

A STUDY OF TRADITIONAL HOUSES WITH DOMICAL VAULTS IN HERAT, AFGHANISTAN

アフガニスタン・ヘラート市のドーム状ヴォールト屋根伝統住居の研究

*Khojesta KAWISH**, *Tetsuya ANDO*** and *Sayed Abdul Basir SAMIMI**

コジャスタ カウイッシュ, 安藤 徹哉, サミミ サイード アブドウル バシール

In the desert areas from the eastern Iran to western Afghanistan, traditional houses have curved roofs. As modernization progresses, such traditional houses are gradually disappearing from the region. However, in Herat, an old city in Western Afghanistan, traditional houses with domical vault are still left in their original form within the urban area. This study examines features of traditional houses with domical vaults in Herat through interviews of traditional builders and case studies of three houses including field surveys and interviews conducted with residents. Through this research, it finds that the structures of walls and domical vault vary depending on the time of construction, number of stories and size of rooms inside the houses. The study also finds that the materials used for walls and roofs differ according to the economic conditions of the families. Some conclusions are drawn about the architectural features of traditional houses with domical vaults in Herat.

Keywords: *Afghanistan, Herat, traditional house, roof types, domical vault, masonry*

アフガニスタン, ヘラート, 伝統住居, 屋根形状, ドーム状ヴォールト, 組積造

1. Introduction

Herat¹⁾ (Fig. 1) is an old city in western Afghanistan located on the Silk Road, the historic routes of economic and cultural exchange stretching across Eurasia from the Far East to Asia Minor (Misra 2009). Afghanistan was once a part of ancient Persian territory. As a result, Great Khorasan and Persian culture had a strong influence on Afghanistan, particularly on architecture. Traditional houses in both eastern Iran and western Afghanistan are constructed with sun-dried brick masonry (mud blocks) to fit its dry climate,ⁱⁱ⁾ available materials and the regional culture. They use masonry curved roof construction (mainly domical vaults) for the roofs.

The history of curved roof construction has been the subject of studies. The use of arch, vault and cupola dome building systems in construction can be traced back to the most ancient times. As early as the third millennium BC, primitive forms of curved roof construction were used in countries in the Middle East and Egypt. Arches, vaults and cupolas were also widely used by Roman, Sassanid and Byzantine builders before being adopted in many regions of Europe (Joffroy et al. 1994). In Jerash, the connection between a square plan and a spherical cap (cupola) is created through pendentives in the shape of spherical triangles; Choisy (1899, vol.1, p. 519) called it a spherical vault. The construction method of building a shallow dome on a square plan supported by four arches and spherical-triangle corners, or pendentives in the Roman architecture of Levant, was already mentioned by Choisy (1899, vol.1, pp.518-519) at the end of the nineteenth century.

In comparison with monumental architecture, ordinary houses have not been taken on as a research subject in Afghanistan.



Fig. 1 Location of Herat

* Doctoral Candidate, Graduate School of Engineering and Science, University of the Ryukyus, M. Sci.

** Prof., Dept. of Civil Engineering and Architecture, University of the Ryukyus, Dr. Eng.

琉球大学大学院理工学研究科 博士後期課程・修士(科学)

琉球大学工学部環境建設工学科 教授・博士(工学)

“Technologie de la Voute” (Besenval 1984) shows some photographs of traditional houses with domical vaults in Iran, Afghanistan and Turkmenistan. “Afghanistan an Atlas of Indigenous Domestic Architecture” (Szabo et al. 1991) is almost the only comprehensive study on houses in Afghanistan. It classifies traditional houses in Afghanistan and indicates their distribution. It also takes up methods of curved roof constructions in rural areas, but does not cover the Herat city area.

Thus, this study examines architectural features of traditional houses with domical vaults in Herat. The scope of the study is to describe the construction method of traditional houses in Herat and examine case studies including some physical and social dimensions of houses in order to determine their tangibility. Firstly, interviews were conducted with traditional house builders in Herat in July 2016 and April 2017. Secondly, three case studies were conducted in Herat in July 2016.ⁱⁱⁱ⁾ Residents of these houses were interviewed as well. While monumental architecture has been surveyed and recorded (Boostani et al. 2007), this is the first study that shows details of ordinary houses in Herat based on field surveys. Construction methods of traditional houses in Herat city and ceiling patterns of domical vaults are explained in Chapter 2. Physical and social characteristics of the three case studies are described in Chapter 3. Chapter 3 also discusses the comparison of the structures of the three case studies. Finally, the conclusion is drawn in Chapter 4.

2. Construction method of traditional house in Herat city and ceiling patterns of domical vaults

The information regarding the construction procedure of a domical vault in Herat city was gathered through interviews in July 2016 and April 2017 with Abdul Salam Abdul Hamid, aged 65, a traditional builder who has 25 years of experience in the construction of domical vault buildings. Another interview was conducted with Abdul Ghafoor Sultan Ahmad in April 2017, age 60, who has 20 years of experience in the construction of traditional houses with domical vaults. They learned the construction methods of traditional houses with domical vaults from their fathers more than 50 years and 45 years ago respectively, but have not built a new domical vault house in Herat city area for the last thirty years. Today, they build modern houses.

According to Abdul Salam and Abdul Ghafoor, there are six common ceiling patterns of domical vaults in Herat City. Four of them are made with sun-dried bricks (Fig 2, 3, 5, 6) and two are made with fired bricks (Fig 7, 8).

2-1. Construction method of traditional houses in Herat city

Firstly, the construction method is explained using *Chahar Sawrak* (four corner), which is the most commonly used ceiling pattern in Herat according to traditional builders (Fig.2). In order to construct a *Chahar Sawrak* domical vault, four *Pols* (wooden beams) which are lathed in length are firstly placed on top of each wall of the room. Then, the *Pols* are pierced in joints at the corners. Traditionally this process is called *Kalava* (twist). The *Pols* and the gaps on either side of the walls are covered by *Gel* (mud) to level out the height of the *Pols*. The first step of construction (① in Fig. 2), starts from the corners. Inclined arches of sun-dried bricks (300mm×300mm×50mm) are created by laying one sun-dried brick upon one corner of the thick bearing walls. The empty space in the joint section of the first piece of sun-dried brick and wall is filled with stone, traditionally called *Aghaz* (beginning). The number of sun-dried bricks is increased one

