https://doi.org/10.22034/2.4.38 *Revitalization School*, *2*(4), 40-49, Autumn 2024

*Review Article*

# An Analysis of the Construction of Iranian Brick Minarets Based on the Oral History of Architecture*

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ARTICLE INFO

**Received:** 09 September 2024
**Revised:** 06 October 2024
**Accepted:** 31 October 2024
**Online available:** 21 November 2024

***Keywords***
Construction minarets
Structural technology of minarets
Construction method minarets
Practical geometry of the minaret

ABSTRACT

Minarets, the tallest Iranian architectural elements, include special construction technology. Oral history of the architecture reveals minaret construction technology. This research reveals the forgotten aspects of the construction of Iranian brick minarets. Nowadays the technology of construction minarets has been forgotten. The latest generation of traditional architects still contains some of the mysteries associated with the process of Construction of such buildings. Most of the studies have historical aspects and very few studies have been done on their practical geometry (how construction and method of design). Researchers have been investigating the minarets using comparative methods only in the departments of morphology, ornamentations, construction, etc. but, the present research examines and analyzes for the first time the practical geometry. This research is the first to analyze the process of construction minarets from the perspective of traditional craftsmen. The most important reference in understanding the construction technology of minarets after desk studies was interviewing craftsmen. In this research, the minarets of Isfahan city have been studied in different historical periods. These surveys divulge the construction methods and different types of minarets in Isfahan.



* This article is exterted from "Safoura Rouhi"'s Doctoral dissertation entitled "Geometry and construction technology in minarets of Iran" which is done under supervision of Dr. "Nima Valibeig" at the Faculty of Economics, University of Tehran, Iran in 2024.

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## Introduction

Today, there is little research and information available on the geometry, structure, and functions of the historic minarets. Alternatively, at times even incorrect explanations are proposed for some examples. In general, the number of available studies about historic minarets is insufficient. Therefore, the major problem in understanding this subject is that there is a lack of knowledge about their construction technologies and structural qualities. On one hand, using traditional construction knowledge and, on the other hand, understanding the geometry of historic minarets are the main approaches this study has adopted. As such, traditional construction knowledge could be analyzed within two domains: Geometry and Construction techniques. Additionally, these minarets could be used as models to construct urban monuments in the future.

## Significance of The Study

- Due to the increasing speed of demolishing the minarets, our knowledge about this significant architectural type and the existing structural examples may diminish or get forgotten soon.
- The minarets deal with many problems such as structural stability against the wind forces or earthquakes. Also, since the construction techniques in building these historic minarets have made them capable of surviving the passage of time, specific information could be extracted from the remaining historic examples to design new high-rise buildings.
- Finally, these minarets are symbolic structures; therefore, investigating their features concerning their context could help identify some of the urban design characteristics in ancient cities of Iran.

## Research Question

How can existing oral history studies reveal the geometric features and construction technologies of minarets?

## Research Methodology

This study attempts to reveal the construction process in building Iranian brick minarets by analyzing the bibliographic DATA, interviewing the traditional craftsmen, and doing field study. The geographical focus of this research is on the minarets located in Isfahan. Preparing the initial documentation drafts is done by the use of tape measure and laser distance measuring tools, a camera, etc. The survey measurements were, then, modeled by digital drafting programs. Consequently, the sketches were verified by the traditional craftsmen who were able to indicate important technical specifications which helped the authors in revisiting the initial models. After the revision of their notes, the necessary corrections were applied to the initial models. Since some minarets had previously been demolished, conducting field research was not possible. Thus, a comparative method was utilized to overcome this issue. Eventually, the stages of the construction process were deduced.

## Literature Review

Some scholars have focused on the structural and seismic aspects of historical minarets (see Bayraktar et al., 2018; Osman et al., 2018; Nohutcu, 2019; Livaoğlu et al., 2016; Iravani et al., 2015; Abdel-Motaal, 2014; Aykut et al., 2010; Cordero et al., 2018; Constantinescu & Dietlinde, 2013; Hacıefendioğlu et al., 2016; Abed & Abdullah, 2013; Bagbancı & Bagbancı, 2018; Doğangün & Tuluk, 2006; Clemente et al., 2014; Korumaz et al., 2017; Cordero et al., 2018; Ercan et al., 2017; Nohutcu et al., 2019). Other researchers have researched the historical, political, and shape aspects of the minaret (see Serhatoğlu & Livaoğlu, 2019; Hosseini & Zare, 2015; Creswell, 1926; Bakhoum, 2016; Devonshire, 1921; Rivoira, 1918; Ahmed, 1941; Gottheil, 1910; Bloom, 1991, 2003; Moline, 1973; Stark, 1935; Bloom, 2018; Whelan, 1996; Frye, 1959; Trousdale, 1965; Hejazi et al., 2016; Batuman, 2013; Dodd, 2015; Slotwinski & Stutzer, 2015; Antonsich & Jones, 2010; Soliman, 2018; Shishavan & Maleki, 2018; Asfour, 2016; Abdellatif, 2012; Farrag, 2017).

