



Spatial and Structural Features of Domes in the Iranian Architecture

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Abstract: Dome is an Iranian construct to which various issues such as their emergence and distinction from domes constructed in other countries, forms difference, process and structural systems, construct resistance, and theoretical bases pertaining to the origin of magnificence and beauty have been allocated. This paper aims at investigating briefly the physical form and its effect on recognition of different domes and studying Iranian domes in terms of structure and presenting case examples among traditional domes in Iran and the impact of developments on construct design and implementation in the Iranian domes. In the end, it regards domes as an example of Iranian Islamic art in the Iranian traditional architecture arena and it has endeavored to take a stride, even short, in preserving and introducing the embodiment of magnificence and preventing it from fading into oblivion.

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Introduction

Domes in Iran have a longstanding background. Lack of solid woods that are in fact the main element of flat coverage made sagh and dome coverage prevalent and replace them particularly in wider spans. The eldest curve forms in the ziggurat lower coverage belong to the second century. In the Achaemenid era, a brilliant architecture with flat coverage in the peak of power and performance is seen; however before and after this era, bringing cedar wood from Jabal and teak from Gondareh were not always feasible due to lack of particular economic conditions, and woods proper for coverage were not grown in the jungles and plains of this land. Thus curved arches and domes find their position as a climatic and structural phenomenon in the Iranian architecture (Ardalan, 2001).

In Sasanian era, domes became so prevalent that from then until now, dome is used as a pattern and a general guideline in terms of construction. Dome building method, whether in Sasanian era or in the Islamic era, follows such a mathematical order in formation and construction that all different kinds of domes resist properly against all pressure and buoyancy forces without needing hanging ladder, frame, and mold. Although some developments have occurred in corner-building from the early Islamic period, dome has always followed its specific cultural and executive feature. It is worth mentioning that this feature makes it different from the Eastern domes both

in terms of form and implementation (not needing mold) (Bolkhari Ghahi, 2005).

When in the path of history, we look at the Spiritual geography of the world and particularly Iran cities, we can see the embodied primordial belongings in the form of enamel domes created on the earth and search the reflection of magnificence, beauty and parting concern in different eras and judge the legacy of the past in the realm of wonder. On the shores of intelligence and aesthetic sense, the passion of predecessors and their spiritual origins cannot be ignored based on habit. Although on the peak of the spiritual effects, dome is defined as a part of a set of elements of these effects, a world of mystery lies at its heart which has been considered from different perspectives (Ferithof, 2001)

Research Background

A brief review of the prior studies reveals that Iranians, not only based on the necessity of wide spaces required to hold spiritual rituals but also by awareness of building materials behavior, have been able to initiate dome construction by innovating modern methods and technologies and set the stage of easy implementation and saving material consumption beyond the technology of their times.

Ghasemi Sijani in 2008 in a paper titled as "Isfahan, the City of Mosques", has regarded the dome formed on a square plan among the Iranian architecture gifts to the world and among Iranian innovations in

Parthian method. He believes that "in the early Islamic centuries (near first to fourth centuries) by construction of Shabestani (bed chamber) mosques, using this form was not prevalent; by establishment of local governments and construction of Amir Ismail Samani Mausoleum in Bukhara, this plan prevailed again".

Pirnia in 1972, in a paper titled as "Iran Gifts to the World of Dome Architecture", relates dome emergence to the second century and believes that Iranians have constructed it for the first time; he maintains that arches and domes have a long lasting background in Iran and ancient architectures have constructed wonderful examples in Ziggurat temple and cellar tombs. He believes that Iranian arch follows philosophy based on special mathematics which has a valuable position in architecture and construction technology.

Hosseinpour in 2008, in his paper titled as "Jame Mosque of Isfahan, Encyclopedia of Iranian Architecture" states that "dome construct has existed in the Iranian architecture before Islam. By entrance of Islam into Iran not only this religion did not confront the manifestations of Persian culture, but it also used some of them like dome in the religious buildings".

Showazi in 2007, in the book "History of Architecture" that has been translated by Dr. Latif Abolghasemi, refers to the Persian methods which have been imitated by the architects of the eldest mosques; the methods established during Sasanian era in Syria were transmitted to Egypt and then to Spain.

Gedar and colleagues in 2008, in the book "Iran Works", regard Iranian initiation in building domes and coordinating dome with the under-roof square as a valuable feature; moreover they deem constructing arches in Iran without aid of scaffold so easy that it is built by using insignificant materials and during a short period of time and consider this sophisticated method as the achievement of a long lasting experience.

Raeisi and Azad in 2007, in a paper titled as "Dome in the Iranian Architecture", discussed the apparent form of domes and different kinds of coverage in terms of form and function, they have regarded books written by Professor Lorzadeh and Professor Pirnia as the mere main references related to the arches issue in the Iranian domes architecture.

