Journal of Energy and Power Engineering 13 (2019) 283-291
doi: 10.17265/1934-8975/2019.08.001

Vernacular Iranian Architecture, Symbiotic of Meaning, Structure and Aesthetics towards Energy Efficient Design

Hessam Ghamari

Department of Family and Consumer Sciences, California State University Northirdge (CSUN), Northridge, CA 91330, USA

Abstract: Iranian traditional architecture can be identified in many of its old famous buildings in the country. The principles and specifications in these buildings show the intelligence of implemented techniques that make them remain sustainable and energy efficient. Thus, it is important to explore the traditional structures and architectural technologies in order to understand the reasons for this sustainability toward the new methods in modern architecture. Many of historical buildings in Iran have remained standing after many years and they show the deep wisdom of their architects. The purpose of this article is studying the various aspects of traditional structure and integration between this well-oriented structure and architecture towards energy efficient sustainable buildings. For reaching this goal, we refer to Tekye-Amir-Chakhmagh in Yazd as our case study, which is one of the most important and noticeable examples of Iranian traditional architecture. By introducing Amir-Chakhmagh Complex, we analyzed the specifications and fundamental elements that played an important role in stability and sustainability of Tekye-Amir-Chakhmagh and thereafter, we assessed the technologies that were used intelligently and intricately in this historical building. In this research, information is collected with field study and library resources. Finally, qualities and characteristics of the structure are studied by drawings and structural analysis and as conclusion, the suggestions and guidelines are presented.

Key words: Structure, Iranian architecture, load, technology, Tekye-Amir-Chakhmagh.

1. Introduction

The Iranian architecture has always attracted most attentions to its positive aspects such as logic, principles, stability, technical and scientific issues of the buildings, humanistic criterion, and the use of local materials, frugality and so forth [1]. Nyaresh (structural method) with deep vision analyzes and simplifies the different aspects of the building. As defined, Nyaresh is all of the techniques which have been applied in the construction of the Iranian architecture. It includes all of the elements which contribute to the stability of the buildings [2]. It is related to the knowledge of static science, techniques of structure and materials [3]. Using the past beneficial experiences and finding the convenient geometry, proportion and traditional architect intelligence, which creates the prominence of the building and Iranian traditional architecture, can provide principles and guidelines for the new construction or restoration of vernacular buildings [4]. Eventually, the great treasure of "Nyaresh", full of past experiences and suitable principles, always has been in-hand of architects and continuously developed. For instance, the traditional architects applied thicker walls and created a lighter architecture according to the Nyaresh Principles [5].

In Iranian traditional architecture, there is no single element that can be used only for one purpose. All of the structural elements integrate with ornamental and architecture. Therefore, we have a complex that has form, function, structure and ornament present simultaneously. For example, we can mention the voids in the walls which allow structure to be lighter and also places to keep the utensil and appliances. "Karbandi" (structural element as a lower ceiling) as a suspended ceiling makes the double-covered roof and

Corresponding author: Hessam Ghamari, Ph.D., assistant professor, research field: interior design.

Fig. 1 Panoramic view of Amir-Chakhmagh complex.

provides temperature and sound isolation besides its structural role [1].

Tekye-Amir Chakhmagh (Fig. 1) is one of the symbols of traditional Iranian architecture where the structural aspects specially have been considered [6]. This building is one of the most prominent buildings of Yazd in the centre of Iran (Figs. 2 and 3). It has been located in the intersection of main streets of city and includes mosque, Tekye, Boghe seti Fatima, Haji Ghanbar Bazaar, Seti Fatima and Ab-anbar. Amir-Chakhmagh complex has been constructed in 14th A.D. by Amir Jalal-e-din Chakhmagh one of the knights of the Shahrokh Teymoori. In this paper we analyze and study the Tekye-Amir-Chakhmagh as one of the Iranian traditional architectures [7].

This research has been done by collecting data from the libraries references and by visiting the building. Most of the data have been reached by accurate observation in the building location, plans and diagrams have been drawn by measurement of the Tekye dimensions.

2. Analyses of Technological Structure of Tekye-Amir-Chakhmagh

In the following, the structural characteristics of the building are analyzed according to different parts which have contributed to the stability of the building (Figs. 4 and 5).