## Stages of Minaret Construction Technology Based on Oral History

Various tools are used during the construction of minarets. Some of these tools, such as the pickaxe or mattock, hoe, and hatchet, are digging tools; and some others such as different types of masonry mortar (bricklaying and flat ones for the plasterwork and coating), mini shovels and metal masonry containers or bucket are used to prepare mortars. Also, the metal masonry container could be used for preparing the grout mixes (N. A. Rezayat, Personal communication, January 1, 2019, November 11, 2019; A. Keshavarz, Personal communication, September 27, 2019).

Another type of construction tool is the transporting one used for moving the materials; such as the hand-barrow or wheelbarrow. Nonetheless, the most well-known construction instruments, specifically used for minaret construction are the leveling control tools to

maintain the surface alignments or lateral slope. To examine the inward slope on the minaret's surface, a string, plumb rule, and bob (consisting of a string tied to a plummet) and an example of a steelyard balance that is locally called "Qapok" was utilized. In particular, Qapok could facilitate controlling the minaret's interior and exterior aligned surfaces. Technically, this instrument consists of a wooden pillar-shaped axis placed along the mast; there is a wooden ring with hanging strings upon this axis. In the following sections, the minaret building stages will be further elaborated (Fig. 1).

**• Stage 1: Selecting the Best Location based on the Soil Features**

In the past, investigating the characteristics of the location's soil was considered to be the initial step and one of the most significant stages in the minaret construction. The bearing capacity of soil to support the load of a minaret in the area upon which it was going to be built, should have been high enough so that the minaret would be constructed on firm ground (B. Oleyki, Personal communication, September 1, 2015; N. A. Rezayat, Personal communication, January 1, 2019, November 11, 2019; A. Keshavarz, Personal communication, September 27, 2019, M. Tavasoli, Personal communication, January 22, 2018).

**• Stage 2: Projecting the Plan, Excavating the Area, Laying out the Foundation**

The architect-designers project the foundation outline on the ground using gypsum powder. Consequently, they would start excavating the area to make a hole. That is because the minaret should be firmly rooted in the ground. These techniques are linked to the use of the properties of construction material, gypsum, which allows impossible operations with other binders. If we were to summarize these properties, we would say that it is a product whose raw material is abundant in many geographical areas, easy to extract, has low manufacturing cost that does not require special technical requirements, has high viscosity and adhesion after kneading, fast setting, moderate resistance to compression, not negligible to traction and high elasticity (Gorbea, 2001). The foundation's depth and diameter must be greatly larger than the minaret's surface area or the diameter itself. After the excavation, the ground is strengthened by soil solidification (R. A. Rezayat, Personal communication, July 1, 2018, February 24, 2020; N. A. Rezayat, Personal communication, January 1, 2019, November 11, 2019; E. Abazari, Personal communication, August 1, 2019; A. Keshavarz, Personal communication, September 27, 2019; Pope& Ackerman, 2009, 1232). Consequently, the solidified area will be filled with mortar to equalize the ground level. It is noteworthy that during the construction phase, in the center of this solidified surface, a cylindrical area with the diameter of a tree trunk will be left empty to avoid any major lateral movement (M. Tavasoli, Personal communication, January 22, 2018).

**- The mortars used in this process are as follows**

**Gypsum and soil mixture (Gach-o-Khāk)**: One of the most commonly used mortars in numerous parts of the minaret is a mortar type made of clay soil and gypsum. The addition of gypsum to the soil can increase the mortar's adhesion (B. Oleyki, Personal communication, September 1, 2015; N. A. Rezayat, Personal communication, January 1, 2019, November 11, 2019; M. Paknezhad, Personal communication, April 23, 2018).

**Gypsum-based mortar (Shefteh-Āhak):** the mixture used for the foundation is usually a gypsum-based mortar made of gypsum, clay soil, rubble, and water (N. A. Rezayat, Personal communication, January 1, 2019, November 11, 2019; R. A. Rezayat, Personal communication, July 1, 2018, February 24, 2020; E. Abazari, Personal communication, August 1, 2019).

**Water-resistant mortar (Sārouj):** Instead of the previous gypsum-based mortar, in some examples, a form of traditional concrete that is locally called Sārouj is used in minaret foundations (B. Oleyki, Personal communication, September 1, 2015; N. A. Rezayat, Personal communication, January 1, 2019, November 11, 2019; A. Keshavarz, Personal communication, September 27, 2019).

