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Analyzing Geometry in Arabha House Facades

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Abstract

Geometry is the basis of Iranian art and architecture; the most famous base units in Iranian architecture are Peymoon. So the most important problem to be considered in the facade is the Peymoon, also, according to Pirnia's opinion, the golden rectangle (which is actually a rectangle inscribed in a hexagon) played an important role in the design of the building but no information is available on how to use it. On the other hand, what appears next to Peymoon is a composition problem, so it has to be looked at the composition alongside Peymoon and the golden rectangle. The results of the analysis show that not only hexagons and also compositions have effects on the design of the facade but form the basis of the facade geometry. And all of the shaping lines correspond to the golden rectangles, with the traditional architect believing that the golden rectangular proportions look beautiful and are very close to the phi proportions.

Keywords: Geometry; Façade; Iranian Islamic; Peymoon

Introduction

Geometry is the one of the branches of mathematics knowledge, which has been used as a design tool throughout history. One of the most obvious manifestations of geometry is Islamic art and Islamic architecture, Geometry has always been an important factor in shaping and creating Iranian architecture, and Iranian architects have always aesthetic principles in mind and tried to use proportions to create balance, harmony and order in the body of thebuilding. On the other hand, since in traditional architecture, shapes that taken from geometry is identifiable and timeless factors in Iranian architecture and they are applicable in all periods of time, so they have the potential to be updated in contemporary architecture. Today using the geometry as a design tool has been ignored and this is one of the most important causes of visual disturbance in the face of cities. In traditional architecture, facade geometry was controlled by peymoon and composition and created a unique structure in the facade. And desert cities, including Yazd, Isfahan, Shiraz, and Kashan, have exhibited the application of these geometrical principles (Peymoon and composition) in magnificent houses, Iranian architecture from ancient times with architectural masterpieces such as Persepolis and Pasargadae has been progressing day by day and maintaining this course and reached its highest level during the Qajar dynasty, but unfortunately this field is disrupted with entering modernity in Iranian architecture, what we see today as architecture. Completely elementary and combined designs without order and harmony without regard to any of the original Iranian architectural values [1].

Arab Zadeh house belongs to the Qajar period and is located in Yazd, Imam Street, Fahadan alley and is also known as the Fahadan House. This house has been registered as one of the national monuments of Iran on March 1, 2009 with registration number 7760. Because of its architecture and decorations, this house belongs to the "Qajar Period". Due to its historic Qajar period and the value of Fahadan house, and also using large Peymoon and the usual compositions in facades of that, this house has been chosen for a case study.

Methodology

The use of field studies and library documents is the first stage of the research, but the main part of the research is belonging to geometrical analysis of the Peymoon, composition and golden proportions. The researcher first analyzed Peymoon and composition as two main features of traditional house facades. Then, considering the common compositions in facades, examines several compositions that have been used extensively in the houses with large Peymoon and then by considering the number of gerehs in the Peymoon and the Composition of facades has obtained the pure geometry of the facades and their main lines. according to the roles of the hexagon regular and the golden rectangle that is inscribed in the hexagon, tested this on the pure geometry that obtained and by examining the position and method of using the hexagon in the facade and then examining this issue on the Arab Zadeh's facade has been discussed [2, 3].

The numbers used in Peymoon and the composition are fixed and particular, without any errors in shapes and drawing and also buildings. And Also, the result of past analyzes was about using Regular foursquare and Regular pentagon but this research discovered that the base of geometry in facade of Iranian houses was regular hexagon. This result is logical that considering the proximity proportion of golden rectangle in hexagon to proportion of phi. Fully customizable to all facades in the large Peymoon. It should be noted that the analysis on other compositions were tested by the researcher and all of the results were unique. In the present study, case study has been chosen from large Peymoon houses. We also selected 3-2-5-2-3 as an example, and the Arab Zadeh House was one of the good ones that responded to both [4].

Previous studies of geometrical analyzes in facade

Geometry and golden proportions define the structure and the form of buildings from early on until the present day; have been the

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object of many previous studies. Some studies that are related to this paper are summarized below.

