



EXAMINATION OF THE EMPLOYING ART OF IRANIAN ARC AND DOME

Saaed Taheri^{1*}, Farhad Moradi²

¹Department of Architecture, Sanandaj Branch, Islamic Azad University, Sanandaj, Iran

²MA of Islamic Art, Tabriz Islamic Art University, Tabriz, Iran

Abstract:

The classification the types of arcs and domes in the Iranian buildings are very diverse in terms of its geometry and efficiency. According to the primary definition, arc and domes are a kind of ancient static system which has contributed considerable by helping Iranian architects in order to widen and coverage openings. Regardless of the geometric shape, factors such as the type of materials, mortar, construction technique and the position of placement are effective in the process of arch implementation. The persistence of these structures indicates high skill and experience of architects and the witness of this claim are remaining arc and dome in ancient Iranian buildings that so far has not broken under natural and human conditions. In this study, we examine the arcs by identifying and finding out how their implementing is practiced in most historical buildings, due to the resistance and static of these buildings. In order to analyze and study, the present study method used executive methods to identify and introducing examples of executive techniques in historical buildings of Iran and experimental methods of architects, as well as books, and articles related to the topic. It can be said that the gathering and procedures for implementation and compilation techniques, the executive practices of these buildings are the inspiration of Iranian expert architects for more generations and will be a good pattern for learning for those interested in this field. Also, the executive procedures could be solution for the problems of restored historic buildings.

Keywords: arch, dome, climate, Iranian architecture, brick arrangement

1. Introduction

The primitive humans, who firstly had not any shelter after a time settled in caves and, with spreading their population and need for better comfort, begun to build shelter and

created housings with limited dimensions by embedding big stones and arranging them on each other, forming a shelter that protected them against wild animals and even the nature. Definitely, building bigger places have been a need of life. The primitive humans have created initial arcs by linking stones to each other and inventing the first arcs as well as exploring limestone.

Architecture as creating space is an issue that has been raised at the beginning of human settlement and human has faced with various obstacles on its evolution and development. Architecture deals with the aim of developing space and more perspective for users. How to cover these openings has been always the problem of architects. This kind of problem is solved in architecture different ways. Designing arc and dome in the small and extended openings is one of the architectural approaches to solving these problems. The oldest arch and dome in Iran comes back about the second millennium before Christ that has used in Zambil Ziggurat. It can be said that: "...arcs are curved lines that their openings are bigger than their waves" (Zamrashi, arc and dome I Iranian architecture)

Iran's architecture is a source of balances, compliances and the arc and dome are one of the basic elements of this architecture. Given that, the lack of knowledge about materials with tensile strength, such as steel is the only method to opening way between two arched structures that transfers the power forced on the arch to the bearing with pressure mechanism. Architecture more than any other discipline, is affected by the climate and art. By examining Iranian buildings can understand that these artists have respected climate and environment more than any in other lands. The first instruction to Iranian architectures is to follow the nature. The arc elements are one of the parts of Iranian buildings that are aligned with the climate. It shines more in the dry and hot climate.

2. Definitions

According to Giasaddin Jamshid Kashani arc is: a curved structure, its mouth is wider than its depth and dome shapes from visualizing an arc in the space. In general, we can say that the arch is a concept to cover the space between the two walls and a shape of dome that in terms of form follows it called arc.

2.1 The terms of the vault and arches in Islamic-Iranian architecture

- Vault: move of an arc along a line, the resulted line is vault.
- Dome: move of an arc around a point in this environment, forms a dome
- Afraz: the height of an arc or dome from the wall to the highest point
- Parasti: the lower part of arc that vertically arises along the wall
- Pakar: the connection point of vault or dome to the bearing wall that is built with Toizeh method

