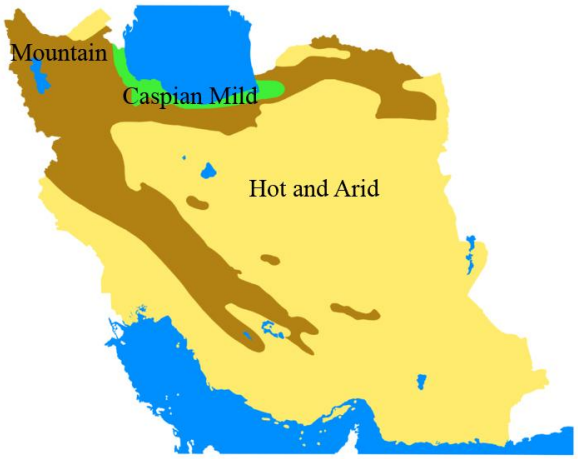

Fig.2: Hot- arid region of Iran

represented the best examples of the finest Iranian traditional houses. Although there are more samples with the same criteria, this study focused on thirty traditional houses due to direct observation, these study samples currently function as exhibitions for tourists. Five of these cases are different parts of Cultural Heritage Organization in different cities. Eight of them are hotels with traditional decoration. Two of them are the Faculty of Architecture of Yazd University. Three of them are Handcraft exhibition for tourists. The others are under the supervision of Cultural Heritage Organization and used as museums for tourists.

These are the finest buildings that have been recognized with high heritage values. For each identified house, there are some write-up on the history of the house, basic information such as house address, owner, year built and site location. Technical information such as scaled floor plans, sections and elevations are also available. Technical visit conducted between July–September 2011 confirmed the locations of these houses and critical measurements. Missing dimensions were also recorded.

There are some limitations for this study. Although these case studies are the best samples of registered valuable buildings in Cultural Heritage Organization, the conditions of a few houses were bad with some parts being damaged and destroyed, thus limits any direct observation.

PROPORTION

Iranian Golden Rectangular

In order to find the best solutions to form the buildings, Iranian architects used geometrical shapes. The geometrical shapes with commensurate ratio have been used by architects and designers in the design of most spaces in traditional houses. This system gives greater advantages for perceiving geometry and providing idea of its building structure and increasing the speed of construction (Bozorgmehri, 1981; Memarian, 2008; Pirnia, 2005). They chose regular hexagonal that could be drawn by regular triangles (see Fig.3).

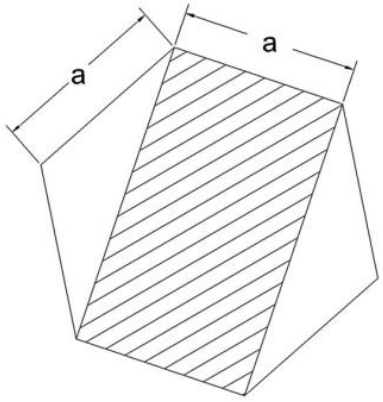

Fig.3: Iranian Golden Rectangle

The levels of scales are achieved through the proper use of a ratio known as the golden ratio. The proper use of the golden ratio is evident in the architecture of many cultures.

In the Iranian architecture, it is known as the "Iranian golden ratio" and is equivalent to the proportions of a rectangle which is embedded inside a hexagon and is slightly different from the ratio of the Fibonacci sequence (a golden rectangle is a rectangle whose side lengths are in the golden ratio).

- The proportions of the rectangle: 3.4×4 or 2×1.7
- The Iranian golden ratio: 1.176
- The Fibonacci sequence: 1,1,2,3,5,8,13,21,…
- The Fibonacci golden ratio: 1.618

In fact, it is believed that the Fibonacci golden ratio is also extracted from the Eastern geomancy, introduced to Europe through translation of an Arabic text by Fibonacci in the 13th century. The golden ratio is believed to be a ratio recurring in the creations of man and nature and as a model of spiral grow. Such spiral grow can be seen in the growing patterns of leaves, pine corns, animal shells and human chromosomes, which were also commonly used in the construction of traditional dwellings (Ardalan *et al.*, 1973; Bozorgmehri, 1981; Bozorgnia, 2005).

As Pirnia (2005) said, "this form has the best proportion between their sides" In designing Iranian traditional buildings, architects and designers used this shape frequently. In traditional houses with courtyards, most of the room and yard forms followed this proportion.

Units of Traditional Measurement in Iran

Utilization of specific units in traditional measurements is well-known in designing traditional buildings. By using specific modules, architects and designers can harmonize all the elements. These units are derived from human scale such as the dimension from fingers to elbow in a medium size person or an open hand (Bozorgmehri, 1981; Pirnia, 2005).

Specific units were adopted for most parts of a traditional building. One of the examples is the used of a specific brick size. Architects could easily use specific bricks to harmonize various buildings together.