**• Stage 3: Base construction**

The base, otherwise called a bench (Sakou), is the lowest part of the minaret, starting from the ground

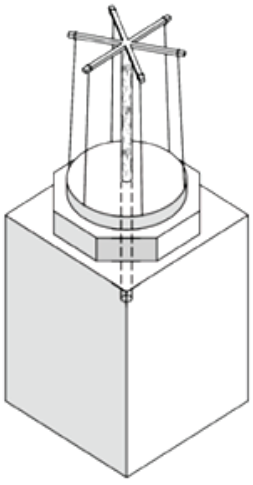


Fig. 1. Qapok in minaret. Source: Authors.

level and connecting the upper circular section to the usually square-shaped or rectangular foundation (B. Oleyki, Personal communication, September 1, 2015). Moreover, the juncture of the mast with the foundation is done through the base which technically increases the load-bearing surface. Hence, it is seen that their surface area is greater than the areas of the shaft and mast, but smaller than the foundation area. Nonetheless, the minarets either may have a base or the shaft shell is directly placed on the foundation. Even though the base plans may have different shapes, the common shapes are: a) regular polygons, b) irregular shapes, c) circular d) without base (Fig. 2). However, most bases appear either in the form of a square or the minaret sits upon the center of a multi-layered bench (M. Paknezhad, Personal communication, April 23, 2018; Tehrani, Personal communication, November 10, 2019).

**• Stage 4: Construction of the Shell, Staircase, and Mast**

The minaret construction involves three parts: a) the shaft shell, b) the staircase, and c) the mast. The construction of these three parts happens simultaneously right after projecting the plan and specifying the location of the entrance and the mast (Fig. 3-a).

**- The Shaft's Shell**

To build the minaret, several bricklaying courses will be made. Consequently, a tree trunk will be placed in the center of the brickwork. In this arrangement, the entrance location will be determined and the marked position will be left empty. The process of putting these brick courses should continue layer by layer (Tehrani, Personal communication, November 10, 2019; B. Oleyki, Personal communication, September 1, 2015; N. A. Rezayat, Personal communication, January 1, 2019, November 11, 2019).

Since the overall shapes of most minarets are similar to a truncated cone, to control the minaret's outward diameter a special minaret alignment leveling tools will be used during the construction process. Therefore, each successive course creeps in a little and the diameter of the minaret's shell will have a gradual decrease from the bottom-top. To achieve this, a string would be attached to the structure every other three meters to level up the Qāpoki. Also, to measure the minaret's diameter, there is a decrease of 3 m in 3 m within the minaret's diameter as we build the courses (Fig. 3-b).

As we move up, reducing the shell's diameter should be done in a manner that the exterior surface wouldn't be seen as a corbelled one. Achieving this technique decently is largely dependent upon the architect's experience. Nevertheless, this is done not only on the external surface but also on the interior to have the shell surfaces look uniform and intact on both sides. This indicates a gradual decrease in shell thickness. To have a surface containing uniform elements, the bricks that are placed on the exterior would be cut from the inside (Fig. 4-A), and the interior bricks are cut outwardly (Fig. 4-B). Moreover, during the arrangement of these courses, they will be placed in a way that the bricks are involved in the staircase bricks as well (Fig. 5).

It is noteworthy that openings are one of the essential features of the shaft to provide enough natural light for the spiral staircase and make the uppermost parts accessible; again, these openings were formed by setting back the brick rows (Fig. 6). In the brick courses, the upper brick-layers should overlap one another to avoid the joints of the successive courses from having similar placements (Fig. 6-b). It is noteworthy that openings are one of the essential features of the shaft to provide enough natural light for the spiral staircase and make the uppermost parts accessible; again, these openings were formed by setting back

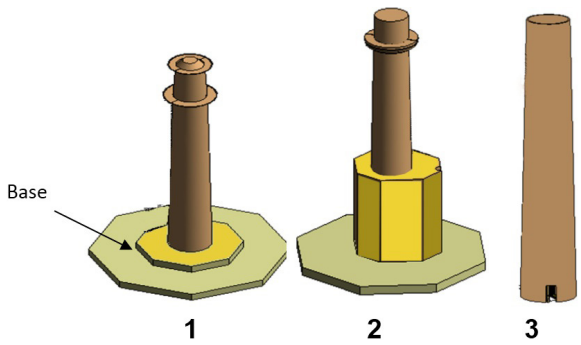



Fig. 2. Different types of bases minaret. Source: Authors.