- Toizeh: a strip arc of bearing in vaults that are constructed with Toizeh method
- Tabreh: Thickness of the arch or dome, which started from the lowest point with greatest thickness and becomes thinner with climbing of arc
- Tizeh: the highest point of the arc in the vault or domes that are built with zigzag and Tizedar style
- Khiz: the ratio of Afraz size to the mouth of a dome
- Mouth: the interval between walls that are covered with vault or dome
- Gaz: Pieces of bricks or tiles that fill the empty space between triangular among the bricks or arranged bricks
- Horno: a hole that is built at the top of the arch or dome for lighting and air movement.(Pirnia, Vaults and arcs)
- Ivargah: 67.5 degree
- Tizeh: 90 degree
- Shekargah: 22.5 degree
- Among the comb: 45 degree

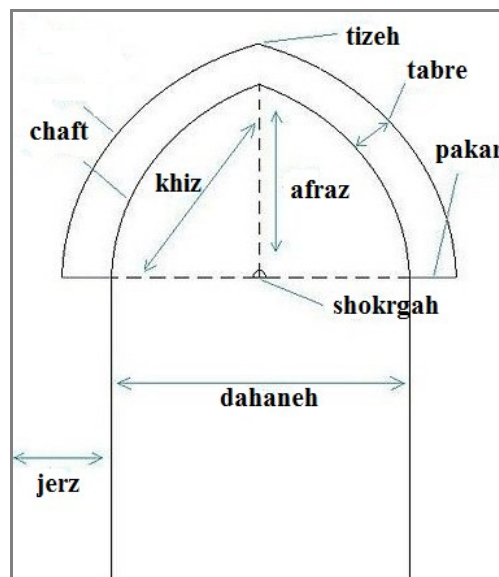


Figure1: Elements of vault (source: Archive of author)

3. The coverage of openings is divided into two types: 1: flat .2segh (2-1 mazedar, 2-2 tizedar)

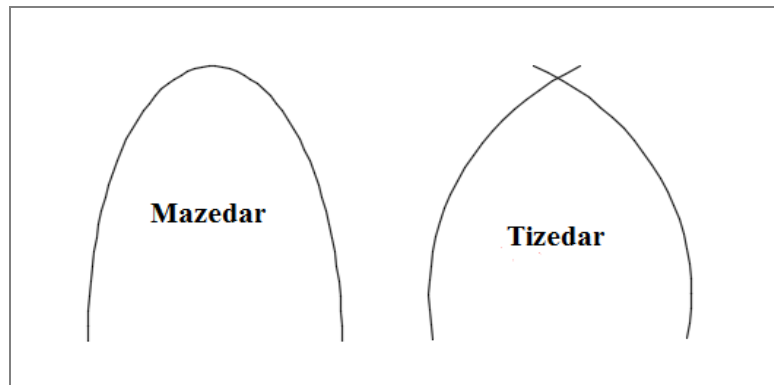


Figure 2: The curved vaults (source: author)

Two types of Segh can be seen in Zanbil Ziggurat.

3.1 Identification of arches

According to segmentations made by Mohammad Karim Pirnia the vaults are divided into four categories:

A. 3-1-track arches: track arches is like a half-cylindrical arch that runs with building materials and placed on two bearing wall and end wall of the arc like Taghe Kasra in Biston ,the used arches in ziggurat Zanbil



Figure 3: the tomb of Ielami in
Sush museum
(the second millennium B.C)



Figure 4: Taghe Kasra or Ivan Madaen
in Tisfon (Iraq)

B. Four part Arch: If the two tracks arches vertically cut off each other, the four arches will create from their intersection and has various types such as tent four part vault.

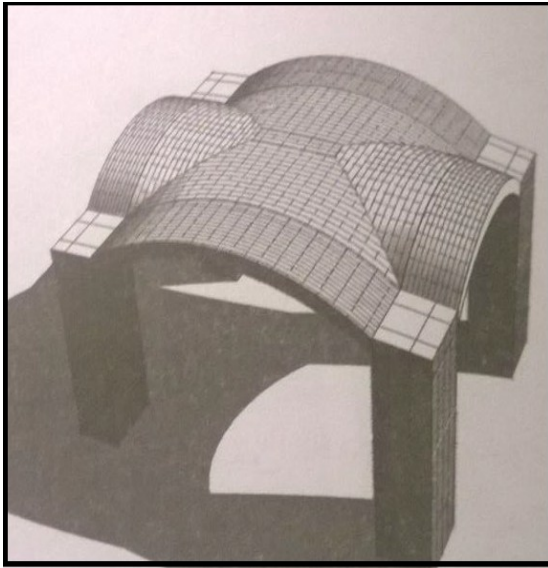


Figure 5: Four part vault
(Memarian)

