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The Geometry of a Domed Architecture: A Stately Example of Kārbandi at Bagh-e Dolat Abad in Yazd

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Abstract This paper analyses the kārbandi of the Hashti pavilion at Bagh-e-Dolat Abad in Yazd. Kārbandi is a spatial system obtained through the projection of a star-shaped drawing onto a curved surface. It is characterised by a complex use of geometry and repetitive symmetry. The analysis of its geometrical aspects contributes to an understanding of the traditional rules underlying the original design. The kārbandi of the octagonal vestibule of the Hashti pavilion consists of a complex roof system that completes the octagonal volume of the room below; its intrados presents a pattern of interlocking ribbed arches. The paper also looks at the drawings, module and proportions of the Hashti pavilion, with the exclusive purpose of providing a key to reading geometries that, while complex in appearance can, in reality, be traced using a simple ruler and compass.

Keywords Design analysis · Geometric analysis · Golden section · Pattern · Polygon · Symmetry

Introduction

From the end of the tenth century in Iran there developed a great skill in drawing and building domed crossed rib structures.[1] These techniques soon spread outside Iran, initially and simultaneously to Armenia and Spain, and later to a much vaster area spanning from Central Asia to North Africa. Developed for both aesthetic

[1] The resolution of spatial issues arising from the complexity of these structures is allowed in Iran by the use of brick, laid in two main types of bonding: edge-laid bonding or Roman bonding.

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purposes and to ensure rapid construction, these structures possess all the spatial values of a dome even if they cannot be defined as such (Galdieri 1997: 56, 58).

Interesting geometric structures, both as two-dimensional drawings and three-dimensional constructions, they are true conceptual demonstrations of the expressive possibilities achievable by the reworking of elemental geometric shapes: in the end they are obtained by projecting a star-shaped drawing onto a curved surface. It is quite clear that these structures could not have been conceived without an adequate knowledge of geometry, whose use has always been a strong feature in Persian architecture. These vaulted structures are realised by the use of big arches that are working as ribs.

There are two basic types, both characterised by a complex use of geometry and repetitive symmetry: structures formed by arches that converge and intersect at the centre or vaults made of an interlacing of arches whose pattern leaves the centre free (Galdieri 1996: 12);[2] a second system, utilised to achieve large spans, is known as *kārbandi*.[3] This term also refers to similar geometric and spatial solutions, including non-structural, with a similar formal design.[4]

In the region of Yazd, where the climate is very dry, the need to ventilate and cool interior spaces led to the development of a local variation that rises up on multiple levels. One of the most interesting examples for its geometry and compositional daring is to be found in the central octagonal hall of the Hashti pavilion at Bagh-e Dolat Abad, to which this short paper is dedicated. While recognising the importance of investigating a work of architecture as a whole, this particular text deals primarily with an analysis of geometrical aspects. The intention is to provide a contribution, in no way exhaustive, to the understanding of the traditional rules underlying its design and the fundamental role of geometry, which regulates the entire design of the kārbandi. Furthermore, this paper analyses the geometric principles that regulate the design of the entire pavilion, in plan and elevation. The analysis described employs the axes, symmetries, repetitions and hierarchies of the lines and forms that contribute to the harmony of the final result. The study confirms the use of geometric proportions to produce the architecture, spaces, surfaces and decorations of the pavilion. For the study of structural implications and aspects of construction reference should be made to further investigations, as the text provides only partial hypotheses in the wake of similar examples.

Bagh-e Dolat Abad

Dolat Abad was a village near Yazd that was incorporated into the city as it expanded. The garden in which the Pavilion examined in this paper stands was constructed by Mohammed Taqi Khan Bafqi (r. 1748–1799), governor of Yazd who

[2] Vault n. 60 of the Friday Mosque of Isfahan (1150), a vault of the Friday Mosque of Ardestan and the vault of the *mihrab* of the Friday Mosque of Na'in represent the oldest examples of structures with ribbed supporting arches that do not converge towards the centre (Galdieri 1996: 12).

[3] According to (Bozorgmehri 1992) "Karbandi is the structure of a kind of roofing, consisting of ribs with a certain arched form which interlock according to certain geometrical rules and form the main frame of the roof". For this and other Arabic terms employed here, refer to the glossary at the end of the text.

[4] When these systems connote merely ornamental solutions, they are called *rasmibandi*.

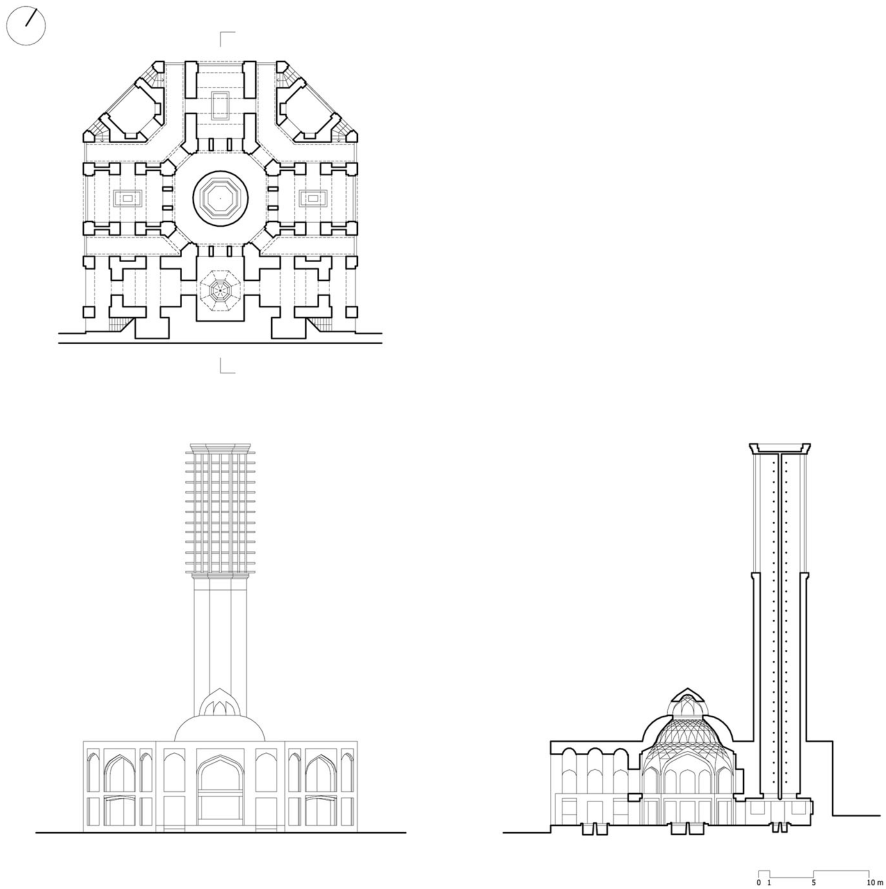

Fig. 1 The Hashti pavilion at Bagh-e Dolat Abad: plan, SE elevation and section

came to power in 1748. During his time in power he built numerous buildings and villages in Yazd and its surrounding areas, as well as the city's subterranean irrigation system. The garden of Dolat Abad is divided into two perpendicular rectangular areas. One, called *andarouni*, was the private part for the governor and his family, while the other, *birouni*, was used for official ceremonies and events. Standing against the wall of the andarouni is the most important building of Bagh-e Dolat Abad known as the Hashti pavilion (Fig. 1). It is located along the main axis of the garden and most probably served as a place of leisure for the governor.[5]

This pavilion is characterised by the presence of an octagonal *badgir* (wind catcher), a natural ventilation structure with two vents on each side (Fig. 2). For the presence of this structure, the tallest in Iran, the Pavilion is often called the Badgir building.

[5] Some scholars believe that the Pavilion was used by a harem, given its location in the private part of the garden.

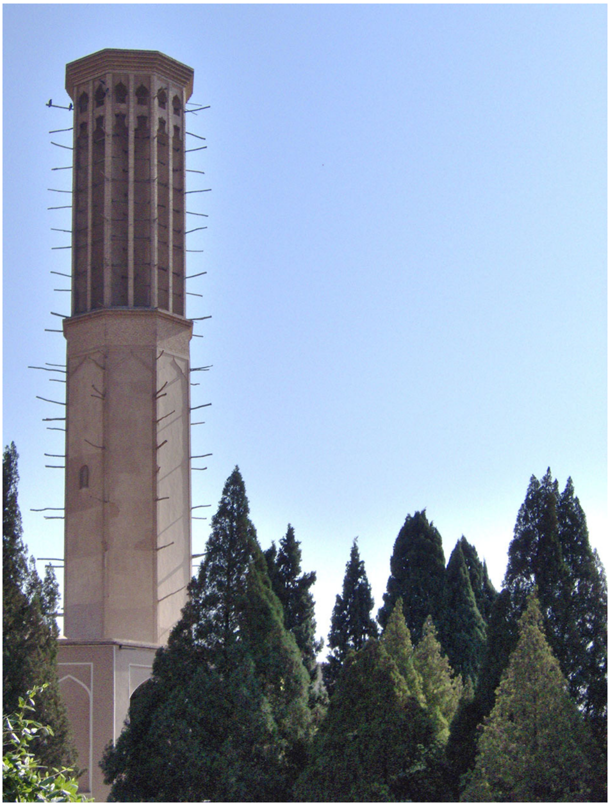

Fig. 2 The octagonal *badgir* of the Hashti pavilion at Bagh-e Dolat Abad

The Hashti pavilion is a two-storey structure with a central vestibule, or *hashti*, which originally "had an eight-sided skylight that has been destroyed over time and has now been replaced by a dome-like version" (Javeherian 2004: 158) with a fine interlaced structure.[6] The plan of the central space is an irregular octagon that serves as a spatial and functional node unifying the entire organism.[7] It is surrounded on the major sides by three vestibules and by the space beneath the wind tower; on the shorter sides it opens directly onto corridors that connect with the outside. At the ground level, the central room and the four others that develop around it and are subordinated to it, contain five pools in the middle of the floor that serve to humidify the air during the hottest months.