Mark A. Reynolds has spoken about ϕ-Related Ratios Joined with √2 and √3. Φ is used as a major ratio in during the history of architecture and √3 especially is used as a major ratio in during of Iranian architecture history. Behzad Molavi has also analyzed the facade of magnificent buildings and has spoken about square and Regular Quadrilateral in the facade of traditional building in Iranian Islamic architecture. That is the base article and important for this paper. (Molavi 1996) geometrical analyses did by lots of researchers especially for finding logical relationships and ratios between elements in architecture. for example, Liz Dewitte studied ratios in the plan and facades of Dom Bellot as a case study and did geometrical analyses in this building. and also Michael G. Smith and Rachel Fletcher do that in Union Trust Guardian as a case study.

Manifestations of geometry in facade

Research in Persian architecture without knowledge of the geometry is impossible. Regardless of the type of architectural orientation, what must necessarily be considered in any design; Its geometry and the formation of a definite system of relationships between sizes and shapes and their conformity to the structure of the design The creation of the geometric structure of architectural designs began at the dawn of architectural history and has been in existence for thousands of years and with the emergence of dozens of schools and historical periods. (Molavi 1996) perhaps the most important tool in the science of geometry as it can be expanded in all directions and resembles a work of art completely to its heavenly principle The main objective of scientists of geometry is discovering the geometric proportions and relations of the components of the base pattern and their repetition way in order to make possible their redrawing with the same basic proportion but at different scales. Geometry plays a fundamental role in design of Persian architectural monuments. From the viewpoint of exterior functioning, the use of geometry as art for creation of shapes, patterns and proportions reminds the Great Architecture of the World and recalls the Archetypes. From the viewpoint of interior functioning, geometry as science for selection of structural dimensions such as height, length and width of the building and its structural elements. Accordingly, the issue of proportion as one of the principal topics of geometry has a prominent status in architecture "Pythagoras discovered that the consonances of the Greek musical system could be expressed by the simple numerical progression—1, 2, 3, 4—and their ratios, 1:2, 1:3, 2:3, 3:4. This relationship led the Greeks to believe they had found the key to the mysterious harmony that pervaded the universe. The Pythagorean creed was “Everything is arranged according to numbers.” Plato later developed Pythagoras’ aesthetics of numbers into aesthetics of proportion. He squared and cubed the simple numerical progression to produce the double and triple progressions, 1, 2, 4, 8, and 1, 3, 9, 27. For Plato, these numbers and their ratios not only contained the consonances of the Greek musical scale but also expressed the harmonic structure of his universe." Proportionality in geometry, architecture, music and art can be said to be a harmonious relationship between the components, and between each component and the whole set., Vitruvius (25 - 70 B.C.) a Roman architect and engineer in the earliest book on the subject, writes that since the nature of the human body fits in such a way that its components are fully proportioned to the body as a whole, ... in complete buildings different components must have exact symmetric ratios relative to the whole design. By means of symmetric ratios, Vitruvius means the same proportions. Through the proportion’s apparatus, all the parts are in harmony with each other and at the same time with the whole set, and thus a pleasing and actionable design is provided. According to Abulqasemi, geometry, niyaresh1 and Peymoon and gaz play an essential role in the developmental stages of an architectural work, sometimes referred to as sacred geometry. Based on traditional knowledge of fitness, beauty does not depend on one's virtuosity and taste, and from the perspective of the knowledge of fitness, there are numerous practices and vast rules. The geometry and proportions are manifested by the tools and methods in traditional house facades [5-7].

Peymoon

Angular Conveyor

Composition of horizontal sizes

Peymoon

One of the most important results related to geometry is the emergence of measurement systems. The most famous base units (based on later measurements and proportion type) are the Peymoon in Iran (which was one door wide) and the European module (whose column diameter was one-third its height) And in China and Japan is ken (which were two axes to the two columns. Modular unit which is called Peymoon in Persian is the basic unit of measurement in Iranian traditional building. Peymoon is measure and is the organs of the building are guaranteed for design, fit, durability and beauty The Peymoon itself is known for two main types: the small Peymoon with 14 gereh and length 93 cm and the large Peymoon 18 gerehs and 120 cm. that was a middle-aged man height.

(Table 1)

Gaz definition

Table 1: Introducing dimensions in the Peymoon system.