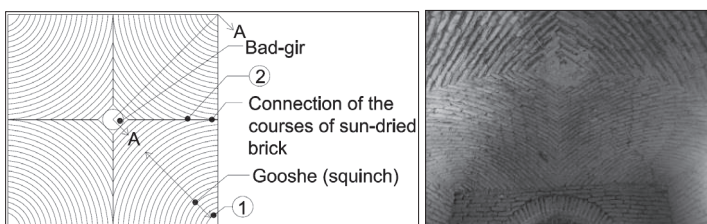


Fig. 2 Left figure) *Chahar Sawrak* pattern, right figure) *Chahar Sawrak* ceiling-Faqir House (A-A section is shown in Fig. 4) (Drawing and photograph by K. Kawish 2017)

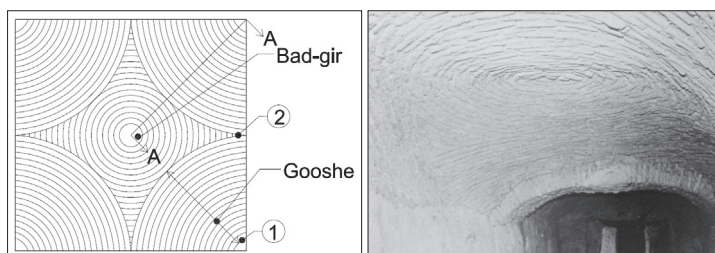


Fig. 3 Left figure) *Chahar Sawrak-e Gerd Poosh* pattern (Drawing by K. Kawish 2017), right figure) *Chahar Sawrak-e Gerd Poosh* ceiling, Herat (A-A section is shown in Fig. 4) (Source: Besenval 1984)

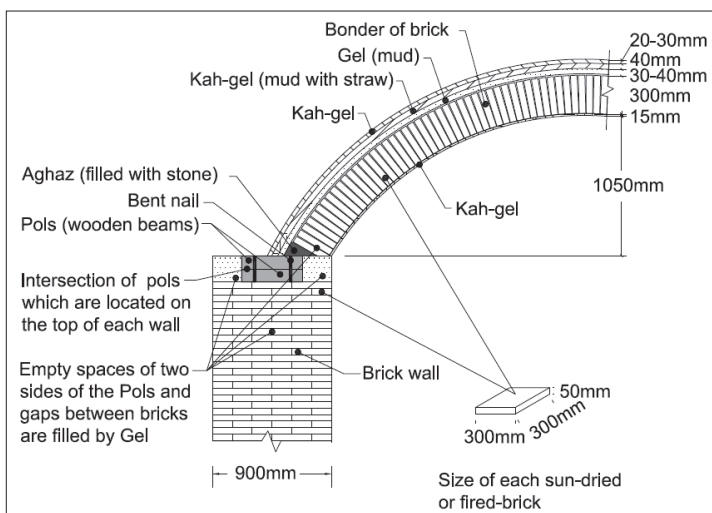


Fig. 4 Cross-section of A-A: section of domical vault (*Chahar Sawrak* pattern) construction (Drawing by K. Kawish 2016)

by one in the next course and they are laid about 10cm above the previous course. The sun-dried bricks are laid on the other three corners through the same method. This process continues until the courses of the adjacent corners connect to one another. For the second step(② in Fig. 2), the number of sun-dried bricks from each corner is decreased one by one until a quarter of *Bad-gir* (wind catcher) at the apex of the domical vault is remaining in order to direct wind to interior of the room. The joints between sun-dried bricks are filled with *Gel*. Finally, the roof is covered with layers of 30-40mm of *Gel* and 40mm of *Kah-gel* (mud with straw). Occasionally, after the final cover is dried, another layer of 20-30mm of *Kah-gel* is added to the roof to prevent rain or snow water penetration to the substrates (Fig. 4). The interior of the domical vault is also covered with a layer of 15mm thick *Kah-gel*.

2-2. Ceiling patterns of domical vaults

The methods of masonry for constructing a domical vault can be categorized through the sections as shown in Fig. 9. The details of the bearing wall and thicknesses of mud, mud-straw, sun-dried and fired-brick are shown in Fig. 4.

1) *Chahar Sawrak* (Fig. 2): The construction method of this pattern is explained in detail in section 2-1.

2) *Chahar Sawrak-e Gerd Poosh* (four corner covered circular) (Fig. 3): To construct a *Chahar Sawrak-e Gerd Poosh* domical vault; firstly (① in Fig. 3), inclined arches of sun-dried bricks that are laid upon each corner of the thick bearing walls are created (Fig. 4). These act as a base from which infilling can be done with inclined courses of sun-dried brick to create a continuous circular base for the domical vault. Next (② in Fig. 3), the upper parts of the domical vault are completed by adding further inclined courses of sun-dried brick (Fig.3).

3) *Romee* (Roman style) (Fig. 5): This pattern has two types: *Gooshes* (squinces) on two frontal walls and *Gooshes* on corners. To construct the type with *Gooshes* on frontal walls, the inclined course of sun-dried brick is laid upon a side of thick bearing wall (Section B, Fig. 9) and further inclined courses of sun-dried brick continue in parallel toward the center of the square. Next, the same procedure is conducted on the other frontal side wall. Finally, the courses of each side meet at the center of the square. The construction of *Romee* pattern with *Gooshes* on corners begins with the construction of about 10 inclined courses of sun-dried bricks on four corners (Section F, Fig. 9). Then, other inclined courses of sun-dried bricks are laid (Section C, Fig. 9). *Romee* pattern with *Gooshes* on two frontal walls are difficult to construct. Therefore some builders firstly construct about 10 courses on the *Gooshes* to make the construction of other courses easier.

4) *Mawjdar* (wavy) (Fig. 6): This pattern does not need centering. Courses of sun-dried bricks are laid parallel to the walls toward the apex (Section B, Fig. 9).