Fig. 2 Complex of Amir Chakhmagh Yazd.

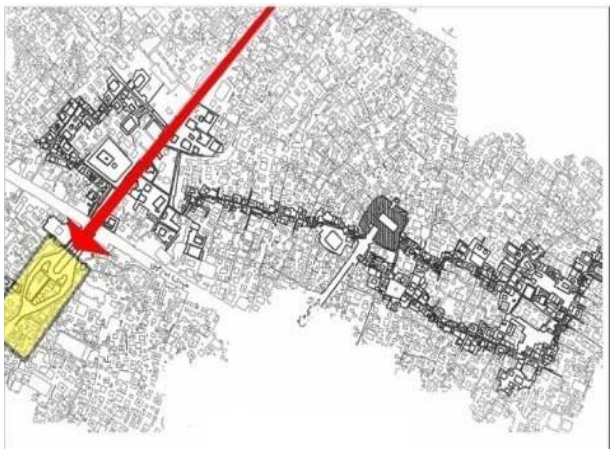

Fig. 3 Location of Amir Chakhmagh in urban texture.

2.1 Foundation

The primary role of the foundations is the transmission of the load from the structure to the ground. The scales

Fig. 4 Plan of Tekye-Amir Chakhmagh.

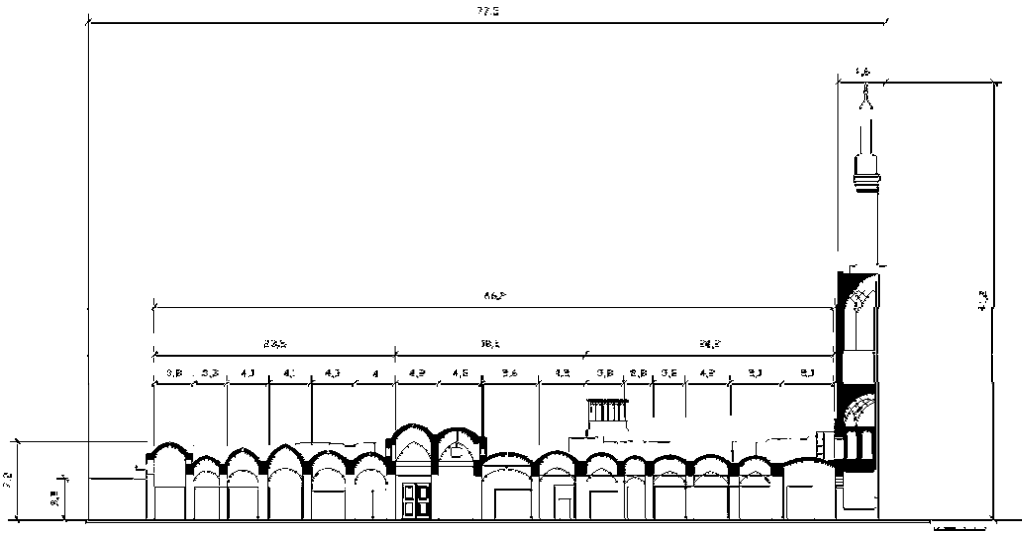

Fig. 5 Section of Tekye-Amir Chakhmagh.

of the foundations will be determined according to the soil that the foundations are constructed on and by the load of the walls. The materials of foundations of Iranian traditional buildings are sarooj (compound materials have been invented by the traditional architects and used as cement exclusively in traditional architecture in Iran), brick, lime or stone. Choice of material depended on the accessibility to the local materials [8].

Traditional architecture prefers to use strip foundations to the single foundations. Strip foundations have a great deal of resistance to the earthquake and they are more economical too. In this type of foundations, the distribution of tensions is monotonous and also the arches between the strips prevent horizontal movements and connect two strips. This tall and narrow building requires using a uniform foundation. One of the innovations of the Iranian architects in building is the changing of the thickness of walls and covers. The thickness of foundation walls depends on its height. The distribution of tensions in foundations is 45 degrees, so the base structure with the step foundation shape reduces the use of materials (Fig. 6).

