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Identification of Structural Systems in Iranian Architecture

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Abstract: Persian architecture is full of hints that it may sometimes be discovered and used and its foundation and tradition is the dynamics and being up to date. So, the biggest features of such a buildings are all-round vision and scientific, technical and administrative discerning to its stability. Since, Iran is located on seismic zone, Iranian architects throughout history have always tried to create and develop architectures species that adapts to the climatic characteristics, uses local materials and be stable against earthquake and ground motions. So, in this way, they have succeeded to develop Niaresh issues and have achieved the sustainable species in designing and implementing coatings. In this research, given that this is a descriptive-analytic study, retrofitting techniques of arches, groins and domes are recognized in traditional Iranian architecture and Niaresh various techniques creating sustainable architecture have been introduced. Thus, according to the resources available, contents relevant to stduy topic are summarized and considered in terms of Niaresh.

Key words: Niaresh, architecture, structural systems, chafd, arch, dome, Iranian architects

INTRODUCTION

Structural engineering science in architecture of Iran in the Islamic period was in fact a continuation of the Niaresh achievements of pre-Islamic period and actually the continuation of that was not the sign of the stop in the past but, the continuation of Intelligent progress process in Niaresh science area which they have already learned. the emphasis on the stability and attention to durability are of principles of Iranian architecture which formed under influence of eastern and Iranian culture. In fact, one of the keys to lasting ancient monuments of Iran is attention to the Niaresh issues and conscious perception of structural stability in their works. All archaeological studies and researches suggest that the history of Iranian architecture is about seventh thousand BC. Since, then, the art is developed and evolved in relation to various issues, especially religious reasons. Iranian architecture has features which is of special value compared to other countries.

Features such as reasonable design, precise calculations, the correct form of coverage, compliance with technical and scientific issues in the building, lofty porch, tall columns and finally, the various ornaments that represent the glorious simple architecture of Iran (Mohammad and Memarian, 1972).

Niaresh reviews the issues deeply with specific procedures and solves them systematically. using forces opposition which is applied consciously with full control leads to static and stable balance. Niaresh story and to better express the architectural story begins with choose a natural material and turn it into thematic structure. In expressing this story, the main goal is to achieve living space. With this aim, natural material turns it into thematic structure, then to a structural organs and eventually becomes a living space (Memarian, 1971).

CHECK THE MEANING OF THE WORD NIARESH

Niaresh means what keeps the building and Niaresh science means the knowledge of keeping building up and all that is done for the stability and sustainability of building named Niaresh. Niaresh is also considered as one of the principles of Iranian architecture which means Understanding and awareness of structure science and how to transfer forces and one of the keys to sustainable architecture is to understand this science. Niaresh Science is composed of three parts:

- Static (structure and analysis and calculation of the forces and building strength)
- Materials science (kind of materials, construction and use of coatings)
- Buildings technique (construction and operating elements and details)

A variety of thematic structure in Iranian architectural brick and mud buildings: Construction of brick buildings has been considered at any time because the soil easily picked and after constructing brick, it is used for buildings.

Traditional brick buildings: The rise of brick buildings in Iran can be seen in the middle of the first millennium BC in Choghazanbil building (Zomarshidi, 1984).

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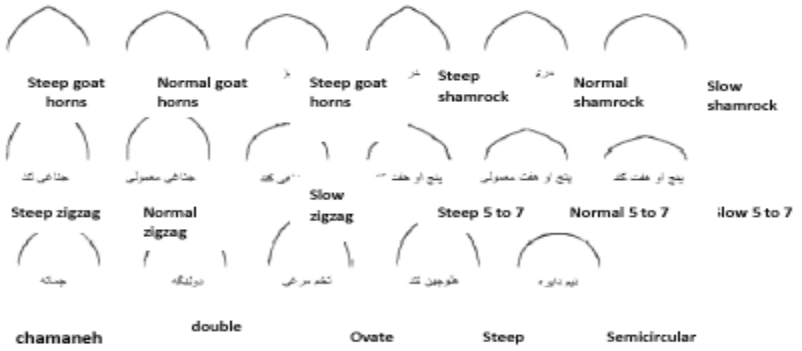

Fig. 1: Arcs species used in Iranian architecture (Zolfagharzadeh in 1394)

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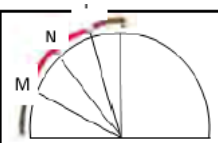

Fig. 2: Various sectors of arc (Zolfagharzadeh in 1394)

Stone buildings: The ancient stone buildings are of particular interest and the massive monuments such as Pasargadae and Naqsh-e Rustam and Persepolis are memorabilia of BC that has remained to this day (Zomarshidi, 1984).