Architectural element	In the metric system (cm)		In the Peymoon system	
	Large Peymoon	Small Peymoon	Large Peymoon	Small Peymoon
Radiation strap	26.6	13.3	4 gerehs	2 gerehs
Width of wall	73	60	11 gerehs	9 gerehs
Width of a door and window	120	93	18 gerehs	14 gerehs
Height of a door	200	187	30 gerehs	28 gerehs
Rosen height	60	60	9 gerehs	9 gerehs
Width of Two doors room (Do-dari)	293	213	44 gerehs (2 gaz and 12 gerehs)	32 gerehs (2 gaz)
Width of Three doors room (Seh-dari)	440	320	66 gerehs (4 gaz and 2 gerehs)	48 gerehs (3 gaz)
Width of Five doors room (Panj-dari)	733	533	110 gerehs (6 gaz and 14 gerehs)	80 gerehs (5gaz)

Gaz is one of the old units of length. Dimensions of Peymoon use from the gaz and its components such as the gereh. Gaz which used to measure dimensions, first used in Babylon and Assyria. The Babylonians and Assyrians took this instrument, at a size of about 0.53 meters from the Assyrians which is used in Mesopotamian civilizations. In Iran, doubling this amount (about 1.06 meters that used as the Great Gaz is the basis of architectural works.) In the eleventh century AH, A royal Gaz, according to Jean Chardin, was 94.745 cm and Ferrer said it was 95 cm according to Jean Chardin, is 106.6 cm, and It is divided into sixteen gerehs. The word 'gaz' comes from 'was' meaning 'open hand'(Lambton 1953), which is variable. The table below summarizes its components and divisions..

(Table 2)

It should be noted that the present study did not set the size of gaz for benchmark because of preventing error from different sizes of gaz, but instead of measure, the number of gerehs being benchmark to match the different gazes used in different facades.

(Figure 1)

(Figure 2)

The method of working with measuring devices called 'Angular Conveyor' is briefly as follows:

Table 2: Introduction of gaz[2] and its components.

Equivalent to centimeters	Equivalent to Gereh	Gaz and its components
106.66cm	16 gerehs	1 gaz
53.23cm	8gerehs	0.5 gaz
26.66cm	4 gerehs	carak
6.66cm	1 gerehs	gereh
3.33cm	0.5 gerehs	bahr

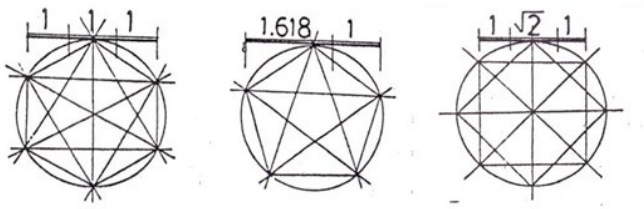

Figure 1: Past proportional measures and measurements (squares, pentagon and hexagon devices).

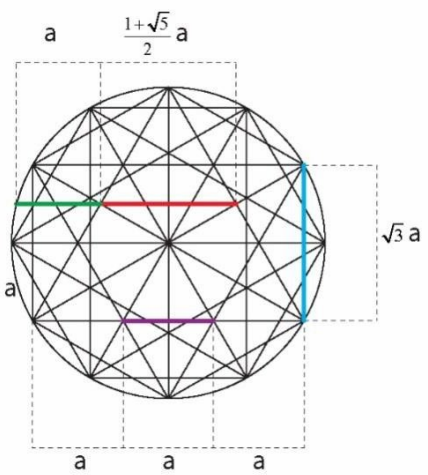

Figure2: Hexagonal properties.

Determine the geometric center of the building's central space

Determine the composition of the facade according to the application space requirements and the hexagonal drawing corresponding to this composition

Draw a grid of hexagonal proportions corresponding to the composition

Determine the horizontal and vertical lines of the façade

We have previously stated that Measuring systems which are based on angular conveyer, are based on the three main geometric shapes of squares, pentagons, and hexagons and also pentagons give us more Greek proportions (phi proportion), and the hexagons give us Iranian gold proportion that used in architecture, and this is exclusively for Iranian architecture [8].