2.2 Transmission of Load

There was a massive lack of materials that could bear the tensile stress in traditional architecture of Iran. In a large region of Iran the use of natural dirt by shaping it through heat and use of a more advanced method like baking the bricks were very common. Brick considered as a heavy material was one of the basic materials in the Islamic architecture. The pressure-resistant bricks have originated or caused the building of the bearing-walls, arches, and domes. The architects used brick in the arch forms to convert the tensile stresses to pressure stresses so it became possible to cover the spans. Using the arch forms and accurate knowledge of applying materials is helpful for the architects to prevent instability and destructive load [8].

Different arches have various resistances to load bearing. These arches have been used in different parts of traditional buildings (Fig. 7). Architects know the arches profoundly and use them in right parts. For example where the bearing of more loads was needed the bearing arches as Panj-O-Haft (a type of Iranian arch) have been used and where the suspended arches were needed the ornamental and non-bearing arches have responded to the needs. Therefore, the traditional buildings of Iran usually have the combination of different arches that have been used in different parts of the building [5].

The primary material used in Tekye-Amir Chakhmagh is brick. The arches are transmitting the load to the columns and the columns transmit it to the foundations. The arches lean on each other so they cancel out adjacent arches loads and transmit the vertical loads, thus there will not be any movement in intersection points of arches. The first and last arches are different from other ones as they are filled and they act as heavy shear walls to control the lateral movement loads (Figs. 8-10).

It is interesting that the pinnacles of the arches are in line, therefore the architects have been aware of the transmission of the entered loads (Fig. 11).

2.3 Lightweight Structure

Obviously, increasing the mass of building makes it vulnerable to the horizontal loads especially to the earthquake. Therefore, lightweight structures and mass reduction are essential principles in current architecture, but also we can see this principle expertly applied in traditional architecture of Iran. The apparent example of these principles is the hollow walls surrounding “Iwan” (portico) and also using the hollow “Khancheh-poosh” (type of arch) arches. The benefits of the hollow spaces in the walls of buildings are not limited only to make a lightweight structure but also to provide temperature and sound isolation layer, diminish the quantity of used materials; this means reaching the maximum functionality with the minimum materials. In Tekye-Amir Chakhmagh, the walls have the essential roles according to their thin and tall lightweight structure [3].

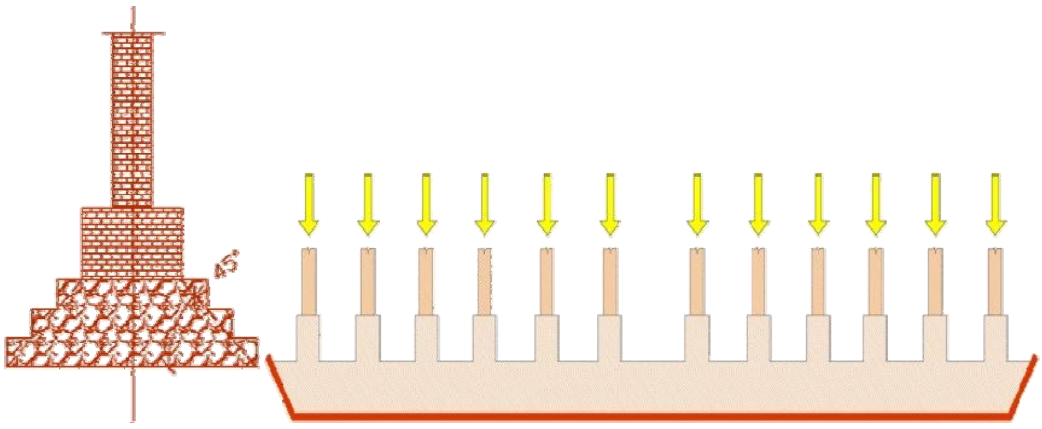

Fig. 6 Strip foundations, bearing walls & transmission of loads on the foundations.

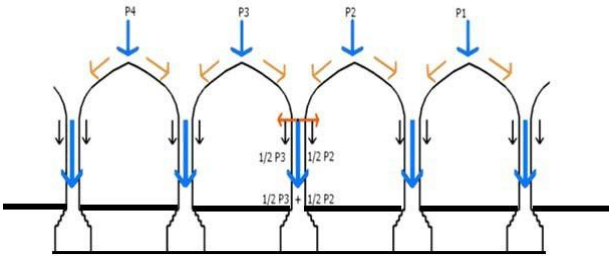

Fig. 7 Equal sharing of loads in every side of arches.