The octagonal vestibule runs for the entire height of the pavilion and presents a double order of openings, rectangular on the first level and four-centred arches on the second level. This central space is characterised by an interesting example of kārbandi, consisting of a complex and carefully modelled roof that covers and

[6] The sketches of (Pope 1976) show an eight-sided skylight proportioned to the Pavilion and the Wind Tower.

[7] Persian architectural terminology refers to this irregular octagon as *Hasht-va-nim-hasht*.

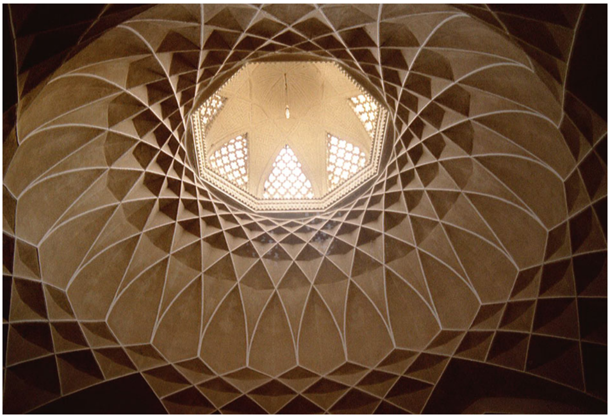

Fig. 3 The covering system of the octagonal vestibule of the Hashti pavilion

completes the octagonal volume of the room, rising up as a continuation of the walls. The intrados of this structure presents a pattern of crossed arches with a ribbed structure (Fig. 3). This type of interlocking pattern guarantees a feeling of weightlessness and contributes to the creation of a sense of continuous space. The interlocking arches of the first level of kārbandi absorb the arches of the openings of the first level and expand the pattern across the space of the room.

Captured by the intertwining projections articulating the space, the pattern of shadows cast by natural light varies throughout the day and in relation to the different areas of the vaulted structure (Fig. 4). Light is "also of paramount importance to Islamic architectural decoration as they generate additional layers of patterns and just as happens with surface decoration, they transform space" (Ghiasvand et al. 2008: 21–22).

This vaulted system develops in a succession of three levels that move from the irregular octagon of the plan to the regular geometry of the lantern, passing through the circumference of the base of the spherical cap topping the room (Fig. 5). All of the four-centred arches (*panj-o-haft*) of one level share the same form; this allows for the achievement at the spring line of the various levels of a single perfectly horizontal plane. The ordered use of homogenous elements also introduces an overall sense of harmony.

The first level, which acts as the point of transition from the octagonal plan to the circular base of the cap, is comprised of a system of interlocking arches that create a pattern of complex connecting elements similar to ribbed pendentives.[8] The intersection of these arches forms a grid of diamond-pointed rhomboid figures.

[8] In Iran these transition systems are called *chapirè* and the drawing of interlaced arches that distinguishes them is called a *rasmibandi* (Petralla 2012). In some cases these connections are referred to using the terms "squinch net", however, according to (Golombek and Wilber 1988: 107) it is preferable to refer to this transition system as an *arch net* because "it is not genetically related to the squinch".

Fig. 4 The octagonal vestibule of the Hashti pavilion

Concave (*ālat*) and folded towards the centre of the space, they assume different names depending on their position: moving upward from the bottom is the succession of *pā bārik* and *shāhparak* (Fig. 6). The uppermost row of *shāhparak* draws a 24-pointed star that forms the basis of the spherical cap (*shamseh*).

The second level consists of the cap, whose intrados is also formed by a dense network of interlaced arches that once again break the surface up into a series of kite-shaped concave facets. The spatial composition of these additional arches, which leave the centre free, generate another 24-pointed star inside which is inscribed a 24-sided polygon[9] that, in turn, inscribes an octagon; set atop this latter is the third level, or the lantern. This element is yet another vaulted system in brick that draws an 8-pointed star formed by eight arches, in parallel couples (Fig. 7). These arches are built from header bricks. The central part of the lantern, which closes the entire vaulted system at its uppermost point, is a domical vault set on an octagonal base consisting of triangular gores made with stretchers placed in the

[9] The triangular elements filling the space between the star-shaped profile and the 24-sided polygon are called *sambusè*.

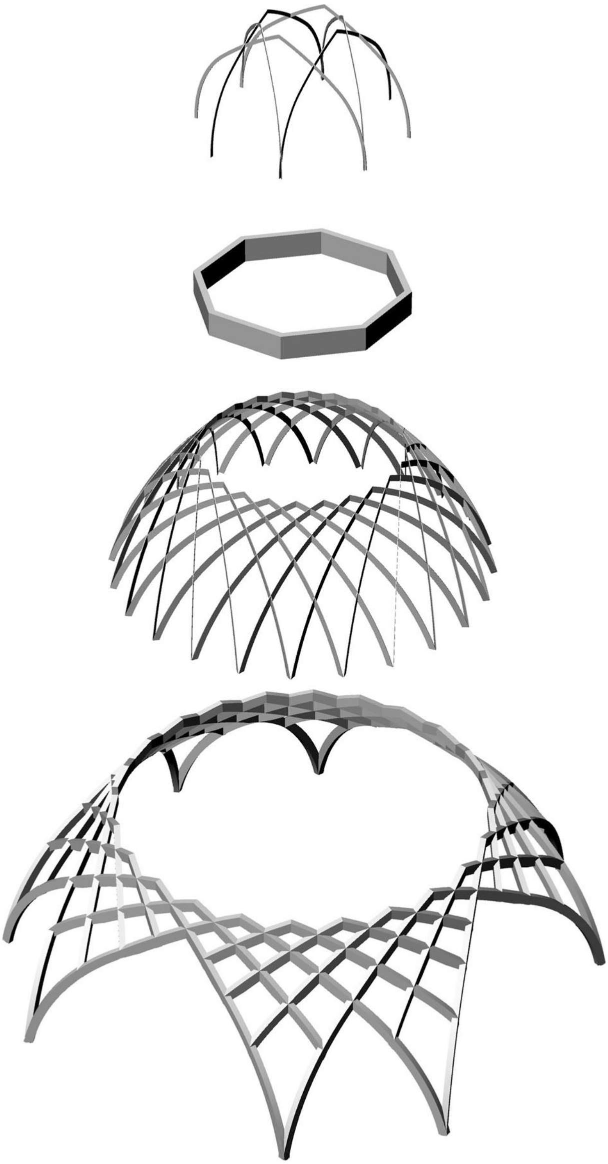

Fig. 5 The levels of the vault system

direction of the triangle height. The bricks filling the points of the star are laid in a simple dovetail pattern. The space that remains free between the points of the star is filled by a perforated layer of brick whose lozenge pattern allows natural light to filter in from outside.

