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Architectural Surface Analysis of Wind Catchers of Yazd to Determine the Optimal Level of Efficiency

Golnar Aryan

Master of Architecture student, Scuola Di Architettura E Societa, Politecnico di Milano, Italy

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ABSTRACT

Wind catcher, as a cooling system, can make use of wind renewable energy in order to provide desirable ventilation. This architectural element can be seen throughout the vernacular architecture of warm climates of Iran. In this study, Yazd has been chosen as a sample of hot and dry climate. Accordingly, this research attempted to address, for the first time, the typology of wind catchers as well as those relationships that governed the architecture of these buildings. The results were derived from the investigations conducted on the physical characteristics of 53 wind catchers as well as some field inferences. Regarding this, the descriptive-analytical research methodology was used in this study. Furthermore, the samples were chosen using a proportional random cluster sampling method. The typology was conducted through structural analysis and detection of common patterns and themes of wind catchers. Furthermore, architectural dimensions of these wind catchers were examined thereof. The quality of the impact of wind catchers' architecture on their performance was determined via analyzing the thermal behavior of archetypes of selected wind catchers. This research made use of Computational Fluid Dynamic (CFD), FLUENT Software and Numerical Analysis as the most accurate analytical methods. The results of these analyses depicted that the physical characteristics of wind catchers contributed a lot to optimum performance. Accordingly, specification of optimal model can pave the way for making anew use of these wind catchers in a better and more efficient way.

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INTRODUCTION

Wind catcher, as its name suggests, is an indispensable part of the skeleton of buildings located in hot and dry or hot and humid climates of Iran. These wind catchers can guide the windflaw and make use of natural clean energy in order to adjust the temperature of residential space to a temperature in the range of human comfort. This research is focused on hot and dry climate. As such, Yazd city has been chosen as the case study sample in this research.

Wind catchers consist of several components that are endowed with aesthetic aspects and heavily affect the performance of wind catchers. Identification of these components contributes to a better understanding of the structure of these wind catchers. In this paper, the physical components include rack, shaft, main and subsidiary blades as well as open and closed apertures. These components are discussed in detail in the following section.

Racks:

These parts are located on the apex of wind catchers and consist of canals passing the airflow.

Shaft:

This is a part of wind catcher that is located between the rack and the roof.

Blade:

Blades are made of mud brick and baked brick, and divide the canal into several smaller canals.

The main blades:

These walls extend to the center of the tower and divide the wind catcher into smaller canals.

The subsidiary blade:

These walls do not extend to the center of the tower and just go to the exterior walls. The subsidiary blades can be compared to canal blades of coolers.

Open and closed apertures:

Regarding the façade of wind catchers, any space between the two blades (whether main or

Corresponding Author: Golnar Aryan, Master of Architecture student, Scuola Di Architettura E Societa, Politecnico di Milano, Italy

subsidiary blade) is called an aperture. If the aperture is open and the air can pass through it, it is an open aperture. Otherwise, it is called a closed aperture (Mahmoodi, 2003, p. 243).

Research methodology:

This study made use of an analytical-computational methodology. Regarding the architecture section, this research was of qualitative type. However, a quantitative type of research was used to analyze the thermal behavior of these structures. The following procedure is used throughout the research process:

The quality of relationship between the hall, wind catcher and yard can determine the placement of wind catcher in any given house (Abouzia, 1985, p. 57).

Data collection method:

library study and field inferences

Data analysis method:

Inductive reasoning and numerical analysis using software.

1. Typology of wind Catchers:

1.1. Typology A:

Typology based on the placement of plan: the placement of wind catchers is not uniform in all houses. As such, this factor has had a significant impact on the climatic performance of these structures. Wind catchers have always been located within the summer-living quarter of houses and they have comprised the southern part of the yard. Hall is the main space of summer-living quarter of the house and its dimension is generally 3 to 5 meters.

Generally, hall is directly linked to the wind catcher. However, this link can be interceded by another space. Regarding the placement of wind catchers and their relationship with the main spaces of summer-living quarter, one can divide the wind catchers into three types:

1.1.1. Type (A-1):

The placement of wind catcher at the back of the hall and over its axis of symmetry. In this way, the axes of symmetry of wind catcher, hall and yard are directed toward a similar point. Regarding this, the Type (A-1) can be split further into the three categories (Figures 1 and 2).

