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From Soil to Domes: Vernacular Architecture and Construction Techniques in Esfahak, South Khurasan

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ABSTRACT

This article examines construction techniques of earthen vernacular architecture, with a particular focus on traditional construction processes of mud brick vaults and domes in contemporary Iran. The village of Esfahak, in South Khurasan, is selected as a case study due to its unique historical circumstances, traditional buildings and construction methods, and recent restoration activities carried out by villagers. The village was damaged by an earthquake in 1978 and abandoned for 30 years until a group of Esfahakis decided to restore their ruined earthen houses. This marked the start of an intergenerational exchange that allowed young villagers to train alongside old masters in a process of rediscovery of long-time abandoned construction techniques. The old village has been reconnected to the lives of current residents, while the reconstructed buildings continue to bear witness to the millennial knowledge and skills of erecting vaults and domes from the plateau's arid soil. This article is based on fieldwork research on building sites and interviews with craftsmen in Esfahak, combined with a review of existing literature on traditional and historical construction techniques in the Persian world.

KEYWORDS

Vernacular architecture; vaults and domes; traditional construction techniques; knowledge transmission; mud bricks

1. From Monumental to Vernacular Architecture

1.1. A Land of Earthen Architecture

The complexity of Iran's millennial and stratified socio-cultural history and its various natural environments has fostered the development of several building and structural typologies. This rich variety increases even more if one looks at the broader Persian world in a historical perspective. Monumental buildings linked to this history across Eurasia are amongst the most prominent construction examples in the world's architecture. Among them, it is possible to notice that earth is one of the most common materials, especially in desert and semi-desert areas.[1] In Persepolis, for example, mud bricks were employed for the construction of large sections of the complex. There is also recent evidence of early settlements near Persepolis, like Tol-e Ajori, in the area of Bagh-e Firuzi, which are entirely built of mud and fired bricks, examples which are of utmost importance for the whole area.[2] The "Gate of Xerxes" or "of all Lands" was faced with glazed tiles but constructed with a core masonry of mud bricks and the fortification lines were also made of mud bricks, and even the Audience Palace of Darius was constructed of 5.32 m-thick mud brick walls coated with lime and mud plaster.[3] Mud brick vaults and domes mark the traditional landscape of the majority of villages, towns and cities in central Iran.[4] By taking a broader look outside central Iran, domed and vaulted village houses of Western and Northern Afghanistan share many common features with those from South Khurasan, from materials to construction techniques and structural elements.[5]

1.2. Defining Vernacular Architecture

For a long time, academic studies and publications on architectural history have focused primarily on monumental buildings[6], with "popular building crafts"

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[1]Baimatowa, 5000 Jahre Kleiss; "Construction Materials"; Pope, *A Survey of Persian Art*
[2]Chaverdi, Callieri and Matin, "Tol-e Ajori", 223
[3]Schmidt "Persepolis I", 64-68; Shapur Shahbazi, "Persepolis"
[4]Wulff, The Traditional Crafts of Persia, 102–106
[5]Szabo and Barfield, *Afghanistan: An Atlas*, 119
[6]Monumental buildings are uncommon buildings such as: palaces, residences of the elite, administrative complexes, political and ceremonial centres like temples (religious buildings), fortifications and defensive compounds, as well as tombs and particular burial sites (Knapp, "Monumental Architecture", 47). These structures represent uncommon examples of architecture that are out of the ordinary and everyday typologies.

receiving much less scholarly attention.[7] These popular building crafts are generally referred to as "vernacular architecture" in contemporary academic debates. In this article, the term "vernacular architecture" is used in reference to the processes and techniques of architectural making, as well as the socio-cultural dimension in which they are embedded, and not only to physical. The *Cambridge Dictionary* defines vernacular architecture as *a local style, in which ordinary houses are built*. Hence, the vernacular kind is "everything that is crafted, woven or reared at home".[8] Vernacular buildings are native to specific environments and available resources, they are built adopting traditional technologies and are customarily owned or community built.[9] Apart from a specific place and cultural group, vernacular architecture is related to a given time. Traditions can be seen as creative actions through which people, as active agents, interpret past knowledge and experiences to face the challenges and demands of the present; ideas prevalent in the contemporary fields of anthropology, cultural geography, history and archaeology, which have all stressed the dynamic and processual nature of tradition.[10] Contemporary research in the field of vernacular architecture argues that these buildings should be considered as dynamic traditions that continuously evolve while remaining distinctive to a place. It is likely that the study of vernacular buildings was not considered very relevant before the widespread industrialisation of building materials. Not only were vernacular constructions "common" and built with locally sourced materials, but the way they were built was widespread – thus a form of "common knowledge" that was taken for granted. Moreover, there is a scarcity of historical evidence regarding vernacular architecture It is difficult to date.[11] It is difficult to date common mud houses and settlements just by considering the way many of them have been remade throughout time.[12] A combination of archaeological discoveries and ethnographic fieldwork research can be a promising way to reveal interesting details on technologies and traditional crafts. It is in fact archaeology, more than purely historical research, that is interested in the making processes of architecture, on building and its technologies. On the other hand, ethnographers have the potential to witness and take part in the building processes today. In contemporary Iran, vernacular architecture is mostly referred to as *me'mari-e bumi*, which could be translated as domestic/indigenous/local architecture). Figure 1.

1.3. Towards the Study of Vernacular Architecture in Iran

From the second half of the twentieth century industrialisation has played a key role in shifting architectural traditions in Iran. This transformation offers an opportunity to retrospectively examine previously overlooked vernacular architecture of the country. The following section outlines a brief chronology of the sources and works that deal with vernacular architecture in Iran. This review is by no means exhaustive but serves to highlight the some of the available material on vernacular constructions, which can be broadly divided into three phases:

1.3.1. 1st Phase: Travel Accounts, Historical Visual Sources and Biographies

There is very little to be found on vernacular buildings and techniques in written works before the twentieth century, and in particular before the mid 1900s. In some instances, travellers have briefly reported short descriptions of common houses, building techniques and materials. In the eighteenth century, Hermann Moll, a famous British geographer, reported that houses in Persia "are being built of mud, whereof they not only make the walls, but even arch them over very artificially".[13] Often, derogatory language is employed in relationship to common constructions. For example, in the nineteenth-century introduction to "The Mechanical Arts of Persia", written by a former engineer working at the Shah's court, the tone of the description is very clear: "Although, perhaps, there is little to be gained in a practical point of view, from the description of the Persian arts, it may still be interesting to contrast our own highly improved manufactures with those of less advanced countries".[14] In these accounts, there is a tendency to generalise practices across regions or declassify the "common-cum-simple". These accounts are nevertheless interesting for they present historical evidence on the ways of looking at these buildings. Figure 2.

It is also widely known that building process depictions are very rare in the Persian world, even though, for example, from the fourteenth century onwards, the depiction of Islamic

[7]Bromberger, "Banna'i"
[8]Guillaud, "Defining Vernacular Architecture", 33
[9]Vellinga, Oliver, and Bridge, *Atlas of Vernacular Architecture,* xiii
[10]Noble, *Vernacular Buildings,* 2; Vellinga and Asquith, Vernacular Architecture, 7
[11]Ferrari, High Altitude Houses, 49
[12]Naiemi, "Residential Compounds", 204
[13]Moll, A system of Geography, 88
[14]Robertson, "On the Mechanical Arts", 52

Figure 1. Roofs and wind tower in Esfahak.

architecture in Persian painting was quite ubiquitous.[15] Nevertheless, what is available is mostly related to the construction of monumental buildings. McClary analyses in his work finely painted two-dimensional miniatures, for example the construction of the Castle of Khwarnaq in Iraq.[16] This image is used as a detailed example which summarise many technical and sociocultural information on the period of the construction as well as the construction process itself .[17] Nevertheless, architecture is represented also through three-dimensional models and not only paintings. Graves, for example, takes into account several portable objects in Middle age Persia which are shaped after architectural models. Among these objects, many are shaped after common houses, which in some cases are, according the Graves' analysis, simplified but elementally intact version of the courtyard house type; a dwelling that has existed in Persia for millennia and that is nowadays iconic of the city of Yazd.[18]

Furthermore, there are many sources of daily life information within the Persian world enclosed in *tazkirat,* or biographies. In these written accounts, in parallel to the descriptions of lives of saints, heroes or poets, there are also descriptions of common events of the time: a collection of memories. These biographies are resistant to critical theory because they are: "drenched in the minutiae of local detail".[19] It is perhaps because of their mundane descriptive character (the reason for which they are criticized by many) that these sources might reveal interesting historical details on phenomena linked to vernacular buildings. When we talk about the twentieth Century, it is important to mention the work of Mohammad Karim Pirnia. His publications focus on the traditional architectural discourse in relation to culture. Pirnia presents for the first time a study of the development and styles of Iranian architecture with a contemporary and international academic approach. In his work he also develops a series of principles

[15]McClary, "Persian Paintings", 215
[16]Contained in Khamse of Nezami. British Library, manuscript OR. MS. 6810, fol 154v
[17]McClary, "Persian Paintings"
[18]Graves, Worlds Writ Small, 46
[19]Hermansen and Lawrence, "Indo–Persian Tazkiras", 150

Figure 2. A hand-carved room (*dastkand*) covered with a vault.