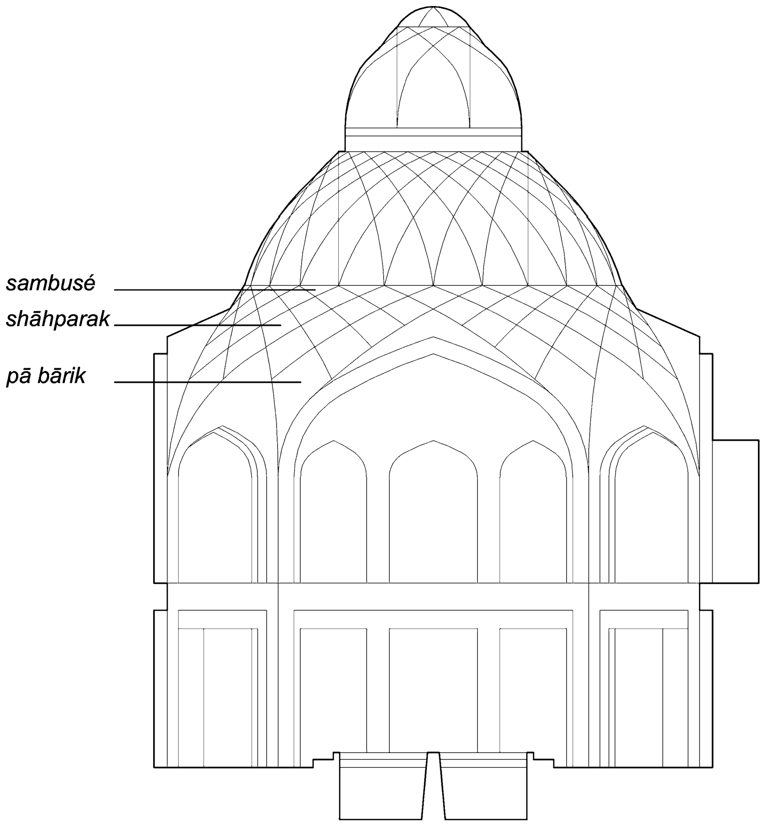

Fig. 6 The *ālat* of the first level

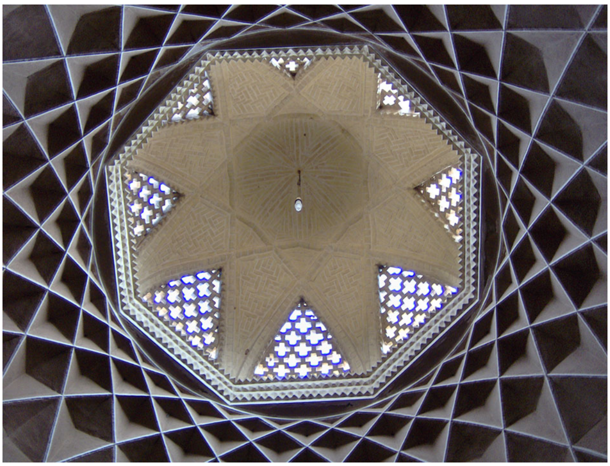

Fig. 7 The lantern at third level

An analysis of the drawings, module and proportions of the Hashti pavilion

Before looking closely at the vaulted structure, it is worth taking examining the more general geometry of the pavilion in an attempt to identify a modular unit of measurement which may have determined the proportions and ratios of the entire composition.[10]

> The architect conceptualized the design of a building project using two processes simultaneously. One was analytic, the other geometric. (…) Once the architect and patron had come to an understanding on the equivalent of the gaz and the general needs and scale of the building, the architect could proceed to work out the details on his own. The actual designing of the building was done theoretically to some extent regardless of the given scale. After the design had been drawn up on the basis of geometric proportions, the architect returned to the analytic process. He selected one dimension within the design to serve as a module, which was either equivalent to, or commensurate with, the gaz. (Golombek and Wilber 1988: 138–139).

A geometrical analysis of the Hashti pavilion reveals the use of a square grid based on the *gaz*, or cubit (Fig. 8).[11] This measure coincides with the thickness of the walls that, as noted by Bulatov, in many works of architecture in Central Asia, establishes the module used in plan.[12] Repeated eight times, in plan this module provides the measure of the central octagonal space (Fig. 9). Bulatov defines this measure as the "generative unit", which normally coincides with the width of the larger room or with the central dome chamber, for the radially planned architecture. The overall dimensions of the system are given by the combination of nine square cells, whose sides are equal to the "generative unit", arranged in a 3×3 matrix.

All general dimensions and geometric proportions, in plan and elevation, are governed by the "generative unit", which also provides the height of the building.

The plan develops around a central point with several axes of symmetry: it is symmetrical with reference to the NW–SE axis as well as the two semi-axes running from the centre to the north and the west (Fig. 10). Instead, the NE–SW axis of symmetry divides the plan into two parts: on one side a half-square and on the other side a half-octagon. This latter is exactly concentric with the octagon of the central space and therefore shares the same centre of symmetry. The apothem of the larger octagon is larger than that of the central octagon by a length equal to the "generative unit".

Different sets of ratios are utilised to design the building: the proportions are given by the use of the square and its diagonal ($\sqrt{2}$), the semi-square (formed by dividing the square into halves) and its diagonal ($\sqrt{5/2}$).[13]

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[10] The graphical analysis presented here was made using drawings published by (Javeherian (2004): 162). It would be desirable to carry out a new accurate survey in order to conduct further research that may provide new and more precise interpretations.

[11] According to (Petralla 2012), from Safavid period 1 gaz is equal to 104 cm. According to (Abol Ghāsemi 2010) it is equal to 106.66 cm. Here it is assumed that 1 gaz is equal to 104 cm.

[12] Chapter 7 of (Golombek and Wilber 1988: 107) analyses the work of (Bulatov 1978).

[13] These analyzes are derived from studies conducted by (Golombek and Wilber 1988: 137–151).

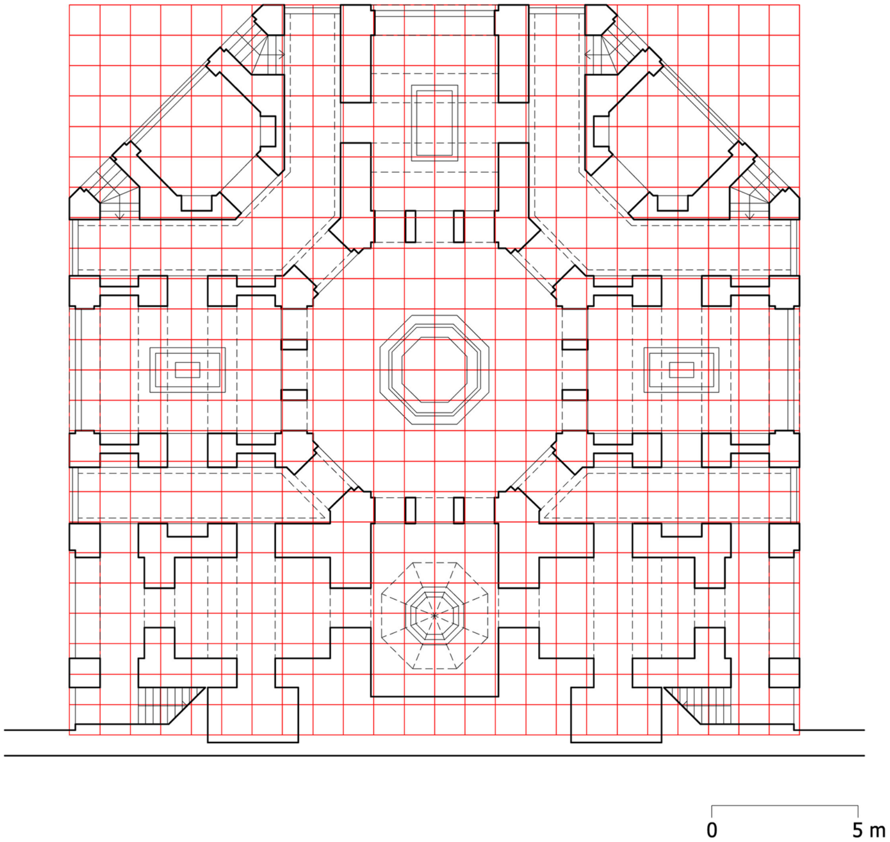


Fig. 8 A geometrical analysis of the Hashti pavilion reveals the use of a grid based on the gaz, the cubit, equal to 104 cm

The position of partition walls and openings within the grid is determined by the properties of the square, whose sides are equal to the "generative unit", and its diagonal ($\sqrt{2}$).

The diagonal ($\sqrt{2}$) of the square contributes to the definition of other dimensions. In plan it provides the positions and dimensions of the passages from one room to another and measures the width of the longer side of the largest octagon (Fig. 11).

The overturning of the diagonals ($\sqrt{5/2}$) of the semi-squares, that lie at the four corners of the plan, generates the position of the vestibules (Fig. 12).

The diagonal ($\sqrt{2}$) of the square in elevation provides the height of the badgir and the proportions of its uppermost part, which is open to the winds (Fig. 13). The gaz, therefore, also gives the overall dimensions of the facade and the height of the badgir (Fig. 14). The overturning of the diagonal ($\sqrt{2}$) of a square, whose sides are equal to the "generative unit", provide the size of the main facade. Some openings of the facade are in proportion to the length of the facade itself: some sizes of the big central arch are equal to half the length of the facade (Fig. 15).