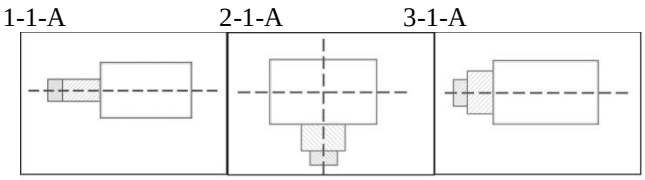


Fig. 1: Different types of relationships among hall, yard and wind catchers in Type A-1 (Source: the author).

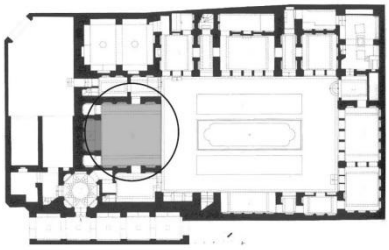


Fig. 2: The House of Alireza Arab, Type A-1. (Source: Ganjnameh Yazd Houses, p. 42)

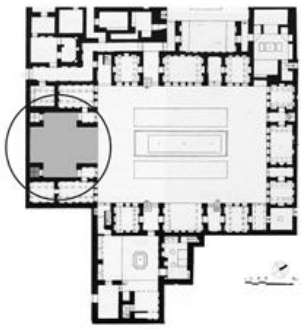


Fig. 3: The House of Mahmoodi, Type A-2. (Source: Ganjnameh Yazd Houses, p. 110).

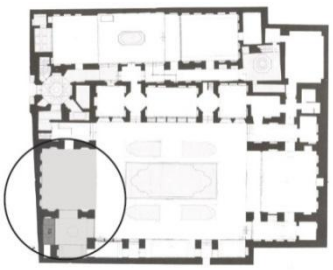


Fig. 4: The House of Rasoolian, Type A-3 (Source: Ganjnameh Yazd Houses, p. 93).

1.1.2. Type (A-2):

The placement of wind catchers over one of the northern corners of the hall. In this type, the cross-shaped hall is aligned with the longitudinal or transverse axis of the yard and the other wind catcher in not located in the axis of symmetry of hall (Figure 3).

1.1.3. Type (A-3):

The placement of wind catcher in the corner of yard. Regarding this type of placement, the wind catcher is linked to the hall via a summerhouse and, thus, is not directly connected to the hall (Figure 4).

2.1. Typology B: Plan typology:

The plan format of wind catchers plays an important role in the formation of wind catchers. The diversity of plans of wind catchers in Yazd city is unparalleled in the Middle East, which shows the ingenuity and creativity of Yazdi architects. Generally, circular, hexagonal, octagonal, square and rectangular plans are observed throughout the wind catchers of Iran. As such, there has been no triangular wind catcher in the Middle East region. Wind catchers based on circular plan are so rare in Iran. Accordingly, there is no such wind catchers in Yazd. However, there is only one such example located in a remote location around Yazd city. Apart from the overall format of plans, wind catchers can be differentiated in terms of the format of internal blades. Furthermore, wind catchers can be classified in accordance with the detailed specifications of their plans. This can be seen in the following figure. Internal blades are formatted into +X, K, I, H shapes. According to the geometrical format of plan and the placement of the blades, one can classify the wind catchers into 3 main categories and 10 sub-categories. Besides, two categories of these ten categories can be further divided into two sub-branches. Regarding the field inferences, it can be argued that rectangular plan consists of 88.6 percent of wind catchers in Yazd. Thus, the skeletal analyses have been focused on five main types of rectangular plans (Figure 5).

Type B-3.1:

Among 53 wind catchers, only two wind catchers are equipped with rectangular plan and X blade. Accordingly, these types of wind catchers are located in the corner of hall (similar to Type A-2). In this type, there is no closed aperture at the lateral side. Generally, the dimension of length to width is 1 to 1.4 meters.

Type B-3.2:

Wind catchers equipped with some perpendicular blades (+) can be considered the most common types of wind catchers in Yazd accompanied by different and diverse dimensions. In this type, there is no closed aperture at the lateral side and all the apertures of lateral side are open thereof. The depth of apertures in the longitudinal side is up 1.2 in lateral side. On the other hand and depending on the length of wind catcher and the number and form of separator blades, the depth of apertures in the lateral side can be up to 1.3 to 1.6 in the longitudinal depth of wind catcher (Figure 7).