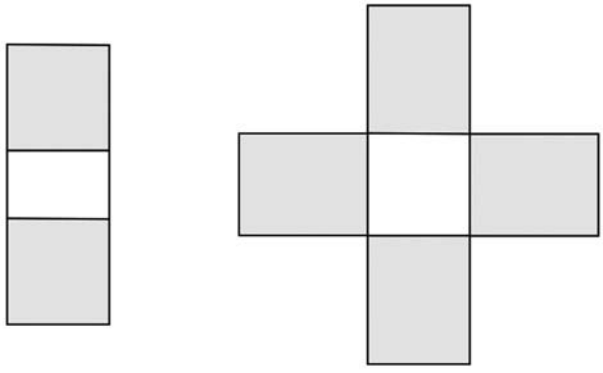

Figure 3. *2-sofeh* and *4-sofeh* patterns.

which, according to him, can be found across the Iranian architectural tradition. Figure 3.

1.3.2. 2nd Phase: Scholarly Research from the Early and mid-twentieth Century

One of the first thorough attempts at analysing vernacular architecture is that by Wulff in the monographic volume *The Traditional Crafts of Persia* (1966). In this book, the construction of village houses is treated as part of a broader documentation of traditional craft practices in different areas of the country. Interestingly, the work focuses on construction techniques. In this way, houses are not catalogued according to their design or typology, but the attention is shifted towards a description of the building processes. Before this attempt, scholars were mostly interested in relating vernacular traditions to monumental architecture considering the former a subclassification of the latter.[20] Beazley and Harverson (1982) carried out a detailed survey of vernacular working buildings in their volume *Living with the Desert*. Construction activities have changed markedly during the last 60 years in most parts of Iran's rural areas. Materials and architectural elements used to be sourced and manufactured *in situ* before the massive introduction of industrial technologies. Fired bricks and cement have almost totally replaced unbacked earth, even in those areas where earth was almost the unique material already available by the 80s.[21] The progressive disappearance of vernacular buildings fostered the interest of some researchers. On the other hand, books like that by the Austrian architect Roland Rainer: *Anonymes Bauen in Iran* (1977), show a very different architectural approach when looking at so-called "anonymous buildings". Rainer, among others, sees in this architecture without

Figure 4. An abandoned *4-sofeh* pattern house, photo collage.

[20] see Godard, Athar-e Iran 1949
[21] Bromberger, "Banna'i"

architects[22] the necessary source of inspiration for future design solutions, sometimes with an excessive romanticised idea of the relationship between people and the environment in Iran. Figure 4.

1.3.3. 3rd Phase: The Twenty-first Century and a Wider Interest in Vernacular Buildings

There has been a growing interest in Iran's vernacular architecture in both English and Persian literature. A number of master theses, PhDs and journal articles published in the last decade is evidence of the popularity of this theme.[23] Many Iranians are authoring works focusing on the architecture of their own towns or villages, showing thriving interest in the exploration of "the local dimension". In most of these works, there is a strong focus on sustainability and technology in relation to the idea of "learning from vernacular (and traditional) architecture". Foruzanmehr investigates vernacular cooling systems in Iran not only from a technical point of view, but also by integrating the study with users' perceptions, basing its work on an analysis of contemporary people's needs.[24] Others, like Naiemi, study residential compounds to analyse desert settlement typologies in more depth.[25] The number of new research studies both inside and outside Iran mark an interesting turning point. While on the one hand a large majority of these works have a purely architectural perspective, on the other there is a growing interest in vernacular architecture by scholars from different fields that take into account common buildings. The contemporary relevance of the vernacular architecture discourse in Iran is also linked to activities carried out within the country, both in and outside universities, but a separate analysis would be needed to analyse all research projects that are currently undertaken in Iran. Figure 5.

2. Domestic Architecture in Esfahak: Past and Present of Traditional Houses

2.1. The Village and its Houses

Esfahak historical settlement presents a very interesting variety of building typologies. Their differences clearly show a transformation of the house form within the village, even though it is not possible to establish an exact chronology with the available data. Esfahak is a classic example of a piedmont village backed towards the north-east by a tract of the Eshdeger mountain range, in a zone of insufficient precipitation but with groundwater. The village had for a long time been watered through *qanat*[26] irrigation, even if increased usage of deep wells powered with mechanical pumps in the last decades have lowered the level of the water table, thus making the *qanat* non-functioning. In a survey by Daneshdust, the village of Esfahak, along with many others, is barely mentioned as one of the *abadi*[27] or *rusta* (villages). In this book, only Tabas is mentioned to have a valuable cluster of historical buildings (*anbuh-e banaha-ye tarikhi*) in the area.[28]

Towards the southern side of the village is one of the oldest parts of the settlement. Here are a series of cave-like rooms which were carved out from the earth. This typology of rooms is known as *dastkand* (hand-carved). Many of these cave rooms are still surviving and the carving tool marks are clearly visible on the soil surface. These dug-out dwellings are the oldest forms of shelter that can be found in Iran. The root word – *kand,* from the verb digging (*kandan*), is still found in many village or town names, like Saraskand, indicating their original shelter form, which was likely caves or tunnels.[29] The name "Esfahak" does not have any reference to this element, even though these carved dwelling typologies are present, thus it is not sure whether these were the first forms of dwellings in Esfahak. The village counts four *qanats* which have a clear designation and possible link to financing sources: Qanat-e Tavakkolabad, Qanat-e Abbasabad, Qanat-e Eskandarabad, and Qanat-e Dehe. As suggested in the interesting *fulanabad* "theory" by Bulliet, the *-abad* suffix may have indicated (in spite of its incorrect philological origin) that a settlement or *qanat* was established after "someone" (*fulan*) financed the bringing of water (*abad*) to the area through the construction of a *qanat*.[30] Nevertheless, the name Esfahak might suggest other origins, as advanced by some of the people in the village. A story among locals narrates that the village used to be – in an unspecified period of time

[22]There was an increasing interest in vernacular architecture in particular after the publication of the book *Architecture without Architects* by Bernard Rudofsky in 1964.
[23]To cite only a few: Farzaneh, "How to Cope with Heat"; Foruzanmehr, *Thermal Comfort*; Pakcheshm, "Roof Typology"
[24]Foruzanmehr, Thermal Comfort, 1–2
[25]Naiemi, "Residential Compounds"
[26]*Qanat*: a tunnel dug out by hand, which conducts water from the level of an aquifer to the open air by means of simple gravity in order to distribute it to lower areas; the technical term 'qanat' (from Arabic) is officially adopted in Iranian administrative documents, preferred to the equivalent and older word *kariz* (Planhol, de, "Kariz").
[27]*Abadi* (from Ashraf 1982): is the Persian term referring to 'settlement, inhabited space'; it is applied to the rural environment, but it is also commonly used in reference to towns and cities.
[28]Daneshdust, *Tabas Shahr keh Bud*, 302.
[29]Wulff, The Traditional Crafts of Persia, 102
[30]Bulliet, Cotton, Climate, and Camels, 17–27

Figure 5. Incomplete house that was being built at the time of the Tabas earthquake by Ostad Habib.

– a courier house (*chapar-khaneh*) because of its strategic location between Yazd, Tabas, Mashhad and Kerman. Here messengers would stop and a garrison was established. Because of the presence of a small army (*sepahak*), the name slowly changed until it became Espahak/Esfahak. There is noticeable similarity with Isfahan here, as we know from quotations of the Ketab-e Esfahani by Hamza Esfahani that a familiar popular etymology of the city is "the armies".[31] Interestingly, it is possible to find the toponym Espahak (spelt with the letter *sin* and not *sad* as commonly found nowadays) in a map of the Tabas area, as reported by Daneshdust.[32] A rectangular precinct wall with four round bastions is still located at the north-easternmost part of the historical settlement, possibly marking the presence of a former fortified settlement, a garrison, or *chapar-khaneh*, which was later converted into agricultural land. Houses in Esfahak can be distinguished according to the methods employed in their building, or according to their plan arrangement and rooms' distribution typology. A first classification is established through the way in which houses were built:

- Dug-out rooms (*dastkand*);
- Hypogeous rooms with roof. Rooms were carved out into the ground or in a protuberance and covered with mud brick vaults and domes;
- Houses entirely made of mud bricks and/or earth-lump walls and mud brick roofs;
- Mixed typologies, that is a mixture of the previously mentioned techniques.

These examples are a starting point towards a typological analysis of houses in the village. In fact, some of the typologies have a direct link to specific building techniques while others have not. Houses often show mixed-plan typologies, or different configurations, and this is generally the result of a slow process of aggregation and transformation through time. Nevertheless, it is possible to recognise the starting framework by knowing some of the main patterns that repeat themselves throughout the village. The main examples in Esfahak are:

- Cave-like dwellings/rooms;
- *2-sofeh*;
- *4-sofeh*;
- Houses with central courtyards.