Fig. 8 Transmission of the load from arches and columns to the foundations.

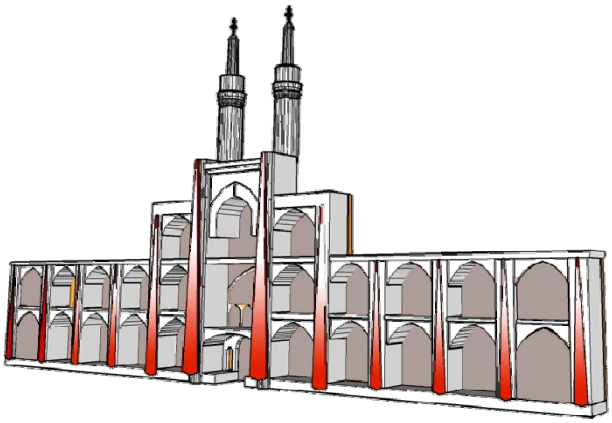

Fig. 9 Transmission of the load from columns to the foundations.

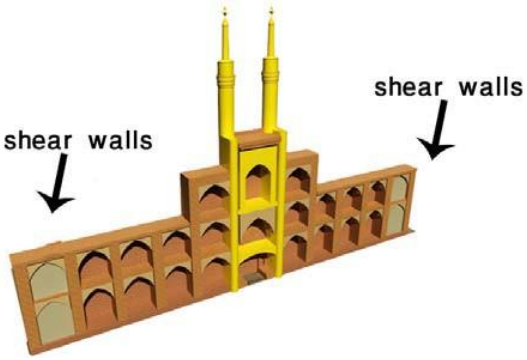

Fig. 10 Role of the first and last arches in controlling of lateral loads.

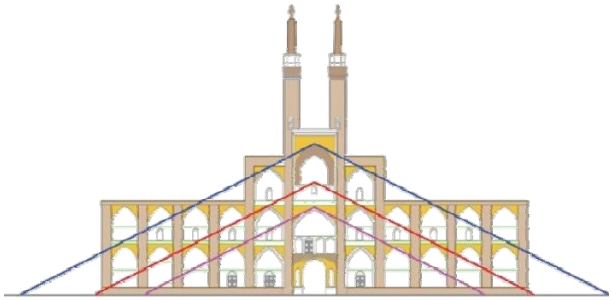

Fig. 11 The axis that shows the extension of pinnacles of the arches in line.

Openings in different parts of the building make the building lighter with reduction of mass and seemingly protect the building against earthquakes. Also it causes the possibility of transmitting of light and air (Fig. 12). These voids and openings can be observed in the three main elements as follows:

(1) Lightweight in minaret;
(2) Lightweight in vaults;
(3) Lightweight in walls.

2.4 Exact Consideration of Geometry and Proportions

Geometry is an organizing and integrating element in Islamic architecture. There is a close relationship between mathematics and geometry. Integration between geometry and mathematics exists in many structures of traditional Islamic Iranian architecture. In Tekye-Amir Chakhmagh the geometry of façade has special proportion which represents the building higher, so height and volume of the building were emphasized [8].

Fig. 12 Voids in walls which allow the lightening of structure.