Type B-3.2.1:

In this type, the blades are located within equal distance from each other into plan. As a result, the derived small canals have equal size. This type of wind catcher is considered the most common type of plan within the wind catchers of Yazd. Plan dimensions (length to width) in this type vary from 1 to 1.4 and 1 to

2.25. The results of field inferences can be summarized in the following items:

The plan dimensions of these wind catchers vary from 1.4 to 2.25. The height of these wind catchers also varies from 6.5 meters to 19.74 meters. Since these wind catchers are four directional and need to receive wind from the four directions, the canals have been separated into smaller parts via the main blades that extend from the wall to the wall of wind catchers. The numbers of blades that divide the canals laterally are 2, 3 or 4 respectively. The presence of main and subsidiary blades have paved the way for creation of open and closed apertures in opening of wind catcher. The numbers of these open and closed apertures are restricted by the following special relationships:

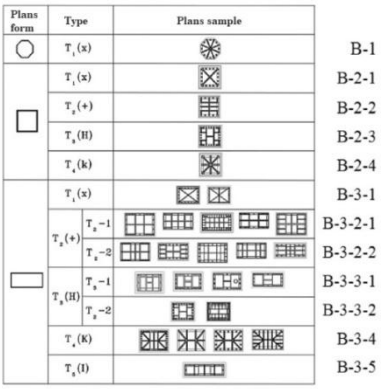


Fig. 5: Typology of wind catchers' plan in Yazd (Source: the author).

Main facade:

If there are 2 main blades in the width of a wind catches, the number of closed apertures would be estimated up to 2 or 3 times more than the number of open apertures.

If there are 3 main blades in the width of a wind catches, the number of closed and open apertures are equal.

If there are 4 main blades in the width of a wind catches, the number of open apertures would be estimated up to1.5 times more than the number of closed apertures.

Lateral facade:

In all cases, the number of open apertures of lateral façade is equal to the number of closed apertures of main façade. Actually, the number of closed apertures is zero.

Type B-3.2.2:

There are more oblong plans in this type of wind catchers. Regarding the re-sketches, the dimensions of plan vary from 1 to 1.58 and 1 to 2.92. The height of these wind catchers also varies from 6.62 meters to 11.7 meters. The numbers of main blades located alongside the width of wind catcher are 2, 3 or 4 respectively. The numbers of open and closed apertures are restricted by the following special relationships:

Main facade:

The number of open apertures would be estimated equal or up to 2 times more than the number of closed apertures.

Lateral facade:

The number of open apertures in the lateral facade would be estimated equal or up to 2 times more than the number of closed apertures in the longitudinal façade. Actually, the number of closed apertures in lateral facade is zero.

Type B-2.3:

In this type, there are some wind catchers equipped with H-shaped blades. The plan is designed in such a way that consists of a main blade crossing the wind catcher by width. As such, the canal is divided into smaller parts. Furthermore, the trunk is located in the center of the canal and in not connected to lateral walls of the wind catcher. Regarding this type, the number of subsidiary blades located in the width of wind catcher can be divided into two sub-categories (Figure 8). It should be noted that these subsidiary blades can alter the lateral subsidiary canals of these wind catchers.

Type B-3.3.1:

An H-shaped blade wind catcher with a main lateral canal. The cross-section of lateral canals is larger than longitudinal canals. Accordingly, the plan of these wind catchers can attract more wind via the lateral side. As such, the placement of this kind of plan is affected by the structure of house, hall and their elongation towards the north and south. In cases where the position of the wind catcher is tended against the windflaw, creative minds of Iranian architects have changed the plans in order to make efficient use of these structures. The number of such wind catchers is very low and only 4 number of 53 wind catchers are of this type.

Type B-3.3.2:

An H-shaped blade wind catcher with multiple main lateral canals. This type of wind catcher makes efficient use of longitudinal windflaw. Accordingly, maximum number of open apertures in the longitudinal façade can be seen in these types of wind catchers. The format of these plans is close to square and there is no rectangular plan among these wind catchers. The dimensions of these kinds of plans are 1 to 1.3 and less. There is no closed aperture in the longitudinal façade. In this design, the maximum use of wind in the longitudinal facade has been achieved. Furthermore, all the open apertures are placed in this façade.

Type B-3.4:

This kind of wind catcher is equipped with K-shaped blades. This type of plan is actually a combination of octagonal and square plans. The following items can be considered as design features of these plans: these wind catchers can attract windflaw from four sides and there is no closed aperture in the lateral or longitudinal façade. The results of the physical analyses of samples are as follows:

The average dimensions of these plans are 1 to 1.5. There is no closed aperture in the longitudinal and lateral facades. This is the only type of four dimensional wind catchers that has no closed aperture. The number of closed apertures in the longitudinal façade is two-third of the number of apertures in the lateral façade (Figure 6).