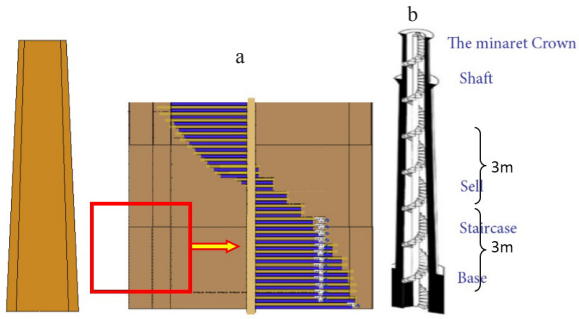



Fig. 3. a) The minaret parts, b) The minaret's diameter decrease. Source: Authors.

the brick rows (Fig. 6). In the brick courses, the upper brick-layers should overlap one another to avoid the joints of the successive courses from having similar placements (Fig. 6-b).

Eventually, on the top of the shaft, the bricks slide in through a corbelled method, creating visible stepped courses. This inverted truncated cone provides the needed space for a gallery[1] (Fig. 7). Consequently, the wooden fences are raised in the upper parts, whereas a simple muqarnas work is installed in the corbelled area (Fig. 8).

**- The Staircase**

One of the most complicated processes in minaret construction is building the stairway. The brickwork in the staircase should maintain a connection both to the shell and mast (Fig. 9). Since the shape of each step is similar to a cubicle, the layout appears as a notched or serrated pattern from underneath, and this creates a stepped spiral that is involved with the shell and mast from the two sides, and also with the upper and lower steps . The stair' cross-section is depicted (Fig. 10). Unlike this example which is seen as a notched and serrated staircase, the examples in Fig. 11 illustrate the stepped layout. Each notch has the height of a brick header and these bricks, usually with a triangular cross-section, have a maximum protrusion of 7 cm at the side (Fig. 12).

In some minarets, especially the tallest ones, also the width of the stairs is gradually decreased. Additionally, the width of each step in the uppermost parts of the stairway is only as wide for a person as passing through the staircase. To make this arrangement, each step is made of approximately four brick tiles and is placed in a way that could keep the shell and mast connected. However, to establish a better connection between the staircase and the shell, usually a wooden beam would be used as well. This beam is not only connected to the vertical stick (Shāhang) from one side and to the shell from the other side but also the

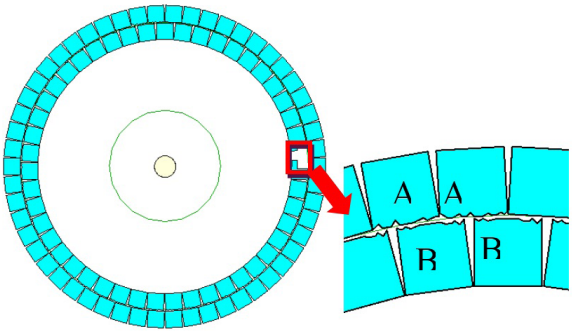



Fig. 4. The bricks placed on the exterior are cut from the inside. Source: Authors.