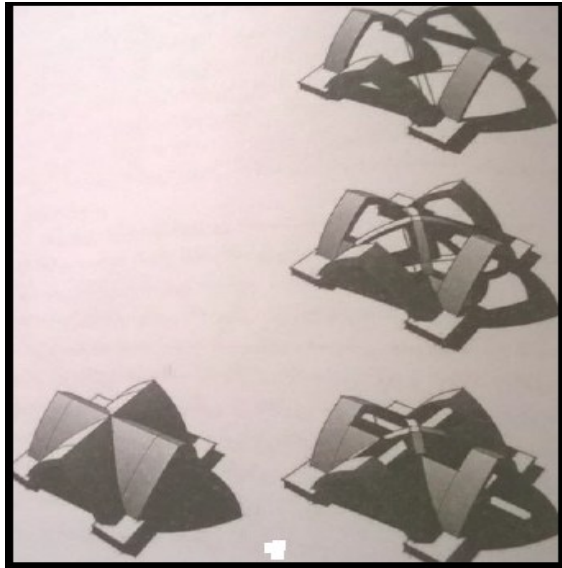


Figure 6: Tent four part vault
(Memarian)

C. Vetoizeh vault: it is like a brick cylindrical that there are arc shapes inside the vault that are called Toizeh and transfers the bearing of the ceiling to the wall. The beam functions in the vault arch like Toizeh.



Figure 7: Vault and Toizeh at the north part of
the Masjedannabi



Figure 8: Sabat Toizeh of Attar
(Dezfol Pirnazar environment)

D. Klombeh vault: to run Klombeh vault firstly four Toizeh installed on the base of the vault then the free space between Toizeh filled with the brick.



Figure 9: Run the Klonbeh vault in Imam Ali masque in Yazd city



Figure 10: The mosque of Khosroabad village of Garos (Bijar)

4. Connecting the arch to the lower elements

4.1 The deepen method (iron): in the section of arc starting, linking it to the pillar, the first row of brick will be running a bit behind. The built dimple is a good place to establish of template and thus there is no need to a base to keep the template. This method is come back to pre-Islamic times (figure 11).

4.2. Hmbad method: In this method, the arch and the lower bearing elements are Hmbad together. By placing wooden pillars under the form of an arch and Jerry they become Hmbad together. This method is most common running approach; in some cases with wooden drums with the protrusions around the pier, the place of locating template will be provided and then it can be used as a decorative section like Masjed Jme Hamedan, figure 12.

4.3 The protruded method: Before the finishing of the pier row run as Lariz following a row last arc which this provide the place of locating .in this method the mouth is smaller, figure 13.

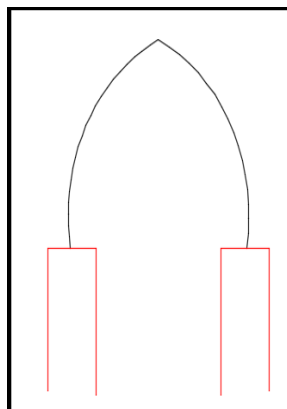


Figure 11: (Author resource)