Type B-3.5:

This kind of wind catcher is equipped with I-shaped blades. There is no main blade in the width of wind catcher. There is a closed aperture in the corresponding angle per any open aperture in the longitudinal façade to prevent the escape of the windflaw. Otherwise, the windflaw can go through an aperture and exist from the other side. The depth of these apertures in the longitudinal façade is adjacent to the wall of wind catcher. This wind catcher is the most oblong rectangular plan in Yazd equipped with the dimensions of 1 to 3.75.

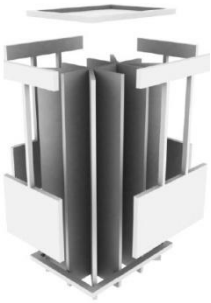


Fig. 6: Wind catcher Type B-3.4. (Source: the author).

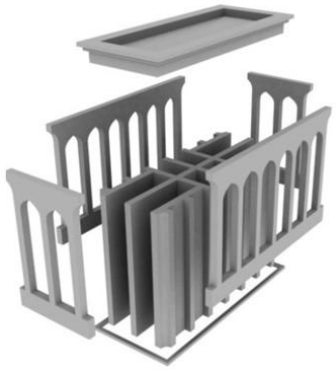


Fig. 7: Wind catcher Type B-3.2. (Source: the author).

Fig. 8: Wind catcher Type B-3.3. (Source: the author).

3.1. Typology C:

Typology of wind catchers on the basis of cross section Compared to wind catchers of other cities located in the hot climate, the wind catchers of Yazd are taller. The wind catchers of Yazd are typically 5 meters above the roof. Accordingly, the tallest wind catcher of Yazd has more than 33.5 meters height (Bahadori Nejad, 2003, p. 60). Those wind catchers created on the basis of cross section are categorized in terms of presence or absence of a basement and summerhouse. Regarding those wind catchers that include a water pool for evaporative cooling, there is an aperture with a diameter between 1 and 1.5 meters and a height of 1.5 meters that is called the summerhouse. Wind catchers can be classified into the following four categories based on different cross sections (Figure 9).

C-1: Wind catchers without any summerhouse and basement

C-2: Simple wind catchers that have some pathways to the basement

C-3: Wind catchers equipped with a summerhouse that sends fresh air to two floors (ground floor and basement).

C-4: Wind catchers equipped with a summerhouse that extends to the ground floor.

2. Archetype selection criteria for analyzing FLUENT:

One of the objectives of this research was to examine the quality of airflow circulating through the various wind catchers. FLUENT Software was used to attain this objective. It should be noted that this software can be considered as the peak of the art of computer programming for modeling fluid flow and heat transfer in complex geometrical figures. Regarding the limited number of wind catchers necessary for modeling flow analysis, some specific numbers of wind catchers were determined on a number of specific criteria. Since it has been seen that a particular types of plans are sometimes represented within one particular type of organization and implementation of the plan or they are accompanied by some particular cross section samples, the overlap matrix of the three aforementioned types was prepared to make use of these results in order to select the appropriate archetypes. The mentioned matrix is presented in the following section (see Figure 10).

Since this was not possible to analyze all existing wind catchers in cases of overlap of matrix with the results of software analysis of the thermal behavior of these structures, only a handful of these wind catchers had to be selected. Therefore, samples were selected from among available wind catchers using the presence of dominance of those samples among the wind catchers of Yazd.

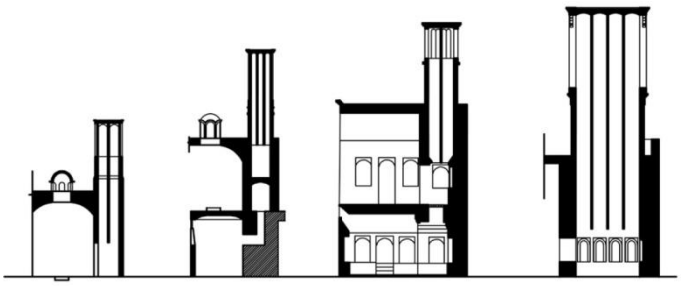


Fig. 9: Different types of wind catchers of Yazd on the basis of cross section (Source: the author).