Hejazi in 2008, by virtue of studies carried out by him and his colleagues regarding Iran traditional buildings from structural engineering perspective, elaborates that those studies imply that art and science of structure in Iran traditional construction are the

result of deep knowledge of engineers and architects of the above mentioned buildings. He maintains that it is unlikely to find a historical building whose structural design rules are inaccurate based on modern structural engineering bylaws. According to him, "Iranian artists have dedicated their expertise to a common tradition which has immersed their individuality. This is not the work of a specific Iranian artist; rather it has been resulted from good faith and honesty of a series of competent artists that authenticated a longstanding tradition".

Research method

This paper has applied a historical – interpretive research method. Iran cultural phenomena are independent variables, and form and plan of architectural spaces in domes are dependent variables of this paper. Data have been gathered through both documentary and field methods. The theoretical framework of this paper is based on the fact that climatic culture has played a significant role in formation of domical roofs.

Analysis

When we face with the word dome, we usually remember a special kind of domes whose is geometrically defined as a construct that is created by rotation of an arch around its axis of symmetry. While studying different kinds of domes reveals clearly that this definition is not comprehensive enough for all kinds of domes. In fact it is necessary to offer separate geometric definitions for different kinds of domes. Yet if we want to mention the common features of all kinds of domes and differentiate them from other arched structures, two key points must be pointed out:

First, the outer view of dome is a matter of particular magnitude, while this is not right about arches. Second, domes are frequently bigger than arches in terms of span dimensions and subsequently their own dimensions (Saeidi, 1995).

The Effect of Form on Domes Recognition

One of the most primary matters that must be considered in domes recognition pertains to their forms. Awareness of "domes classification in terms of form" is more important when we note that the outer form and view has been an important matter in designing domes (Ameli, 2003). Domes are classified into Rok and Nar domes in terms of form in the Iranian architecture.

Rok Domes

The word Rok has at least two general and specific meanings in the issues related to domes. Here, the general meaning of Rok is considered which includes different kinds of high domes (with different forms including pyramidal, conical, synthetic, pineapple, and even cedar¹ forms). Besides height (to put it more accurately, high edema), balanced dome building can be mentioned as a common feature for all kinds of Rok domes. So Rok dome may be defined as a tall dome whose edema is more than one and materials decoration is "balanced" (Pirnia, 1991).

Nar (Nari) Domes

All curved domes are created by rotation² of an arch around a vertical axis. Usually the arch in Nar domes has an edema less than one or near one. In fact if the edema of this arch is high, the dome will not be fit and we will face with a kind of Rok dome (in terms of both function and implementation). It is clear that the outer view of Nar domes will be less than Rok domes. So we see that in Nar domes (where we need more outer view) this matter is solved by high graves, while there is no need to high grave in Rok domes (Pirnia, 1991) (figure 1).

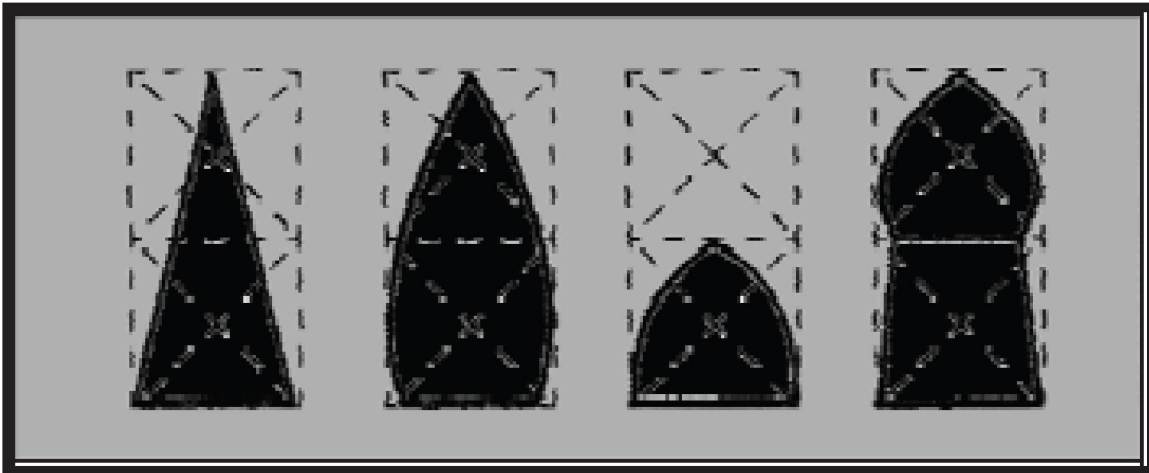


Figure 1- Height in two examples of Rok domes and two examples of Nar domes. In Nar domes, high grave is used for high elevation.