The measurement unit in Iran is called *Gaz* (Table 1). All elements, especially openings, used to be built based on this unit and its proportion.

TABLE 1
Units of Traditional Measurement

1	One *Gereh* = 1/16 *Gaz* = 6.66 cm
2	One *Gaz* = 16 *Gereh* = 106.66 cm

RESULTS AND DISCUSSION

After analyzing thirty traditional houses in the hot-arid region (Table *2*), it can be concluded that most Iranian architectural principles, highlighted by Pirnia (2005 & 2007), are applicable in these houses. However, unlike the public traditional buildings (such as Bazars, mosques, gardens and schools), the principles in the traditional houses are different in that:

a. All of these houses have inner rectangular courtyard and main spaces surrounding the courtyard. The author examined the proportion of these rectangular (length/ width) and cross-checked this value against the Iranian golden ratio. It is not similar across board, but in some cases, it was repeated. The proportion of these rectangular (length/ width) courtyards ranges between 1:3 to 1:7, depending on land size and building forms.

b. There is a meaningful proportion between the two main rooms in traditional houses. Bedroom (with three opening) and living room (with five opening). The dimension of the rooms are related to their respective function, *sedari*; is a room with three doors (see Fig.4), has played the role of a bedroom, was smaller than a living room and is suitable for regular human heights. According to literature review, rooms are classified according to their corresponding morphology (Mirmoghtadaee, 2009), and the number of doors or windows: *panjdari* (see Fig.4), is a room with five doors, and functions as a living room. Bedrooms were designed in accordance with human height, and enough space for a man to lie in the room. All these spaces are rectangular in a traditional layout, and according to their function, *panjdari* is bigger than *sedari,* with a ratio between their respective widths and lengths (Pirnia, 2005).

If a room was built larger than another, its height, as well as its architectural elements such as the arches, the shelves, and the doors, would need to be built bigger following the same ratio. Thus, all of the elements of any architectural space would be proportionate to the size of the place (Mirmoghtadaee, 2009; Soltanzadeh, 2005).

c. The rectangular rooms with five doors (*panjdari*), located around the courtyard were examined. Most of them possess

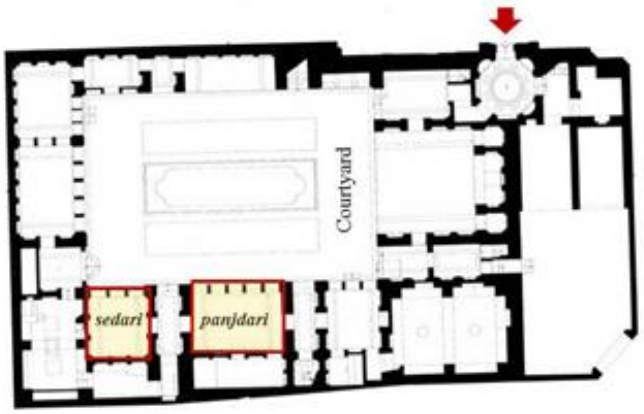

Fig.4: *Sedari* and *Panjdari* in Traditional House

similar proportion of length/ width. The ratio of Iranian golden rectangular was used when designing this space. With the exception of houses that lacks living spaces around the courtyard, the proportion of the others (19 from 23) is 1.70.

d. The openings of rooms are examined, and the traditional measurements were checked as well. All opening widths were equal to 14 *Gereh* (93.5 cm), which is suitable for passing a normal size person. These types of opening are present in almost all parts of a traditional house. For example, for *panjdari* (living room) five of them are placed right next to each other, and three of them for *sedari* (bedroom). It plays an important role in providing harmony in the main façade of traditional houses that surrounds a courtyard. As per the literature review; the elements of openings in traditional houses matches the size of an average person (Memarian, 2008; Pirnia, 2005).

They were suitable and quite enough for a person to pass through, and also allow ample daylight in. An opening in an Iranian courtyard house is composed of multiple details that are salient towards the optimizing of daylight (Pirnia, 2005). Furthermore, the defined proportion of opening increases the speed of construction, due to the exact dimension of the different rooms.

e. All of these openings are made using a lattice frame and a beautiful wooden frame with unique motifs to control day light, especially intense sun rays in the hot summer. These frames are covered with colorful glasses.