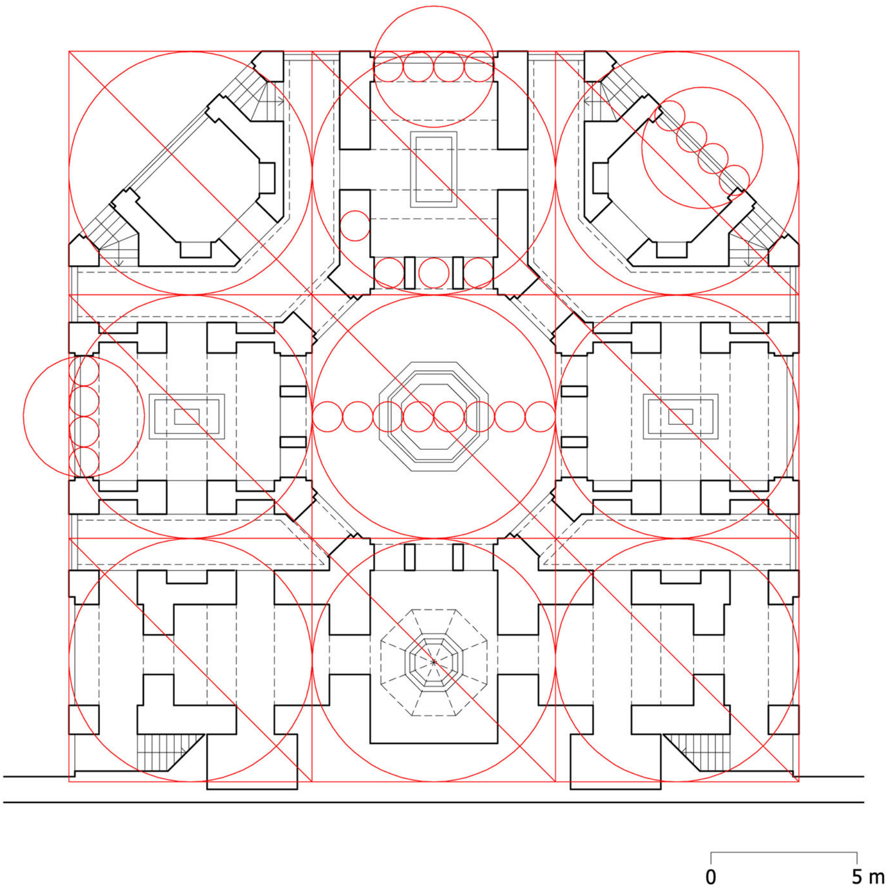


Fig. 9 Study of the proportions of the plan. The module, repeated 8 times, defines the "generative unit" and provides the dimensions in plan of the octagonal central space. The overall dimensions of the system result from the combination of nine square cells, whose sides are equal to the "generative unit", arranged in a 3 × 3 matrix

In conclusion, although we do not know with certainty the geometric rules used to design the Pavilion, a graphical analysis does provide some possible indications about the proportions of the whole and its parts.

The geometry of the vaulted structure of the Hashti pavilion

The realisation of a stellate arch-net requires the use of two-dimensional patterns based on a vocabulary of geometric shapes, generated by linking a number of points of intersection between construction lines (Fig. 16):

> To build the Kar-bandi we need the plan and the mould. First the plan is drawn on the ground plane with a one to one scale. The mould of the type of arch that

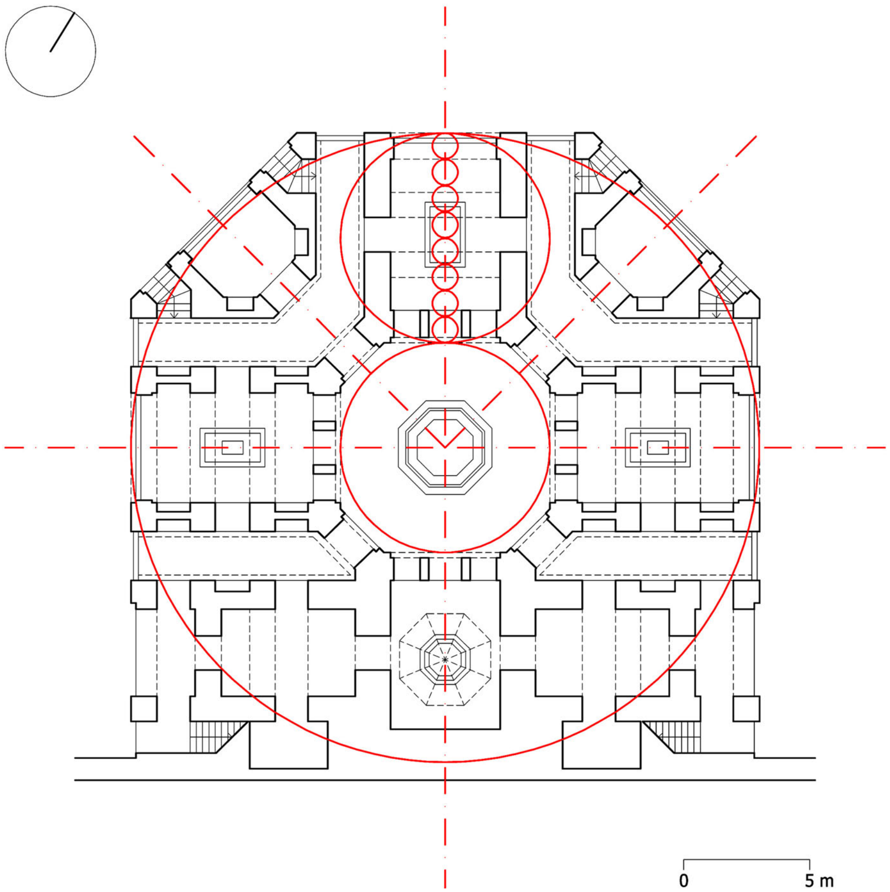


Fig. 10 Study of the proportions of the plan. The axis of symmetry of the plan. The apothem of the larger *octagon* is larger than that of the central *octagon* by a length equal to the "generative unit"

is going to be used will be made using wood or stucco with a one to one scale. On the plan the intersecting points are marked, using a plumb line (or any other tool that would have the same function), they are converted to the mould. This procedure is repeated for all the arches of the Kar-bandi. Some of the moulds are a full piece and some contain a part of the arch. The moulds that contain a full arch are the ones that will carry the main loads and transfer them into the columns (Raiszadeh and Mofid 2006; Mojtahedzadeh 2012:492).

Geometric patterns are of considerable importance to Persian and Islamic architecture in general. They are fundamental to the creation of particular types of interlacing, such as that analysed here. An Islamic tradition, very common in ancient times, employed scrolls to collect various geometric drawings, from layouts of vaults to architectural ornaments to epigraphic panels. Surviving examples

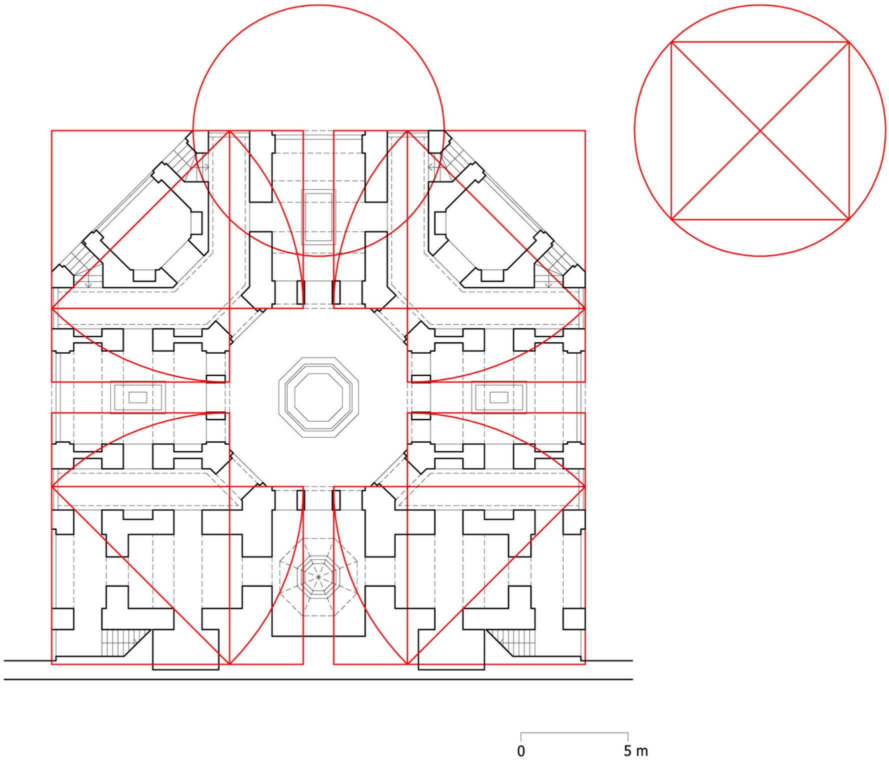


Fig. 11 Study of the proportions of the plan. The diagonal ($\sqrt{2}$) of the square provides the positions and dimensions of the passages from one room to another and measures the width of the longer side of the largest *octago*n

provide a catalogue of ideal types that stand as evidence of historic architectural practices.

Some ancient treatises on practical geometry, common between the tenth and fourteenth centuries, also report geometric notions on the drawing of regular polygons inside a circumference, with the aim of mastering the drawing of the transition from the square to the circle and, successively, of Persian geometric architectural patterns known as *girih* (lit. knot) (Koliji 2012: 295–296):

> The traditional master builder Asgar Shi'rbaf classified both planar and spatial geometric patterns under the mode of design called *girih* or *kār-bandī* (knot work, work that binds, joins, and fastens together), terms referring to tightly interlocking systems of two- and three-dimensional geometric shapes governed by knotlike grids (Necipoğlu 1995: 22).