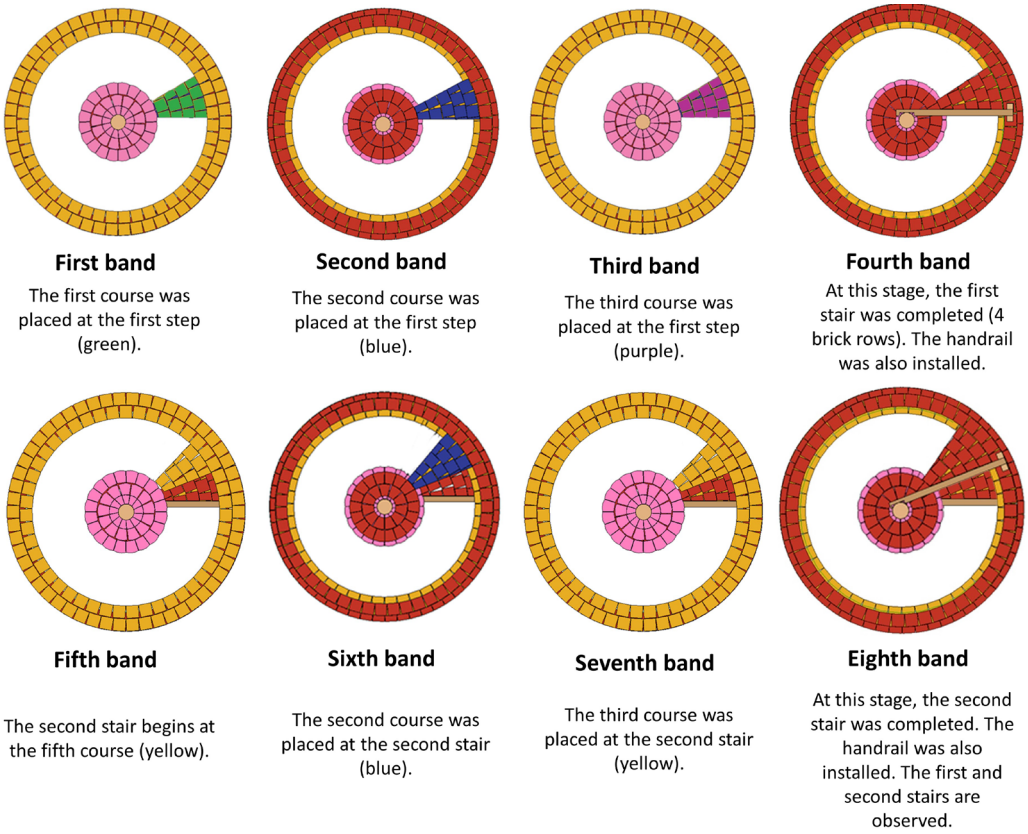



Fig. 5. Building the stairway processes. Source: Authors.

mast in the middle will be attached to it. This wooden lumber mostly surpasses the stairs' edges and becomes visible (Fig. 13).

At last, the stairway placements may vary depending on the minaret type. These types are mentioned below: A: The minarets placed on the building roof/ B: Any minaret whose entrance is at the ground level/ C: Any minaret whose entrance is at an elevated level from the ground. Examples of this type can be seen in the Chehel-Dokhtarān, Bāghoush-khāneh, and Sāreban minarets in Isfahan (Tehrani, Personal communication, November 10, 2019; E. Abazari, Personal communication, August 1, 2019) (Fig. 14).

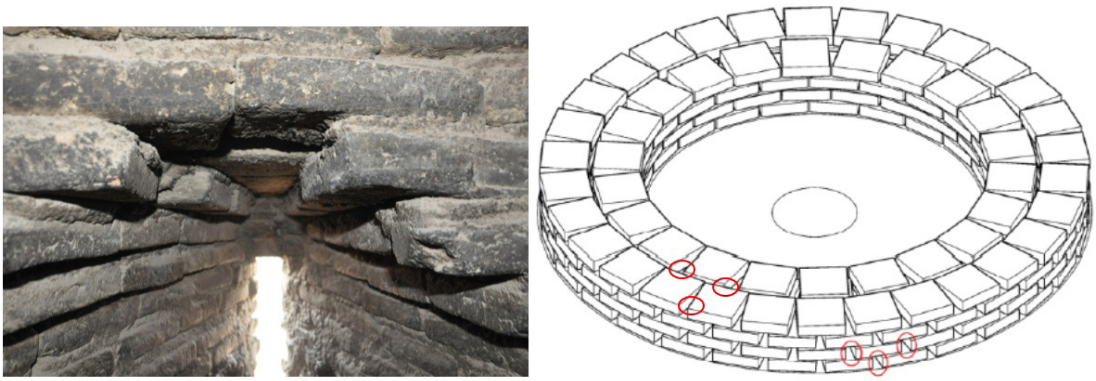
- **The mast**

Since the mast's diameter is less than that of the shell if the bricks are fully fitted in, they would form a serrated façade; therefore, the bricks are usually cut from one side so that their shape becomes curved or almost circular (Fig. 15). This technique gives the mast an overall cylindrical outlook (B. Oleyki, Personal communication, September 1, 2015; Tehrani, Personal communication, November 10, 2019) (Fig. 15). Because the mast shape is similar to an inverted cone, the upper part is smaller than the lower section.

To build Shāhang, or the vertical stick in the middle of the minaret's structure, a wooden instrument called Qāpoki would be installed within every 3 meters through stretching strings. Qāpoki consists of two wooden tongue-and-groove pieces and is installed in the middle of the structure before the first step in the staircase is constructed (Fig. 16). The two pieces of Qāpoki, namely Ghalam-tarāsh and fāgh (respectively, meaning sharpener and fissure are in such a way that Ghalam-tarāsh or the tongue would be inserted in the fāgh) (M. Tavasoli, Personal communication, January 22, 2018; E. Abazari, Personal communication, August 1, 2019 ).

**• Stage 5: The Minaret Crown**

The minaret crown is built on top of the shaft. Nonetheless, there is a possibility to access the uppermost sections of the minaret and reach the



(a) (b)

Fig. 6. a) Brick arrangement for opening, b) Brick straps do not overlap in each course (horizontal, vertical). Source: Authors.