Only a small number of cave-like dwellings, mostly single rooms, have remained today. For the inhabitants of this semi-desert area, it was possible to excavate

[31]Hansman, "Isfahan. Pre-Islamic Period"
[32]Daneshdust, *Tabas Shahr keh Bud*, 302–303

compact but relatively soft clay-rich soil, especially to build hypogeous rooms. This reflects a very important need shared in different parts of Iran, i.e. to shelter animals during the winter. This need frequently led to the construction of more complex buildings, and when natural conditions in cold and treeless areas allowed it, the underground level was used as stabling underneath the area where the family lived.[33] Some of the roofless carved rooms that have remained in the southern part of the village continue to be used as pens for small animals today. The cave rooms differ from other house typologies found in the historical village, since the latter show more elaborate plan forms and constitute more clearly identifiable examples of architectural patterns. Figure 6.

The *2-sofeh* (or *do-sofeh*) is a one-axis plan pattern with a central space, sided by two rooms on the same axis. The word *sofeh* can be defined as: *ayvan*,[34] covered *ayvan*, a hall covered with a curved structure, a covered and higher platform, as described in the *Farhang-e Vajehha-ye Me'mari-e Sonnati-e Iran*.[35] The two rooms, the *sofeh*, are covered with vaults and are closed from the outside, generally having no windows but only doors onto other rooms of the house and/or distribution spaces. The whole pattern is limited to the centre of the dwelling, and there is no external direct access to it. It is from the central space of the pattern, the connecting centre which divides the axis in two, that the rooms are illuminated through a skylight (*nurgir*). This skylight is an opening that rises on top of the dome that encloses the central space. In the past, this roof-window was a simple hole that was open to the sky, and was only closed temporarily with vegetable fibres, when needed. The opening was also used to collect the scarce rainwater. For this reason, that the central floor space is always lower than the lateral *sofeh* (that are elevated), which are separated by a low step. It is only in more recent restoration projects that wooden frames closed with glass or plastic were introduced on top of skylights. The *2-sofeh* arrangement is spatially very clear and allows for the annexation of other units from all sides. A larger and more spatially sophisticated version of the first pattern is the *4-sofeh* (*chohar-sofeh*). In this plan typology, the main module is a double-axis version of the *2-sofeh*, one having two perpendicular axes hinged on a central square space, sided on all four sides by four square or rectangular spaces. The *4-sofeh* is a larger pattern, which allows

Figure 6. Interior of a restored house, *2-sofeh* pattern.

the addition of four extra rooms at each one of the four corners of the cross-plan. As for the *2-sofeh*, the central space is the one open to the roof which brings light inside. All the other lateral spaces are closed and are only connected to other rooms or distribution spaces in the house. These house patterns seem to be among the oldest in the village, only superseded later by the better-known house with central courtyard (*khaneh-ye hayat markazi / khaneh hayatdar*). It is clear from an analysis of the documented dwellings in the old settlement that central-court houses were built either by adding new rooms and transforming previously existing houses of the *2-sofeh* and *4-sofeh* types, or they were built anew in the decades before the earthquake. This analysis is reinforced by what many of the old villagers remember about families commissioning new central-court typologies. It was mostly in the mid-twentieth century that wealthier people in the village decided to destroy or severely alter their former houses (in particular, *dastkand* rooms were replaced) and enlarge their buildings by

[33]Planhol, de, "Geography of Settlements", 420

[34]. *Ayvan,* according to Grabar: a Persian word used also in Arabic and Turkish. In classical Persian or Arabic texts, *ayvan* refers most of the time to a palatial function, either a whole palace or the most important and formal part of a palace (Grabar, "Ayvan-Eyvan"). By extension, it can mean the most official or impressive part of any building.

[35]Fallahfar, Farhang-e Vajeh-ha-ye Me'mari, 174).

introducing central courtyard models.[36] The process gradually saw the addition of porches (*ayvan*) to *2-sofeh* and *4-sofeh* houses, so that larger buildings could be hinged on inner courtyards often provided with water pools (*hoz*). The pools, in Esfahak locally called *daryacheh*, were new important spatial centres for dwellings. Figure 7.

Wind towers, or wind-catchers (*badgir*), are a prevalent feature of the old village since they are present in all houses. It is known that wind towers throughout hot and arid regions perform a similar function, that is to channel "prevailing winds trapped in vents above the roofs of buildings down to cool and ventilate the rooms below".[37] Nevertheless, there are regional variations differing in shape, height and design. The type of wind-catchers in Esfahak are more similar to those found in Western or Northern Afghanistan. Wind-catchers in Esfahak vary in height (they can reach up to one or two metres) but they usually never reach the height of those in cities like Yazd, which can be as high as five metres. In Esfahak, wind towers are mono-directional: pointing north and oriented towards the mountain chain behind the village, from where cool air naturally flows. The openings used to let air in are often divided in sections of plastered mud bricks, which are set in parallel sections to form slits (*dahan*). Figure 8.

Figure 7. The courtyard of a restored house with a pool.

2.2. The Tabas-e Golshan Earthquake

On the 16th September 1978 the Tabas-e Golshan earthquake hit Esfahak. As reported by Balland, Borjian and colleagues, this event "was one of the two most catastrophic earthquakes to have occurred in Iran in the twentieth century, as the shake destroyed or severely damaged about ninety villages, and completely demolished the oasis town of Tabas-e-Golšan, where 85 percent of the inhabitants (11,000 out of 13,000) perished".[38] In the case of Esfahak,[39] the fate of the village was determined when villagers decided to rebuild a new settlement in an area on the north-western side of the former one. The new Esfahak, similarly to Ferdaws, was completely rebuilt on a different site. Tabas, which was hit much more severely, was erected anew in place of the older settlement. By 1981, the historical town of Tabas no longer existed, with the exception of a few surviving monumental buildings such as the fort. The decision to move the village resulted in the abandonment of the majority of Esfahak's historical homes and, in this way, houses were spared from complete destruction. Esfahak lost around 15 per cent of its houses and 20 per cent of its inhabitants as a consequence of the earthquake. In the end, the material damage was not as great as the human one that continues to affect its population until today. The memory of the event marked a tragic shifting point for the whole village, and the catastrophic event even affected generations born after the earthquake. With time, the old village was partly erased to make space for more agricultural land, and the earth of houses recycled to increase cultivable fields. In fact, many areas around the old village were used for cultivation because of the presence of groundwater. The old settlement was generally referred to as "the old soil" (*gel-e kohneh*): many houses were demolished, and no one had an interest in its material continuation, which possibly suggests how local people perceived it and what their

[36]Interview with Mohsen Mehdizadeh (September 2019).
[37]Roaf, "Badgir"
[38]Balland, Borjian, De Planhol and Berberian, "Earthquake"
[39]Most of the information concerning the Tabas-e Golshan earthquake of 1978 was collected from interviews conducted in the village in April and September 2019.

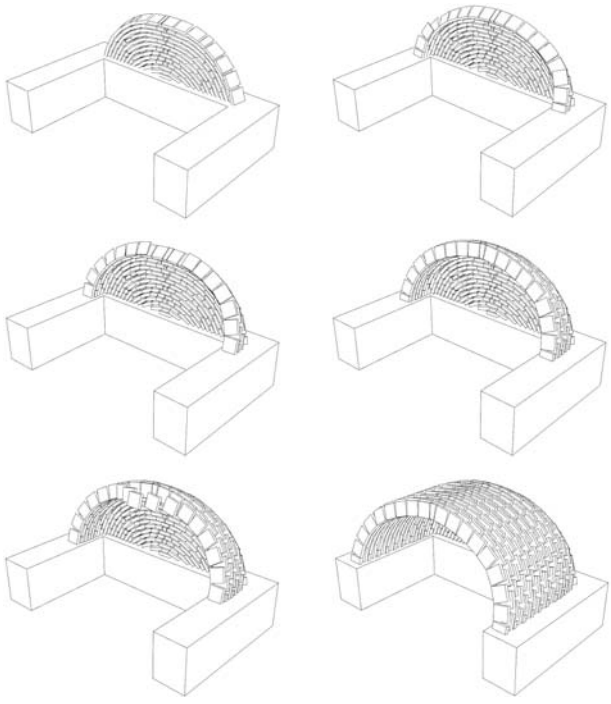

Figure 8. Making process of a sitting vault.

relationship was with it. Until the time of the earthquake, construction activities in the village were carried out employing mostly local materials. Several craftsmen were active there by the end of the 70s, for example Ostad Habib, who was in the process of constructing a large house that was left incomplete after the earthquake.[40] This building is still visible, and all its perimeter and inner walls had been completed and only the vaults were missing. From that time, many craftsmen left the village to work elsewhere, and those who carried out new constructions in Esfahak changed to using industrialised materials, completely abandoning earth. This tendency is clearly visible in the new settlement, which is built with fired bricks, reinforced concrete and cement plaster. Figure 9.