Definition of Iranian Golden Rectangle

While reading about Iranian architecture, there has been talk of an Iranian golden rectangle that great's architects such as Pirnia have verified that this rectangle is the base of geometry in Iranian architectures and explicitly point out. And using it in drawing the map or the rooms, and the courtyard, etc., The Iranian Golden Rectangle is obtained by inserting a rectangle inside a regular hexagon and it has 3 proportions. In the houses with a central courtyard the proportions of yard, Five doors room (Panj-dari), Three doors room (Seh-dari) and other elements were based on this proportion. It should be born in mind that a regular hexagon is a shape that cannot be mistakenly drawn because it uses a parallelogram triangle. Using the triangle is one of the characteristics of Iranian architecture from the pre- Islamic period. Later, Iranian architects used this process to create more complicated and elaborate form in the design of their buildings. Therefore, it was used in other arts such as Khatam as well as carpets on the floor of Holy shrine and houses and to obtain the Iranian golden rectangle use it. They also used regular hexagons to design geometric motifs.

Compositions of horizontal measurement

Always in the history of architecture proportion and ratios are used to create a sense of order and harmony Ordering systems of ratios are more than simple determinant functional and technical elements of architecture space which provide aesthetical relation between dimensions and sizes. Molavi in his article identifies five main categories of facade compositions in terms of the horizontal dimensions that were common in traditional house facades, which in fact combine layout of the main facade elements, namely the Three doors room (Seh-dari), Five doors room (Panj-dari), narrow corridor, and wide-corridor facades. Specified for the narrow corridors with number 1, wide corridors with number 2, Three doors room (Seh- dari) with number 3, and Five doors room (Panj-dari) with five.

(Table 3)

In the table number 4, the plan of compositions is plotted in terms of the number of gerehs. As it can be seen, it has two transverse broad corridors and one transverse narrow corridor, so it would make sense to consider the acronyms 2 and 1 for the corridors.

(Table 4)

Considering the composition of horizontal dimensions, the following table can be used for common types in the facade of Qajar houses in large Peymoon.

(Table 5)

Table 3: Composition of horizontal dimensions in traditional house façade.

type	composition	symbol
first	Seh dari- narrow corridors – Seh dari- narrow corridors – Seh dari	3-1-3-1-3
second	Seh dari- wide corridors -Seh dari- wide corridors – Seh dari	3-2-3-2-3
third	Seh dari- narrow corridors – Panj dari- narrow corridors – Seh dari	3-1-5-1-3
fourth	Seh-dari- wide corridors – Panj dari- wide corridors – Seh dari	3-2-5-2-3
five	Seh-dari- Seh-dari- Seh-dari- Seh-dari- Seh-dari	3-3-3-3-3

Table 4: Number of gerehs in the elements of facade in large Peymoon.

Architectural element in facade	The number of gerehs in the largePeymoon	Plan (Drawing by the author)
Five doors room(Panj-dari)	2+18+4+18+4+18+4+18+4+18+2=110	
Three doors room(Seh-dari)	2+18+4+18+4+18+2=66	
wide corridors	2+18+4+18+2=44	
narrow corridors	2+18+2=22	
Wall thickness	11	

Table 5: Number of gerehs in common types in view in large Peymoon.

type	symbol	The number of gerehs in the largePeymoon	Plan (Drawing by the author)
first	3-1-3-1-3	11+66+11+22+11+66+11+22+11+66+11=308	
second	**3-2-3-2-3**	11+66+11+44+11+66+11+44+11+66+11=352	
third	**3-1-5-1-3**	11+66+11+22+11+110+11+22+11+6+6+11=352	
forth	**3-2-5-2-3**	11+66+11+44+11+110+11+44+11+6+6+11=396	
fifth	**3-3-3-3-3**	11+66+11+66+11+66+11+66+11+66+11=396	
sixth	**2-1-3-1-2**	11+44+11+22+11+66+11+22+11+44+11=264	
seventh	**1-3-1**	11+22+11+66+11+22+11=154	
eight	**1-5-1**	11+22+11+110+11+22+11=198	
ninth	**2-5-2**	11+44+11+110+11+44+11=242	