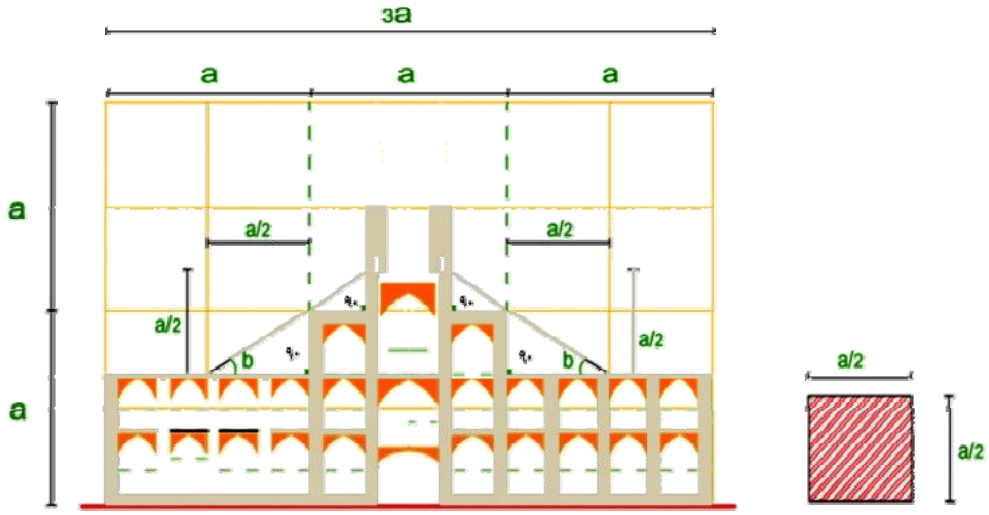

Fig. 13 Facade geometry and proportions of Tekye-Amir Chakhmagh.

The geometry plays an essential role for stability and statics of this building in addition to its aesthetical aspects provided in the fa çade. The triangles in the lower caption function as anchor and will improve the resistance of structure (Fig. 13).

2.5 Deep Considerations of the Symmetry, Balance and Equilibrium

Symmetry, balance and equilibrium are three basic elements that play an essential role in stability and sustainability of the structure in a building of traditional Islamic architecture. These three principles in traditional architecture provide equal distribution of load so the structure has a great resistance to earthquake (Figs. 14 and 15). The plans and facade of Tekye-Amir Chakhmagh are symmetrical, thus, we have equal mass in two sides of building [5].

2.6 Goldasteh, Minaret as Thin Towers

Minaret, tall and thin tower, is an important element in traditional Islamic architecture. The traditional architect inspired this element from the religious belief as it used for announcing Azan and public information.

The most important characteristic of minaret is that it is hollowing inside. The traditional architecture has kept the inside of the minaret hollow to reduce its mass on the top. The circle section of the minaret has less friction facing to the intensity of airflow of the wind. Hollow section of the Minaret makes the minimum ratio of the mass to its volume, thus it will be able to withstand for the vibration movement during earthquakes (Fig. 16).

Additionally, the highest point of the minaret known as "mazaneh" is the lightest. In fact, the final point of

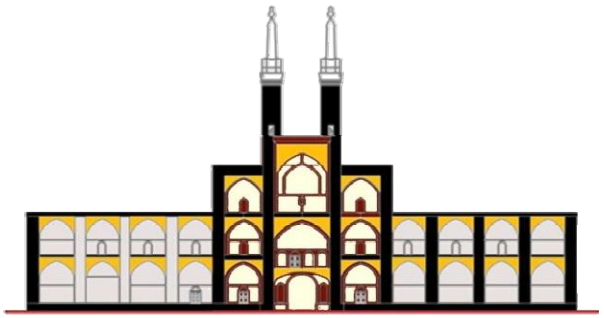

Fig. 14 The symmetry, balance and equilibrium of Tekye-Amir Chakhmagh.

Fig. 15 Symmetry in fa çade of Tekye-Amir Chakhmagh.

Fig. 16 Goldasteh, minaret as thin towers.

the minaret is the lightest while at the bottom the heavier materials are applied in the foundation.

Choosing the cylindrical form for the minaret has also another reason. It is for magnifying the height of the building with consideration of its important functional role and location. The dual cylindrical minaret creates vision distortion and shows the building even taller.

2.7 Reduction of Wind Loads

The thin and tall walls have made the Tekye-Amir Chakhmagh vulnerable to the horizontal loads and have harmful effects on the structure. For this reason, there were suitable solutions applied to reduction in the effect of wind load. There are some openings in the walls of the structure, which allow transmission of the air. The airflow between openings prevents the suction in one side of the building and leads to depletion of wind loads. In addition the circular section for minaret and use of the aerodynamic form decrease the wind loads effect and improve the resistance to the earthquake (Figs. 17 and 18).