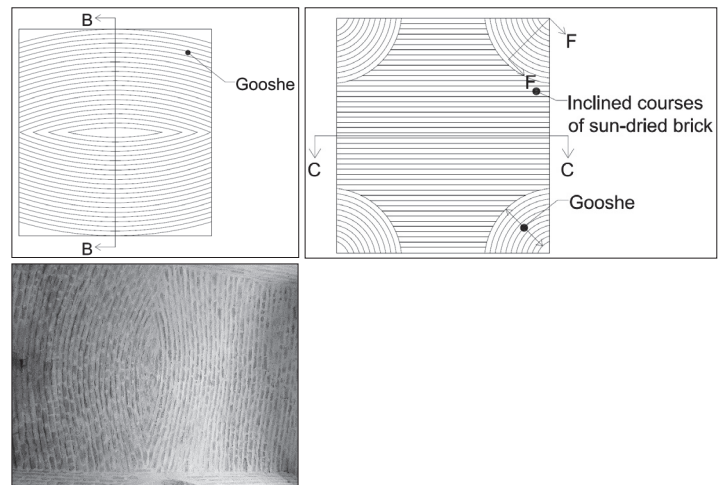


Fig. 5 Top figures) *Romee* patterns, bottom figure) *Romee* ceiling, Azadan village, Herat (B-B, C-C and F-F sections are shown in Fig. 9) (Drawing and photograph by K. Kawish 2017)

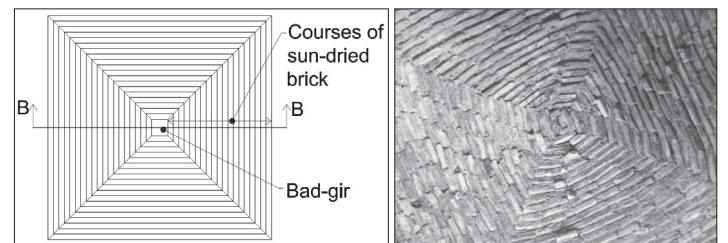


Fig. 6 Left figure) *Mawjdar* pattern, right figure) *Mawjdar* ceiling, Azadan village, Herat (B-B section is shown in Fig. 9) (Drawing and photograph by K. Kawish 2017)

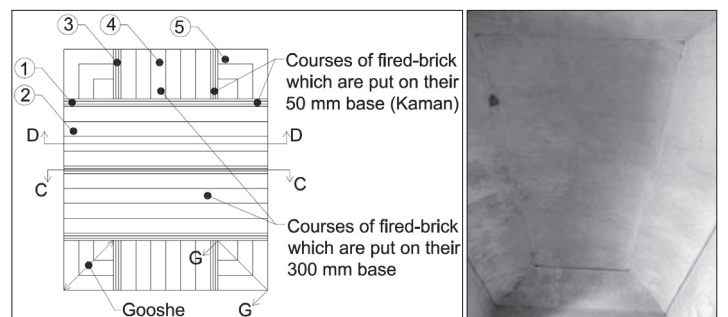


Fig. 7 Left figure) *Tegh Poosh* pattern, right figure) *Tegh Poosh* ceiling - Nabi house (C-C, D-D and G-G sections are shown in Fig. 9) (Drawing and photograph by K. Kawish 2017)

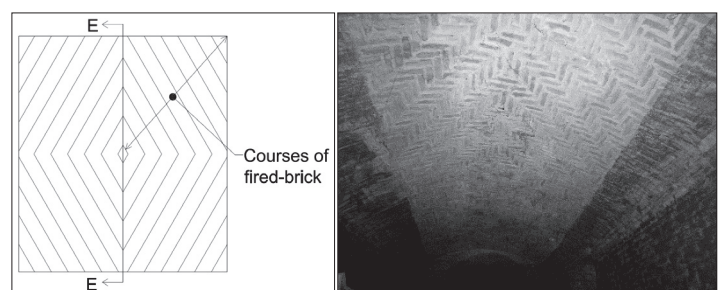


Fig. 8 Left figure) *Khandan* pattern, right figure) *Khandan* ceiling - Nabi house (E-E section is shown in Fig. 9) (Drawing and photograph by K. Kawish 2017)

5) *Tegh Poosh* (covered arch) (Fig. 7): This pattern is constructed with fired-bricks and is used for larger rooms. Because the number of fired-bricks needed is less compared with other methods, it has lesser weight and is suitable for covering large spaces. In contrast to other patterns, the courses of fired-bricks do not start from the corners. For some number of *Kamans* (arcs of fired-bricks which are put vertically, on their 50mm base), each consist of 3 courses of fired-bricks are constructed as framework like beams. The number of *Kamans* is dependent on the size of the rooms. For instance; for a 3x4 m² room, three *Kamans* are enough, while larger rooms require more *Kamans*. Firstly (① in Fig. 7), *Lenga* (wooden template bridging between the two long sides of the rectangular plan is set as a template in shape of an arc a distance about 1m from the corners. Then, the *Lenga* is covered with gypsum to make it smooth. The construction of the domical vault starts with setting the first course of fired-brick contiguous to the *Lenga* vertically on their 50mm base with the same inclination of the *Lenga* (see Section C, Fig. 9). Then, the *Lenga* is removed. Two other identical courses of fired-brick are set contiguous to the previous course and one *Kaman* is constructed. For the next step (② in Fig. 7), some courses of fired-bricks are set horizontally, on their 300 mm base with the same inclination of the *Kaman* (see Section D, Fig. 9). Then, the second *Kaman* is constructed and the procedure continues until the final *Kaman* is completed. Thirdly (③ in Fig. 7), two half *Kamans* which bridging between the long *Kaman* and the short edge at a distance of about 1m from the corner are constructed. Fourthly (④ in Fig. 7), some courses of fired-bricks are set horizontally between the two half *Kamans* with the same inclination of them. In the fifth step (⑤ in Fig. 7), the courses of fired-bricks are set to construct the *Gooshes* (Section G, Fig. 9). Finally, the empty space between the fired-bricks of *Kamans* and fired-bricks which are laid on their 300mm base is filled by soil or ash. Gypsum is used to fill the joints between fired-bricks instead of *Kah-gel* to increase the integrity and strength of the domical vault. The technique of using gypsum for joints between the fired-bricks is traditionally called *Hangaft*. *Bad-gir* is constructed sometimes at the center and sometimes at the sides of the roof.

6) *Khandan* (laughing) (Fig. 8): This pattern is also constructed with fired-bricks. Firstly *Lenga* is set along the diagonals of the square or rectangular plan and cross each other at the center of the plan. The construction of the domical vault starts with laying wedge-shaped course of fired-brick from the four corners towards the apex and *Lenga* is removed (Section E, Fig. 9). Sometimes the center of the roof is left empty for *Bad-gir*. Gypsum is used to fill the joints between the fired-bricks (*Hangaft*). The ceiling is not covered with mortar due to its beauty.

The field survey of several houses proved that *Chahar Sawrak* is the most common pattern found in Herat city. According to traditional builders, Herat people tend to prefer lower domical vaults and *Chahar Sawrak* is used because of its lower height compared to other methods. *Tegh Poosh* and *Khandan* patterns are mostly used for large spaces, very big houses and monuments and they are more expensive because of fired-brick construction with gypsum. *Romee* pattern is mostly used to cover long rectangular shaped rooms because its construction is easier for long rooms than other patterns. *Mawjdar* Pattern is mostly used for small spaces.