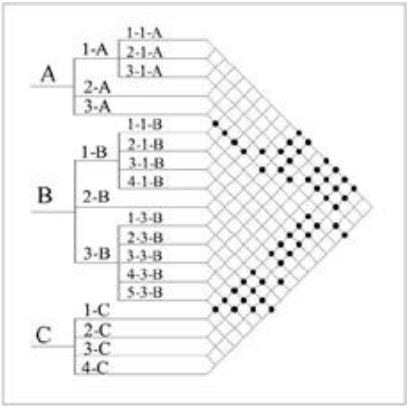
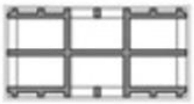
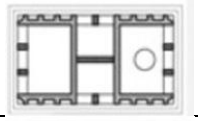
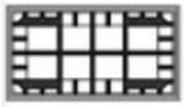


Fig. 10: The overlap matrix between the different types of wind catchers (Source: the author).

Given the importance of the placement of wind catcher in the plan and regarding the three main types of group A, the house was selected as the basis for FLUENT analyses. Accordingly, selection criteria were as follow: houses embossed with historic-architectural value included in the Ganjnameh and the wind catchers were re-sketched by field inferences. Having selected the models, as shown in Table 1, the houses and, then, the wind catchers were modeled in the Gambit Software.

Table 1: Physical characteristics of the chosen models for software analysis.

Model's name	Modeled house type	Modeled cross type	Type of wind catcher plan	Wind catcher plan
Model 1	Rasoolian's House 3-A	With summerhouse 4-c	B-3-2-1	
Model 2	Rasoolian's House 3-A	With summerhouse 4-c	B-3-3-1	
Model 3	Rasoolian's House 3-A	With summerhouse 4-c	B-3-2-2	
Model 4	Roohanion's house 1-A	Simple 1-c	B-2-4	
Model 5	Mahmoodi's house 2-A	With basement 2-c	B-3-2-1	

(Source: the author).

3. The simulation of models and analysis of the thermal behavior of the models:

There are three ways to solve problems related to fluid mechanics including empirical, analytical and numerical methods. There have been considerable improvements in numerical methods in a variety of sciences over the past centuries. However, these methods are not deep-rooted in Iran and their life does not exceed two or three decades. Due to the high cost of the experimental methods and weakness of analytical methods to solve engineering problems, nowadays most researchers tend to use numerical methods. This study is the first to analyze the thermal behavior of the wind catchers vi a numerical method.

Mr. Dr. Bahadori Nejad has conducted several investigations on wind catchers using analytical methods. For further reading, see :

Bahadori, M.N (1985) "An lmproved Design of wind Towers for Natural Ventilation and Passive Cooling"; Solar Energy; vol 35; No. 2.

Bahadori, M.N(1994) "Viability of wind towers in achieving summer comfort in hot arid regions of the middle east"; Third World Renewable Energy Congress. United kingdom.

Bahadori, M.N (1981) " Pressure coefficients to Eveluate Air Flow Patterms in wind Towers"; international Passive and Hybrid cooling conferences; Miami Beach; Florida.

The geometrical dimensions of wind catchers as well as the surrounding building were introduced into Gambit Software in order to examine the behavior of airflow through the wind catchers. It should be noted that the above-mentioned characteristics were collected using existing maps and documents as well as site observation. Then, the three-dimensional diagram was transferred to the FLUENT Software. It should be noted that this software can be considered as the peak of the art of computer programming for modeling fluid flow and heat transfer in complex geometrical figures (Soltani, 2003, p. 5). Tetragonal unstructured grids were used to grid the whole range of solutions with regard to the current geometrical figure. It is mentioned that after gridding the model into the FLUENT Software and running the Gambit Software, grids should be modified to achieve better results. This modification requires increase in the density of grids in critical points, especially where there are severe gradients of a physical variable such as pressure, velocity and temperature. There are about 1000000 grids analyzed in these analyses (Figure 11).

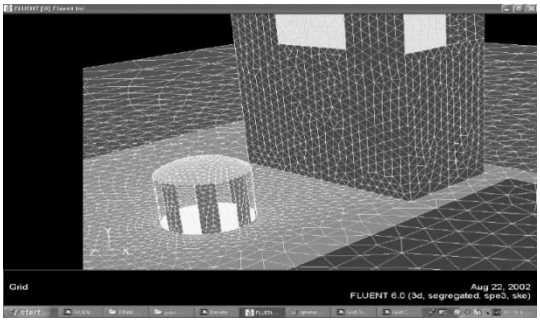


Fig. 11: A view of the geometry and mesh of wind of catcher and summerhouse of model 1.