According to Table 4 and Table 5, the number of gerehs of the Three doors room (Seh-dari) and Five doors room(Panj-dari) elements and the corridors and wall thicknesses as well as the mentioned compositions and theirrelationship with the angular conveyors formed on the basis of squares, pentagon and hexagons were investigated , and also all of these numbers were evaluated in the small Peymoon, but in the small Peymoon the system was unfortunately not discovered by the researcher, but in the large Peymoon after examining all the conveyors on the hexagonal conveyor, some lines of compositions were matched completely on the lines of conveyors without any errors, and so this study shows that the important vertical facade lines were formed on the hexagonal basis, which incidentally derives from the golden proportions of Iranian architecture. Table 6 summarizes the angular conveyer in all the compositions found in the traditional house facades, and the important vertical lines caused by the conveyer that were in full compliance with the original facade lines (in terms of gerehs) ,these lines are marked in red. Traditional architects are expected to use the same geometry and conveyor; since precise geometry is true for all compositions without any error of analysis [9, 10].

(Table 6)

Angular convectors are used to organize all the elements around the central courtyard in accordance with the common configurations. They are depicted in the table, since the focus in this article is on the facade, so the analysis of the type facades is discussed below.

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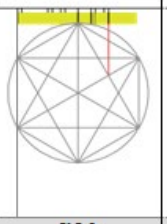
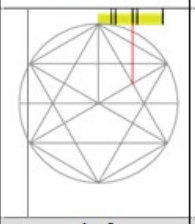
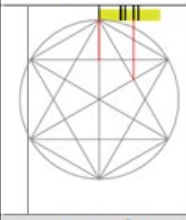
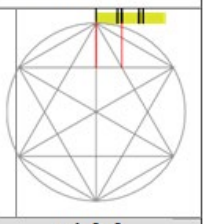
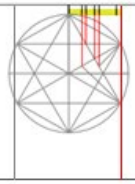
How to obtain Horizontal and Vertical Lines of facade type 3-2-5-2-3 from Hexagonal Diameters

At this point, we claim that the geometric grid obtained by the angle converter. For facade type 3-2-5-2-3 is fully match with the geometry of the facade, so first explain how to obtain this grid and then prove our claim in the next section.

In the Figure 3 we go to the first figure in left. First, the intersection of the hexagonal diameters with the length of the inscribed rectangle in the hexagon divides the length of the rectangle into three equal parts. (It should be noted that the properties of an inscribed rectangle in a regular hexagon are that by dividing its length into three equal parts three golden rectangles are created.) Thus, the blue and white rectangles are smaller in size and all of them are golden rectangle. The white golden rectangle gives us a width of five doors room (Panj-dari). Now, given the intersection of the lengths of the blue rectangles of the second figure with hexagonal diameters, each of them becomes three smaller golden rectangles.in the third figure green and white rectangles are obtained

Table 6: Hexagonal angular conveyor and its relation to common residential compositions in the large Peymoon.

type	first	second	third	forth
symbol	3-1-3-1-3	3-2-3-2-3	3-1-5-1-3	3-2-5-2-3
Conformance of Angular Conveyor to Composition Lines. Drawing by author				
type	fifth	sixth	seventh	eighth
symbol	2-1-3-1-2	1-3-1	1-5-1	2-5-2
Conformance of Angular Conveyor to Composition Lines. Drawing by author				

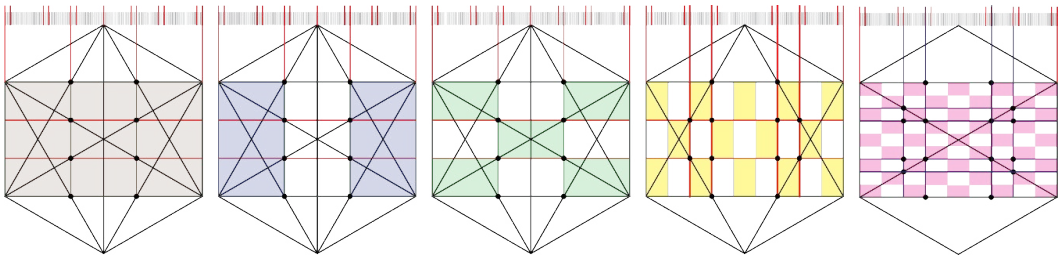


Figure 3: How to obtain horizontal and vertical line of types 3-2-5-2-3 from hexagonal diameter.

in this way, and in this figure we have five green and four white golden rectangles that give us two horizontal lines and two main vertical lines. In the fourth step, consider the intersection of the hexagonal diameters of the green golden rectangles, that each white and green rectangle is divided into three smaller yellow and white rectangles. All of them are golden rectangles. The resulting vertical lines give us the boundary between the three doors room (Seh-dari) and the wide corridor. Finally, consider the intersection of the hexagonal diagonals with the yellow golden rectangle, and obtain the corresponding horizontal lines.