Types of Rok Domes

- a. Rok: a pyramidal dome that is a Regular polygon which has rarely less than 10 sides. Geometrically speaking, it is created by the interrupted rotation of an isosceles triangle around bisector of its top angle. Based on a better definition, it is a locus that links perimeter of a polygon to a point on the top of the polygon and on the vertical axis.
- b. Kharastuk³: a dome that is a perfect cone⁴. That is, it is created by complete rotation of an isosceles triangle around bisector of its vertex angle. According to a more precise definition, it is a locus that joins the circle perimeter to a point on the top of the circle plate and on the snake vertical axis.

¹ Cedar dome is in fact a kind of Rok dome that was frequently used at Buwayhid time in Shiraz. For further information in this regard, please refer to Pirnia, 1991.

² This rotation may be complete or interrupted.

³ Conic Dome

⁴ The vertex angle of conic and pyramidal Rok domes is usually an obtuse angle.

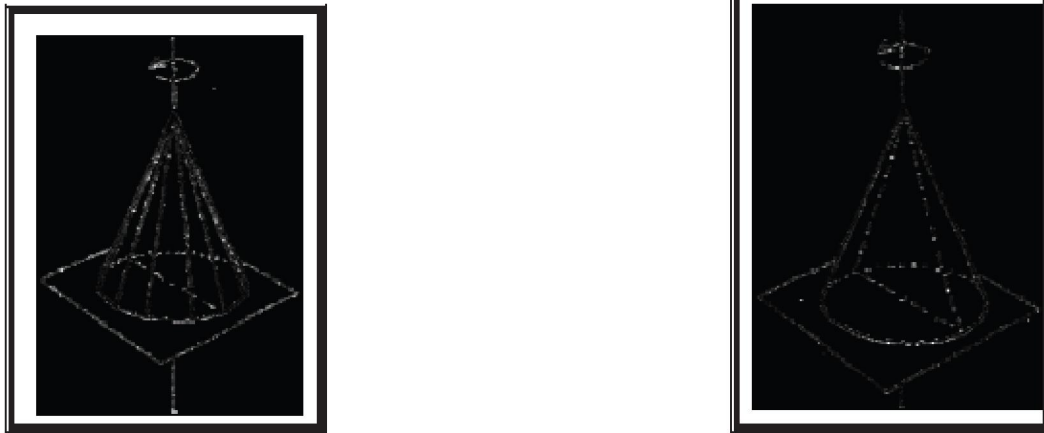


Figure 2- Theoretical geometry of pyramidal Rok dome (right side) and theoretical geometry of Kharastuk (conic) dome (left side)

- c. Orchin¹: sometimes Rok domes are built in a staircase manner. In this case, every several rows of materials are applied as one unit. This kind of dome can be built by using stone and brick. Curving the material row sometimes makes the dome to become moqarnad. In fact, this is among the first types of moqarnads. Maybe that is why it is called "Moqarnad dome". These domes are mainly found in the Southern parts of Iran.
- d. Rok created by rotation of drawn arches: as mentioned earlier, Rok domes are created by rotation of some drawn arches like cedar dome. For example, Shah Cheraq, Ali bin Hamzeh, and Ala'eddin Hossein domes in Shiraz are all cedar domes – witnessed by old paintings existing in the book Old Shiraz. In fact as edema gets more, the dome closes from Nar to Rok.
- e. Combination of Rok and Nar: it is a combination of Nar dome abdomen and Rok dome vertex. That is, Rok dome is placed on the Nar dome. These kinds of domes are mainly found in North and North West of Iran. There are some examples in the Eastern parts of Iran as well. Most of these domes are Chafd Shabdari up to a specific height, and then there is a straight line up to the vertex instead of curve line (Pirnia, 1991). "Reskt Dome" and "Lajim Dome" in Mazandaran, "Chehel Dokhtaran Dome" in Damghan that have remained intact and "Pir Dome" in Takestan whose tip has been reconstructed wrongly are some examples of this kind of dome (Pirnia, 1991). In fact this dome must be regarded a kind of Rok dome due to implementation, form, and proportions.
- f.