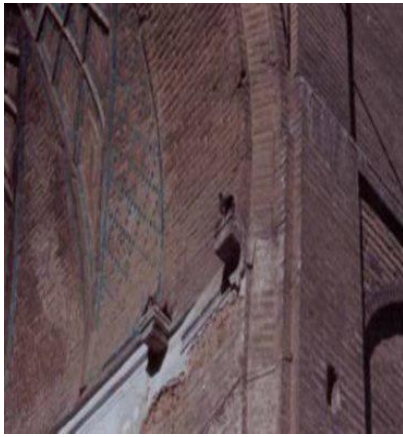


Figure 12: The south of
Ivan of Hamedan mosque

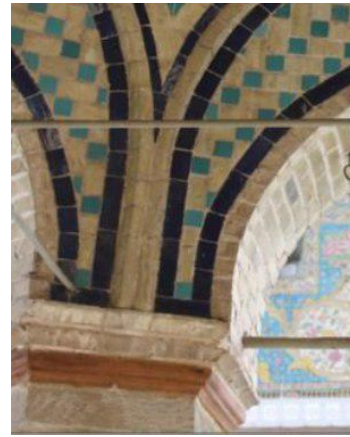


Figure 13: Hashti of
Qazvin Emamzade

5. Executive materials

A variety of building materials that usually are practical in Iran is used for the vault. They are wall glue, brick, clay, road metal stone, cleaner stone etc. (Zamarshadi, Iranian architecture). Different properties of these materials are causing advantages or limitations on the run: for example, the homogeneity of the mortar to brick and helper stone. Since this integration is created, enjoying the coordination mortar and materials.

The material properties are important in connection with mortar stiffness. Iranian arch implement a special place because of certain circumstances. Brick and clay have the most of adhesion volume to the plaster and stone has the lowest rate of adherence to these mortars. Also, the way of forming these materials is considered. By using materials such as wall glue, which itself is formless in the arc forms (arch or dome) to complete drying is required to use templates. Wall glue is the only a part of the set of materials that is formless and integrated and it can be formed as desired during implementation (Tehrani, beyond the geometry of arc and dome, journal page 6 to 8).

6. Executive techniques

These techniques provide the possibility of space coverage by means of vault building and lead to vault adherence. These techniques can be divided into two categories: 1) ability to run without form and 2) run by means of template (Baznoal, Vault technology, 55)

6.1 Run without template

6-1-1: image on the Esper: executive is done by a wall or the arc for vaults that have pillars. In this case, the load-bearing wall in one of the two extremes is connected to

each other. This arc or the wall is higher from the height of wall bearing wall at least as the height of dome. The generator is drawn on this arc by the mortar. If this path is not regarded, the essential is to create a bearing surface. Bricks that make up the first vessel of the arc, adhered on the fresh mortar and is drawn the generator arc. Then this first vessel is considered as bearing surface for the second vessel that established with different sections on the first vessel. In this case, progress of arch is horizontal. With the progress of building and in each moment, the formed vault is static in comparison with its final shape but it should be noted that this is only permissible when they used a mortar that is very high steak (Baznaval, arc technology, 60).

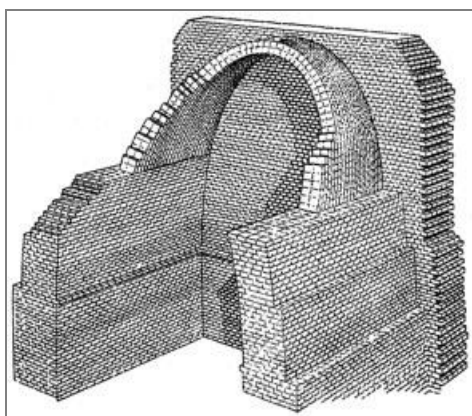


Figure 14: A picture on the Esper (Sasani track arc) (source: Baznaval, arc technology, 60)

6.1.2 Jahazeh vault: The arch, which usually runs in small openings is as a transfer restriction among ceilings and openings in fact it similar to a port brick horseshoe that in one hand transfer the ceiling load to the opening and on the other hand prepare the required bearing conditions for locating vault to the right corner of downstream. Running is that firstly builder try to making exponential arch with covering layout on a wooden port or sometimes directly among each of the sides of four wall. After some initial vessel arranging of this arch continued by reaching to desired balance, running the main vault is started. Lintel brick port is the same lairized vessel which transfers the load of vault to the openings. Sometimes, in cases that covering big mouth is needed, a vault that is run with romance layout. In this case the romance vault acts like lintel brick and the role of covered vessels is template.