The drawing of the plan and the spatial configuration of the entire centrally symmetrical roof of the Hashti pavilion are obtained from the combination and repetition of simple geometrical shapes (triangles, squares, octagons). The skeleton of this vault was probably realised by intersecting large arches with a fairly narrow

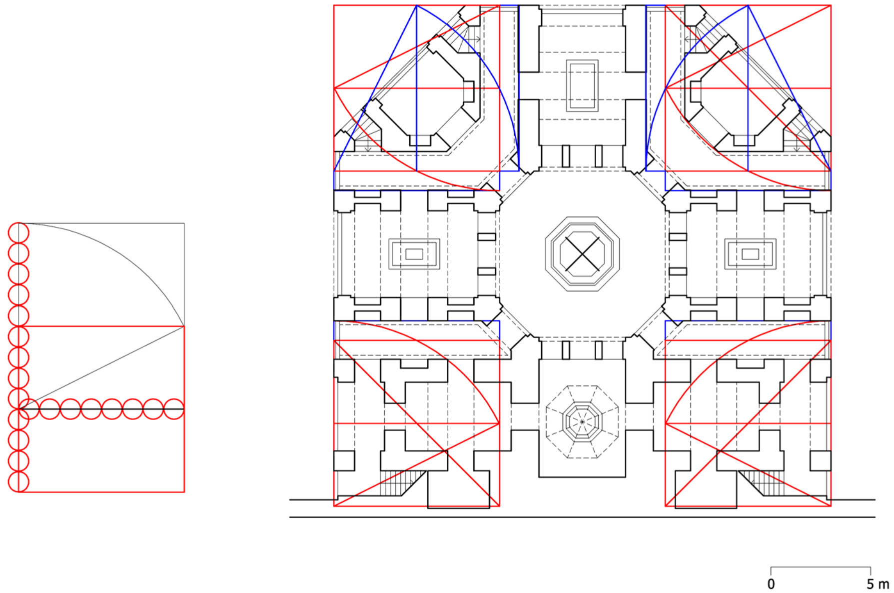


Fig. 12 Study of the proportions of the plan. The overturning of the diagonals ($\sqrt{5/2}$) of the semi-squares, that lie at the four corners of the plan, generates the position of the vestibules

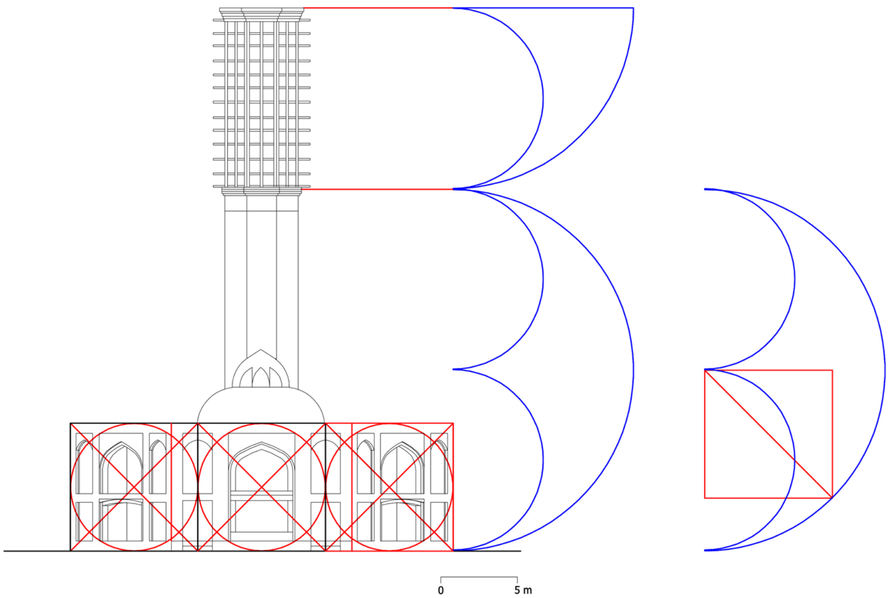


Fig. 13 Study of the proportions of the SE front. The diagonal ($\sqrt{2}$) of the square provides the height of the badgir and the proportions of its uppermost part, which is open to the winds

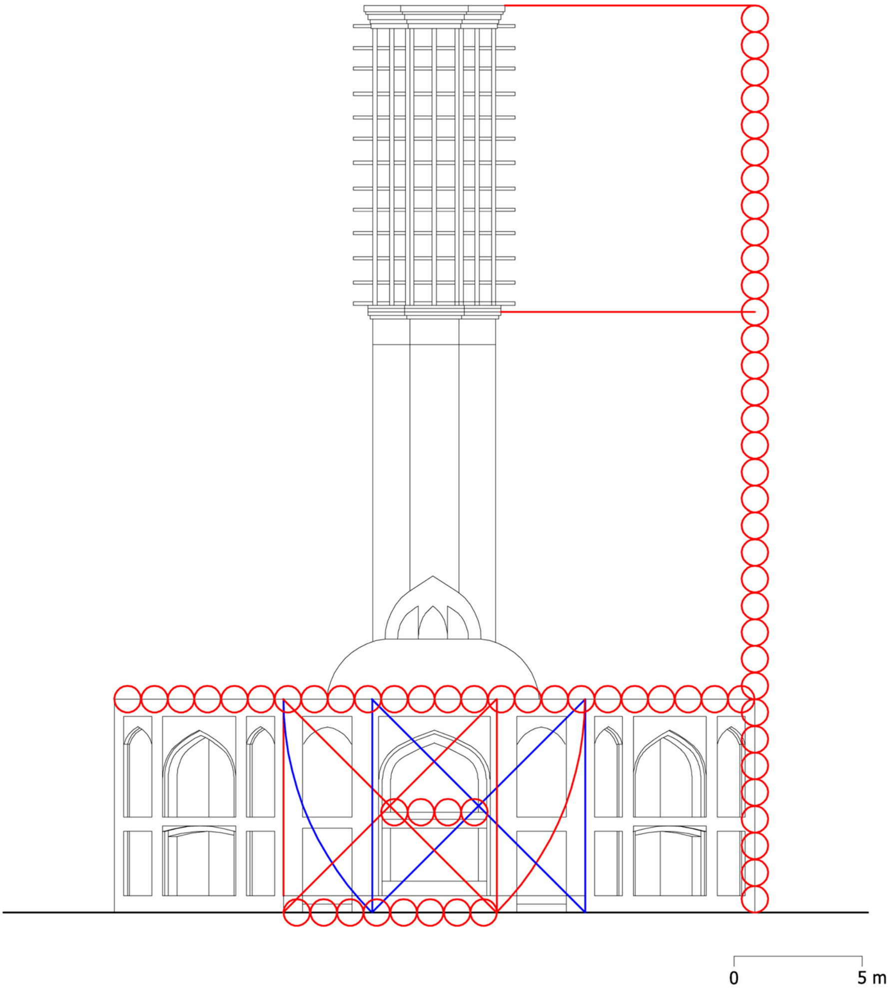


Fig. 14 Study of the proportions of the SE front. The *gaz* gives the overall dimensions of the facade and the height of the *badgir*

section that work as ribs, while the architectural space is defined by a more or less articulated secondary infill surface. The structural elements are covered with a skin that defines the pattern of the intrados of the roof and its decoration:

> Enclosed space, defined by walls, arcades and vaults, is the most important element of Iranian architecture. With the exception of the dome and the entrance portal, decoration in Islamic and Iranian architecture is reserved for the articulation and embellishment of the interior. Islamic decoration does not emphasize the actual mechanics of a building, the balance and counterbalance of loads and stresses instead; it is a part of the Islamic and Iranian architectural

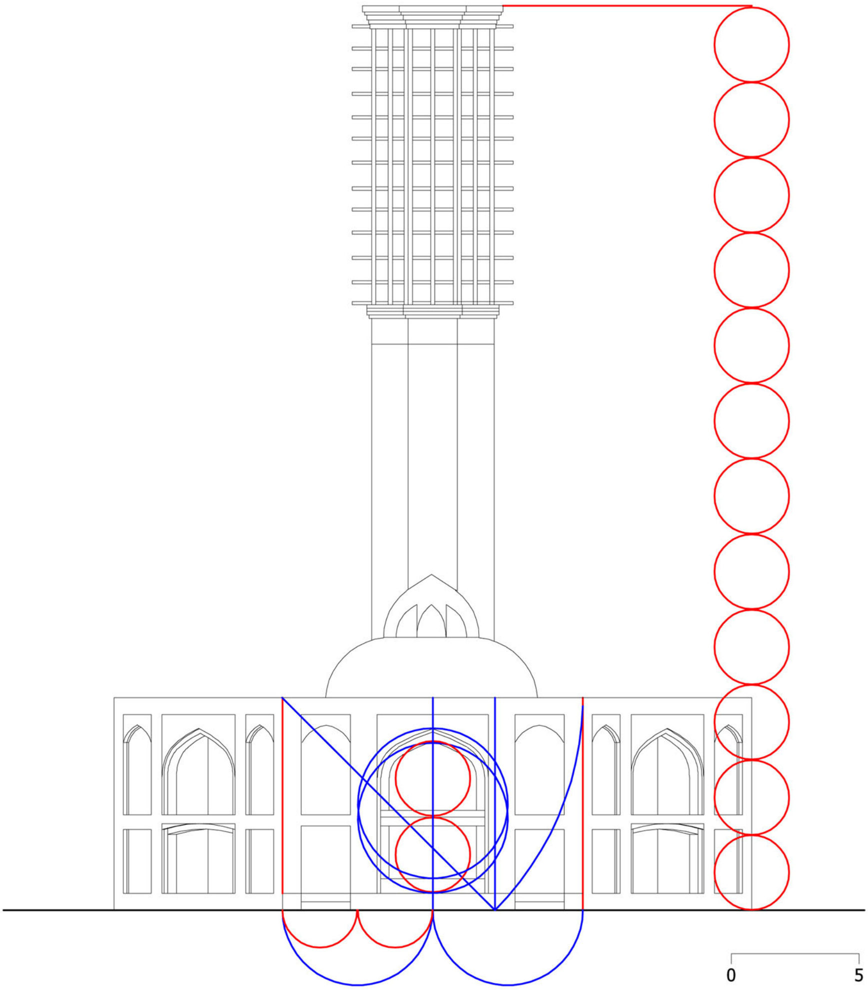
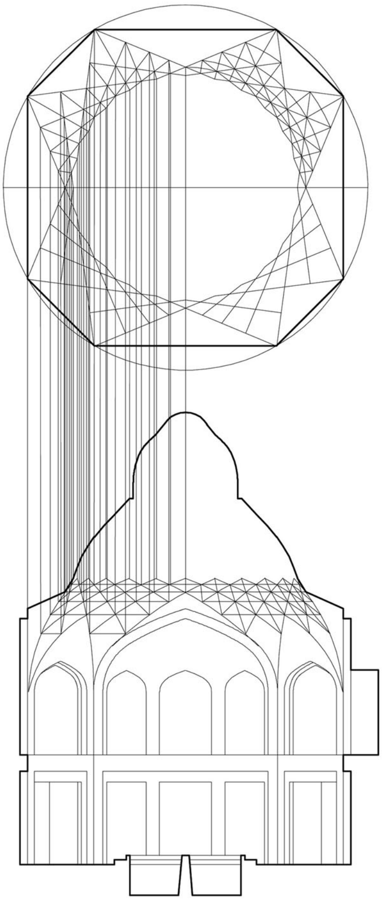