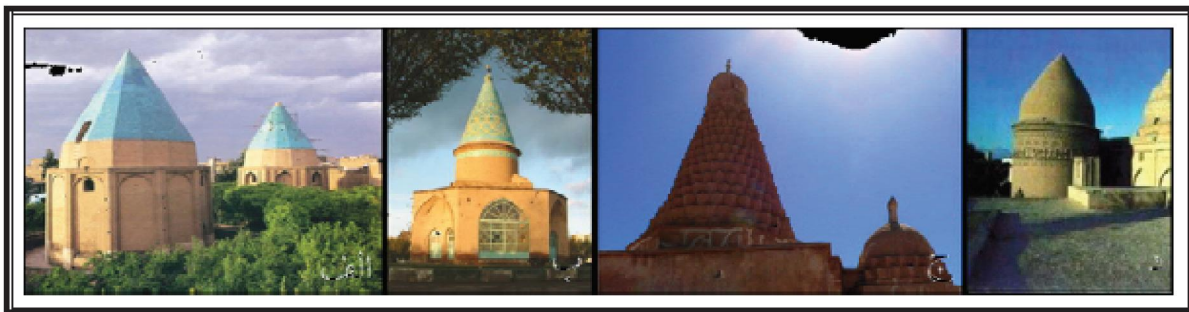


Figure 3- different kinds of Rok domes. a- Rok in "Maqaber Sabz" in Qom, b- Kharastuk, c- Orchin in "Imamzadeh Seyed Mir Mohammad" in Khark, d- combination of Rok and Nari in "Chehel Dokhtaran" in Damghan.

¹ Corbelled Dome

Types of Nar Domes

- a. Bent domes: it is created by the complete rotation of a Chafd around the snake vertical axis on its vertex.
- b. Faceted domes: it is created by the interrupted rotation of a Chafd around the snake vertical axis on its vertex (figure 4). An example of this dome is found in Moshtaqieh (three domes) of Kerman.



Figure 4- theoretical geometry of ordinary bent dome (left) and theoretical geometry of faceted bent dome (right)

Different Iranian Domes in terms of General Structure

Single-shell Domes

The simplest kind of domes is single-shell dome. It is used for ordinary buildings in small scales like villages. Construction of these domes is simpler and less costly compared with double-shell domes (Ameli, 2008). In these domes, since the dome shell is seen from inside of the dome and the outer view of the dome is not so visible, thickness reduction occurs frequently in the dome. Sometimes these fractures are filled by materials so that the outer surface seems flat. Albeit, sometimes double-shell domes whose outer shell has been eliminated is likely to be mistaken by single-shell dome. Many examples can be mentioned for these domes including stone domes of Sasanian era buildings, domes of cisterns, domes of mosques like "Seyed", "Hakim", etc. in Isfahan or "Rig" Mosques and "Sahl bin Ali" Monument in Yazd (Ameli, 2008).

Double-shell Domes

- Interior shell (parietal)
- Exterior shell (self)

The interior shell of dome is towards the interior space and its external surface is usually ridged. It is evident that self unlike parietal has outer view and its internal surface is ridged. As we know, being double-shell (or better say, distance between the inner and outer coverings) provides some advantages for domes including increasing outer view of dome, protecting the interior shell against climatic factors, moderating proportions of dome inner space, improving structural function particularly in double-shell domes, creating an empty space that acts as an insulator, ventilation between two shells in the hot seasons, and so on. It is obvious that these items have been mentioned generally and accurate case studies clear that what functions have been considered by the architect in designing a specific dome. The methods of placing self on the parietal are divided into three groups, so double-shell domes are classified into three types (Ameli, 2008).

- a. Continuous Double-shell Domes: in these domes, self is immediately placed on parietal and just the dome vertex in self gets sharp to have sufficient slope for driving rain and snow. The best example is dome of

"Sheikh Lotfollah" Mosque in Isfahan. Its feature in terms of implementation is that unlike other domes, the parietal is placed on Arbaneh¹. Around the Arbaneh, latticed windows are seen.

- b. Hollow double shell domes: parietal and self are quite continuous up to Shekargah area, i.e. 22.5 degree angle relative to the horizontal surface and then two shells gradually fall apart and work separately.