Of wooden buildings: Wooden buildings are constructed in the simple form of small woodsy and residential cottages on the fringes of the forest, as well as residential buildings in villages small and large towns (Zomarshidi, 1984). Niaresh of arched and domed structures in Iranian architecture.

Arc: Arc in geometrical definition is the line or shape of the curve and in terms of architecture it is referred to the arch beam which is placed in a port (input).

Types of Iranian arc

Sharp and fillet arc: This classification is based on profile shape of arc. sharp arcs are created through the collision of two symmetrical curves in the sharp point. fillet arcs are crescent-shaped head and part of an ellipse or circle.

Porter and array arcs: In this category, arcs are named according to their structural task. porter arcs are used for grand openings and array arcs are used for small openings.

The simple and combined arcs: In simple arcs, a set of curved lines makes a single arc. combined arcs are obtained from a combination of two types of arcs.

The sharp, steep, slow arcs: This category is used for both fillet and sharp arcs. Here, leap of the arc is criterion. each arc can be created as one of these four types (Fig 1 and 2).

Arch and dome in architecture of Iran

Arch: Arch is the move or several arcs along an axis or different axes On the surface enclosed between two porter walls or at least four porter columns.

Performing arches procedure: Depending on the orientation of brick, arches are implemented in three ways:

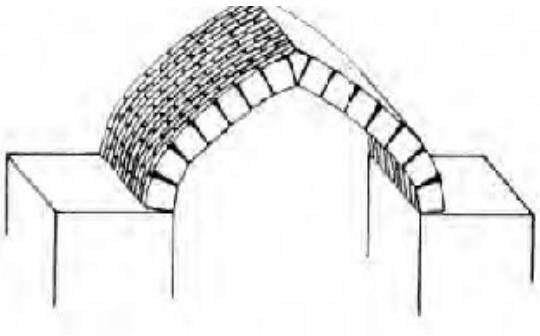

Fig. 3: Barrel performing arch procedure (http:// www. cafed exign.com/)

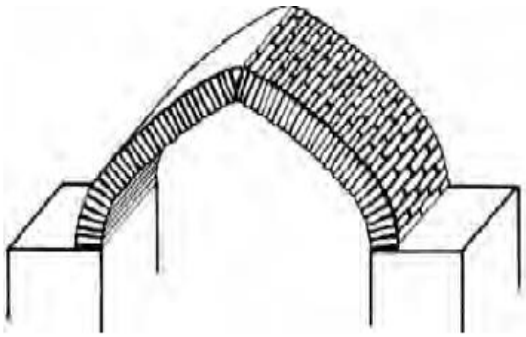

Fig. 4: Roman performing arch procedure (http://www. cafedexign. com)

- Barrel arch
- Roman arch
- Blade arch

Barrel arch: In this type of performance, brick or adobe is placed from the front or the full page of its own and it can be seen as roman from below. In this performance a row of bricks is laid and in the next round the bricks are stacked so that the segment of two rows is not overlapped and thus the strength of the coating increases. The implementation of this type of arch is unique to Iran and its history is to 3500 year old in the implementation of the barrel arch, first the side walls of arch that are porter be made then the end platform of the two walls is constructed (Mohammad, 1969) (Fig. 3).

Herrera or roman arch: In this type of performance, the order of bricks or adobe is such a way that it can be seen as a narreh from the head-on perspective namely the narrow segment of the brick is observed the arch