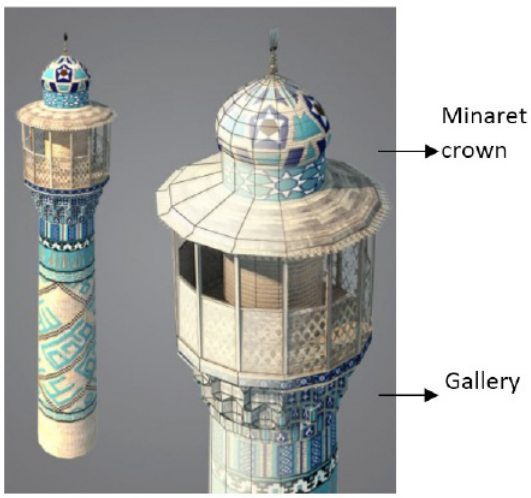



Fig. 7. The minaret crown. Source: Authors.

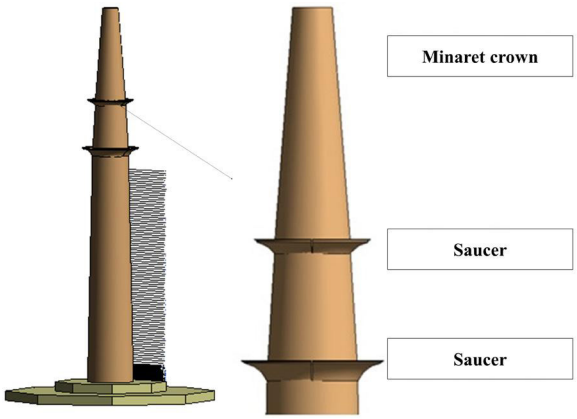



Fig. 8. The detials of minaret. Source: Authors.

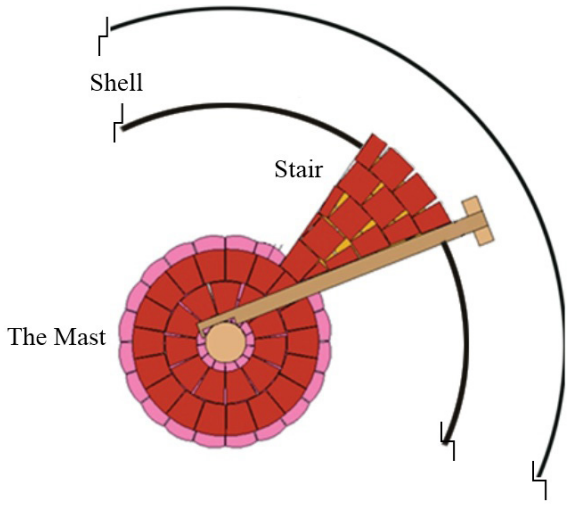



Fig. 9. A section minaret of the first stair. Source: Authors.

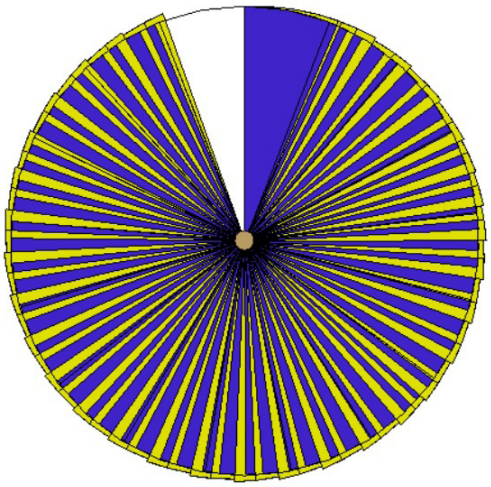


Fig. 12. View from down to up stair. Source: Authors.

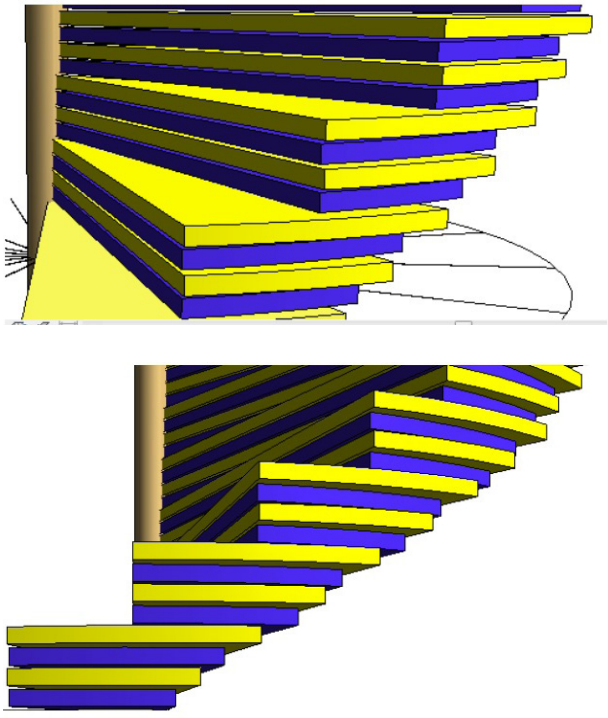


Fig. 10. A view of minaret stairs. Source: Authors.