Besenal (1984) shows patterns of *Chahar Sawrak-e Gerd Poosh* (pp. 48-49) and *Romee* (p. 43) in Herat, *Chahar Sawrak* (p.45) and *Romee* (p.43) in Iran, and *Chahar Sawrak* (p.46) in Turkmenistan. Szabo et al. (1991) show patterns of *Chahar Sawrak-e Gerd Poosh* and *Romee* with *Gooshes* on corners (p. 119) in Girishk, Helmand province, Afghanistan. Hejazi et al. (2014) show patterns of *Chahar Sawrak-e Gerd Poosh*, *Chahar Sawrak*, *Mawjdar* and *Khandan* in Iran (vol. structure, pp. 46-49 and p. 81). Thus, Afghanistan and Iran share the technology of building domical vaults.

3. Case studies

Three traditional houses with domical vaults of Herat area are selected for case studies according to age. They are 110, 75 and 30 years old (Fig. 10).

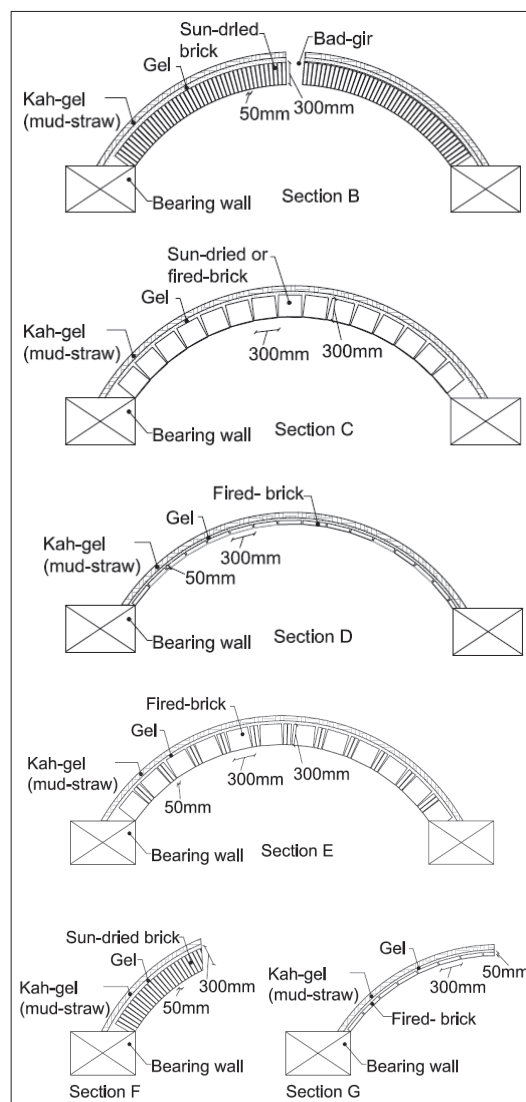


Fig. 9 Cross-sections of masonry for constructing domical vaults (Drawing by K. Kawish 2017)

3.1 Faqir house (Fig. 11, 12, 13)

Faqir house is located on Daneshjoo Street outside the boundary wall of Herat Old City (Fig. 10). The house was constructed 110 years ago by traditional builders. It is a two-story building with a sun-dried brick structure (Fig. 11); generally two-story houses built during this time meant family wealth in the village, while it indicated urbanity and high-density in the town. The house has been kept almost in its original form; only a bathroom was newly constructed in 2014 using traditional materials in the traditional style.

The floor area of the house is 173.5m² with a 50m² courtyard. This house consists of open and closed spaces.^{iv)} The open spaces of the house include a courtyard and *Takht-bam* (flat-roof), an open space in the second floor similar to a courtyard (Fig. 12). The first story of Faqir house is used for cattle and the second story is for the family. Living rooms, a traditional kitchen, a bathroom and *Takht-bam* are organized in the second story. The house is oriented into a north-south direction for better natural ventilation during summers and winters (Fig. 13).

Since Faqir house is a two-story sun-dried brick building with a domical vault, the walls are thick enough to bear the load of the building. The thickness of the exterior and interior walls is 120cm and 80cm in the first floor. The thickness of the exterior wall is decreased to 90cm and interior walls to 60cm and 40cm in the second floor because it does not bear as much of a load as the first floor (Fig. 13). The height of walls is 210cm on the first floor and 220cm on the second floor. The height of vaults is 80cm on the first floor and is increased to 120cm on the second floor which has larger rooms. Therefore the height of vaults depends on the size of the room they cover as well as the construction materials of the vaults. Bigger rooms are covered with higher vaults for stability.

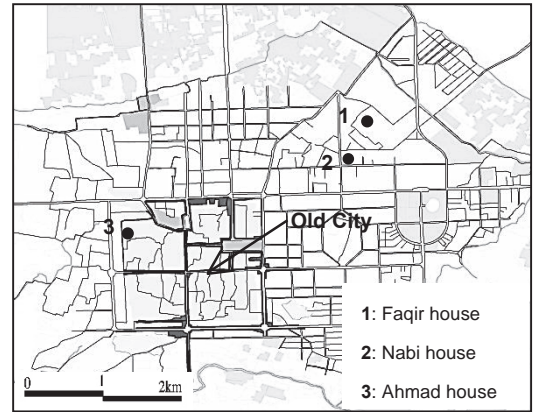


Fig. 10 Location of the case studies on the map (Source: AIMS Herat Office 2003)

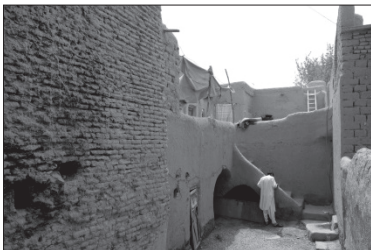


Fig. 11 A view of Faqir house from courtyard (7) (Photograph by K. Kawish 2016)

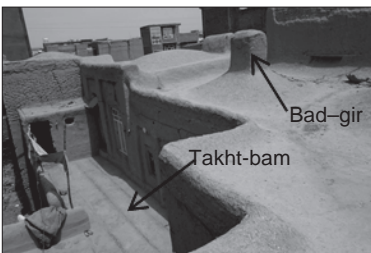


Fig. 12 A view of Bad-gir and Takht-bam (Photograph by K. Kawish 2016)