(Figure 3)

As can be seen, the vertical lines of the facade are perfectly consistent with the lines obtained by the composition of the angular Conveyor (the tiny black lines at the top of the regular hexagons), and since the lines of compositions obtained by the numbers and Lines from the intersection of hexagonal diameters are perfectly intersect able with composition which shows the wonders of using geometry in the facade. It is also clever to use Peymoon to reach the golden rectangles for designing traditional architectural facades are wonderful. In the figure 4, main horizontal and vertical lines obtained from the number of gerehs in the wall thickness.

(Figure 4)

Examine the geometric lines of the facade in the Arabha house

The case study (Arabha house) is based on the geometry of the composition 3-2-5-2-3 and has the large Peymoon with an approximate area of 2000 square meters.

(Figure 5)

(Figure 6)

As shown in the plan, all four sides of the right-hand courtyard have a composition of 3-2-5-2-3 and are designed in the large Peymoon. Of course, the eastern and western fronts have type 2-3-2-5-2-3-2. The facade you are looking at is as follows.

(Figure 7)

First, we draw the rectangle and hexagon corresponding to the composition of the facade according to the width of the doors. Obtain the vertical lines of the facade from type of plan and apply the rectangle inscribed hexagon (the golden rectangle fit to the facade type). It is enough that these vertical lines intersect with the rectangle diameter and give us horizontal lines as can be seen in Figure 8. All horizontal lines correspond to the horizontal lines of the facade, and this shows the correct alignment of the horizontal and vertical lines with the geometric grid we obtained.

(Figure 8)

As it can be seen in Figure 8, the lines correspond perfectly to the horizontal lines of the facade, and even the distance between the first-floor doors and the second-floor doors is exactly the corresponding wall

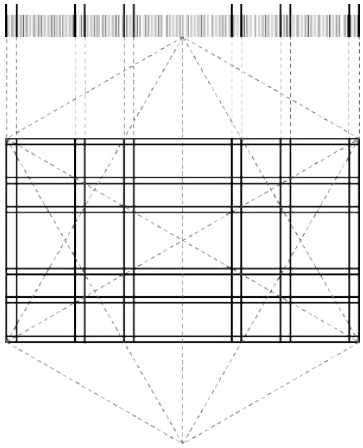


Figure 4: Geometric grid derived from angular conveyor for type composition 3-2-5-2-3.

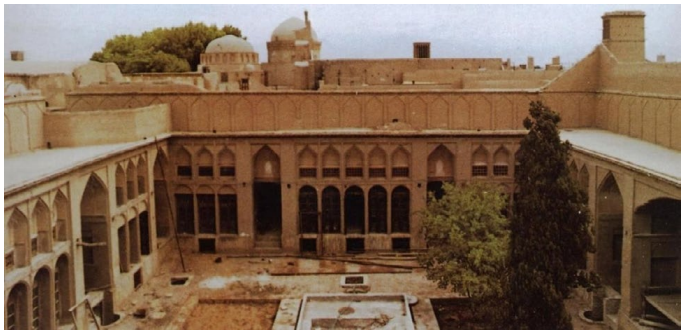


Figure 5: Arabha complex in Fahadan neighbourhood in Yazd (Haji Qasemi and Rasouli and Jalilian and Zarini and Shahnavaz.

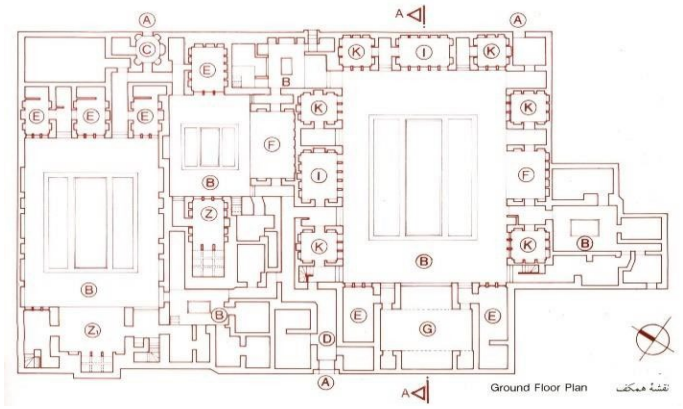


Figure 6: Plan of Arabha complex in Fahadan neighbourhood in Yazd (Haji Qasemi and Rasouli and Jalilian and Zarini and Shahnavaz 2004.