2.3. The Regeneration of the old Village

In 2012, a group of young people from Esfahak fostered the first initiatives concerning the regeneration of the old village. For some of the villagers, despite the great sorrow that remained from the time of the earthquake, there was an interest in tackling a new project for their former settlement. One of the initial objectives was to give the village the status of a "government registered tourist station", attracting visitors and offering new business opportunities for some of the village' young people. A restoration project was needed in order to convert ruined houses into tourist facilities. A large number of buildings from the historical village were documented through a detailed survey conducted directly by this first group of stakeholders. Following these first activities, it was from 2014 that restoration works slowly began, thanks to the accidental acquaintance of an architect who passed by the village and stopped there for a chat with the stakeholders.[41]From that time onwards, many collaborations were initiated with professionals and universities. It is in this dynamic environment that several restoration projects were gradually completed, with a great deal of effort offered by some of the villagers, who financed and worked in most of the building activities, also taking part in their construction and reconstruction. The first house was completed in 2015 and other interventions started while more villagers became interested in restoring the old dwellings. The efforts put in by the locals were great indeed, considering that all construction techniques linked to earthen-based materials were abandoned in favour of other materials. Young people had to find old masters from Esfahak and nearby villages to learn how to reconstruct earthen structures. This was a "new beginning" for traditional building techniques, in particular those concerning the vaulted and domed structures, which were those mostly damaged by the earthquake and by protracted abandonment. Old masters re-engaged and familiarised themselves again with the techniques that they practised in their youth. An active intergenerational cooperation started with these activities. Together with this, a newer breed of craftsmen has begun as well as a new generation of aspiring masters. The empirical knowledge of construction re-emerged after many years of having been left aside. The interest in these traditional buildings and construction techniques has been growing even outside the village. Not only professionals, but also university students and other enthusiasts became interested in vernacular architecture and construction techniques. Groups of people from different backgrounds started to come to the village and to take part in courses on

[40]Interview Ostad Habib (April 2019).

[41]Architect Faramarz Parsi visited the village and was interested in the variety of houses, building techniques, integrity of the overall settlement, and not least the interest shown by the group of young local people. The architect and his firm collaborated with the village, starting from the consolidation of the damaged buildings that were planned to be restored. Following the first interventions, professionals and other collaborators from outside the village have tried to methodologically support a detailed study of the house typologies and interiors to make sure that, with any new restoration, most of the houses' characteristics from before the earthquake would be maintained.

Figure 9. A sitting vault with different pitched-brick dispositions; Chiruk, a village near to Esfahak.

vault making organised in partnership with the villagers and craftsmen who were already involved in the restoration initiative.[42]

Experience is of primary importance when working on craft-based techniques. Building skills are developed based on knowledge that is refined through years of empirical practice. Even the most experienced craftsman had to confront with the difficulties of restarting work with earth-based materials. One particular example is significant in showing this fact: in one of the first buildings restored, a barrel vault collapsed in the process of being erected.[43] Not all first attempts were successful, even though gradually, craftsmen have developed or redeveloped their skills, starting a new phase of learning and experimenting with traditional construction methods. Not only were a number of houses restored, but also the old mosque (in partnership with the Ministry of Cultural Heritage, Tourism and Handicrafts) parts of houses were converted into other facilities – a canteen and reception for guests visiting the village, handicraft and local product shops – and the old public bath was also restored and brought back to function, with the creation of a "diffused welcoming facility" that spread throughout the old settlement. Considerable resources were invested in the public bath project and, differently from all previous restorations, the project became a real challenge. The scale of the project would normally have required more expertise and collaborators, but despite the difficulties the group of villagers who engaged with this project did not give up. The project was completed and delivered and the building was adapted to become a fully functioning bath again. The public bath project was an occasion to send a call-out for volunteers, which had no response from within Esfahak itself but from elsewhere, as volunteers came from other towns and cities. They were people originally from Esfahak but who were working in other places and decided to answer this call for help. This was an occasion to tie new bonds with these Esfahakis, giving them a reason to come back and collaborate in the regeneration of the old village. Figure 10.

Restored houses were integrated with gas stoves, electricity and flushing toilets, but were not fitted with air

[42]The 'Esfahak Mud Centre' was established in collaboration with architect Pouya Khazaeli. The centre has become the main hinge around which courses on traditional building techniques are held.
[43]Interview with Ostad Hossein and Mohsen Mehdizadeh (April 2019).

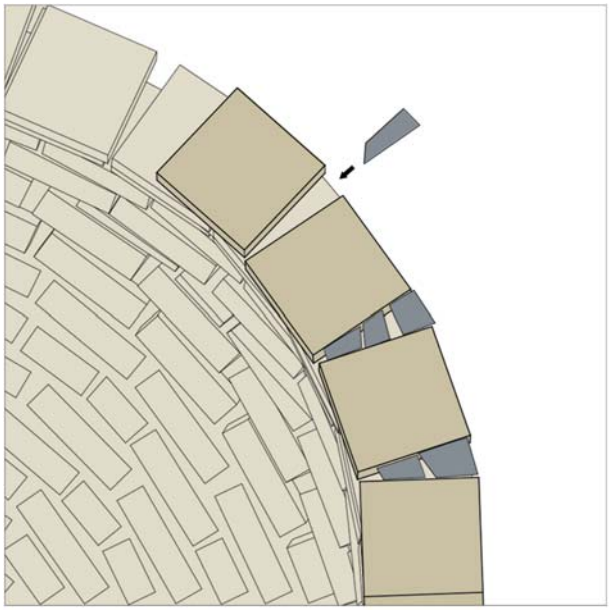

Figure 10. Placing stones (*gaaz*) between mud brick joints in a vault.

conditioning or heating. These pieces of equipment were not considered necessary within traditional buildings, which offered an alternative response to climatic factors. There has been a will not to completely alter these buildings with the introduction of large-scale equipment, and to keep on utilising traditional building techniques. Buildings were reinforced with steel tie rods between vaults and some of the vaults themselves were integrated with detachable mesh-nets, both of which are retrofitting techniques allowing masonry structures to better cope with earthquakes. In this sense, only a few removable elements were added to the buildings. The building techniques are unaltered in their essential constituting elements. The whole structure of these buildings is earthen and vaults' implementation, which is mostly centring-free and executed by eye, owing to the bricklayers' skill. Figure 11.

It is interesting to notice that from the time these initiatives started, many people changed their way of referring to the old settlement. They have moved from defining it as "the old soil" to "the historical fabric" (*baft-e tarikhi* or *baft-e qadimi*). Surely, not all villagers might agree on the new definition, but this shift made by some was the result of a transformation process which has much to do with the intense restoration activities carried out in the last six years. Perhaps, this also shows a change in local awareness and perception of the old settlement, a transformation that was unlikely to happen in the past. In the last few years, many more people from Esfahak have become convinced of the quality of the restoration projects carried out and on further possibilities offered to the village by this new initiative.

3. Traditional Construction Techniques: Re-Engaging with Local Material and Immaterial Architectural Heritage

آنچه در آیینه جوان بیند، پیر در خشت خام بیند

What the young man sees in a mirror, the aged man sees in a mud brick' (popular saying)

Traditional construction techniques are generally the common ground shared between any kind of historical building, especially in areas that are defined by similar material availability. The same technologies and structural systems can often be found both in village houses and in mosques or palaces. At the village level, there are today but a few craftsmen who still actively work with traditional construction methods as a consequence of the progressive disappearance of these techniques as part of everyday construction activities. It is only in some restoration projects that careful attention is paid to traditional building methodologies.[44] Nevertheless, restoration projects are generally coordinated by a team of trained professionals – architects and engineers – whose education and life experience are often devoid of direct connection to a place, whether socially, economically, or even linguistically. Figure 12.

In any case, large-scale projects are drastically different if compared to constructions at the village scale. Traditionally, the building activity in villages is not only the prerogative of specialised professionals, but is often a collective practice which sees inhabitants directly engaged in construction activities. It is known that vernacular architecture is often "without architects, but not without builders".[45] The construction of houses, especially in the past, was integrated in the larger village organisation system, comprising the management of water, agriculture and animal breeding. Traditional builders in small areas were often farmers involved in many other activities. Building was amongst that necessary set of skills that were needed to live in a fruitful relationship with a place. Figure 13.

3.1. Mud Bricks at the Base of Almost Everything

Except from the cultivated fields, the arid soil of South Khurasan can be easily employed for mud bricks, the

[44]Talebian and Ebrahimi, "Traditional Experiences", 135
[45]Schefold, R. "Anthropological", 8

Figure 11. Ostad Ali during the construction of a 1:2 model of a sitting vault in a workshop in 2018.

Figure 12. The making of a squinch vault during a workshop in February 2018.