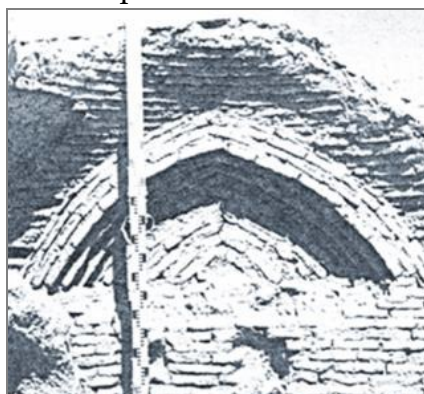


Figure 15: Jahazeh room (Bam Citadel)

6.2 A variety of templates: using template in implementation of arc coverings can facilitate work for administrators as well as using it more resistant and shape that is more regular can be obtained.

6.2.1 Straw and plaster template: in cases that there is no Ahang and fallen vault and there is no Esper wall we required to use template. A template that is associated with both the anchor and a bearing to start instead of Esper. Straw and plaster template has the tolerance of low load in Iran used instead of wooden mold that after install over Jarz and fixing it the bricks are stick to it. Straw and plaster template after implementation remains in the work and can be a bent texture for joinery. Straw and plaster templates are either integrated that are commonly small and sharp or leaves, not sharp and have relatively large openings that with plaster mortar become to vault (figure, 16)

6.2.2. A plume template vault: for larger and sensitive openings instead of installing template that is generally wooden set out to create a row with their arch and the feather vault Ahang is created by fattening it. The room itself is a Roman arch form.

6.2.3 Dbbeh template: is a resistant wooden template that in executive phase prevents until reaching to two double room and mostly used as romance method in order to stone or brick vaults.



Figure 16: Mold and straw



Figure 14: Daeh template

7. Methods of arranging adobe and brick

Arranging of adobe and brick is done with two ways:

7.1 The method of vessel ordering: in this method the execution materials (clay, brick, and stone) in comparison with previous vessel comes forward a little and all vessels are parallel to the opening. The projection of vessels cause that the mouth becomes narrow thus the arch becomes heavy. In this way, each vault door is stationary alone and when the two doors reach together, their balance and stability will be added. in vessel ordering running vault is done behind the vault. The amount of projection in this

method is done with view of architecture that it is effective in the height space. in this method the rows are less Laryzed the run vault is more high and the external pressure is reduced. Due to the implementation method, the number of buildings of vessel ordering is less than Drochin method (figure 18)

7.2 Dorchin method: in this way, the brick angle is variable to the horizon. Bricks are always in line with the radius of the creator arc. How to locating the bricks in the Dorchin is with different styles such as Romance, feather, blade, cut head or a combination of them that each containing different performance, the development potential of forms of bearing resistance. The main Toizeh of bearer usually run with romance method or a combination of them in two modes. in building generally to belter control and reducing asymmetrical pressure on their vault run them as symmetrical. in most cases laying brick is done as feather to the Toizeh. With the help of arched form, the shape can be corrected. If the architect's diagnosis base on the pressure of load over the template, to continue the work must use the candle to keep template and vault. Also, the implementation path can be changed (figure 18).

Implementation with Dorchin method due to type of implementation, existence of thickness difference of mortar on the exterior and interior part .to more homogenies run to the Shekargah implemented as romance and feather. The difference amount of waste mortar is considerable such that according to investigated examination if in the section of Shekargah bricklaying run as feather thick mortar differences 6 cm and if it be as romance method it is 1.5 cm. in the Shekargah to Tizeh if bricklaying is done with romance mode, the difference of mortar weed would be 0.28 cm and if it be full the thickness difference will be 1.4 cm that two figures of 1.5 and 1.14 are closer. This method is used when there is a difference of homogeneity in the mortar emanates. If the amount of this homogeneity is added, the architecture can apply different layouts (Tehrani et al, 2011, 7)