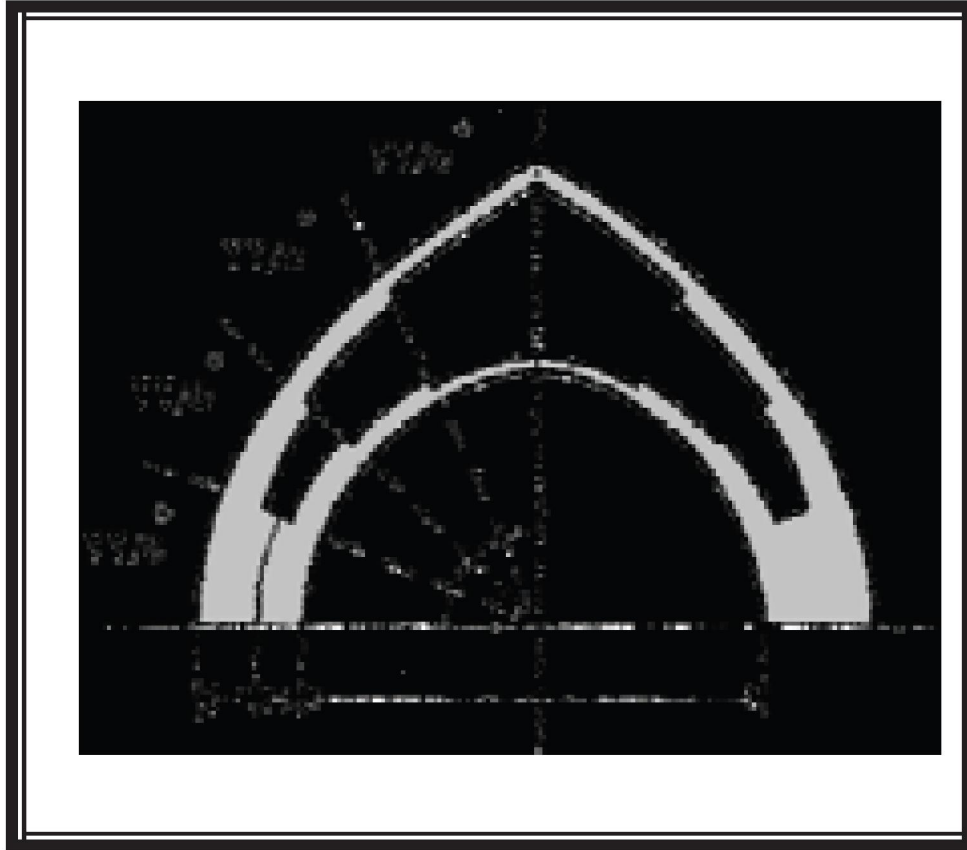


Figure 5- Junction of self and parietal up to Shekargah is essentially seen in all domes.

Dome of "Jame Ardestan" Mosque is one of the eldest domes of eighth century which has been built by this method. A good example is "Seyed Rokneddin" dome in Yazd in which there is no junction between two shells from Shekargah area to dome vertex. However in Kerman, the space between two shells is mainly crated up². These crates are created between self and parietal. In this case, the dome is like continuous double-shell dome in terms of structure. In fact, the empty space between crates reduces the redundant load of dome (Safaei pour, 2007).

¹ It is a short disc that is built on the dome parietal so that the self is placed on that. For further information, please refer to sections 3-5 (dome parts and organs).

² In so doing, four bricks are placed vertically and one brick is placed on them.

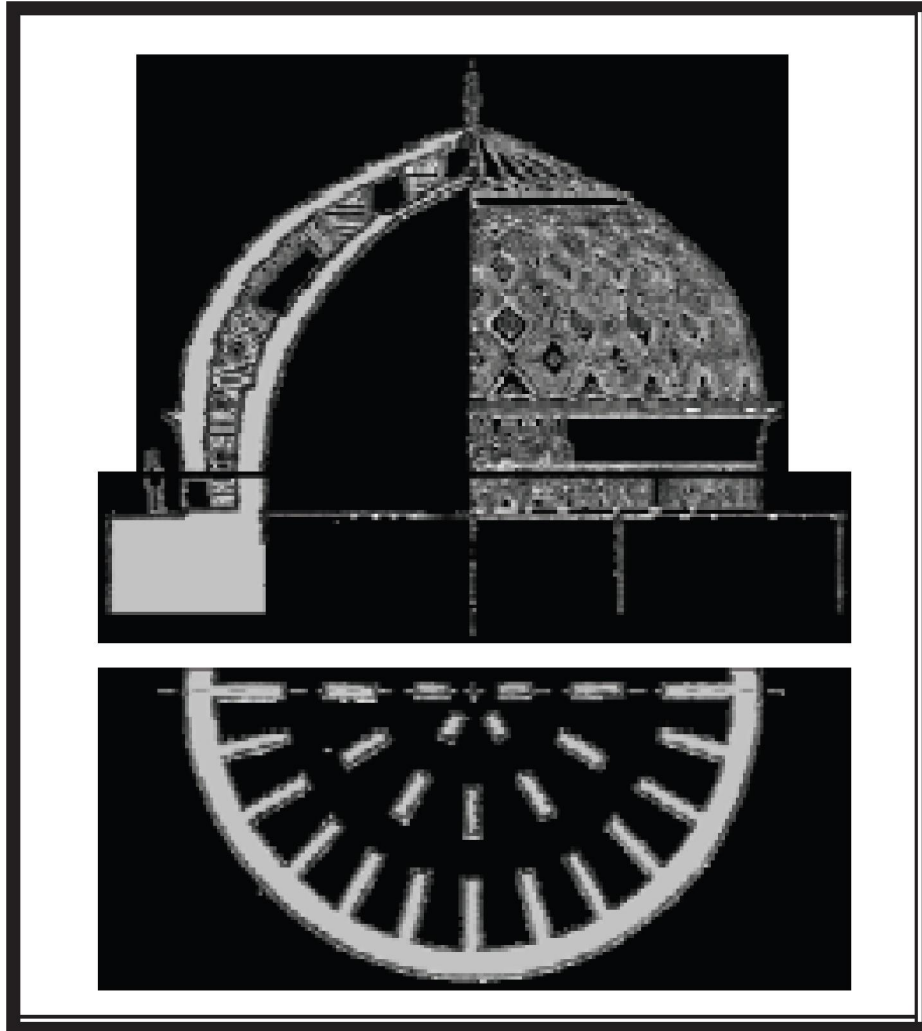


Figure 6- a view of dome of Jame Mosque in Yazd, a schematic plan of geometry of partitions between two shells