Figure 13. Perpendicular arches on the side of a vault (*palaneh*).

almost exclusive building material available. The arid regions of Eastern Iran are characterised by a massive use of earth and gypsum for construction, techniques that were to remain fixed characteristics from the Medes times onwards.[46] In Esfahak, the use of timber is scarce, remaining confined to the making of wooden frames. Figure 14.

Mud bricks, known as *khesht,* are the essential construction units in Esfahak. They are sun-dried, therefore unfired. The optimal time to make bricks is when it is neither too hot nor too cold. The bricks need to dry out thoroughly, but slowly, to avoid fast shrinkage in summer and cracking, or freezing in winter months.[47] If bricks are to be made in the summer, they should be dried in a shaded area to avoid rapid drying. Brick preparation requires planning and storage space, which in a

[46]Stronach, "Archeology-Iran"
[47]All data gathered on mud bricks in Esfahak were collected primarily through direct experience of their production in the village in January–February 2018 and September 2019. Interviews were also carried out via mobile phone in October and November 2020 with Mohsen Mehdizadeh.

Figure 14. The making of gypsum frameworks (*tavizeh*) during a workshop in September 2019.

village is not always possible. Bricks are of square shape and their size is generally 20 cm by 5–6 cm thick. These proportions have been widely standardised across different regions in Iran, with travellers' accounts already reporting on them in the early twentieth century.[48] Bricks of these dimensions can be easily handled by the bricklayer or master mason, particularly when they have to be raised above one's head during the construction of a vault or dome. In some parts of Iran, bricks are composite building elements constituted by earth rich in clay and chopped chaff, which is needed to compensate the high shrinkage of clayey soil, as well as making the bricks more compact and lighter.[49] In Esfahak and nearby villages, mud bricks are made without vegetal fibres, while sometimes they are rich in small stone fragments as the earth was not always sieved. Brick making as well as brick components are not always the same across Iran, not even in nearby areas. Figure 15.

Mud bricks for construction were usually larger in antiquity and the early Middle Ages compared to contemporary ones, which can vary within a size of 20–22 cm per side; much smaller if compared to those of the seventh and eighth centuries B.C.E. found in Urartian fortresses, which measured about $50 \times 50 \times 12$ cm.[50] The availability of clay-rich soils in Iran fostered the use of mud for construction, originally with amorphous shape or in a plano-convex one – similar to bread loaves. These primordial earthen construction units came into being in Persia possibly in the eighth or seventh millennia B.C.E.[51]; they were cigar-shaped and located at Ganj Dareh near Kermansha in the level E walls.[52] The most ancient examples of mud bricks were hand-formed and employed when not completely dried. As specified by Callieri, it is only in a later stage that moulds were employed to make bricks, facilitating not only their manufacture, which became quicker, but also allowing for an alternation of the vertical and inner joints in the masonry that permitted the use of mud mortar, with the result of obtaining a more compact structural system.[53]

[48]Floor, Traditional Crafts, 48–54
[49]Hejazi and Saradj, *Persian Architectural Heritage*, 12
[50]Baimatowa, 5000 Jahre, 31-39; Kleiss, "Construction Materials"
[51]Ibid.
[52]Azarpay, "Brick"
[53]Callieri, "Terra e Pietra", 88

Figure 15. The use of a gypsum centring for the construction of a *rumi* arch on a door.

Fired bricks, known as *ajor*, are less commonly employed in desert village architecture. Their firing in kilns was an expensive and elaborate procedure that was not possible except for use in smaller quantities for common houses. As reported by Floor in a passage from Afzal Al-Molk Kermani from his *Safarnameh-ye Khurasan va Kerman*: "in Ferdaws the quality of mud bricks was such that houses were even 300 years old at the beginning of the twentieth century, underlining that only the floor covering of houses" entries were paved with fired bricks'[54] In Esfahak, this is confirmed by the analysis of houses in the old settlement and helped by the observation of the restored buildings, which were mostly based on a "philological" reconstruction carried out with the help of village families who described their old houses. In the historical village, the restored constructions present fired bricks only inside and around water basins (*hoz*) and/or to pave parts of the inner courtyards. Figure 16.

3.2. Cineh, an Alternative to Mud Bricks

As an alternative to sun-dried mud bricks, many walls are built with earth lumps, with a technique called *cineh*. This method is amongst the most economic ways of building with earth, a technique that is known in Russian archaeology as *pakhsa*[55], a term still in use in Afghanistan today. These walls are made of an earth mixture, which is very lightly dampened and thoroughly mixed. The earth used does not need to be very rich in clay, but it can be relatively rich in stone fragments, sand and pebbles. In Esfahak, the earth is mixed and shovelled into large lumps (locally called *gondeh*) to form the wall. Once a layer is formed by juxtaposition of a series of lumps (circa 30–50 cm), a new course can often be started as the scarce amount of water allows each layer to dry very quickly. Many refer to this technique with the French term *pisè* or the English equivalent "rammed-earth". It needs to be specified that these terms may be incorrect equivalents since earth lumps are often (as is the case in Esfahak) put into place without the use of frameworks or ramming tools. Lumps are placed and shaped only with a shovel. The technique is more similar to cob, considering the way it is implemented, but even with cob it may have differences. Cob walls are generally made with a mixture of earth and light fibres (usually vegetal) needed to obtain a more cohesive mix and prevent cracking. A builder is in charge of coordinating the construction while assistants mix the mud and shovel it according to instructions. *Cineh* is mostly employed for walls of great length, like precincts and fortifications. In some cases, especially in Esfahak, thick walls for residential constructions are also built using this technique. This technique becomes crucial when there is no possibility to make bricks in advance or there is a paucity of water. In Esfahak, *cineh* is also used in combination with mud bricks and it is common to see a brick course laid every 50–60 cm in house walls. These are used to straighten the horizontal courses and help maintain a constant wall thickness. As explained by Ostad Habib, when earth is dug out from a site and it is abundant (especially when a construction is partly sunk into the ground), *cineh* is the quickest way to employ earth for wall construction: it is practical and allows for improvisation. Little water is needed, as it is only used in minimal amounts to activate the binding properties of clay. Thus, the mixture is relatively hard and cannot be

[54]Floor, Traditional Crafts, 50
[55]Callieri, "Terra e Pietra", 88

Figure 16. Abandoned house in ruin, March 2018.

poured like the one used for brick making. The best mixture is obtained when it is workable but stiff at the same time. This also explains why this technique is more often used for boundary walls, or when there is no time to plan the production of bricks. The higher content of sand and stones also helps the wall to avoid excessive shrinkage and cracking. Figure 17.

3.3. Vaults and Domes in Esfahak

Softly curved rooftops are the hallmark of Esfahak's traditional landscape. In this treeless region it is not only impossible to procure enough wood for beams, but it is also unfeasible to rely on temporary structures to support the construction of vaults. It is only through specific building techniques combined with a wise use of local resources that it is possible for traditional builders to cover any kind of space with mud bricks. It is argued here that this capacity lies mostly in the empirical skill of adapting the vault shape to any kind of plan typology and that this is achieved thanks to a specific bricklaying technique sometimes combined with the use of gypsum frameworks. When one type of vaulted roof is not sufficient, more types are combined together.

3.3.1. Typologies of Vaulted Roofs According to Brick Disposition

One of the fundamental characteristics which defines vault and dome construction is the way bricks are laid. There are four types of brick dispositions: 1. corbelled; 2. radial arch of the "thin" type; 3. radial arch of the "thick" type; 4. pitched-brick arch type, or *pitched-brick courses*. The corbelling technique is rarely found in Esfahak. Domes and vaults built with corbelling elements present a curved shape even if their structural behaviour differs substantially from that of the other types. Structurally, a corbelled building only transfers its loads vertically onto the lower part of the masonry and foundations. In corbelled structures there are no lateral thrusts to be transferred, while arched, vaulted and domed constructions necessitate a way to distribute lateral thrusts through the walls to the foundations.

The latter three methods are commonly employed in Esfahak and in particular the last one:

1. The radial arch of the "thin" type. Bricks are laid having their broad face towards the intrados. This technique is only used to span small openings or corridors, given the overall thinness of the arch or vault obtained, which is only as thick as a brick.

Figure 17. Abandoned house (same as the previous photograph) in the process of being restored, September 2019.