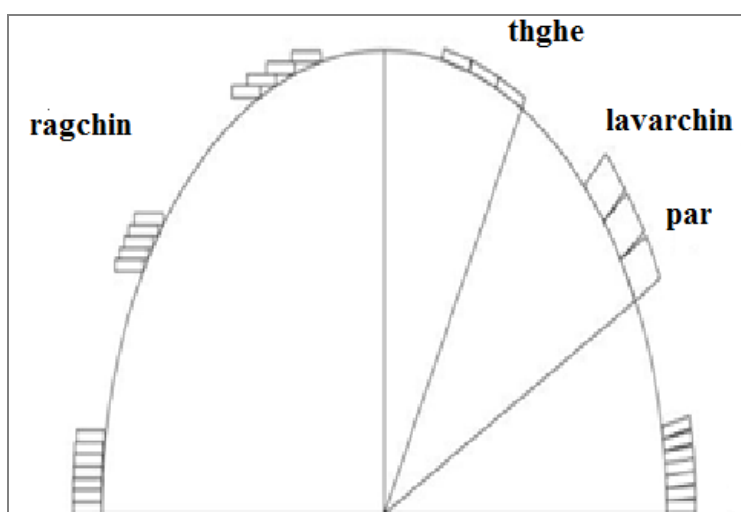
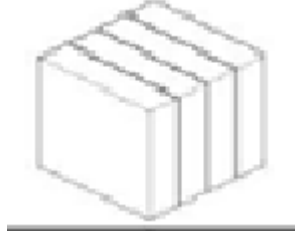
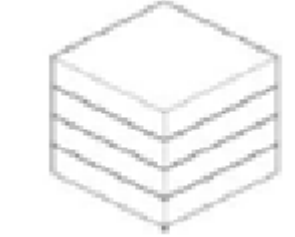
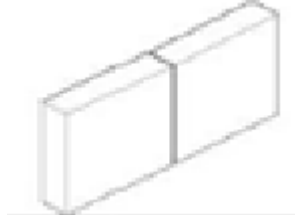
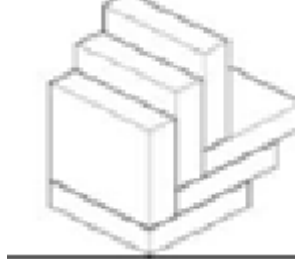


Figure 18: The arrangement of adobe and brick

Table 1: Examining the methods of brick arrangement in the track vault

Type of brick arrangement	Feature	Map	How to develop the arch
Beat bricklayer	<ul style="list-style-type: none"> - Its run is easy -It is less durable than the Roman style - it is arranged more in the middle of arc buildings 		Development in line with the room length
Romance bricklayer	<ul style="list-style-type: none"> Has more resistance due to being stuck in the vertical plane -until Shekargah run without template - after running template is run from two sides and ends in Tizeh 		Develop in line of room width
Chbile bricklayer	<ul style="list-style-type: none"> - the thickness of brick forms the thickness of arc - it used more for balancing of the arc 		Develop in line of room width
Sleeping bricklayer orders	Used for decoration low parts of the room		Development in the diagonal line(45 degree)
Combined bricklayer (romance, beat, blade)	<ul style="list-style-type: none"> It is used for the arch resistant against buoyancy forces - the romance bricklayer to the Shekargah and from then beat bricklayer is used 	A bricklayer on a perpendicular arc, the romance and blade bricklayer in line with the arc has run development such that how to implement bricklayer with how to develop it makes 90 degree angle.	

Source: Fakhar Tehrani article

8. Review mechanism of arches

Since many traditional building materials such as stone and brick despite resistance suits against compressive stress, have little ability to withstand tensile stress.the arc design of the vault could be very useful. In an arch, a large section of the vertical load without bending moment and therefore no member of the arch will not be under tensile

stress. However, what about vaults may be complex, the tensile stress is the stress arising from buoyancy forces. This driving force that is always in the horizontal and outward pressure on both sides of the arch where the arch sits peak on the walls of the anchor that this can be breaking in the big arcs this problem with these methods is well solved.