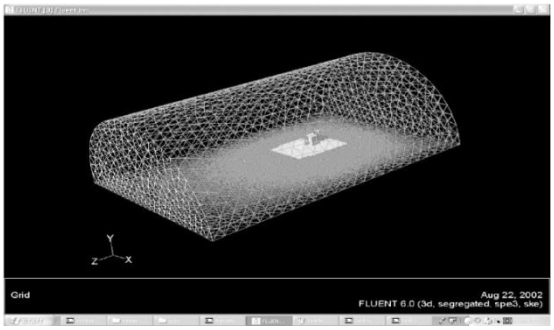


Fig. 12: A view of the geometry of the House Rasoolian within the range of airflow.

Inlet velocity boundary conditions and outlet pressure boundary conditions were determined as the inlet boundary and outlet boundary respectively in order to exert boundary conditions for the analysis of the flow field. Regarding the distribution of existing buildings and making use of uniform building code as well as data on weather conditions of Yazd region (such as temperature, relative humidity and wind speed), appropriate boundary conditions were determined. In addition, the inlet and outlet boundaries were determined enough away from the buildings so that the impact of the uniformity of flow could be maintained (Figure 12). Turbulence flow conditions were also determined in accordance with turbulence intensity and the relative viscosity turbulence. Outlet static pressure was used at the outer boundary. For other surfaces, walls boundary conditions were determined considering the ambient temperature. A multi-phase flow analysis was required to examine the physical conditions that governed the flow. Regarding the physical behavior of the flow in this project and given this fact that the volume fraction of particles in discrete phase (water droplets) was far less than in the continuous phase, Eulerian-Lagrangian method was adopted thereof. In this view, discrete phase model can be used to analyze two-phase flow in the FLUENT Software.

Since the physical conditions of the flow required a continuous flow, the flow analysis was carried out continuously. According to the inlet airflow (and thus the speed of inlet airflow), it could be concluded that this was an incompressible flow. Accordingly, these conditions were accompanied by incompressible conditions for the air density. Therefore, discrete analysis method was used to solve the equations. The governing equations for analyzing continuity equations include energy-momentum relation. Regarding the type of continuous phase fluid (air) and the discrete phase (water), equations of chemical components for volume fraction of water vapor and air were added to the dominant equations. Regarding the impact of discrete phase on flow field of continuous phase, the author attempted to calculate the amount of particle path, particle transfer, heat transfer, mass and momentum gained or lost by the particle flow that follows the path. These values were included in the next calculations on the continuous phase. Accordingly, as long as the continuous phase was dealing with the discrete phase, the effects of discrete phase on the continuous phase could be evaluated. This two-way interaction continued until the analysis of alternative equations of continuous and discrete phases achieved a state of changelessness.

In the following figures, the numerical analysis of thermal behavior of wind catchers Model 1 is shown (Figures 13, 14, 15 and 16). The results of the application of the Software on the mentioned five models are summarized in Table 2. The results of analysis indicate the impact of wind catcher' outlet air temperature, the air mass flow, wind speed, geometry and cross section of wind catcher, thickness and geometry of wet surface on the performance of the wind catcher.

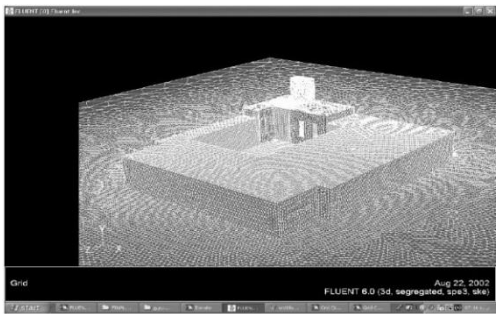


Fig. 13: Modeling of the House of Rasoolian by the Software (Source: the author).

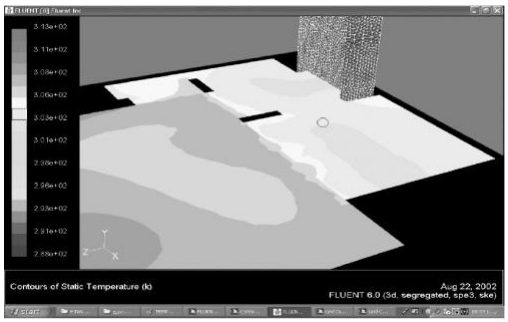


Fig. 14: Temperature results contour in Model 1(Source: the author).