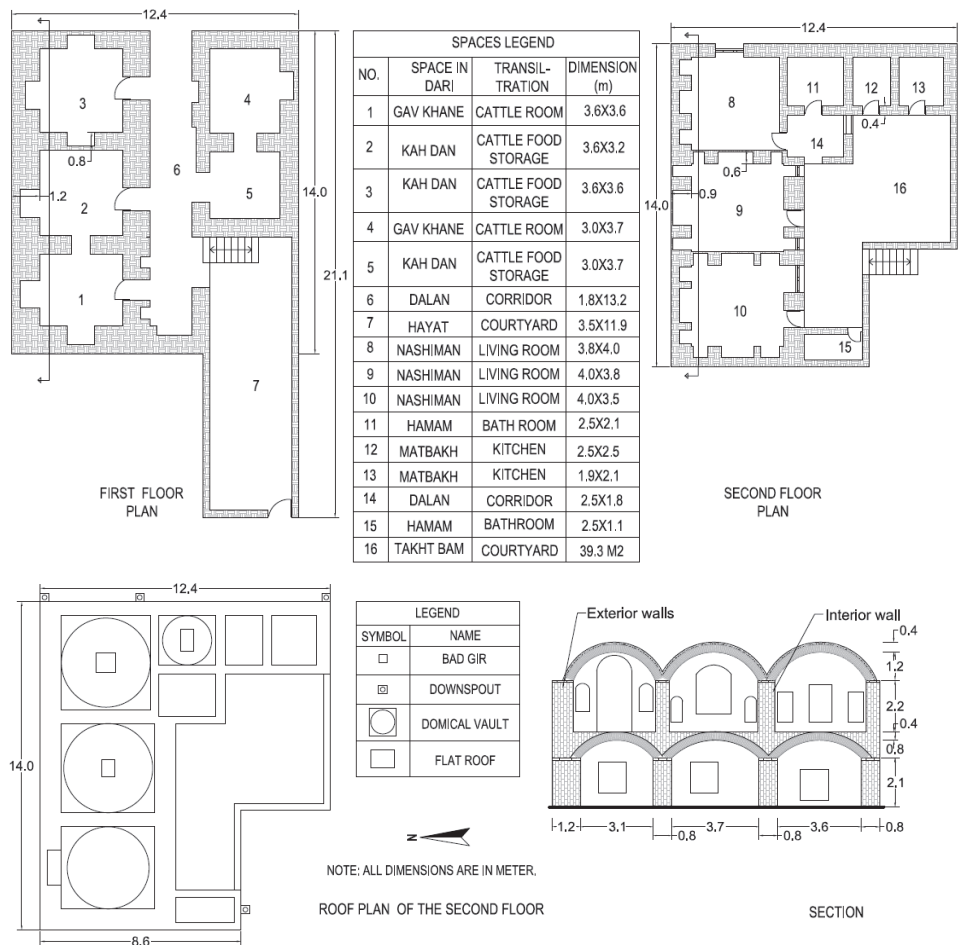


Fig. 13 First floor plan, second floor plan, roof plan and section of Faqir house (Drawing by K. Kawish 2016)

The main feature of the house is the two stories, both with domical vault constructions (first floor ceiling and second floor roof). The main interior elements of the house are the domical vault ceilings and windows. The exterior of the house is covered with mud, which is simple and without any ostentation. The house is designed with simple geometric shapes and local construction materials.

The roof types of the house are domical vault, barrel vault (open end vault consisting of a succession of identical arches (Joffroy et al. 1994), traditionally called *Zarbi Poosh* (covered with intense)) and flat. In the first story, barrel vault and domical vaults are used. The corridor is covered with a barrel vault and all other spaces are covered with domical vaults. In the second story, all spaces are covered with domical vaults except the kitchen, corridor and bathroom which have flat roofs because they are small (less than 5m²) and can be easily covered by flat roofs (Fig. 13).

The house did not have an electricity system at first, but now does. The water had been drawn from a well and Joye Enjil (Herat's main canal) 30 years ago, but the house is now equipped with a water supply system. The ventilation of the first story is provided through windows. The second story has *Bad-girs* to serve as ventilation. *Bad-gir* is the specific feature of traditional architecture for ventilation in the majority of warm regions (Fig. 12). They are temporarily closed with mud during winter and are opened during the warm seasons. The rooms of the Faqir house have multiple uses, as living rooms, rooms for hosting guests, and for eating and sleeping. The courtyard serves as an interior open space, private and secure for all family members, especially for women and children. *Takht-bam* is used as a gathering space for family members in the evening and sleeping during the summer and spring nights. It is also the place for social communication with neighbors. The separation of public and private spaces is not considered in the architecture of the house due to a shortage of space, but women do not interact with strangers because of their religious and cultural beliefs. To keep the privacy of the women, male guests are hosted separately in one of the living rooms. Three families of five, three and four members live in the house and each living room belongs to one family. Food is cooked together and each family eats separately in their own rooms.

3.2 Nabi house (Fig.14 and 15)

Nabi house is located on Nawaee Street outside the boundary wall of Herat Old City (Fig. 10). It was built by traditional builders 75 years ago. It is a one-story building with fired-brick and sun-dried brick structure. The construction materials of the house are locally available (Fig. 14).

The house has a floor area of 831.0m², on a site which originally occupied an area of approximately 50,000m² and was then reduced to 10,402.6m². The house consists of open and closed spaces. The open spaces of the house include yard, garden and rooftops. The rooftops of some big vault houses in Herat City are embanked to become flat to be used as a place for sleeping during spring and summer nights. During winter, sweeping the snow is much easier for flat roofs than vaults. The closed spaces of the house include living rooms, guest halls, bedrooms, corridors, a kitchen, lavatories, a traditional kitchen with *Tanoor khane* (traditional oven), a traditional bathroom, workers rooms, cattle rooms, cattle food storages, a pool and gardens. A traditional kitchen and bathroom, workers' rooms, cattle rooms, and food storage were removed 35 years ago. The two flat roofs of the winter guest rooms were removed 15 years ago and were re-constructed using modern materials in the flat style. The lavatories and the tea room are modernized 14 years ago. Furthermore, the house has been painted several times. The last painting took place in 2016 with a few changes in the interior design of the winter living room and its adjacent corridor.