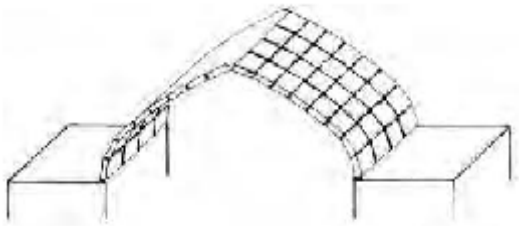

Fig. 5: Blade performing arch procedure

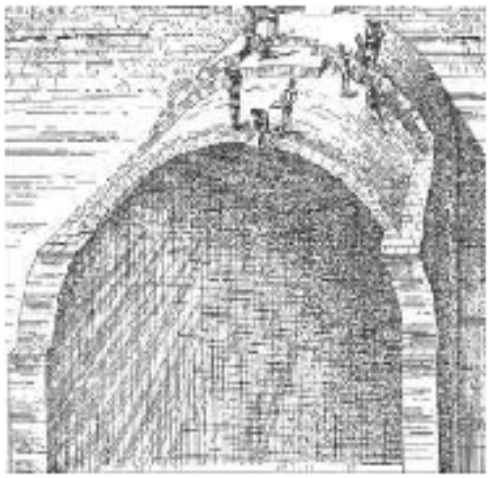

Fig. 6: Fillet cadence arch by barrel procedure

performed with this method is of good strength, because the full surface of brick is imbued with mortar.in the implementation of roman arch, it is important to note that the picking up a brick is done from two sides of wall to be interlocked in top (Mohammad, 1969) (Fig. 4).

Blade arch: In this type of performance, the order of bricks is such a way that the narrow edge of the brick can be seen from the front, but unlike the roman procedure that the narrow edge is seen stand-u in this procedure narrow edge is placed lateral. This method is applied for the arches that are used solely to cover a space that the bearing element floor does not fall on that Pir Nia, Mohammad, 1969) (Fig. 5).

ARCH TYPES

Cadence arch (cradle or tube): This arch is obtained by moving an arch on two equal parallel walls. in the implementation of cadence arch 3 procedures of picking brick can be used: barrel-roman-blade (Memarian, 1971) (Fig. 6).

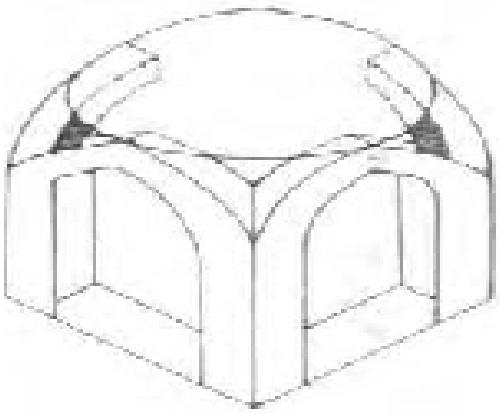

Fig. 7: Implementation of Colombo arch on four porter groins

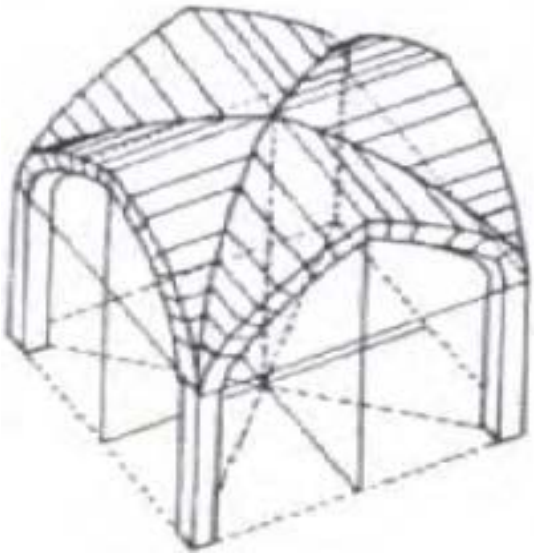

Fig. 8: Three-dimentional four part arch

Colombo arch: This arch is of closed rotational arches which is considered as one of the main fillers in Iranian architecture. colombo is a small dome that mainly has no infrastructure, cornering and contortion and is performed on four walls or columns on square area (Mohammad, 1969) (Fig. 7).

The four part arch: This arch is created through the intersection of four cadence arches which are clashed perpendicularly. This arch is composed of four parts. Graphically, its image on plan is four crack. So, it may be confused with cracked arch in the plan but it is completely different in a three-dimensional view or cut (Fig. 8)

Fig. 9: An example of Palanquin arch in palace of forty columns of Isfahan

Fig. 10: Lid arch

Four gardehpoosh arch: The implementation procedure of this arch is like four part arch with the difference that in the implementation of his arch stencil is placed on the sharpness of groin.

Palanquin arch: Palanquin arch is a curved surface obtained from a curve move on the two main groin.in this arch, larger groin is sharp and moving curve can be sharp on non-sharp. The simplest type is the arch implementation between two groins four groins. (Fig. 9).