- c. Completely disjointed double-shell domes: in such combination, self and parietal are completely separate from each other. Dome of Shrine of Imam Reza (PBUH) and dome of Imam Mosque of Isfahan are among good examples. In this case, self and parietal have a relatively large distance with each other. In these domes, to keep self on the parietal, some partitions are built on the parietal. These partitions are known as "Khashkhashi". Khashkhashies are joined to each other and all are stamped in the center so that two shells work with each other in terms of division of loads and forces and the dome becomes integrated (Ameli, 2008).

Triple-shell Domes

Most triple-shell domes are in fact double-shell domes to which a decorative ceiling (Amood) is added from below. This decorative ceiling sometimes bears the self load by itself and sometimes is dependent upon the middle shell (frequently in the form of hanger). For the first type, some tombs of Central Asia whose decorative

coverage is usually "Karbandi"¹ can be mentioned as example like "Eshrat-khaneh" Tomb in Samarghand. For the second type, Mullah Hasan Kashi Tomb in Sultanieh or "Sheikh Abd al-Samad" Monument in Natanz can be mentioned as examples in which the lower coverage is moqarnad and in the form of hanger (Ameli, 2008).

Parts and Organs of a Dome

First, we mention three main areas of a dome structure:

- 1) Bashan: dome foundation or walls.
- 2) Transition region: a part in which changes required for placing dome on the walls occur.
- 3) Dome: the main part of a domical building.

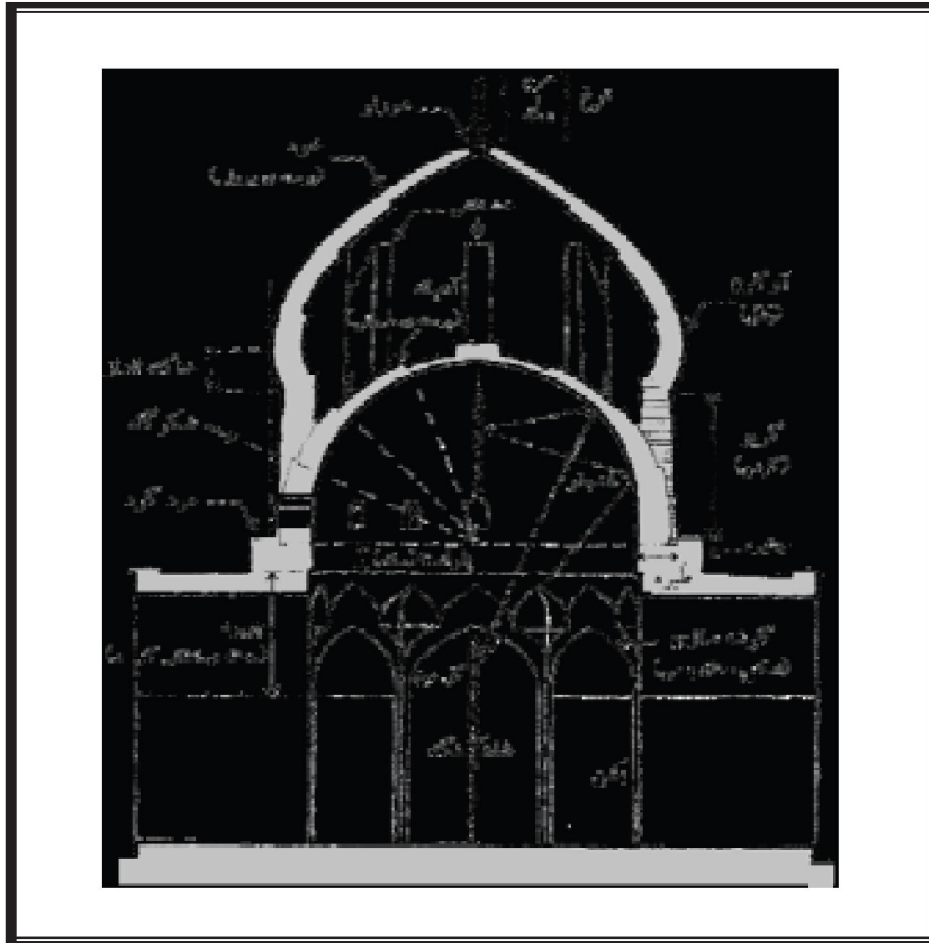


Figure 7- important parts of a domical building

It is clear that a domical building is meaningless without a dome, however two other parts can be eliminated, if necessary. For example, the dome of cisterns does not have transition region, or in the dome of fridges even walls have been removed and the dome is placed immediately on the earth. Domes of mosques have usually all three parts.