This method is known in Farsi as *chapileh* or *lapush*.[56] According to Pirnia, this method is sometimes used above windows that already have a thin wooden beam so that loads are better distributed onto lateral walls. In this way, more than one layer can be overlapped, creating a series of concentric arches, which are known as *palaneh*[57];

2. The radial arch of the "thick" type. Bricks are laid having their stretchers towards the intrados and extrados of the structure, and having their broad face parallel to the long side of the room. It is necessary to use a temporary supporting structure to lay bricks. This technique requires the use of centrings and it is known in Iran as *rumi*, which might easily sound as if this method was related to the Eastern Roman empire.[58] It is widely known that radial vaults were in use in Egypt and Mesopotamia much earlier than when employed by the Romans, therefore a more precise explanation for the adoption of this term would be necessary;
3. The pitched-brick arch type. Bricks are laid having their stretchers towards the intrados and extrados of the structure and having their broad face parallel to the shorter side of the room. To implement this technique, it is necessary to lay bricks in inclined courses, a way that is defined in this article as the *pitched-brick-course* method, or as it was once defined by Galdieri, "reclined segments" (from Italian *segmenti reclinati*). The term "pitched-brick" was originally coined to describe a type of vaulting technique that developed in mud brick in Egypt and Mesopotamia around the third millennium B.C.E..[59]

3.3.2. At the Origins of Vaults and Domes in the Iranian World

Before tackling the technological details of the specific kinds of vaults and domes in Esfahk, it is worth analysing the ancient models and predecessors of these roof typologies. Vaults made of mud bricks were common in the Near East from the fourth millennium B.C.E., with many examples in ancient Egyptian sites. Vaulting became common in Persia in the second millennium

[56]Pirnia, "Cefd-ha va Taq-ha", 43
[57]*Ibid*., 57
[58]*Ibid*., 53
[59]Lancaster, "Early Examples", 371

B.C.E., even if vaults of fired brick with gypsum mortar had already been introduced at the Elamite site of Haft Tepe.[60] Until the first century C.E., wooden roofs were used in parallel to the development of vaulted structures[61], even though it is likely that climatic conditions of timberless regions had already imposed the employment of vaults much earlier. The paucity of wood makes centring-free vaults a necessity rather than a choice.[62] It is for this reason that pitched-brick vaults, more than other kinds, became necessary in many areas of the Iranian plateau. The technique is generally agreed to have been developed as a way to avoid or reduce the use of wooden centring[63]:

> the main materials used were mud bricks, mud mortar or alternatively mortar made from gypsum, which required a much lower burning temperature (200 °C) as compared to limestone (900 °C); moreover, gypsum mortar also sets much faster (in minutes) than does lime mortar (3–4 h). Thus, the structure was built by "gluing" the first layer of bricks against a wall in the appropriate curved shape also thanks to the quick setting mortar.

Median builders depended heavily on the use of mud brick and plaster, which was to remain a fixed feature in the arid zones – "this determination to build wherever possible with mud brick elements, including curved vault struts, recalls a similar inclination in the less forested regions of the east Iranian world" – with the interest in wooden columnar construction that had already taken a strong hold in the northern Zagros from the beginning of the Iron Age.[64] It is attested in the site of Tepe Nush-e Jan, around the seventh century B.C.E.in Media, that another kind of pseudo-vault was used to cover narrow spaces like corridors and ramps: prefabricated curved elements (or vault struts) were cast using reeds or thin branches, which were held together by a mud mixture that was left to dry in the sun. These elements, made in pairs and symmetric, were later combined to form a type of vaulted roof to cover short spans. In the late Parthian period, the application of the vaulted *ayvan* to the main units of a building revolutionised the visual aspect of Iranian architecture with the replacement of columns by vaults, even though: "barrel vaults of brick had been built as much as a millennium and a half earlier".[65] In the ancient world, the acme of pitched-brick vaulting was reached in the Taq Kisra, in the great hall of the palace at Ctesiphon in today's Iraq, made of fired bricks spanning more than 25 metres. This vault has a parabolic section, a characteristic of many Iranian vaults of the time, which has an ideal shape for the thrust forces to be transferred to the ground.[66]

The dome, the other fundamental structural element, first appears consistently in the Sassanid period, after the isolated example of the Round Hall in Parthian Nisa (in today's Turkmenistan).[67] It is widely accepted that parabolic domes are one of the most essential innovations of the time, used for reception halls in palaces and temples.[68] The necessity to cover a square room with a dome needed a specific technical solution. The transition between the square plan and the circular springer seems to have developed autonomously in the Iranian world as compared to the solutions adopted in the Eastern-Roman empire. The Romans solved this issue with pendentives (which are portions of a sphere), while in ancient Iran the technological answer was not originally geometric, but empirical; even if the structural distinctions between the two elements are not significant.[69] Amongst the remaining buildings in which this methodological innovation was adopted are: *chahar-taq*[70] structures, many of which possibly fire temples like Nisar, and the monumental dome of the Qaleh-ye Dokhtar and the Palace of Ardashir I in Firuzabad, both erected in the early third century C.E..[71] The method is based on a device called a "squinch", where a series of concentric arches, which are built across the corner of the square, advance one above the other until the overall dimension of the plan is reduced enough so that it is possible to start the construction of the domes' circular base.[72] The squinch employed

[60]Kleiss, "Construction Materials", quoting Negahban
[61]Callieri, "Terra e Pietra", 90
[62]Diez, "B. The Principles and Types", 918
[63]Lancaster, "Early Examples", 372
[64]Stronach, "Archeology-Iran"
[65]Keall, "Architecture Iran"
[66]Callieri, "Terra e Pietra", 91; Creswell, Early Muslim Architecture
[67]Baimatowa, 5000 Jahre, 204-214; Callieri, "Terra e Pietra", 91
[68]Ashkan and Ahmad, "Persian Domes", 101
[69]Callieri, "Terra e Pietra", 91; Gye, "Arches and Domes", 143
[70]*Chahar-taq*. Huff and O'Kane define it as 'four arches' and this is a modern way to refer to 'an equilateral architectural unit consisting of four arches or short barrel vaults between four corner piers, with a dome on squinches over the central square; The term probably originally became current because it seems descriptive of many ruins that can be observed in Iran. Most of these ruins are, however, only the surviving cores of more complex buildings from which surrounding walls, ambulatories, and subsidiary rooms have disappeared' (Huff and O'Kane, "Chahartaq"). Nevertheless, the term cannot be used to define a unique functional building type, and it is preferable to consider it in its literal sense as a way to refer to an architectural form (*Ibid.*)
[71]Huff, "Firuzabad"; Kleiss, "Construction Materials"
[72]Creswell, "The History and Evolution", 683

to erect a dome might derive from the squinch vault, a vault constituted by four half-cones advancing towards the centre of the room.[73] The use of these ancient types of vaults, including the squinch vault and dome are clearly visible in many domestic buildings in Esfahk and other villages, especially in Central and South Iran. It is clear that ancient models of the barrel vault and the dome are rooted in the traditional buildings of the people.[74]

3.3.3. Constructing Without Centring, or the "Pitched-brick-course" Technique

The erection of vaults without centring is the characteristic element of Esfahak's architecture. A fine observation of existing vernacular buildings also reveals that, usually, more than one typology of vaults and brick dispositions are combined together. This gives rise to interesting mixed roof typologies. Often, arches erected with centrings are also used as starting points for vaults and domes without centring. Nevertheless, at the base of all these variations are some basic typologies.

The pitched-brick-course method relies on inclined bricks to make sure that successive layers are positioned and loads are transferred directly to the lower structure, whether to the walls, an arch, or a previous brick course. Because each layer supports the next one, pitched-brick constructions can be stopped almost at any time, since the structure would remain up right without the need for a temporary support; moreover, mud mortar spread thick between the bricks keeps them from slipping.[75] The success of this method mostly relies on the empirical experience of the master mason, since these structures are built mostly by eye. Often, the vault shape does not conform to a definite geometrical model replicated by precise measurements. The experienced mason adapts the shape of the roof to each specific building plan and case scenario. The geometric model is only ideally replicated sometimes: a semicircle, a parabolic arch, etc. The vault is generally improvised on the spot. This is achieved through a delicate balance of the right inclination of the courses, which is always obtained empirically, thus with no pre-fixed formula. The possibility "to model" the right roof like a sculptor is to be seen as a great advantage, especially if one thinks of the construction of a house in the past. When material resources are limited and time is precious, the great skills of a master mason can play a crucial role in the erection of a house, which is a primary necessity for any settled group of people. Retrospectively, this knowledge might have made the difference between perishing or surviving in these harsh climatic conditions. Timewise, the execution by means of the pitched-brick-course technique is very convenient compared to other ways requiring centrings. The reason for this is that a radial vault, which is built on bricks and rubble centrings, is very time-consuming. The material necessary for the operation and the time needed to first fill in and later empty the whole structure is inconvenient for everyday-use buildings.

The main typological differences of pitched-brick-course structures are between those covering rectangular plan rooms, or any kind of elongated and narrow space, against those covering central spaces, which are typically square rooms. Barrel vaults are employed to cover rectangular rooms, and these are referred to as *taq-e zarbi* or *par*.[76] Pirnia claims that the term *zarb* is used in architectural jargon with the meaning of *zadan* (hit, slap, strike).[77] Perhaps this refers to the way bricks are placed during the execution of the pitched-brick-course method. Bricks are firmly slapped onto the previous layer, which is covered with thick mud mortar. Otherwise, *taq-e zarbi* could simply mean multiplicated arch.