Since the spaces of the Nabi house are large with big vaults, the walls are thick enough to bear the load. The thickness of the interior walls is 100cm and the thickness of the exterior walls is 120cm (Fig. 15). The height of the walls is 460cm and the height of the vaults vary from 70cm to 120cm depending on the size of rooms.

Nabi house is surrounded by the yard and garden (Fig. 15). The house is consisted of two parts of winter stay spaces (southern parts) and summer stay spaces (northern parts) to provide comfort in both cold and warm seasons. The house has an introversion style of architecture. The main interior design elements of the house are vault ceilings, large vaults and windows in each closed space. The exterior of the house is covered by fired-brick. One of the important features of the house is privacy and the separation of public (guests) and private (family) spaces. The eastern parts are public and western parts are private spaces with separate entrances. Another feature of the house is the orientation of the house in the north-south direction, which provides better ventilation and inner temperature for the house.

Roof structures vary depending on the shape of the rooms. Large rooms for guests have flat roofs. Family rooms are smaller and have domical vaults. The largest room with a domical vault is 7x4 m². The corridors that have long rectangular shapes have barrel vaults (Fig. 15).

The house has been equipped with electricity system since the beginning of its construction. There was no electricity system in Herat at that time and they installed their own power supplies. The water was provided by a well 35 years ago but is now supplied by an urban water supply system. The ventilation of the house is provided through windows and three *Bad-girs* which are both for ventilation and for allowing light into the house. All spaces of the house are equipped with chimneys to release smoke from the traditional heaters.

The yard is the place for relations with neighbors as well as the place for daily activities and sleeping. In the house, each room has its specific functions. One family with thirteen children lives in the house. The daily life of residents is very similar to a modern life style than a traditional one. Both men and women of the house spend their time outdoors.



Fig. 14 A view of Nabi house, from southern yard near room 2 (Photograph by K. Kawish 2016)

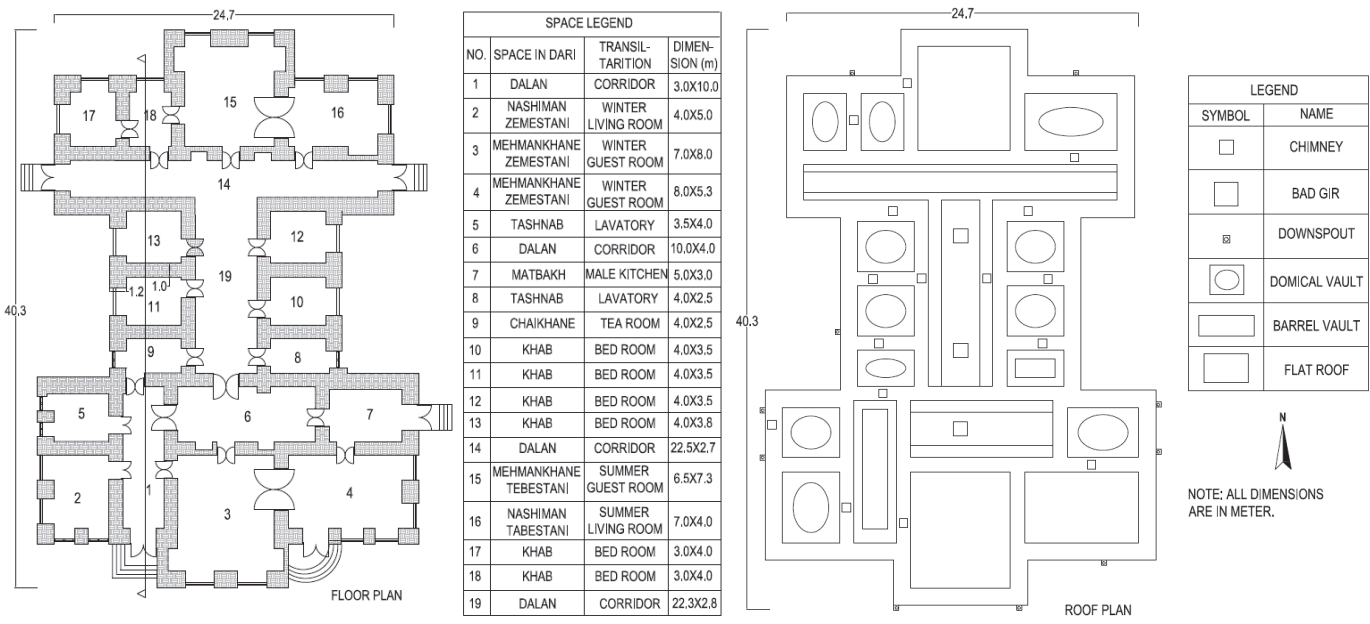
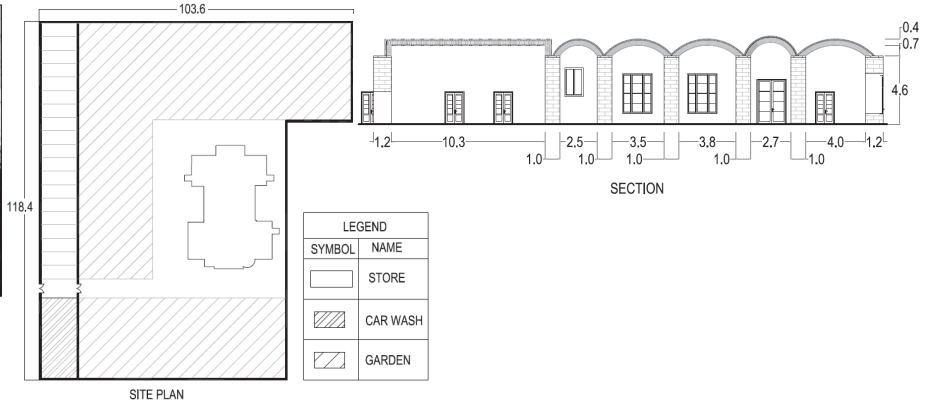


Fig. 15 Floor plan, roof plan, site plan and section of Nabi house (Drawing by K. Kawish 2016)

3.3 Ahmad house (Fig.16, 17, 18)

Ahmad house is a one-story building located on Arg Street of Herat Old City (Fig. 10). The house has a mud and sun-dried brick structure which was constructed by traditional builders 30 years ago (Fig. 16). The total floor area of the house with its courtyard is 242m². This house has both open and closed spaces. The courtyard is the open space of the house. Closed spaces of the house include a guest room, a bedroom, a living room, a traditional kitchen and a bathroom (Fig. 18).