Fig. 15 Study of the proportions of the SE front. The overturning of the diagonal ($\sqrt{2}$) of the square, whose sides are equal to the "generative unit", provide the size of the facade. Some openings are in proportion to the length of the facade itself

tradition that aims at a visual negation of the reality of weight and the necessity of support (Ghiasvand et al. 2008: 21).

The first level of the kārbandi consists of a first frame of arches with a complete profile, known as *zirhafthì*. They rest directly on the piers, in correspondence with two non-consecutive vertices of the base octagon, and a second series of arches, referred to as *do-pa-dar-hava*, whose ends rest at various heights on the previous elements (Figs. 17, 18, 19, 20, 21, 22, 23). The points at which the arches intersect draw a vertical succession of horizontal planes of arrangement.



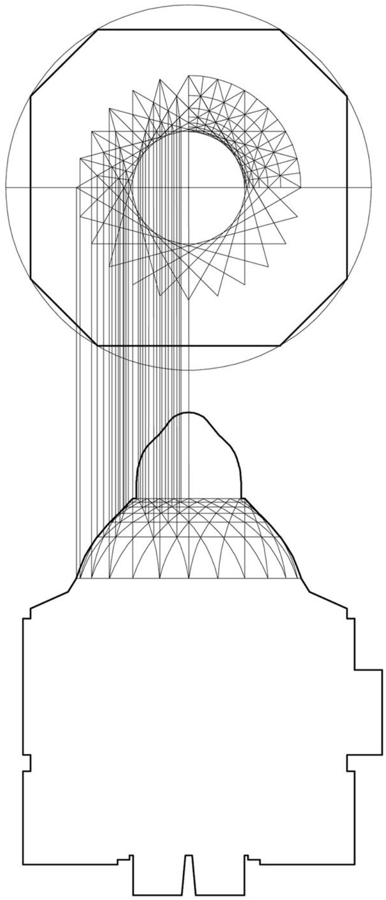


Fig. 16 Diagram of how to lay out the *kārbandi*

The construction of the geometry in plan begins with the circumference and its subdivision into equal parts. The layout of the plan is obtained by drawing intersecting lines that connect the dividing points of the circumference.

The design of a kārbandi begins with the drawing of a star-shaped polygon (*shamseh*) that, in the case of a rectangular or square space, must have an even number of wings (Pour Ahmadi 2014: 327–328).

The example analysed here utilises a 24-pointed star base (Fig. 24). To obtain the pattern on the intrados of the vaulted structure, the central octagonal room is inscribed in a circumference that is successively divided into 24 segments (Fig. 25). By joining together eight of the points identified on the circumference we obtain the sides of the octagon that generate the kārbandi; the irregular octagon is drawn by joining the vertices of two squares that rotate around the same centre at an angle of

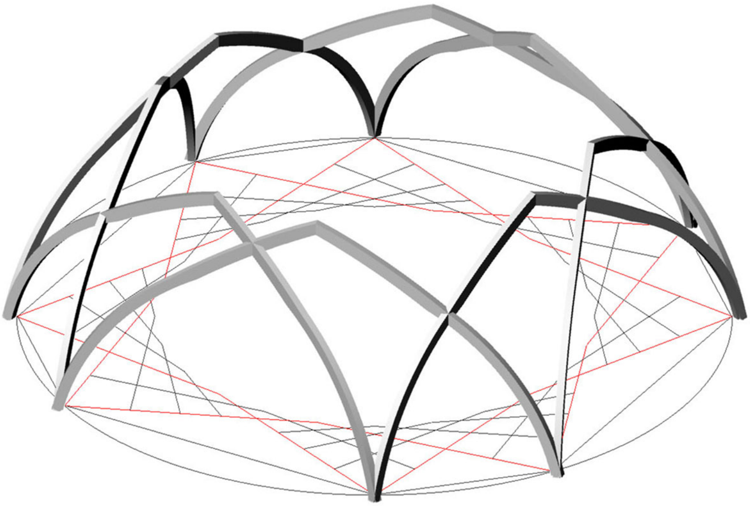


Fig. 17 The spatial configuration of the first level consists of a first frame of arches with a full profile, called *zirhafthì*, which directly rest on the piers below

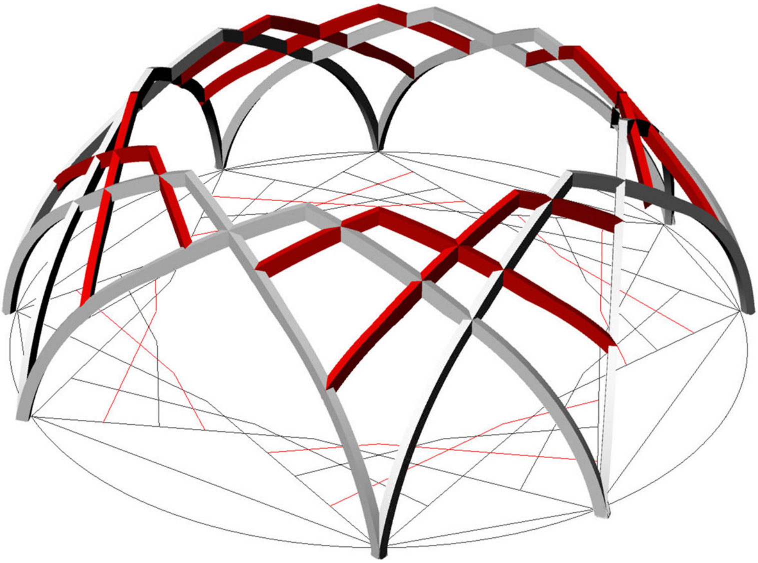


Fig. 18 The spatial configuration of the first level: the diagram highlights a second series of arches with an incomplete profile, called *do podar havà*, whose ends rest at various heights on first frame of arches

60°. Subsequently, each point of division of the circumference must be connected to the other two at intervals of 7 to obtain a star. The resulting drawing is larger than the space of the room (Fig. 26).

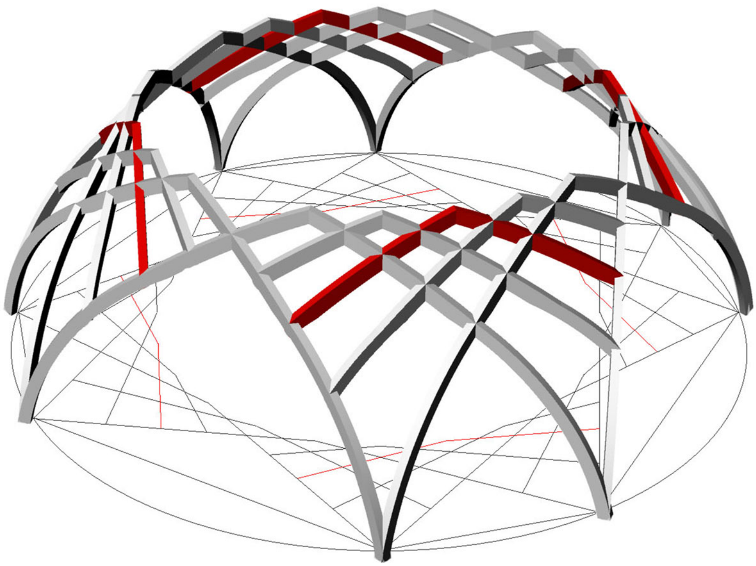


Fig. 19 The spatial configuration of the first level: the diagram highlights a third series of arches with an incomplete profile, called *do podar havà*, whose ends rest at various heights on first frame of arches