Lid arch: This arch in one of the most controversial in Iranian architecture. Main organs of the arch are two parallel groinsthe groins are equal to width of bottom coating space (Memarian, 1971). This arch is used for skylight and Gholamgard and is decorative not structural (Fig. 10). The 7-groin the groin means rainbow and curved branches. Girders are groin sample in modern arches and

Fig. 11: Preparation of plaster stencil on earth (Aniran in 1392)

Fig. 12: Implementation of groin with plaster stencil (Aniran in 1392)

Fig. 13: Final procss of plaster stencil

play the role of groin in fact, groin or pendant is a porter arch rib (Mohammad, 1969) (Fig. 11-13).

Fig. 14: The implementation of fastening of Tarikhaneh Mosque of Damghan

Fig. 15: Jame Mosque of Isfahan

Bricklaying in groin is performed by two ways barrel and roman or combination of the two which called stand-up and lateral.

Strengthening way of arch and groin :

- Saddle arch and groin
- Reduce the thickness of groin
- The implementation of fastening to reduce the driving force of arch and groin (Fig. 14-18)
- Thickening the wall
- widening the groin
- Use of minar around the arch
- The use of compounds of brick laying
- Queuing(styling)

Cache beams: Wooden beams are used in the Pakar part of groin which are named "cache ".Cache beam is a wood that connects arch Pakars to inhibit the movement of the wall or column foundations or arch below the groin or arch. Also among and within the columns, vertical woods with the role of vertical ties were used to strengthening and cache woods were connected to the vertical wooden ties (Fig. 19).

Fig. 16: Amir Chakhmagh square of Yazd (Aniran in 1392)

Fig. 17: Queuing in Mir Bahaoddin bridge of Zanjan (Aniran in 1392)

Fig. 18: Implementation of queuing between two cadence arches in Saraye Dokhan of Zanjan

Dome in Iranian-Islamic architecture: Iranian architecture and architects of Iran has always sought to find new ways to facilitate the implementation as well as strength and Niaresh with regard to aesthetic factors. One of these strategies was devising dome. In fact, dome is one of the characteristics and definiteness of Iranian architecture and in many old cities, it was sign of majesty and power of the city.

Fig. 19: Using Cache beam in groins of Saraye Dokhan of Zanjan (Aniran in 1392)

Appearance factors of dome: In fact , the main factor of dome appearance was the absence of wood to cover large openings and hence Iranian architecture used local materials such as mud and adobe and set out to invent arc-shaped ceilings and thus able to create domed ceilings. At first, domes only met the needs of large openings. But, later mystical and philosophical reasons continued the use of domed ceilings (Vafamehr and Taghavi, 1968). The former domes were circular-based (Mohammadi *et al*., 1970).

Dome features:

- Dome is the lightest structure with the biggest volume (Vafamehr and Taghavi, 1968)
- Climatic characteristics
- Arch height from floor to soffit is high and can create vertical ventilation in hot and dry areas. Considering the weight of the cold and hot weather and creating valves around or tip up the arch, hot air that is lighter can be removed from the up valves so the normal flow of air can be established from bottom up
- Dome due to its arc-shaped form, creates shadows and shading on the roof by one side of it and causes part of the roof stay cool
- In cold regions in order to retain heat, the height of hall under dome is usually considered less and the opening levels around the walls are also less
- Wind easily passes over the convex surfaces and causes less erosion and degradation

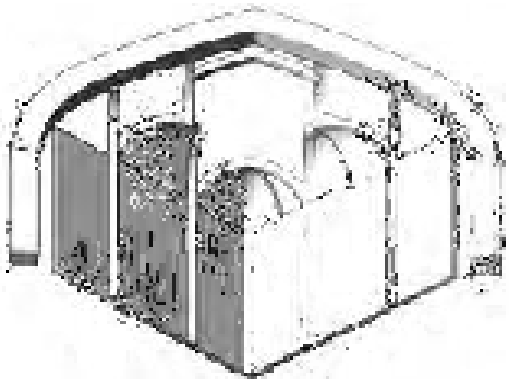

Fig. 20: Cornering of Potkaneh (http:// www. iran-eng. com)

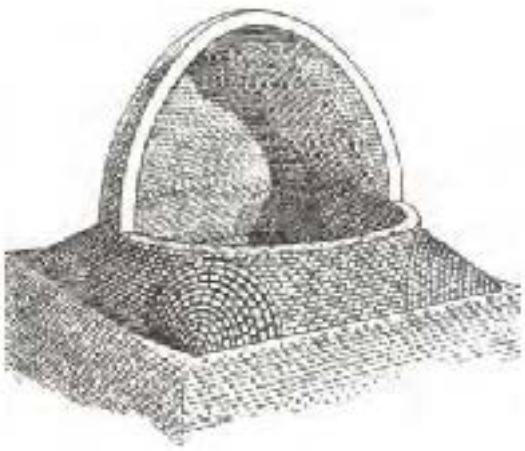

Fig. 21: Cornering of Filpoush (Farshad, 1956)