Since the house is small and one-storied, the walls are not very thick. The thickness of the interior walls is 70cm and the thickness of exterior walls varies. The thickness of the northern exterior wall is 70cm and the thickness of eastern exterior wall is 50cm because it is semi-detached from the wall of the neighboring house. The thickness of the western and part of the southern surrounding walls is 40cm and the thickness of the eastern and a part of the southern surrounding walls which are newly reconstructed is 20cm (Fig. 18). Tie-bars are used on the ceiling of the living room and guest room to avoid tension of the walls (Fig. 17). By using tie-bars, the walls can be made thinner and thus cost less. The height of the walls is 260cm and the height of the vaults is 70cm.

Ahmad house is a central-single courtyard house. The guest room, living room, bedroom and corridor of the house are connected to one another and located in the north side of the house. The kitchen, lavatory and warehouse are located separately in the south side of the house (Fig. 18). Privacy is accounted for the architecture of the house via separate entrance for the guest room. The house has a north-south orientation. The alterations made to the house include the construction of a new 20cm surrounding wall and reconstruction

of the kitchen, warehouse, bathroom and toilet in the traditional style using traditional materials in 2012. The interior of the house was painted recently. In addition, some wooden windows have been replaced by steel ones.

The guest room, bedroom and living room have domical vaults, while the corridor has a barrel vault because of its longer rectangular shape. The kitchen, warehouse and lavatory were formerly covered by domical vaults but were reconstructed in flat type in 2012.

The house did not have an electricity system at first, but has been equipped with electricity since 2010. The water still comes from a well.

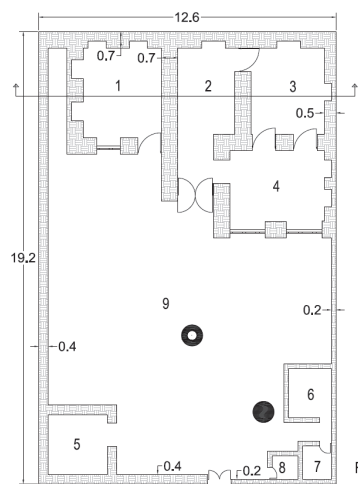
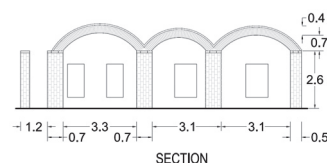
The living room is used as the space for gathering family members and very close family friends to eat and sleep. The courtyard serves as an interior open space, private and secure for all family members, especially women and children. One family of 5 members lives in the house and they lead a traditional lifestyle: most of the women's lives are spent indoors and the men's outdoors.



Fig.16 A view of Ahmad house (Photograph by K. Kawish 2016)

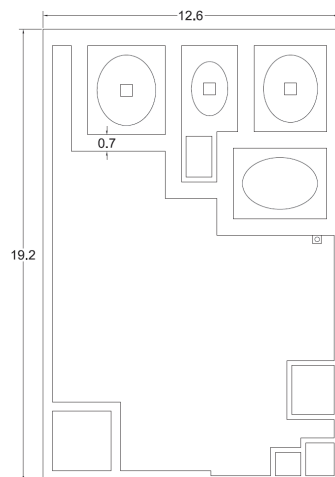


Fig.17 Tie-bars on ceiling of living room- Ahmad house (Photograph K. Kawish 2016)



SPACES LEGEND			
NO.	SPACE IN DARI	TRANSLITERATION	DIMENSION (m)
1	MEHMAN KHANE	GUEST ROOM	3.3X3.8
2	DALAN	CORRIDOR	2.4X6.5
3	KHAB	BED ROOM	3.1X3.7
4	NASHIMAN	LIVING ROOM	4.0X3.0
5	MATBAKH	KITCHEN	2.5X2.5
6	ANBAR	WAREHOUSE	1.8X2.1
7	HAMAM	BATHROOM	1.2X1.4
8	TASHNAB	TOILET	1.1X1.1
9	HAYAT	COURTYARD	12.0X11.6

LEGEND	
●	OLD WELL
○	NEW WELL



LEGEND	
SYMBOL	NAME
□	BAD GIR
⊠	DOWNSPOUT
○	DOMICAL VAULT
▭	BARREL VAULT
□	FLAT ROOF



NOTE: ALL DIMENSIONS ARE IN METER.

ROOF PLAN

Fig.18 Floor plan, roof plan and section of Ahmad house (Drawing by K. Kawish 2016)

3.4 Comparison of the structure of the three case study houses

After studying the structural methods of traditional builders and characteristics of the three case studies, it is found that the same size of sun-dried or fired-brick is used, which is 300mmx300mmx50mm. Barrel vault and *Chahar Sawrak* patterns of domical vault are used for the construction of the Faqir house and Ahmad house, while for Nabi house, *Chahar Sawrak Gerd Poosh*, *Tegh Poosh* and *Khandan* patterns are also used in addition to these two patterns. Wooden beams are used in the roof structure of all three case studies. Based on the interviews with traditional builders, the most common pattern in Herat is *Chahar Sawrak*. This is also proved by the case studies, as most of the spaces of each house are covered by the *Chahar Sawrak* pattern of domical vault. *Tegh Poosh* and *Khandan* patterns are constructed with fired bricks. Other patterns are mostly constructed with sun-dried bricks, except for several exceptions such as big houses which are constructed with fired-bricks.

By examining the characteristics of the three houses, wall thickness, construction materials and domical vault heights are found to be the main physical properties of the three houses and they are therefore compared.

Through a comparison of the exterior walls of the three houses (Table 1), the findings were as follows: the walls of the first story of Faqir house are thicker than the second story walls because the first story of two story buildings bears the loads of both the first and the

second floors. The walls of both Faqir and Nabi houses are thicker than those of the Ahmad house. This is because bigger spaces bear a heavier load than smaller spaces due to their higher and bigger vaults. A low vault, lower than 70cm, is structurally unstable and may require very thick wall (more than 100cm) as support. However, by using steel tie-bars, the thickness of the wall is actually reduced to 70cm in Ahmad House. Although Faqir house is smaller than Nabi house, the walls of the first story of Faqir house have the same thickness of 120cm as the walls of Nabi house. Faqir house is older than Nabi house, and it seems that older buildings have thicker walls. Over the years builders may have started to construct houses with domical vaults with thinner walls due to land shortage caused by an increase in population and to reduce the cost.