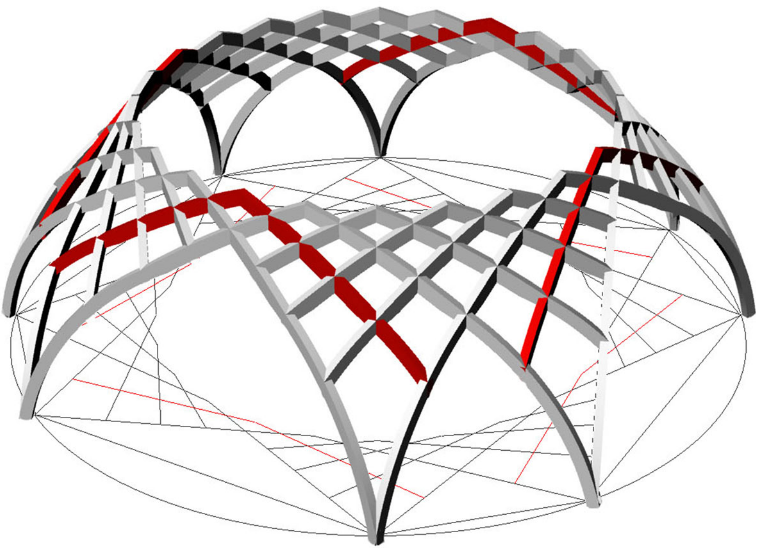


Fig. 20 The spatial configuration of the first level: the diagram highlights a fourth series of arches with an incomplete profile, called *do podar havà*, whose ends rest at various heights on first frame of arches

The plan drawing of the intrados of the pendentives, that is of the first level, forms an icositetragram {24/7}: a 24-sided star polygon. This self-intersecting non-convex polygon is obtained by linking pairs of non-adjacent vertices of a regular icositetragon (a

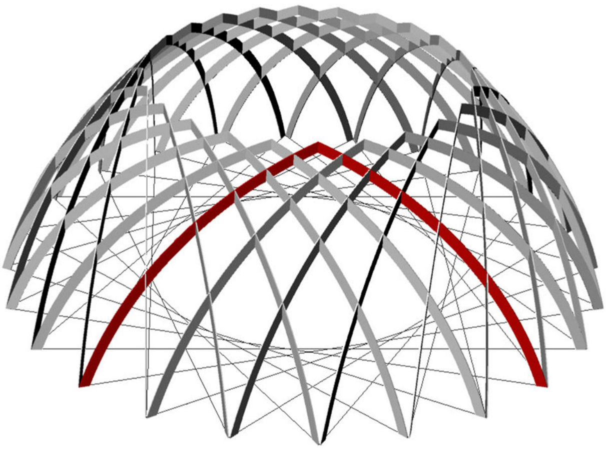


Fig. 21 The interwoven arches at the second level of the *kārbandi*

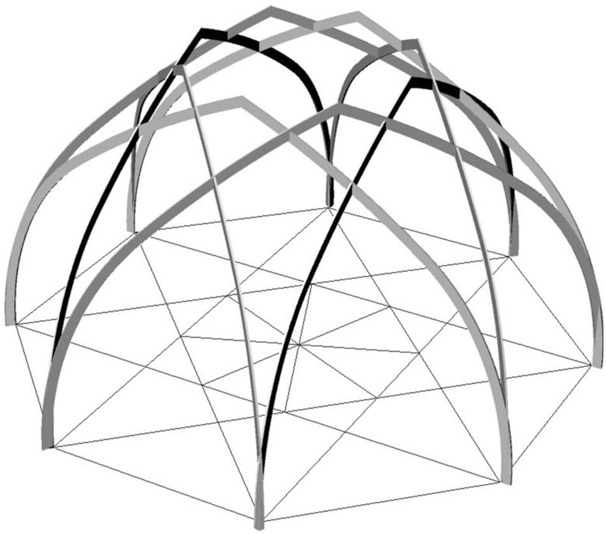


Fig. 22 The interwoven arches at the level of the lantern

24-sided polygon) through a single continuous line, until the first vertex is reached again. The symbol {24/7} indicates that the first polygon of the construction has 24 sides (or it is a circle divided by 24 equidistant points) and that to draw the star polygon it must link two vertices (or two points) at an interval of one every 7.

In the three-dimensional development of the structure, each segment that connects two points of the circumference in plan represents a pair of ribs (*tavizè*). When they trace a straight line in plan the arch is plumb; if, instead, they trace a V, the arch is out of plumb. The arches of the structure analysed are out of plumb; in

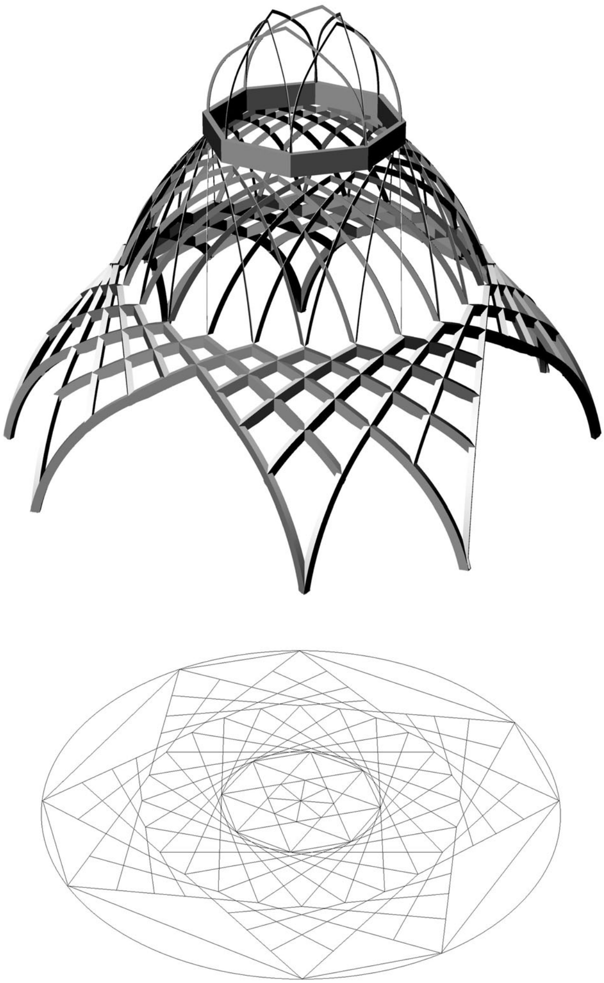


Fig. 23 The levels of the kārbandi

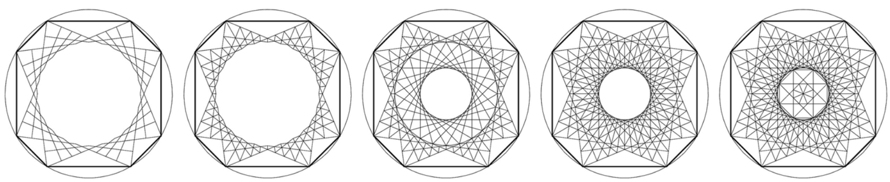


Fig. 24 The levels of kārbandi in succession. From the pattern of the lower level to the overall design

other words, their spring line and keystone are not located along the same vertical plane but lean in toward the centre (*Ghāleb Sarseft*); this reduces the diameter of the circular spring point of the dome.

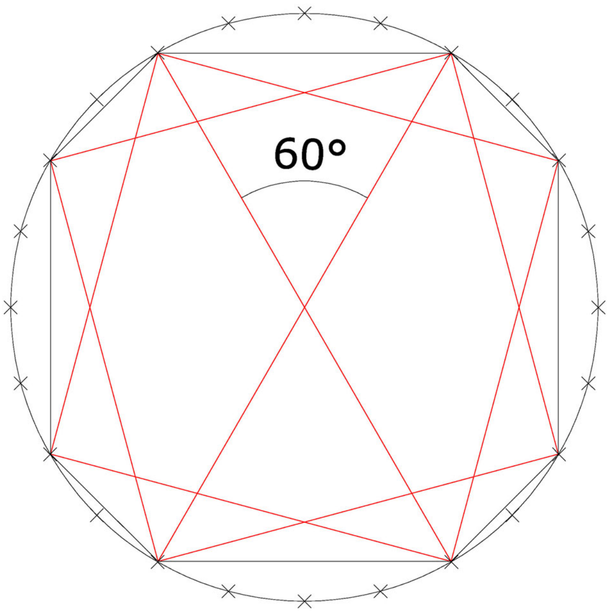


Fig. 25 The octagonal room is inscribed within a circumference divided into 24 segments. The irregular octagon is drawn by joining the vertices of two squares that rotate around the same centre at an angle of 60°