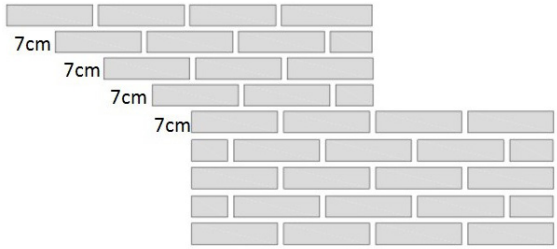



Fig. 11. Serrated brick at stair. Source: Authors.

highest section without even entering the crown if the stairway could be further ascended. This is usually the case in those minarets in which the crown is placed on the minaret shaft or stem (E. Abazari, Personal communication, August 1, 2019; M. Paknezhad, Personal communication, April 23, 2018; N. A. Rezayat, Personal communication, January 1, 2019, November 11, 2019; R. A. Rezayat, Personal communication, July 1, 2018, February 24, 2020).

## Conclusion

Studying oral history was the approach chosen for this study to compensate for the shortcomings of the descriptive documents in explaining the minaret construction methods. In other words, the knowledge of local craftsmen and their acquaintance with the traditional technology made it possible for us to obtain a new understanding of the minaret construction procedure and helped the preparation of more accurate three-dimensional minaret models. In this process, the actual stages of minaret construction, from building the foundation to the crown were all modeled step by step. This information revealed how the dimensions, sizes, and construction methods may especially vary from the perspective of craftspeople coming from different locations and expertise. However, this investigation demonstrated an overall similar construction process with only slight differences in the practical details that had no major impact on the whole construction process. Therefore, it is concluded that studying the oral history of architecture could reveal the process of minaret construction and result in acquiring similar major information.

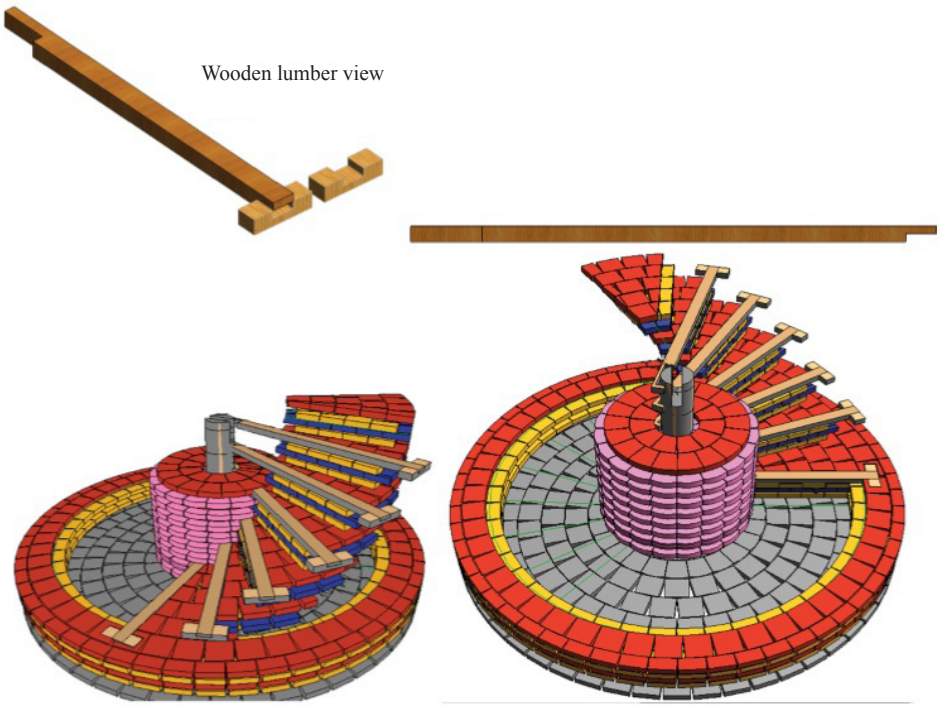



Fig. 13. The details of the handrails of the stairs, three-dimensional cover, and stair. Source: Authors.

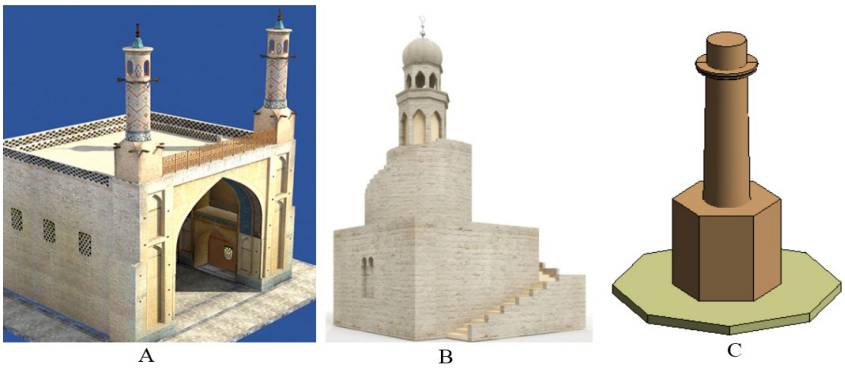



Fig. 14. the minaret type entrance. Source: Authors.