3.3.3.1. **Taq-e Zarbi** *(Barrel Vault) Without Centring: Execution's Procedure.* There are two kinds of pitched-brick-course barrel vaults in Esfahak: *aspardar* (which can be translated as: having a shield or non-load-bearing wall – *aspar* or *separ* – from now on referred to as *shielded vault,* and internationally known as Nubian vault), and *kunbezamin* (which, to avoid its crude translation, is from now on referred to as *sitting vault*).[78] The difference between these structures is only in the way they are started. Their longitudinal development in plan is the same, as well as the way in which they are closed at the end.

Starting a *shielded vault* – Once the vault's springer level is reached, a supporting wall needs to be erected on one of the shorter sides of the rectangular room. This wall is erected so that it is at least as high as the vault that needs to be built. This structure supports

[73]Godard, *Athar-e Iran 1949*, 195-196, after Reuther and Diez
[74]Diez, "B. The Principles and Types", 916
[75]Van Beek, "Arches and Vaults", 100
[76]Bromberger, "Banna'i"; Pirnia, "Cefd-ha va Taq-ha"
[77]Pirnia, "Cefd-ha va Taq-ha", 48
[78]All data on vault making were gathered in January–Febraury 2018 and September 2019 during the making of mud brick vaults in Esfahak. The researcher took part as a volunteer builder under the guidance of three expert masons (Ostad Ali and Ostad Habib, respectively from Chiruk and Esfahak, and their younger fellow Ostad Hossein), in collaboration with the Esfahak Mud Centre.

the first pitched-brick-course arches. Stone fragments and brick pieces are mixed with mortar and placed on both vertical corners onto the back wall: they are modelled to form a reclined base on which to set the first pitched bricks. On these bases – symmetrically on both sides – bricks are placed so that they can lean against the back wall. At the beginning, only a series of incomplete arches are built: they are symmetrical and not closed at the top with key mud bricks. After one or more layers of incomplete arches, the vault starts taking shape when the first complete arch is closed and the structure starts to develop horizontally towards the main room axis.

Starting a *sitting vault*[79] – Once the vault's springer level is reached, the vault can already be started, as one of the advantages of this kind of roof is that there is no need for any other supporting wall. A first brick is laid with mud mortar in the middle point of the shorter wall side. On top of it are placed a few bricks (two / two and a half), which are secured with mud mortar and form the first and smallest arch of the vault. Above them rise a series of arches, which are laid along the wall until the wall corners are reached. From this point, this series of arches is warped so that the vault structure itself curves at the corners. The vault literally wraps the room's corners and takes an external round shape, which is similar to a semi-dome "sitting" on the walls from the outside. After the structure reaches beyond the corners, the builder slowly forms a pitched laying bed for the brick courses.

a. The arch courses

For the arch courses, bricks are always laid from both sides of the longitudinal axis walls. Bricks are placed in a symmetrical way until the mason reaches the top of the arch/vault. The craftsman generally shapes the last brick (the key) with an axe, to fit it precisely between its two sides. For the next arch, joints are shifted by means of halving or reducing the size of the first bricks laid on both sides.

b. Mortaring bricks

A thick layer of mud mortar (2– 3 cm) is spread by hand on the previous arch. The mortar is placed so that it is thicker in the central axis of the arch. In this way, it can be spread evenly under the following course once new bricks are pushed and glued over it. The excess mortar is squeezed out from the layers and it is scraped by hand with quick movements while courses are levelled.

c. The pitch or inward tilt

With the construction and extension of the vault along the longitudinal axis of the room, bricks can be slightly tilted inward towards the intrados, even if never placed vertically. It is only near the edges before a vault is closed that bricks are fitted almost in a vertical way. This is only possible if bricks are firmly slotted between previously set courses from both sides. The more these courses are set in a vertical way, the more they are susceptible to cracking, sliding and collapsing. These ends are the most fragile barrel vault sections.

d. Lateral tilt, square bricks and *gaz*

Bricks are also tilted along the arch axis. The builder slightly tilts every new brick rotating it laterally so as to follow the shape of the imaginary arch that is to be built. Thus, brick stretchers do not perfectly adhere to each other. Square brick stretchers' sides touch each other's on the inward edge only. A triangular space is left between them, which is generally filled with stone fragments. These stones are called *gaz* (meaning tooth, a sharp tooth, perhaps because the ideal stones have to be of triangular shape and of the right size to fit in between two brick stretchers). The importance of *gaz* was remarked on by Ostad Habib when he remembers a former fellow builder of his who decided to speed up the construction process of a vault without putting any *gaz* between bricks.[80] The vault tragically collapsed on the man, who lost his life in the endeavour. Mud mortar shrinks creating discontinuities and it is necessary to fill up any empty spaces between bricks with solid pieces of stone or bricks. Only in this way it is possible to guarantee the overall vault's stability.[81] Square bricks are ideal for a centring-less vault making as they assure the minimum thickness of 20–25 cm, which is generally enough to erect village houses of one or two floors.

[79]It is worth mentioning that this vault is relatively uncommon compared to the *aspardar* one, and found mostly in the central regions of the plateau, in particular in Khurasan and Sistan (Wulff, *The Traditional Crafts of Persia*, 112).
[80]Interview with Ostad Habib April 2019.
[81]This is an issue that can be explained by the application of thrust line analysis, a way to determine the amount of lateral thrust in structures under a given set of conditions. As clearly explained by Lancaster: 'the line of thrust in a vault is a graphic representation of the internal line of force vectors within the structure. As long as the thrust line remains within the structure it is stable. Places where the thrust line touches the boundaries of the walls or vaults are where cracks may develop and threaten stability ("Early Examples", 385).

d. Closing the vault

Vaults can be closed in many ways. In some cases, they are left open at one end so that it is possible to just leave the last course with the same pitch as the rest of the vault. This solution is very stable but it can hardly be used for houses and it is more common for working buildings since the end side is inclined. In many cases, vaults are closed at an intermediate point as the construction proceeds not only from one of the short sides of the room, but from both. In this case, the two sides merge at one point and courses are alternated until the elliptical slit that is left open in the roof is closed with brick fragments and mortar, or a skylight is created. Sometimes the vault finishes against an arch of the *rumi* type that has been erected earlier, or otherwise against a gypsum formwork.[82]

Much has been written on domes, e.g. their evolution and transformations across Iranian history[83] thus what is presented here is only a limited coverage regarding their use and execution in Esfahak. To cover central spaces with roofs is achieved by either squinch vaults or domes (*gonbad*) of spherical or conical shape. Commonly, squinch vaults, or quadripartite vaults[84], are built on square rooms. Four squinches are built at each corner and extended to meet towards the central point of the room. Also in this case, thanks to the use of the pitched-brick courses, the four squinches can advance and cover the space. As seen in many historical examples, large rooms can be covered by combining the squinches to a dome that surmounts them. Even here it is necessary to apply the pitched-brick-course technique when the dome on the squinches is built with mud mortar only and no gypsum, since mud mortar has very little gluing effect. Domes are more often found on top of central spaces, for example rooms across the main house axis at the centre of the *2-sofeh* and *4-sofeh* patterns, or else on top of a vestibule (*hashti*)[85], which is only found in large houses. The use of domes is generally intertwined with that of gypsum arches and *rumi* arches, which results in spatially interesting solutions having different heights and functions inside the house. The construction of a dome between arches (*rumi* type) is made by first filling the spaces left between the arches with courses of mud bricks. These are also set with an inclination so that once the springer level of the dome is reached, a circular layer of inclined bricks serves as the base for the continuation of the dome above the arches' crown.

An interesting device used to obtain flat roofs above vaults is known in Esfahak as *palaneh*.[86] *Palaneh* are a series of small arches above thin walls built on both sides of a vault.[87] These are built with bricks laid in the *lapush* way, rising across the lateral sides of a vault, and allowing the juxtaposition of a flat surface, which puts minimum weight on the lower structure (a hollow superstructure). In this way, a minimum amount of material is needed to make the arches. Arches and walls also form perpendicular partitions above the vault (similar to ribs), which have been shown to be excellent structural reinforcement in the event of an earthquake; this was revealed from an analysis of the vaults that survived the Tabas earthquake. Flat roof areas are used to eat and sleep during summer evenings as they are elevated platforms, functioning also as passageways to inspect the roof and carry out the maintenance of earth layers used as external protection coating. All vaults are generally covered both outside and inside with a mixture of earth and hay (*kah-gel*). Sometimes the inner surface of important rooms is coated with gypsum to obtain a more luminous and smooth finishing.