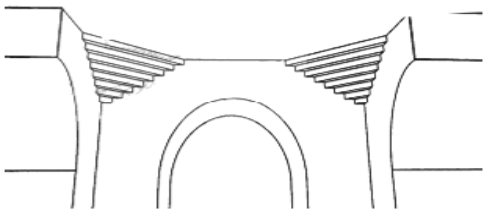

Fig. 22: Cornering of Toronbeh with wood (Pirnia in 1387)

- Since, the arc-shaped dome or arch is a three-dimensional structure, it shows more resistance against lateral forces such as wind and earthquake (Qobadian, 1965)

Implementation of the dome: Dome in the geometric definition is the points which is created by specific arc rotation around a vertical axis. But in the architectural language, it is coverage that is set up on the round base. the dome is composed of three parts.

Fig. 23: Cornering of petkin in the prison of Harun Al-Rashid

Dome house: Means base of dome.

Jump: The part that pops up on the undertone base as cube.

Chapireh: Chapireh or cornering technique is of architectural elements that is taken decorative aspect during its development and on the other hand, has been recognized as one of the decorative arts. this technique that was began before Islam, achieved its dramatic evolution in the Islamic period (Fig. 20-23). Structurally, the Iranian domes can be divided into three categories:

- One shell
- Two shells
- Three shells

Types of the dome: After cornering, jump phase begins namely constructing dome itself based on the structural type and shape. according to Donald Wilbur, the most important architectural type and form of pre-Islamic in Sassanid era and Islamic architecture is construction of dome on a square-shaped base (Wilbur, 1945).

Ahianeh and Khood: In the two-shell domes, the inner shell is Ahianeh and the outer shell is Khood. Khood is placed on Ahianeh in three ways.

Continuous two-shell: In this way, Khood and Ahineh are used Integrated from Pakar of dome to a close sharpness of dome and are interconnected and the fall apart just near the dome to tilt more to dispose of atmospheric precipitation (Mohammad, 1969) (Fig. 24).

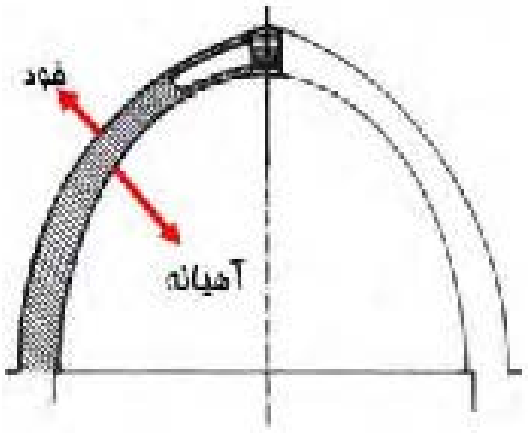

Fig. 24: The section of continuous two-shell dome (Zolfagharzadeh in 1394)

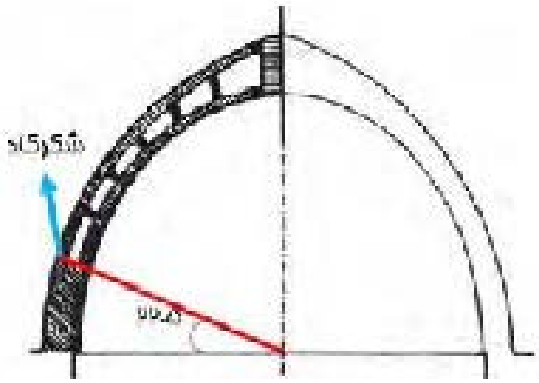

Fig. 25: The section of hollow continuous two-shell dome (Zolfagharzadeh in 1394-776)

Hollow continuous two-shell: In this way, Khood and Ahianeh are interconnected to Shekargah part and fall gradually apart from this part to dome sharpness (Mohammad, 1969) (Fig. 25).