thickness lines obtained from the intersection with the golden rectangle diameter. Also, the distance from the courtyard to the first- floor corresponds perfectly to the first horizontal sub-line and the horizontal line which divides the second-floor windows corresponds perfectly to the sub-dividing line of facade. In addition, the roof is perfectly aligned with the line of the proposed geometry. According to the case study, the horizontal and vertical lines of the facade have been readily adapted, confirming the validity of the use of the hexagon in the large Peymoon and in designing facade of the traditional Iranian house. The interesting thing is that not only do all facades lines follow the golden rectangle geometry, but even the roof and ground line thicknesses do. And that

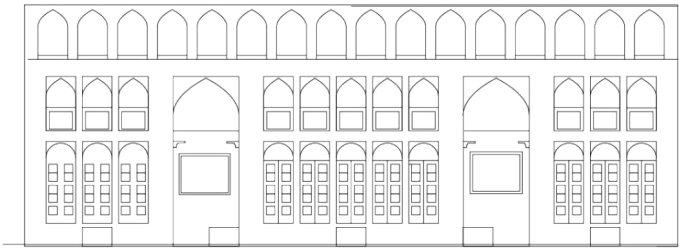


Figure 7: View of the north facade of the Arabha complex in Fahadan neighbourhood in Yazd.

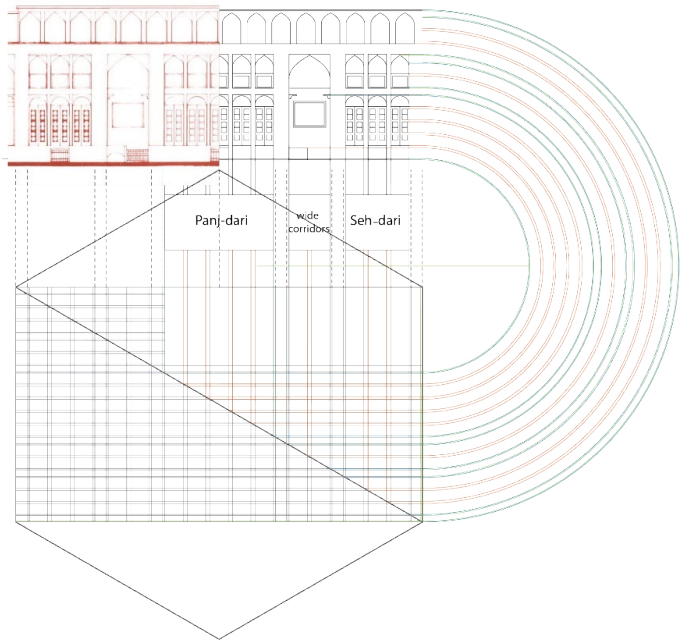


Figure 8: Matching facade lines to geometric grid obtained from this research.

shows just how large Peymoon has been great in the aesthetics and the matching of the lines, and the interesting thing about the Arabha house is the elevation. That Coming from the width of the 'wall- three doors room (Seh-dari)-wall – double front (wide corridors)-wall- Five doors room (Panj-dari).

Conclusion

On the basis of the studies carried out in the current paper ,Considering Pirnia's remarks on the use of the golden rectangle (rectangle surrounded by hexagon) and proportions in traditional Iranian Islamic architecture , We investigated this and by using the precise sizes of conventional facial compositions in terms of number of gerehs and width of door, in the large Peymoon and three doors room (Seh-dari) and Five doors room (Panj-dari), as well as wall thickness and composition of these dimensions with hexagonal geometry, it was concluded that the result of reading is in full agreement with the conventional facades, and the case study chosen by the Arabha House in Yazd completely confirmed this. Of course, this combination and geometry is generalizable to all types of facades in tables 5 and 6.

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