The main structural materials of Nabi, Faqir and Ahmad houses are fired-brick, sun-dried brick and mud (Table 2). Mud-straw as finishing and mud as mortar are used commonly in all three cases, but in some parts of Nabi house, gypsum is used as finishing, lime as mortar and stone in foundations. It seems that the selection of construction materials of traditional houses depend on the structural necessity and the economic situation of the owners. Wealthy people in big houses seem to use more expensive and hardy materials.

The domical vaults of second floor rooms are higher than the domical vaults of the first floor in Faqir house. The domical vaults of Nabi house are higher than the domical vaults of Ahmad house. Therefore, a determining factor for domical vault heights is the room size. The bigger the room, the higher the domical vaults are. This is because elevated domical vaults are stronger. Although the rooms of Nabi house are bigger than the rooms on the second floor of Faqir house, their domical vaults have almost the same height. The rooms of both Faqir house and Ahmad house are about the same size but Faqir house has higher domical vaults than Ahmad house. It is possible that older houses may have higher domical vaults than new ones.

Table1 Physical dimensions of the biggest room in each case study

Case study	Room length	Room width	Interior wall thickness	Exterior wall thickness	Wall height	Domical vault height
Faqir house 1 st story	360cm	360cm	80cm	120cm	210cm	80cm
Faqir house 2 nd story	400cm	380cm	60cm	90cm	220cm	120cm
Nabi house	700cm	400cm	100cm	120cm	460cm	120cm
Ahmad house	400cm	300cm	70cm	50cm	260cm	70cm

Table2 Construction materials of the three case studies

Case Study	Foundat-ion	Floors	Walls	Roof	Finishing	Interior
Faqir house (110 years old)	Stone, mud-straw	Mud, mud-straw	Sun-dried brick, mud, mud-straw	Sun-dried brick, mud, mud-straw	Mud, mud-straw	Mud-straw
Nabi house (75 years old)	Stone, sun-dried brick, lime	Fired-brick, mud	Sun-dried brick, mud, mud-straw	Fired-brick mud, mud-straw	Fired-brick, mud	Mud-straw, gypsum
Ahmad house (30 years old)	Mud, mud-straw	Mud, mud-straw	Sun-dried brick, mud, mud-straw	Sun-dried brick, mud-straw	Mud-straw, mud	Mud-straw, mud

4. Conclusion

It was found that Afghanistan and Iran share a common technology for building traditional houses with domical vaults. The similarities are seen in the construction methods and construction materials used for domical vaults. There are six patterns for domical vaults in Herat area and some of them are seen in Iran, Turkmenistan and other part of Afghanistan. Differences are observed as well. Traditional builders in Herat use *Pols* on top of each wall in order to avoid tension of the walls, whereas in Iran, wooden beams are not used for connecting walls and domical vaults.

The findings from the case studies of three traditional houses with domical vaults can be summarized as the following. Common features are the construction methods and materials (sun-dried and fired-bricks) used to construct domical vaults. The standard size of sun-dried or fired-brick used by traditional builders and in the three case study houses is 300mm×300mm×50mm. Domical vaults in all three cases are constructed by using *Pols* on the top of the walls of the domical vault room. The walls are made of sun-dried bricks. The thickness of walls supporting domical vaults varies from 70cm to 120cm depending on the number of floors the walls are supporting, size of the rooms, the location of walls (exterior or interior), ceiling heights, use of tie-bars and the age of buildings. The height of domical vaults varies from 70cm to 120cm depending on the size of the rooms.

References

- 1) Misra, A. and Davar, M.: Afghanistan: now you see me?: Afghanistan – the regional dimension, London School of Economics and Political Science, 2009
- 2) Joffroy, T. and Guillaud, H.: The Basics of Building with Arches, Vaults and Cupolas, SKAT Publication, 1994
- 3) Choisy, A.: Histoire de l'architecture, Gauthier-Villars, Imprimeur-Libraire, vol. 1, 1899
- 4) Besenval, R.: Technologie de la voule dans l'Orient ancien, Recherche sur les civilisations, 1984
- 5) Szabo, A. and Barfield, T. J.: Afghanistan an Atlas of Indigenous Domestic Architecture, University of Texas Press, 1991
- 6) Hejazi, M. and Mehdizadeh, F.: Persian Architectural Heritage (Structure), WIT Press, 2014
- 7) Boostani, A. and Jolyon L.: Conservation and Urban Rehabilitation in Herat, Aga Khan Historic Cities Programme: Urban Conservation and Area Development in Afghanistan, Aga Khan Trust for Culture, 2007

- 8) Ganji, H.: Examining the Impact of the 120 Day Winds on Evapotranspiration Considering Irrigation in West Region of Afghanistan, Masters Thesis, Graduate School of Bioresources, Mie University, 2015

Notes

- i) Herat is one of the major and most populous cities in Afghanistan situated in the fertile of Herai River and also in western part of the country. The city shares border with Iran in the west and Turkmenistan in the north. Herat dates back to ancient times. The city has a number of historic monuments, including but not limited to the Qala Ekhtiar Aldin, Masjid Jame and Musalla Complex. The city is the industrial, cultural and artistic hub in Afghanistan.
- ii) Herat is characterized by a desert climate, in which the average annual precipitation ranges from 152 to 214 mm. The summer climate is temperate, and the maximum degree of hotness ranges from 38 °C to 43 °C (Ganji 2015)
- iii) The current condition of security in Afghanistan is extremely unstable and means of conducting field surveys were limited.
- iv) Open space: spaces without roof, which has only floor and wall like courtyard. Closed space: spaces which have floors, roofs, walls and other components such as windows and doors like rooms.

和文要約

イラン東部からアフガニスタン西部にかけての乾燥地帯には、ドーム状ヴォールト屋根の伝統住居が分布している。国家の近代化に伴い、こうした伝統住居は減少しつつあるが、アフガニスタン西部の中心都市であるヘラート市内には、まだ多くの伝統住居が建造当時のままの姿で残っている。本研究は、伝統住居の建設技術者に対する聞き取り調査と3件(築年数110年、75年、30年)のケーススタディ(実測および

聞き取り調査)により、ヘラート市のドーム状ヴォールト屋根伝統住居の特徴を明らかにするものである。調査の結果、ドーム状ヴォールト屋根の建造方法には6種類あること、壁や屋根の構造は築年数や建築規模(階数・スパン)によって差があり、壁や屋根に用いられる材料や仕上げ材は経済的要因によって異なることなどが明らかになった。

(2016年11月30日原稿受理, 2017年7月6日採用決定)