¹ A kind of coverage comprised of beams of arches with specific bent that intersect each other according to special geometric rules.

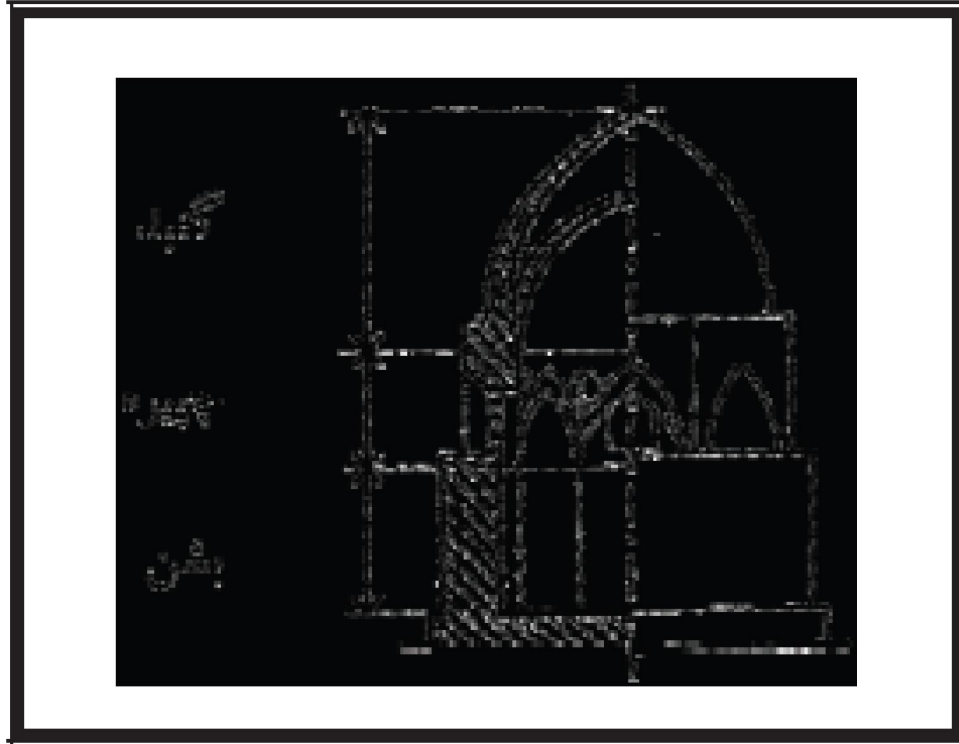


Figure 8- main parts of a domical building

Bashan¹

It is a part of building that is raised in the form of square and dome is placed on it (Pirnia, 1991). The form of Bashan is among important factors in domes design. For example when the plan of Bashan is circle, the transition region is removed and dome is placed on it easily without needing corner-building. The difference between Iranian and Roman domes is essentially in the form of their Bashan. Iranian domes have wide spans and are usually placed on square Bashan. While Roman domes are frequently placed on circle Bashan. Here, we only introduce different forms of Bashan.

- Circle Bashan: like Dome of the Pantheon in Rome, dome of most Iranian cisterns and fridges, etc.
- Eight Bashan: like Sultanieh Dome, Jabalieh Dome in Kerman, Chahar Sugh Shahi of Yazd, Kashmar Tower, Taj Mahal in India, Church of Santa Maria Novella in Florence, San Vitale in Ravenna, Italy, etc.
- Square Bashan: domes of most mosques or buildings in Sasanian era like Sarvestan and Firouzabad Palaces in Fars.
- Rectangular Bashan: domes have been rarely built on the rectangular surface. In this case, rectangular
- Bashan is converted into an oval plan. The dome that is placed on an oval plan is called "Kombizeh".

Among examples of this dome with oval plan, "Haj Rajab Ali Mosque" in Tehran, "Imamzadeh Abollah and Abidollah" (Rasouli, 2005) in Damavand, and "Imamzadeh Zeid bin Ali" in Varamin can be mentioned (Pirnia, 1991).

¹ "Bashan" in common language of some parts of the country (e.g. in Kerman) is applied in the meaning of "skirt". So "Bashan" can be interpreted as the skirt of dome. So in fact, the distance between Chapireh to dome floor which mainly includes dome walls is called "Bashan".