8.1 Add the curvature of the arc (rising more prone of the arch): This method is an efficient way to reducing and even full removing of driving force. Since with more mast deflection and curvature the arch more arcs, horizontal buoyancy forces are gradually being replaced by vertical compressive forces. Further, sharpen the arch to strengthen its stability against the stresses thrust takes place in a horizontal orientation. However, this method has some limitations and it is adding to the weight of the building due to rising of the vault that it is possible that increasing pressure on the entire overhead structures. However, the remedy for this problem and it is thought to reduce the thickness or pier the arch with each Reggie Tabreh that the stigma (the tip of the arch) goes up. As with the arch to last row, Tabreh may be only the size of the slim narrowest section of a brick. Another limitation is that the longer the arch structural engineering and aesthetic arguments beyond its structure and attractive returns. It discusses in particular the traditional architecture of the building fits under the popular principle which has long been highly regarded architectural Iran. What structures that is too long may be unpleasant and distress viewers and passersby. Perhaps for this reason that the vault with arc has long been used in water reservoirs. That half of the water storage structures are placed in the ground and this is a reduced height of self. (Pirnia, Vaults and arcs, Cultural Heritage).

8.2 Adding the thickness of the Jarz: in this method the walls that have the role of the support are made thicker that this helps, stability of the wall to be against arch thrust pressures. The thickness varies depending on the type of building materials that its sizes have been measured and gathered. For example the minimum of jarz for a 35 cm wall (equal to 5 g) and for a brick wall 80 cm (equal to 12 gr) to create a necessary resistance. In this size as the curvature of arc becomes less and the arc close to smoothly line that followed by increasing driving force it should for occurred tension the thickness of the Jarz be added until the resistance established by this way the vaults will built with less curvature. With fact that arc at the least amount of deflection transfers the most driving force to the walls and this increasing force requires the most thickness force for containment. Just why that the less curvature arcs that are called Kafteh are used always in Eshkobs that are Low Floor coverings Structures since the most Jarz is in the lower floors of the building. In the construction of bridges and dams as mountain or lumbar is the support that has the function of Jarz with the best method can use arcs with the less curvature. However, the curvature usually does not exceed a certain

proportion. When arcs closer to the straight line that brings unpleasant vibrations in structures. These vibrations in the flat coverage's becomes high that is one of the less chance to flat coverage's in Iranian architecture despite using powerful beams to more consistent of the same objection tremor.

9. Regional correlation of arc and vault; since the emergence and development of these architectural elements used more in climates

These forms, comply not only with materials and structural reasons, but in addition to having thermo physical reasons. It is also appropriate to reduce heat transfer. Firstly, because they are spherical convex shape is perfectly suited to emit thermal radiation and makes it easier becoming it cool during night. Secondly, during the day and during the morning and afternoon a half of the dome is in the shadow of the other half and this is plays an important role in reducing roof temperature. Also, domed roof due to the raised is being exposed to the wind and therefore heat leaves less effect on it.

a. Building ceilings higher than usual: Warmer air moves upward and inward fresh air enters the lower openings and this issue is caused air moving ,arch height can be expressed this issue.

b. Building double ceilings: the temperature capacity of air is very low and equals to BTU/F 0.018 and the air between the two shell acts as a thermal insulator and, therefore, less heat is transferred into the inside and in summer, the inner shell will be cooler than the outer layer (figure 19).