2.8 Preventing of Structural Movement

Iranian traditional architects had great knowledge in analyzing the transmission of the loads. In traditional architecture, the building was conceived as a total complex and exact control of the structural elements

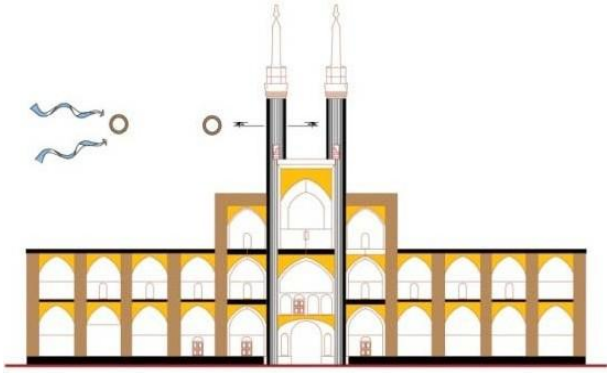

Fig. 17 Aero dynamical shape of Minaret in opposition to wind loads.

that provide static and dynamic stability [8]. In the middle of the building, at the entrance there was a "Daste-Sabadi" arch (a type of Iranian arch) which has a lower height "Maze-dar arch", unlike many of the arches in the Iranian traditional buildings. The tall height arches called "Tize-Dar" bear the vertical load. The purpose of using a Maze-Dar arch in the middle of the Tekye-Amir Chakhmagh is to cancel structural movement and depletion of adjacent load entered on the vaults (Fig. 19).

2.9 Arayeh and Ornaments

We can observe the use of tile and brick simultaneously in Tekye Amir Chakhmagh that is called Moagheli. It is important to note that the use of ornamental elements has also a structural role. Traditional architect has mixed structure and ornaments intelligently connecting each element in addition to the ornaments functional behavior (Figs. 20 and 21).

According to these characteristics, it can be inferred that there are a great number of structural principles which contribute to resisting to the destructive loads. These principles are the essential reasons of stability in the traditional buildings. Therefore, there are many lessons and ideas from traditional architecture in Iran which help architects construct more stable and resistant buildings. In Table 1, in the first column there are the essential structural concepts and in the second column the suggestions for stable design in current architecture are mentioned.

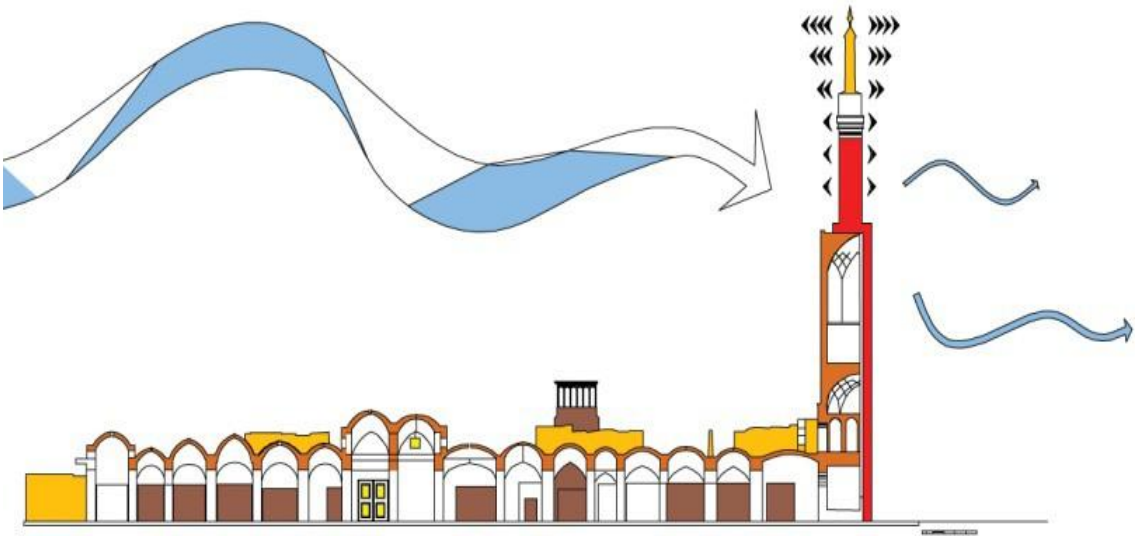

Fig. 18 Voids in narrow tall walls to allow transmission of the air in opposition to wind loads.