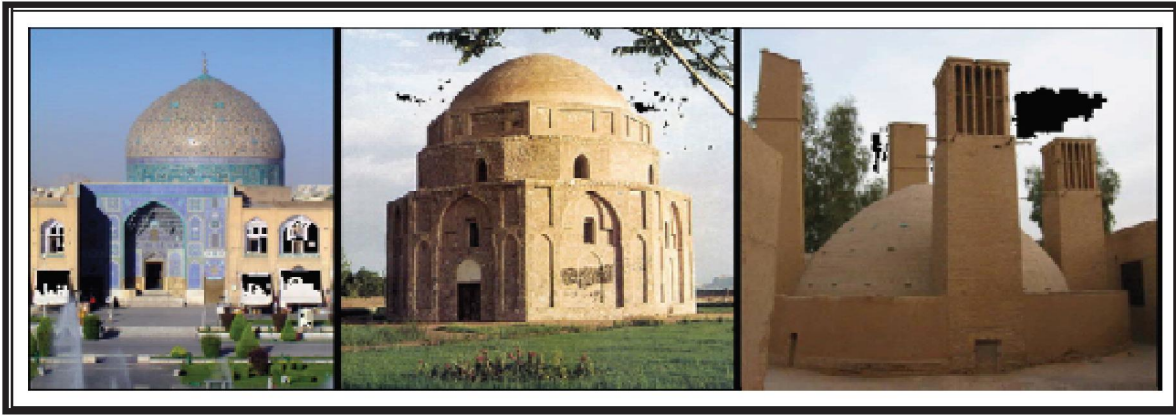


Figure 9- common types of Bashan in domes: circle, eight, and square

Chapireh

Building dome corners to convert square plan to circle has different types. "Chapireh" is a word that refers to all types of "corner-building". In fact, Chapireh is the "transition region" in domes. That is, Chapireh equals to such concepts as "corner-building", "three corners", and so on. However in domes terminology, any of these concepts refers to a specific type of Chapireh. Its equivalent in English language is squinch. Yet its different types of Chapireh do not have clear equivalents in this language. In fact, this indicates the special position of "corner-building" in the Iranian architecture and its absence in the West. In practice, the word squinch in the West refers frequently to "Filpoush corner-building". Chapireh in the Iranian domes is divided into two main parts: corner-building and contortion. These two have some similarities and differences. In "corner-building", Bashan square plan is necessarily converted into an octagon, while in "contortion" this is not necessary and Bashan square is frequently converted into polygons bigger than octagon (Rasouli, 2005).

- a. Corner-building: it refers to converting four corners of "Bashan" into eight corners and then respectively into 16, 32, 64 corners and finally into circle or converting rectangle into an oval form (in Kombizeh domes). Corner-building includes five parts: corner-building by wood, three corners, Filpoush Trombeh, Patkin Trombeh, Patkaneh Trombeh. Three late ones are different kinds of "Trombeh". In French language the word tromp refers to corner-building which is different from our Trombeh.

- b. Contortion: it refers to the folds created in the corner of dome. These folds are created to convert the square surface into a circle or rectangular surface into an oval form. Contortion is implemented via Karbandi and arching.

Karbandi and arching are similar in terms of historical background like three-corners and Trombeh, and both have become prevalent in one period. In the following, form and types of important arches in domes must be stated. The arches issue in the Iranian domes architecture is a detailed issue and its type is specified with regard to the dome crater and the required edema and the internal and social function of building.

Conclusions and discussion

The nature of Iranian traditional architecture is such that it does not reveal its secrets easily. Yet it seems that research and study in this field and listening to the secret whispers of this silent art contribute to its eternity and to keep this flame alive even under ashes (Memarian, 2005). Dome as one of the main organs and an important element in the Iranian architecture has different dimensions that might not be stated properly in a short paper. On the other hand, if inquiries lead to find out the motivation of endeavors and origin of innovations in the predecessors works, they will provide a wide perspective which associates this path with a precious baggage. This paper indicated briefly that Iran has not only been the origin of dome emergence, but Iranian domes have also remarkable distinctions with domes built in other countries. Determination of various forms of domes was shortly

elaborated and wisdom of their builders was underscored by virtue of structural proportions and systems in historical domes. Extension of inherent features of dome to the contemporary concrete shell constructs are still the outlet of innovations of Iranian predecessors. Unlike what was mentioned, with regard to the developments occurred in the contemporary world and necessity of familiarity with new innovations, lack of creative presence of Iranian engineers in this arena was stated and necessity of continuing predecessor path by the contemporary Iranian engineers and their creative effect on this path were underscored.

Suggestions for Future Research

- Familiarity with the left valuable heritage and fining out its concealed and revealed dimensions set the stage of presence in an infinite range in the path of civil engineering promotion and make a deeper attention to its various dimensions inevitable.
- Attention to the mosques architecture as a key to understand Iranian Islamic architecture and the mere attention to one of the elements of this architecture reveal various effects of this issue. Studying and understanding basic principles mentioned in this paper bring about many capabilities for creating new works at any time and in any location. Lack of familiarity with them will lead to nothing but persecution.
- It seems that other parts of the promised heaven can be embodied in the works of Iranian committed artists which may bring about efflorescence of a longstanding civilization with a modern magnificence.

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