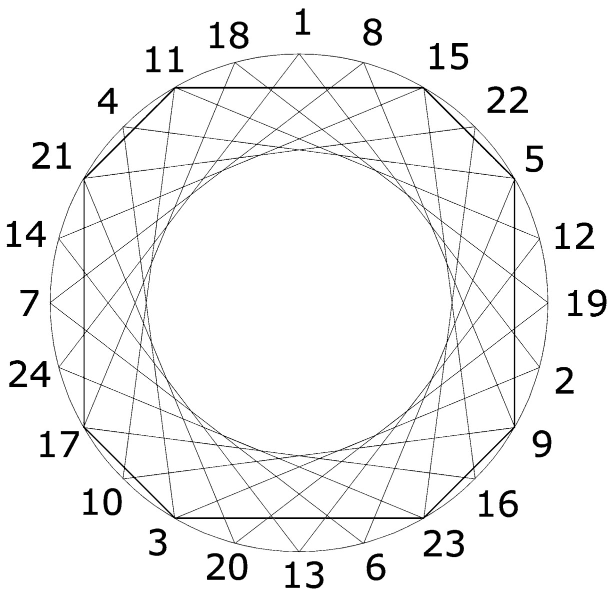


Fig. 26 Diagram of the construction of the 24-sided star polygon known as an icositetragram

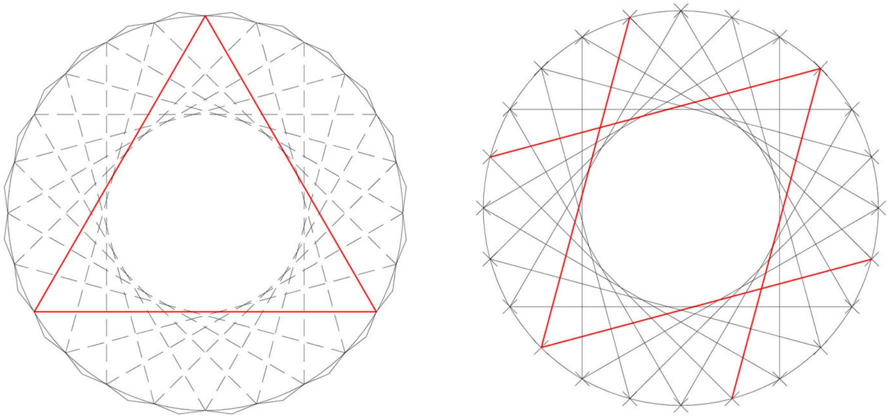


Fig. 27 Plan diagram of the second level. The drawing is realised by rotating eight equilateral triangles around their own centre. They are inscribed within the circumference drawn through the interior vertices of the 24-pointed star of the first level. The same drawing is obtained by tracing pairs of parallel lines between opposite points at intervals of 8 on the circumference divided into 24 parts

From the inner vertices of the 24-pointed star, which concludes the first level, rises a second series of arches which constitute the intrados of the second level, i.e., the spherical cap.

These arches are drawn in plan through the rotation, around its own centre, of eight equilateral triangles inscribed into the circumference that passes through the inner vertices of the 24-pointed star (Fig. 27). The same drawing is obtained by tracing, on the circumference divided into 24 parts, pairs of parallel lines linking opposite points at intervals of 8. This planar rotation generates a continuous internal profile with the shape of a 24-pointed star on a horizontal plane, and allows for the passage from an octagon to a nearly circular profile. In three dimensions, the segments drawn in plan correspond with arches whose keystones define the ends of the 24-pointed star.

The level of the lantern is also drawn in plan by tracing a regular star polygon (Fig. 28). In this case it is an {8/3} octagram constructed within a regular octagon. The octagram is a self-intersecting polygon obtained by linking pairs of non-adjacent vertices of a regular octagon through a single continuous line, until the first vertex is reached again. The symbol {8/3} indicates that the first polygon of the construction is a regular octagon (or a circumference divided by 8 equidistant points) and that to draw the star polygon it is necessary to link two vertices (or two points) every 3.

Conclusion

An a posteriori geometric reconstruction requires a careful analysis of proportions that in some cases may be misleading. There is no doubt that the use of geometry is both an important and basic factor to both the conception and the realisation of

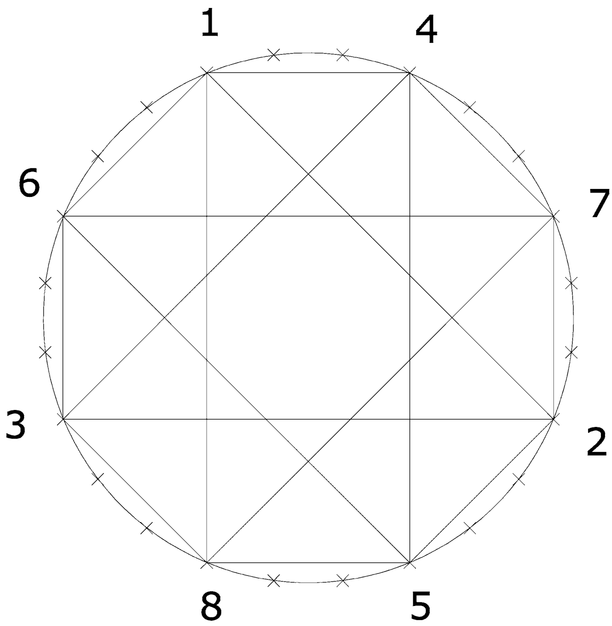


Fig. 28 Plan diagram of the level of the lantern. This plan can also be drawn by tracing a regular star polygon, an octagram, constructed inside a regular octagon

Persian architecture. Nevertheless, a slavish search for rules may hinder a very simple observation:

> The graphic method of point-joining used in constructing geometric patterns does not necessarily require any familiarity with Euclidean geometry. It is a practical geometry, utilised by the broadly illiterate craftsmen, as a means simply to create and reproduce *geometric art* (El-Said 1993: 24).

This paper has the sole objective of providing a key to analysing geometries that, while they appear to be complex, can in reality be laid out using a simple ruler and compass, beginning with the division of a circumference into equal parts. The paper reveals the geometric basis in the proportions of spatial design of the pavilion and in the realisation of the kārbandi. The geometric analysis indicates that were utilised various system of proportion that generates a unity of design and renders the architecture pleasing to the eye. This does not prove with certainty that these systems have been used, but simply that there is harmony of the proportions and of the parts.

Acknowledgments The author gratefully acknowledges Mrs. Alessandra Galdieri Ragno for the permission to consult the private library of the Architect Eugenio Galdieri.

Glossary

ālat	the cells that make up the grid of the *rasmibandi*[14]
andarouni	(inner) it is generally the interior or private part of a house complex which has its own courtyard. Here the term is used to indicate the interior garden
badgir	wind tower; these constructions are found in a vast area stretching from Pakistan to North Africa; their use is widespread in the desert region of Yazd for the ventilation and passive air-conditioning of buildings
bagh	garden
birouni	it is the name for the exterior or the more public part of a great house. Here the term is used to indicate the exterior garden
chapirè	zone of transition between an octagonal plan and the circular spring line of a dome
do-pa-dar-hava	*do* (two) *pa* (foot), *dar* (in) *hava* (air), literally "two raised feet", this term is used for the arches of *rasmibandi* that do not rest directly on piers, but are raised and supported by other arches
Ghāleb Sarseft	in Farsi *Having thrusting-headed formwork; ghāleb* refers to the mould of the main arches and *sarseft* indicates that the mould is not perpendicular to the ground plane
gaz	cubit, unit of linear measurement based on the distance between the shoulder and the clenched fist; this unit of length varies over time and location
girih	literally "knot"a Persian unit of linear measurement; in architecture it refers to the interlocking geometric patterns found in two-dimensional decorations or vaults or three-dimensional structures
hasht-va-nim-hasht	which literally means "eight and half-eight"is a type of octagon
hashti	an eight-sided vestibule, *hasht* means eight
kārbandi	arrangement of diagonal arches in different directions assigned by geometric rules that create a vault. "Karbandi is the structure of a kind of roofing, consisting of ribs with a certain arched form which interlock according to certain geometrical rules and form the main frame of the roof (Bozorgmehri 1992: 1)
mihrab	niche used to indicate the direction of Mecca in a mosque
pā bārik	a Farsi term for *having a thin foot;* it is one of the *ālat*, a quadrangular element in the lower part of a *rasmibandi* that rests directly on piers

[14] For the terms used in this paper reference was made to (Petersen 1996), (Pour Ahmadi 2014) and to the comprehensive glossary compiled by (Petralla 2012). Reference should also be made to this latter text for the detailed study of kārbandi vaults.

panj-o-haft	which literally means “five and seven” is a four-centred pointed arch utilised in the construction of vaults
rasmibandi	term used as an act of making interlocking patterns in construction; a form of decoration on the intrados of a vault created by the intersection of arches. It resolves the transition from a square plan to a circular spring line of a dome formed by a level of *pā bārik*one or more overlapping layers of *shāhparak* and a level of *sambusè*
sambusè	one of the *ālat;* curved triangular elements at the upper part of a *rasmibandi* closer to the *shamseh*
shāhparak	one of the *ālat;* Farsi for *butterfly,* it indicates curved quadrangular elements in the middle of a *kārbandi* between the *pā bārik* and the *sambusè*; they can also be composed on multiple layers
shamseh	literally “sun-like”, it refers to sun-shaped elements, the highest part of the vault in the *rasmibandi*
tavizè	literally “rib”; supporting arches that form the structure of a *kārbandi* and which transfer loads to the piers
zirhafthì	the first arch of the construction with a complete profile

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