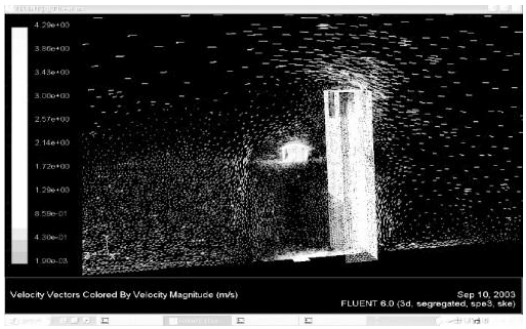


Fig. 15: Speed contour in Model 1 (Source: the author).

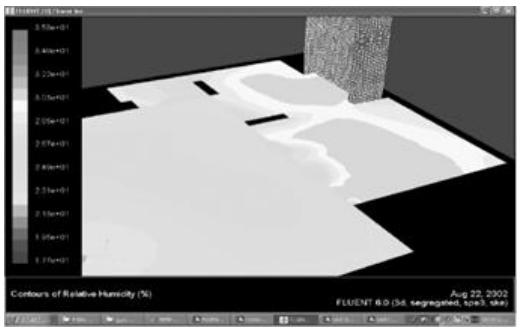


Fig. 16: Humidity contour in Model 1 (Source: the author).

Table 2: The results of software analysis of Yazd Model in terms of decrease in temperature and increase in humidity.

Parameters affecting the welfare conditions	Model 1	Model 2	Model 3	Model 4	Model 5
Temperature drop below 40 ° C	29.3	30.8	32.2	33.1	29
Increase in humidity up 17%	36.7 %	34.15 %	32.9 %	31.5 %	44.7 %

(Source: the author)

The effect of air mass flow:

In a wind catcher, the value of air mass flow varies throughout the day. The maximum effectiveness of air mass flow is achieved when the evaporation rate is higher. That is, the greater volume of humidity in the humid surface is evaporated. Actually, this factor increases the evaporation efficiency and greatly reduces the temperature.

The impact of wind speed:

Vertical ventilation of shaft is only effective when the wind speed is more than 2.5 meters per second (Battle McCarthy, 1999, p. 24). Air velocity or airflow requires less time for optimum evaporation and, thus, reduces the evaporation efficiency. However, it seems that this is not true in all the cases because different speeds physically exert different effects on evaporation efficiency. In fact, more speed generates more flow of air and this volume of cold air is certainly more helpful in cooling the building. Therefore, it must be said that the evaporation efficiency depends on greater volume of air running at a constant speed. That means that as the entrance cross section of a wind catchers increases, a greater volume of air enters into the building at a constant speed and the efficiency of evaporation increases as well.

The effect of geometry and cross-section of wind catcher:

Two factors that affect the efficiency of evaporation or the performance of wind catchers are the mass flow entering into the buildings and wet system. Surely, as the level of evaporation rate increases, there will be a better efficiency. The level of evaporation is also determined by air volume. Accordingly, it seems that as a greater volume of air encounters humid surface at a constant speed, there will be more space and time for evaporation and the efficiency level of wind catcher increases as well. Accordingly, the geometry of cross section of wind catchers should be designed in a way that maximum volume of air can penetrate into the building at a constant speed.

The impact of thickness and geometry of the wet surface:

Wet surface area depends on the amount of evaporation. In fact, as the area of wet surface increases, the level of evaporation and evaporative cooling system of wind catchers increase as well. If air is cooled and evaporated at the top of the wind catcher, the air will be cooled and heavier at the beginning of the canal. Then, the gravity force can pull it down faster.

Conclusion:

Three factors can be identified that have implications for differences in the architecture of wind catchers in Yazd. Firstly, the creativity of Yazdi architects in designing wind catchers so that there is no wind catcher that is completely similar to another wind catcher. This factor has allocated some unique identity to these wind catchers and this factor, in turn, has hel these wind catchers to maintain the identity of these houses and neighborhoods.

Secondly, there are some cases in which the architecture and design of the house and hall have influenced the architecture and, particularly, the plan of wind catchers. For example and regarding the geometry of the plan, where the hall of a house has a cross-shaped design, the wind catcher should be located in one of the corners of the hall. On the other hand, where the format of a plan is a square-shaped one, the wind catcher should be placed in the summerhouse of the house.

Regarding other cases, the format of plan is an H-shaped one equipped with internal blades. It should be noted that these plans are always used in the organization of Type A-3 houses. In these cases, the wind catchers are (indirectly and with 90 degree toward the hall) connected to summerhouse. The number of open and closed apertures in the longitudinal façade draws the attention.