3.3.4. The Master Mason on Site: A "Sculpture of the Soil"

The main audible voice throughout the construction process is that of the master mason, who is also the bricklayer. Bricklayers rhythmically beat the time with their alternated requests for mortar, bricks and stone fragments, which are shouted with long sounds: *gel, khesht, gaz*. Bricklayers stand next to the vault and are provided with materials by assistants as the execution proceeds quickly. A group of people bring materials while a few others constantly prepare mud mortar in a pit near to the site. The division of labour on site today is comparable to that of the few historical images available regarding constructions in the Persian world from medieval to modern times: for example, a large number of workers assisting the master mason/s.[88] Some tools have changed – for example, clay pots are replaced by plastic hoses and wooden-cloth containers are replaced by metal wheelbarrows. Nevertheless,

[82]Gypsum formworks making is explained in the concluding part of this section.
[83]See for example: Bromberger, "Banna'i"; Creswell, "The History and Evolution"; Galdieri, Masg˘id-i G˘um'a; Godard, *Athar-e Iran* 1949; Labisi, "Squinches and Semi-Domes"; O'Kane, "Domes"
[84]Beazley and Harverson, *Living with the Desert*, 24; Godard, *Athar-e Iran 1949*, 221–223
[85]Foruzanmehr, *Thermal Comfort*, 26
[86]Interview with Ostad Hossein February 2018, and with Ostad Habib in April 2019.
[87]Wulff, The Traditional Crafts of Persia, 112
[88]McClary, "Persian Paintings", 221

many others – like shovels and the bricklayer's axe – have remained consistently the same. Many actions of the making process are similarly depicted in ancient paintings from the fifteenth to the nineteenth century alike, e.g. preparing mortar and laying bricks.[89] In historical images, bricklayers have a superior hierarchical position that is underlined by their clothing. For the construction of vernacular buildings today in Esfahak, master masons are no different to anyone else in terms of clothing, even though they remain the focus of attention because of their knowledge. If scarce attention was paid to construction works in the past, as evidenced by the limited number of depictions available, it is nowadays interesting to witness quite the opposite phenomenon in Esfahak. During the courses held in the village for professionals, students and even amateurs, a small crowd gathers around the master mason. People take pictures and record the bricklayers' actions for the whole construction. Documentation pictures are also taken informally by the villagers while they are reconstructing their own houses in what was earlier referred to as "the process of learning and re-learning these techniques". All work on-site converges on the masters' hands and actions, since that is the focal point of both material and immaterial processes. The instantiation of mud brick structures unfolds under the master masons' skilful hand gestures. This latter fleeting aspect is nowadays commonly video-recorded in an attempt to preserve at least part of it.

3.3.5. Constructing with Gypsum Arches: Tavizeh

Tavizeh is a composite architectural device that is made out of gypsum and thin tree branches. In Esfahak, *tavizeh* is "reinforced" with pomegranate branches or alternatively with palm leaves. These are in the form of arches and are used both as centrings and semi-structural or structural elements. In many areas of Southern Iran, they are known as *tavizeh* – possibly meaning curved branches or rainbow, even if they are also called *langeh, barikeh* or *chashmeh*.[90] In domestic architecture, they are often used as centrings for small radial arches (*rumi*) on top of doors and windows, or at the intersection of other vaults. *Tavizeh* is made by casting the arch shape into a mould. Therefore, the ground is levelled and covered with a thin layer of dust or earth to avoid the gypsum from sticking to pebbles and so as to easily remove the casted arch once dried. The cast is marked off with bricks on the ground. Bricks are laid next to each other and also placed according to the desired final thickness of the curved formwork. Brick stretchers define the curvature and, in the case where the final arch will be used inside the structure, it is very important to carefully mark out the outline with precision.

In contrast, when *tavizeh* is used to build centrings as a temporary support, only its upper surface needs to be smoothly cast. In this case, the manufacturing of the inner surface is irrelevant and it can be roughly outlined. Once the cast is ready, a first dose of dry gypsum powder is mixed with water and activated. Once it is thoroughly mixed, gypsum is poured into the mould until half of the cast is filled. Available branches or vegetal fibres are laid inside the mould in semi-hardened gypsum. The rest of the gypsum is prepared with water and rapidly poured into the mould. Once the gypsum in the formwork has partly set, it is important to remove all bricks around it. Nowadays, in the village, a plastic sheet is put on the ground to mark the arch's outline, which is also helpful in easily removing the finished *tavizeh*. Entire arches can be cast in this way, but only of small size, so generally not exceeding a span of 2 metres. To create larger arches and centrings it is necessary to cast different parts to be later joined with more gypsum[91], since they are relatively heavy and fragile to handle.

When *tavizeh* is used as centring, the formwork is placed by two people between the walls where the arch will have to be erected. To avoid leaving an empty gap at the arch's springer when the formwork is placed on top of the walls, *tavizeh* is temporarily fixed by means of gypsum. A thick gypsum paste is put on the wall sides as a base for the centring, acting as two cantilevers. Because of the rapid solidification of gypsum, the formwork can be placed rapidly. When the centring is ready, mud bricks can be laid radially on top of the *tavizeh*. When the arch is complete, the temporary gypsum cantilevers are hammered off the wall and the formwork is gently removed.

In Esfahak there are many examples of *tavizeh* used partly as a structural element and partly as end sections of a barrel vault. The fact that they can be pre-cast makes them useful and precise references to construct the rest of the roof; as explained, for example, by Godard in the *chahar-taq* of Nisar, as well as for modern constructions like the Imamzadeh Yahya in Tehran at the beginning of the twentieth century.[92] When *tavizeh* is used to complete one end of a barrel vault, the formwork is placed on the short side of the rectangular room, opposite to the side where the vault was started. *Tavizeh*

[89] *Ibid*.
[90] Pirnia, "Cefd-ha va Taq-ha", 84–86
[91] Godard, *The Art of Iran,* 186–190; Pirnia, "Cefd-ha va Taq-ha", 91
[92] Godard, Athar-e Iran 1949, 196–207

is needed in this case to create a vertical closing element for the terminal part of the pitched-brick-courses barrel vault, which would otherwise be inclined. In Esfahak, the use of *tavizeh* is always present on the external side of an *ayvan*, but it is also used towards the inner space of both *2-sofeh* and *4-sofeh* houses at the crossing of the rooms along the main axis. These formworks are partly structural elements and partly centrings as they remain embedded in the structure and foster the laying of successive brick courses. When the roof extends upwards above the crossing point of different rooms, domes or other vaults are built on top of these embedded *tavizeh*.

4. Conclusions

The construction of vaults and domes, in particular without centrings, is a millennial architectural tradition that persisted with several local variants throughout the Iranian plateau and many other parts of the Persian World. This building tradition was in many cases drastically left behind in the last century in Iran. During the twentieth century, material, economic and social factors contributed to the abandonment of traditional building techniques. Among the first group of factors was the growing industrial production of architectural elements and the introduction of different technologies, which fostered a widespread substitution of locally sourced materials. Part of the latter are the several social reasons that are connected to village life transformation, water and land management, and working opportunities linked to mobility. In Esfahak, this process took place abruptly after the Tabas-e Golshan earthquake. The old settlement of Esfahak was abandoned and another village was built anew with completely different materials, techniques, house patterns and overall planning criteria. After 1978, earthen buildings were left together with their related construction techniques. In that moment, the experience and knowledge of possibly the last generation of craftsmen was about to be lost. Agricultural practices were maintained around the old village, but for more than 30 years houses were completely abandoned. The former settlement decayed progressively as it was widely referred to by older and newer generations as the "old mud". The recent transformation of the old settlement allowed for a reintegration of traditional architecture into the village life: materially, economically, socially and culturally. The transformation of the neglected settlement into the "historical fabric" is not just the mere consequence of architectural restoration, nor of a change in name, but it also marks a transformation of values. If economic aspects linked to the idea of bringing tourists to the village was one of the main initial motivations for some villagers to begin architectural restoration, the reconstruction process allowed for many other possibilities. This momentum also brought about a different awareness towards the "old", as more and more villagers gained a new perspective on their vernacular architecture, partly due to their direct experience on the building sites and witnessing the results of their work. What was lying around them was not merely "old mud". Stakeholders in the village had to take care of the construction themselves, and only with minimal external help. It was crucial for them to find someone who could implement the desired restoration works. At the initial stage it was important to involve old master builders in the process: they were those masters who had once used as a material for construction, and the only ones who could re-engage with it. They were the linking elements of a generational interconnection that had been interrupted for decades. Old masters have begun to work beside a newer generation, forming together a team that has provided the necessary skills for this enterprise. These immaterial aspects are at the very base of the material transformation that has been taking place in the last six years.

The intergenerational relationship also allowed the creative interpretation of the local building tradition. In fact, the "historical fabric" is now a diffused hosting structure, which includes many functions that were not available in the past, like a cafe, a public bath that is open to tourists, and a shop to sell products made in the village. Tourists can now visit the village and also reside there. At the same time, some Esfahakis have restored their houses to spend time in the old settlement.

If the popular saying "*what the young man sees in a mirror, the aged man sees in a mud brick*" stresses the importance of older people's experience, in Esfahak the importance of intergenerational exchange has to be acknowledged. The continuation and transformation of the village's architectural knowledge and tradition was possible thanks to this exchange process and the creation of new opportunities for old and young people to share practical experience. The old village did not remain a ruin, neither was it transformed into an untouchable open-air museum, but it has been reconnected to the lives of the people. The reconstructed and newly constructed buildings bear witness to the millennial knowledge and skills of erecting vaults and domes simply from the plateau's arid soil.

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