Discrete two-shell: In this way, Khood and Ahianeh are completely separated and Khood weight is transmitted to Ahianeh by wooden walls named Khashkhashi. distance carried between the Pakar of Ahianeh and Pakar of Khood is idiomatically called neck of dome. if the distance is between zero to 1 meter it is called Arbaneh and if it is more than 1 meter it is named Greve (Fig. 26). In two-shell domes, the arcs considered for Khood include:

- Steep shamrock
- Slow shamrock

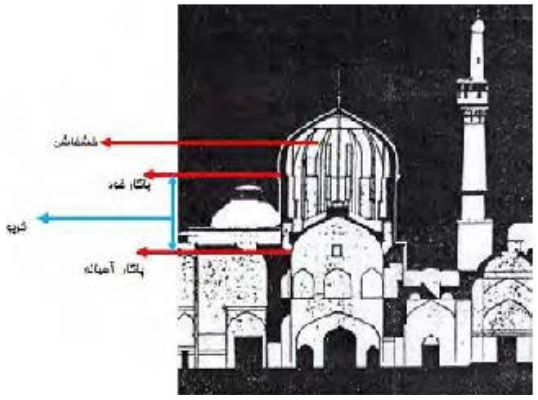

Fig. 26: The section of discrete two-shell dome (Zolfagharzadeh in 1394)

- Pato Pa
- Chomaneh
- Serook

In general, the types of domes that have been built in Iran include:

- Nar: Like most Dome (Imam Mosque in Isfahan, Jame Mosque of Isfahan, Sheikh Lotfollah Mosque, etc.)
- Rek: Rek Dome that is cone-shaped is also made as multi-faceted pyramid. (Tower of Mazandaran Ardakan, Gonbad-e Qabus, etc).

Adobe or mud structures were most basic shelter for people and the oldest construction materials used for a sturdy structure was being applied so far as it is used in various forms. these buildings actually have summarized human history in themselves. The oldest houses and adobe structures can be found in Silk of Kashan and Choghazanbil of Shoosh .

Identification of damage factors in adobe structures: Obsolescence and erosion of adobe and mud buildings over time, Environmental conditions, reduce and increase of loads to adobe structures create complications and ultimately will cause destruction and loss of the buildings (Rajabi and Mozaffari, 1972).

Strategies for conservation and restoration: For preservation and restoration of adobe structures, mortars matched with a brick like thatch, mud, lime and can be used as stabilizers or for pasting parts. the proceedings taken must be accompanied by continuity and stability.

CONCLUSION

Creation of different Niaresh and structural techniques and the introduction of new techniques in

traditional architecture such as arches and domes have always caused strength and sustainability of buildings.in various environmental and climatic conditions and factors , Iranian architects were seeking solutions to deal with the factors that affect the building. Resulting in the creation of methods and techniques with regards to principles of aesthetics and conflation of art and science. Therefore, these principles because of the strength and sustainability of in the building and also creating works of art established gradually as a principle in Iranian architecture. Principles known as the stability and strength factors to the building have been experimentally transferred to the next generation chest to chest and thus lead to the formation of Niaresh science. Knowledge that is the foundation of sustainable architecture. The knowledge that is the foundation of sustainable architecture.

REFERENCES

Farshad, M., 1956. The History of Engineering in Iran. Balkh Publication, Tehran, Iran,.

Memarian, G.H., 1971. Niaresh Iranian Architecture. Naghmeh Navadish Publications, Tehran, Iran,.

Mohammad, P.N.K. and G.H. Memarian, 1972. Introduction to Islamic Architecture of Iran. Soroush Danesh Publications, Tehran, Iran,.

Mohammad, P.N.K., 1950. Dome in architecture of Iran. J. Sci. Techn. Artistic, 20: 165-165.

Mohammad, P.N.K., 1969. Architecture Stylistics of Iran. Soroush Danesh Publications, Tehran, Iran,.

Mohammadi, M., J. Nistani, M. Moosavi and H. Alireza, 1970. The study of typology, elements and implementation of architecture of Iran in the Sassanid era. Pub. Archaeol., 1: 83-104.

Qobadian, V., 1965. The Climate Investigation of Traditional Buildings in Iran. Publishing and Printing Institute of Tehran University, Tehran, Iran,.

Rajabi, M. and A. Mozaffari, 1972. Theory and Practice of Monuments, (Pathology and Technology). Jamal Art Publishing, Tehran, Iran,.

Vafamehr, M. and S. Taghavi, 1968. Investigating the formation of the dome with a review of Islamic and Iranian domes. Int. Mag. Road Build., 63: 46-55.

Wilbur, D., 1945. Islamic Architecture during Ilkhani. Cultural and Scientific Publications, Tehran, Iran,.

Zomarshidi, H., 1948. Implementation of Building with Traditional Materials. Afshar Publications, Tehran, Iran,.