Regarding those wind catchers equipped with H-shaped plans, the number of closed apertures is more than the number of open apertures in the longitudinal façade. However, the following question has always been concerned: "why did not the architect design narrower apertures in the lateral façade in order to reserve more space for open apertures in the longitudinal façade. However, the research indicated that these wind catchers received the dominant windflaw from the lateral façade and they were stretched from the northwest to the southeast. In addition, H-shaped plans equipped with deep lateral apertures allow more dominant wind to be drawn into these structures. On the other hand, the geometry of the plan does not allow the canal to be stretched parallel to the hall so that it encounters dominant wind in the longitudinal façade. As a result, the architects attempted to make use of H-shaped structure as well as internal blades in order to resolve this problem. The performance of wind catcher and its thermal behavior are among other factors affecting the form and architecture of these wind catchers. In all cases where there is a pool of water in the vicinity of wind catcher, the pool is embedded in a way that the hall is connected to this room. There is no pool of water in the hall.

The important point about the Type A-3 structures is that the location of the wind catcher, which is the site where the wind passes, and the entrance of summerhouse to the hall, where the wind flows from the summerhouse to the hall, are designed in such a way that the wind flows through the pool with a 90-degree to enter the hall. There is no open door in front of the wind catcher in the summerhouse. According to the analyses of fluid mechanics, this factor along with the placement of

summerhouse in the roof generates a vortex flow that can produce higher level of evaporation. Otherwise, the evaporation efficiency can be greatly reduced (Figure 17).

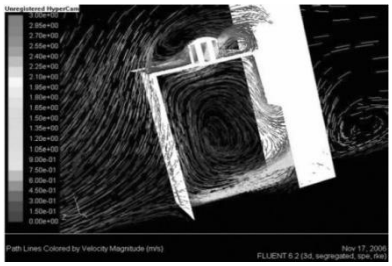


Fig. 17: Aircirculation contourand generation of a vortex flow over the pool of water in model 1 (Source: the author).

This is also true about the basement. Since the basement has only a narrow pathway to the yard, the airflow output is not so great. In cases where there is a pool of water in the basement, the windflaw collides with walls of the pool of water and creates a vortex above the pool that leads to more effective evaporation.

The Section of identification of architecture ends with some typological materials. Due to the limitations of modeling and analysis of thermal behavior, typological archetypes were determined using criteria outlined in Section III. Furthermore, the thermal behavior of these structures was studied via the Software. Regarding the first three models, three different wind catchers in the House of Rasoolian were examined. Although the plan, the placement of wind catchers, the cross section as well as height and level of cross section were similar throughput these structures, some different and diverse results were obtained. Therefore, it can be concluded that the architecture and the format of blades can influence the thermal behavior of wind catchers. Regarding the mentioned three types of wind catchers, those wind catchers equipped with H-shaped blades can deliver the best performance. As such, those wind catchers equipped with + shaped plan can reveal the best performance. It should be noted that these wind catcher are placed within the yard of these houses (Model 2). One interesting point is that this kind of wind catcher is the most dominant wind catcher in Yazd. Then, it is probable that people and architects have found the best performance of these structures based on their own experiences. The results of simulation and numerical analysis were compared with the results of an empirical research conducted by Susan Roaf which, due the similarity of the results, the scientific validity of the simulation was confirmed thereof.

REFERENCES

Abouzia, F. and M.R. Qezelbash, 1985. Everything about the physical characteristics of traditional buildings of Yazd. Planning and Budgeting Publications.

Battle McCarthy, 1999. Wind tower: detail in building. Translated by Mohammad Ahmadi Nejad. KhakPubliucations: Isfahan.

BahadoriNejad, M., 2003. Cooling efficiency of wind catchers. Journal of Air Conditioning. 8.

Haji Qasemi, K., 2003. Encylopeida of Iranian Islamic Architecture (Ganjnameh Yazd houses). Tehran: ShahidBeheshti University and Rozaneh Publications.

Soltani, M. and R. Ramimiolasl, 2003. Computational fluid dynamics with the help of FLUENT Software. Tarh Publications: Tehran.

Mahmoodi, M. and M. Mofidi, 2003. The impact of climate on the skeleton of wind catchers of Yazd and Bandar-e Lenge. Proceedings of the Third Conference on optimizing fuel consumption. First ed. Karami, Mohammad Jafar, earthquake and building, Kermit press of Paris, Tehran, 1999.