CONCLUSION

From the thirty samples selected from the hot-arid region of Iran, it can be concluded that there are many different ways of utilizing the module in the traditional houses. Due to the fact that these are private houses, it could not utilize these modules in a way that traditional buildings can with regards to proportion and geometry in every

Fig.5: Typical living room (*Panjdari*) - Outside and inside

TABLE 2
Courtyard, Room proportion and Opening proportion in Traditional House

	Name	Place/ Year of Built (AD)	Courtyard	Courtyard ratio (length/width)	Room with five opening *(Panjdari)*		Having *sedari* and *panjdari* with specific proportion
					Length/ width	Opening width	
1	Al- e Yasin	Kashan/ 1860	Rectangular	1.4	1.6	14 *Gereh*	√
2	Akhavan	Yazd/ 1864	Rectangular	1.6	No *Panjdari around* courtyard		
3	Ardakanian	Yazd/ 1868	Rectangular	1.6	1.7	14 *Gereh*	√
4	Arab- alireza	Yazd/ 1860	Rectangular	1.5	1.7	14 *Gereh*	√
5	Arab- bibirq	Yazd/ 1860	Rectangular	1.7	1.7	14 *Gereh*	√
6	Arab- ha	Yazd/ 1855	Rectangular	1.4	No *Panjdari around* courtyard		
7	Abbasian	Kashan/ 1850	Rectangular	1.5	1.7	14 *Gereh*	√
8	Broujerdi- ha	Kashan/ 1853	Rectangular	1.5	No *Panjdari around* courtyard		
9	Emam- zadee	Isfahan/ 1872	Rectangular	1.5	1.7	14 *Gereh*	√
10	Esfehanian	Isfahan/ 1863	Rectangular	1.4	No *Panjdari around* courtyard		
11	Farhangi	Yazd/ 1870	Rectangular	1.4	1.2	14 *Gereh*	√
12	Fateh- ha	Yazd/ 1867	Rectangular	1.5	1.7	14 *Gereh*	√
13	Gerami	Yazd/ 1873	Rectangular	1.4	1.7	14 *Gereh*	√
14	Golshan	Yazd/ 1870	Rectangular	1.3	1.7	14 *Gereh*	√
15	Keroghli	Yazd/ 1865	Rectangular	1.3	No *Panjdari around* courtyard		
16	Lari- ha	Yazd/ 1855	Rectangular	1.7	1.7	14 *Gereh*	√
17	Mahmoodi	Yazd/ 1855	Rectangular	1.5	1.7	14 *Gereh*	√
18	Malek	Yazd/ 1877	Rectangular	1.3	1.7	14 *Gereh*	√
19	Malek- zadeh	Yazd/ 1860	Rectangular	1.3	1.7	14 *Gereh*	√
20	Mashrooteh	Yazd/ 1871	Rectangular	1.3	No *Panjdari around* courtyard		
21	Mozaffari	Yazd/ 1864	Rectangular	1.3	1.3	14 *Gereh*	√
22	Meshkian	Yazd/ 1870	Rectangular	1.3	1.7	14 *Gereh*	√
23	Mortaz	Yazd/1852	Rectangular	1.5	1.7	14 *Gereh*	√
24	Mr. wye	Yazd/ 1860	Rectangular	1.7	1.7&1.9	14 *Gereh*	√
25	Olumi- ha	Yazd/ 1875	Rectangular	1.6	1.7	14 *Gereh*	√
26	Rasoolian	Yazd/ 1856	Rectangular	1.3	1.7	14 *Gereh*	√
27	Rismanian	Yazd/ 1864	Rectangular	1.5	1.7	14 *Gereh*	√
28	Semsar	Yazd/ 1868	Rectangular	1.3	1.5	14 *Gereh*	√
29	Shokoohi	Yazd/ 1858	Rectangular	1.3	1.7	14 *Gereh*	√
30	Tehrani- ha	Yazd/ 1855	Rectangular	1.7	No *Panjdari around* courtyard		

available space. Limitations of land and owners' opinions and demands have resulted in pronounced differences. By and large, there are logical proportions and scales in important spaces of the traditional houses in the hot-arid region of Iran. These include building forms and courtyards, important rooms for family members and guests. It is suggested that these techniques have improved the speed of construction while harmonising and beautifying these houses at the same time.

It is also concluded that despite the fact that it is impossible to adopt and apply all of the traditional strategies and techniques to contemporary houses, it is possible to adopt suitable corresponding strategies that apply to a modern layout. By using these rules in contemporary houses, the dimension of the rooms are related to their functions and also all the elements of those spaces will be in harmony with their dimension. For example, a bedroom will have enough space for one or two persons and specific opening of this particular space will receive sufficient daylight for bedroom. This process can be generalised for all spaces in the contemporary layout. New houses can be designed by using harmonious proportion in order to establish proportional spaces and improve aesthetics, which might be suitable for contemporary houses.

REFERENCES

Ardalan, N., Bakhtiar, L., & Haider, S. G. (1973). *The sense of unity: the Sufi tradition in Persian architecture.* Chicago: University of Chicago Press.

Barati, N. (2003). Rediscovering the Concept of House in Persian Language and Culture. *Journal of Art and Culture,* 24-55.