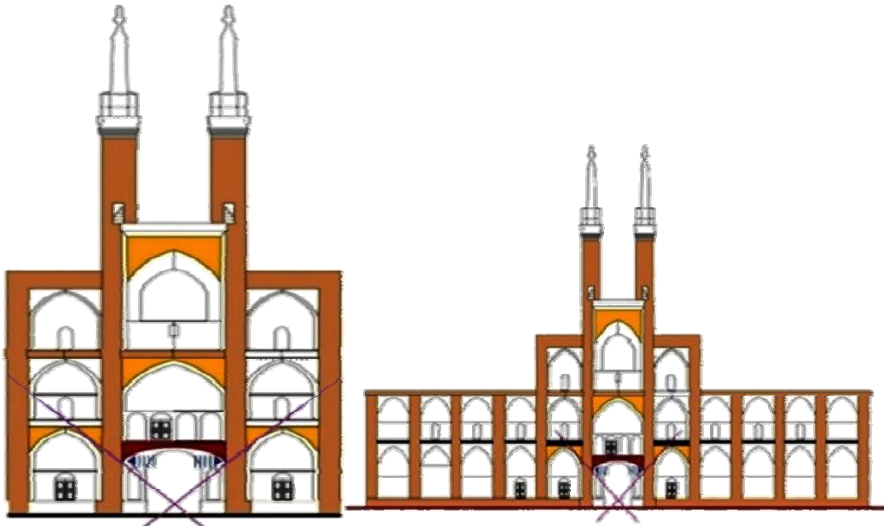

Fig. 19 Low height Daste-Sabadi arch in opposition to the structural movement.

Table 1 Innovative responses of kinetic intelligent buildings to ever-changing requirement.

Traditional structural innovative methods	Suggestions and guidelines for current designing
Transmission of loads.	Using the appropriate structures for transmitting of loads with light and narrow elements.
Decreasing the lateral movement using the suitable arches.	Accurate consideration of lateral and horizontal load and utilization of braces and shear walls in opposition to its destructive effect.
Using the various arches which provide the long span to be covered.	Implementation of proper geometry and basis units can enhance the building to keep its stability.
Exact consideration of geometries and proportions. Lightweight structure in opposition to the destructive earthquake and wind load.	Using lightweight flexible modern materials to decrease destructive effect of earthquake and wind loads.
Reduction of wind loads which provided with voids and aero dynamical forms.	Wind tunnel experiments to find out the optimized form in opposition to the wind load.

Fig. 20 Structural and ornamental multi-purposes arches.

Fig. 21 Ornamental Karbandi.

3. Conclusion

Complete integration between structure and architecture is an important principle that can be found in this building as in many others. Structure, architecture and ornaments are closely related in Tekye-Amir Chakhmagh building. The vaults, arches and walls unite with each other to form the complex and to define the spaces. This integrated and complicated complex through use of architecture and structure has created a building that can be resistant against both inner and outer loads. Therefore, we can consider the specification of technologies that have been used in traditional Iranian structure as Tekye Amir Chakhmagh in four following statements:

(1) There are many sophisticated skills and exact consideration of structure which are applied in this building and other similar buildings that cause they last for a long time after they were created.

(2) These technologies incorporate human needs and requirements.

(3) They have reached the maximum functionality with minimum material.

(4) Deep understanding and consideration of different problems can be seen in the lightness of the structure that has been applied for different reasons. Good reaction to the horizontal loads specially earthquake, temperature and sound isolation uses the correct material and convenient construction.

References

[1] Abolghassemi, L. 2000. *Harmony of the Iranian Garden in the Mirror of History*. Tehran: Ettelaat Newspaper.

[2] Pirnia, M. K. 1993. *Styles of Iranian Architecture*. Tehran: Honar Eslami Publication.

[3] Memarian, G. H. 2008. *Iranian Architecture*. Tehran: Soroosh Danesh Publication.

[4] Hillenbrand, R. 1998. *Islamic Art and Architecture*. Thames & Hudson.

[5] Vafamehr, M. 2008. *Traditional Structure of Iranian Architecture*. Science and Technology University of Iran Publication.

[6] Afshar, I. 1995. *Memories from Yazd*. Tehran: Iranian Cultural Publication.

[7] Katebyazdi, A. B. H. 1981. *The New History of Yazd*. Tehran: Iraj Afshar Publication.

[8] Zomorshidi, H. 1995. *Vaults and Arches in Iranian Architecture*. Tehran: Keyhan Publications.