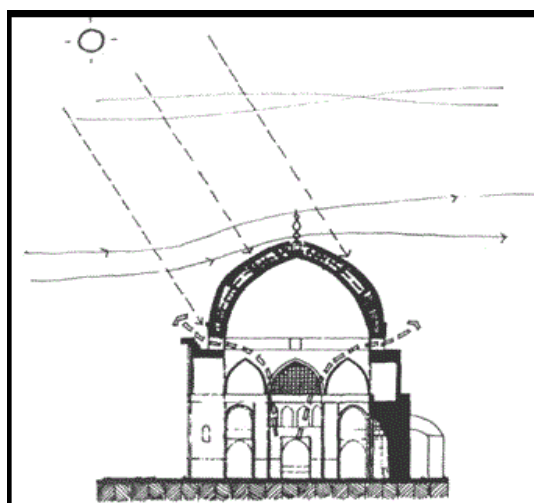


Figure 19: The impact of climate on vault elements
(Yazd Jame masque, double shell dome)

10. Conclusion

In this paper, the process of architectures skills in building arc and vault as well as inventing such buildings and running them from the first to the end examined. Certainly, considering experiences of predecessors and studying them always will lead to the discovery of artistic facts. Examining all types of the vaults and these covering elements according to verity and expanding Iranian vaults is out of the scope of this study but the result of such a study, to learn the skill and accuracy of modern architecture from the skill and accuracy of past architectures. Although these techniques of predecessors, today is outdated in the building however, the result of a new building using today's modern technology, is bound to observe the notes of these artists so that today, fortunately, in most views, bridges, our new buildings still see traditional arch and vaults. No doubt to show an Iranian architecture and separating it from the modern world we need to use these elements. The result of this research could be a guide for the correct application of contemporary buildings or for rebuilding arch of historical buildings.

References

1. Banzoal, Rolan, 2015, Technology of arc and vault in ancient east ,translation of Saed Mohsen Habibi, first publication, Tehran, Cultural Heritage Organization.
2. Pirnia, Mohammad Karim, 2003, Style architecture of Iran, Tehran, Soroush Publications knowledge
3. Pirnia, Mohammad Karim, 1993, "Arcs and vaults", compilation of Zohreh Bozorgmehri, Asar journal, number 24, Tehran, Cultural Heritage Organization
4. Zamrashidi, Hossein, 2004. Implementation of building with traditional materials, Sixth Edition, Tehran, Azadeh Press
5. Zamrashidi, Hossein, 1993, Arch and vault in Iran's architecture, printing, Tehran, Kaihan publication
6. Fakhar Tehran, Farhad, 1993, "Beyond the arch and dome geometry" general magazine; the second, 6 to 8.
7. Kashani, Giasaddin Jamshid (1193 AH); vault treatise, translated by Alireza absorption, Tehran, Soroush Publications
8. Memarian, G. H, 2012, Iranian architecture; Niaresh, Volume I; First Edition, Tehran, Press N. forward thinking
9. Memarian, G. H.; 1995; Niaresh arched structures in Iran, Tehran, University of Science and Technology

10. Fkharthwany, Farhad and Hamkar; 2013; establishing effective enforcement techniques in promoting arch resistance; Journal of architectural ideas; the first year; the first issue
11. Pirnia, Mohammad Karim, 1992; dome architecture of Iran, the magazine works, issue of, published by the Cultural Heritage Organization
12. Perna, M., 2008; Master restoration revival of historical monuments of tissue and release free.

Creative Commons licensing terms

Author(s) will retain the copyright of their published articles agreeing that a Creative Commons Attribution 4.0 International License (CC BY 4.0) terms will be applied to their work. Under the terms of this license, no permission is required from the author(s) or publisher for members of the community to copy, distribute, transmit or adapt the article content, providing a proper, prominent and unambiguous attribution to the authors in a manner that makes clear that the materials are being reused under permission of a Creative Commons License. Views, opinions and conclusions expressed in this research article are views, opinions and conclusions of the author(s). Open Access Publishing Group and European Journal of Social Sciences Studies shall not be responsible or answerable for any loss, damage or liability caused in relation to/arising out of conflicts of interest, copyright violations and inappropriate or inaccurate use of any kind content related or integrated into the research work. All the published works are meeting the Open Access Publishing requirements and can be freely accessed, shared, modified, distributed and used in educational, commercial and non-commercial purposes under a [Creative Commons Attribution 4.0 International License \(CC BY 4.0\)](https://creativecommons.org/licenses/by/4.0/).