Bekleyen, A. & Dalkiliç, N. (2011). The influence of climate and privacy on indigenous courtyard houses in Diyarbakır, Turkey. *Scientific Research and Essays, 6*(4), 908-922.

Belakehal, A., Tabet Aoul, K., & Bennadji, A. (2004). Sunlighting and daylighting strategies in the traditional urban spaces and buildings of the hot arid regions. *Renewable Energy, 29*(5), 687-702.

Bemanian, M. R., & Moradchelleh, A. (2011). Residential Architecture of Bushehr, Connector of Introversion and Extraversion in Architecture. *World Applied Sciences Journal, 13*(7), 1643-1648.

Bozorgmehri, Z. (1981). *Geometry in Iranian Architecture*. Iran, Tehran: Protection of National Monuments Organization.

Bozorgnia, Z. (2005). *Iranian Architects from Islamic era till Qajarian era*. Tehran, Iran: Cultural Heritage Organization.

Corbusier, L. (1931). *Towards a new architecture*. United States: Courier Dover Publications.

El-Said, I., El-Bouri, T., Critchlow, K., & Damlūji, S. S. (1993). *Islamic art and architecture: the system of geometric design, Garnet Pub*.

Golombek, L., Wilber, D. N., & Allen, T. (1988). *The Timurid Architecture of Iran and Turan (Vol. 1)*. New Jersey: Princeton University Press.

Golombek, L. & Mankovskaia, L. (1985). *Towards the Study of Forms in Central Asian Architecture at the End of the Fourteenth Century: The Mausoleum of Khvāja Ahmad Yasavī.* British Institute of Persian Studies, 23, 109-127.

Grütter, J. K. (1987). *Ästhetik der Architektur: Grundlagen der Architektur-Wahrnehmung*: Verlag W. Kohlhammer.

Hartshorne, R. (2000). *Geometry: Euclid and beyond*. New York: Springer-Verlag.

Herdeg, K. & Doshi, B. (1990). *Formal structure in Indian architecture.* New York: Rizzoli.

Memarian, G. H. (2008). *Iranian architecture.* Tehran, Iran: Soroosh Danesh.

Mirmoghtadaee, M. (2009). Process of housing transformation in Iran. *Journal of Construction in Developing Countries, 14*(1), 69-80.

Moosavi, M. (2011). An Analysis to Historic Roots of Climatic Design in Ancient Architecture of Central Zone of Iran. *International Proceedings of Economics Development & Research, 17*.

Moradi, A. M. & Akhtarkavan, M. (2008). Sustainable architecture in the hot, arid and sunny regions of Iran. *Architect Engineering Special Issue, 19*(6), 21-29.

Pirnia, M. K. (2005). *Introduction to Islamic Architecture in Iran (Vol. 10)*. Tehran, Iran: Soroosh Danesh.

Pirnia, M. K. (2007). *Architectural styles in Iran (Vol. 5)*. Tehran, Iran: Soroosh Danesh.

Qobadian, V. (2006). *A Survey on the Climatic design of the Iranian traditional buildings*. Tehran, Iran: Tehran University.

Ratiia, Sh. E. (1950). *The Bibi Khanum Mosque in Samarkand. A Study and Essay at a Restoration*. Moska: Gos. izd- vo. Architektury i gradostroitel' stva.

Ratti, C., Raydan, D., & Steemers, K. (2003). Building form and environmental performance: archetypes, analysis and an arid climate. *Energy and Buildings, 35*(1), 49-59.

Shabani, M. M., Tahir, M. M., Shabankareh, H., Arjmandi, H., & Mazaheri, F. (2011). Relation of cultural and social attributes in dwelling, responding to privacy in Iranian Traditional House. *e-BANGI: Jurnal Sains Sosial dan Kemanusiaan, 6*(2), 273-287.

Soltanzadeh, H. (2005). From House to Apartment. *Architecture and Culture Quarterly*, 142-154.

Talischi, G. & Ansari, H. (2000). Trends and Challenges in Contemporary Architecture of Iran. *Tavoos Online Artistic Journal, 11*(4).

Vakili-Ardebili, A. & Boussabaine, A. H. (2006). Q*uality concept in Persian precedent architecture: A lesson in eco-building design*. PLEA 2006.

Vitruvius, P. & Morgan, M. H. (1960). *The ten books on architecture.* New York: Dover Publications.

Voronina, V., Rempel, A. (1990). Architecture of India and Central Asia. *Research Comparison. Indian National Science Academy, 2*, 285.

Wilber, D. N. (1955). *The Architecture of Islamic Iran. The II Khānid Period.* USA: Princeton University Press.

Zarkesh, A., Moradchelleh, A., & Khnlari, E. (2012). Region Based Classification of Design and Construction Consistent with Climate. *Middle-East Journal of Scientific Research, 11*(1), 66- 76.