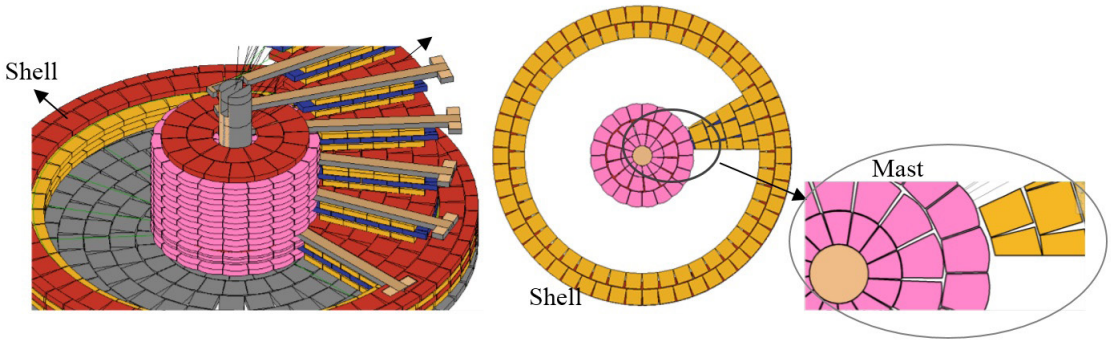



Fig. 15. The mast brick (pink color). Source: Authors.

Understanding the tools that have been used in this process is another significant information. These tools could be divided into two categories: common and special tools. Respectively the common tools category includes string, plumb rule and bob (consisting of a string tied to a plummet), trowel, shovel, and masonry container, and among the specific tools, steelyard balance could be mentioned.

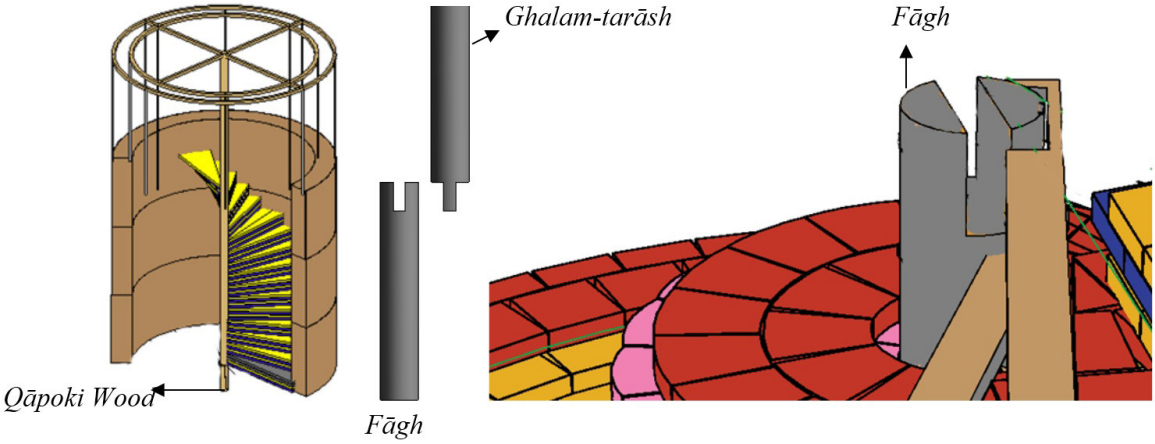


Fig. 16. Qāpoki wood section. Source: Authors.

## Suggestions For Further Studies

It is suggested that similar research studies or findings of this study would be considered in other countries like Afghanistan or central Asian countries to conduct a comparative study on minaret construction techniques and ancient technologies.

## Conflict of Interest

The authors declare that there was no conflict for them in conducting this research.

## Endnotes

1. The gallery is the balcony encircling the uppermost section of minaret; the muezzin may give the call to prayer from here.

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*HOW TO CITE THIS ARTICLE*

Rouhi, S., Valibeig, N., Khodayari Mafi, M., & Almagro Gorbea, A. A. (2024). An Analysis of the Construction of Iranian Brick Minarets Based on the Oral History of Architecture. *Journal of Revitalization School*, *2*(4), 40-49.

**DOI:** https://doi.org/10.22034/2.4.38
**URL:** https://jors-sj.com/article-1-43-en.html