Bagh-e Nazar

Bagh-e Nazar, 20(125), 23-44/ Nov. 2023
DOI: 10.22034/BAGH.2023.385984.5336

Persian translation of this paper entitled:
نقش پارامترهای مؤثر طارمه در بهبود تهویهٔ طبیعی در خانه‌های حیاط‌مرکزی بافت تاریخی بوشهر
published in this issue of journal

Original Research Article

The Role of the Effective Parameters of Taremeh in Improving Natural Ventilation in the Courtyard Houses of Bushehr in the Historical Context*

Neda Ghahraman Izadi [1], Malihe Taghipour [2**], Hamid Eskandari [3], Khosro Movahed[4]

1. Ph.D. Candidate, Department of Architecture, Faculty of Art and Architecture, Shiraz Branch, Islamic Azad University, Shiraz, Iran.
2. Associate Professor of Architecture, Department of Architecture, Faculty of Art and Architecture, Shiraz Branch, Islamic Azad University, Shiraz, Iran.
3. Assistant Professor of Architecture, Department of Civil engineering, faculty of Technical and Engineering, Yasouj University, Yasouj, Iran.
4. Associate Professor of Architecture, Department of Architecture and urban sustainability, University of the District of Columbia, Washington DC, USA.

Received: 22/02/2023 ; accepted: 18/06/2023 ; available online: 23/10/2023

Abstract

Problem Statement: The city of Bushehr on the northern coast of the Persian Gulf is one of the most critical hot and humid climates in Iran. Always, natural ventilation has been one of the common methods of providing thermal comfort to residents Taremeh is one of the semi-open spaces effective in natural ventilation. This research is trying to investigate the ventilation in the residential area of Bushehr based on the Taremeh and its parameters.

Research objectives: This research was carried out to investigate the natural ventilation caused by the potential of the Taremeh.

Research method: This study employed a mixed research method including field survey, library research, and document reviews of historical buildings. In the experimental part of the study,the independent variables affecting the quality of natural ventilation were identified and the dependent variables were measured by accurate digital devices in a case study (Dehdashti building) and then its data was used for software validation. After the validation, the models were simulated in Cfd Autodesk 2018 software, relying on the CFD method. velocity and age of air as well as the wind circulation were evaluated.

Conclusion: The results show that the "inner Taremeh " in a linear form in a state that is a part of the yard area has the highest and the 4-sided Taremeh has the lowest velocity. Wind circulation is less in the middle area and more towards the walls. The internal U-shaped Taremeh has the highest speed in the room. By reducing the number of columns and increasing the dimensions of the columns in the Taremeh, the speed of airflow in the Taremeh space decreases. As the height increases from the ground floor to the first and second floors, the velocity in Taremeh increases in all cases. In the "middle Taremeh ", increasing the width of the Taremeh reduces the velocity to some extent. From the perspective of depth, the depth of 3.5m for the Taremeh has the most optimal ventilation in terms of velocity and the lowest age of air.

Keywords: *Bushehr, Natural Ventilation, Taremeh, CFD Method.*

*This article extracted from Ph.D. thesis of "Architecture" entitled "Improving natural ventilation efficiency in residential buildings with hot and humid climate by prioritizing the effective parameters of semi-open spaces (Case study: Bushehr city)" that under supervision of Dr. "malihe taghipour" and in consultation of Dr."hamid eskandari" and Dr. "khosro movahed"which has been done at Islamic Azad University, shiraz Branch, Faculty of Art and Architecture, shiraz, Iran in 2023.

**Corresponding author : 989173146379+ Malihe.Taghipour@iau.ac.ir

Introduction and Problem Statement

Natural ventilation in hot and humid areas is one of the most important factors in creating thermal comfort (Hedayat & Ziaei, 2011). The quality of this ventilation in the interior spaces of the houses in the central courtyard of the historical context of Bushehr was an issue that, in addition to the atmospheric and climatic conditions, also depended on the form of the building and the geometry of its architectural components. For this reason, the common form of the historical buildings of this city has often been elongated, and narrow, with wide and open plans and the use of semi-open spaces such as Taremeh, to create more blinds and make maximum use of the sea breeze and prevailing winds. In Bushehr, the relative humidity is at least 35 to 55% and at most 70 to 85% and the main problem is the heat combined with high humidity shahi & Takapoomanesh, 2006). That's why Taremeh has played an essential role in this process with its capabilities of entering the outside airflow into the building and also distributing the wind in the interior spaces. Also, the architecture of Bushehr has been formed in such a way that the air flows in the best way and the whole structure of Bushehr is at the service of the wind to the extent that to achieve this goal in the western and northern sides, the height of the buildings is lower than the area where the wind flow enters inside. provide context (Ansari, 2013). The existence of wide porches and Taremeh has an effective contribution in bringing in the favorable wind and creating internal ventilation (Karimi, 2012). Therefore, in the current research, the main goal was to improve the ventilation of the indoor space with regard to the semi-open spaces(Taremeh). By placing semi-open spaces next to closed spaces and more permeable facades of buildings, stagnant temperatures will be prevented. Therefore, air circulation, creating shade, and minimal absorption of temperature will be the result of such a strategy. The physical form and proportions of responsive climatic elements such as porches and their reaction to the weather conditions of the surrounding environment have been the most important structure of this research. Based on this, knowing the thermal performance of eco-oriented climate elements and their effectiveness in improving ventilation has been the Significance of the study. This article examines the effective components of Taremeh and their role in improving natural ventilation. To analyze the most optimal mode of benefiting from wind for natural ventilation in semi-open spaces, the most common architectural characteristics of houses in the central courtyard of Bushehr's historical context in terms of room form, courtyard form, semi-open space form, type of room entrance and exit openings, depth of semi-open space, number and the dimensions of the Taremeh's columns as well as the height levels have been categorized and applied in the simulation phase of the models. Such research will be the background for developing models to provide optimal ventilation in buildings. Therefore, knowing the physical components of semi-open spaces (Taremeh) and effective natural ventilation has been one of the innovative results of this research. In this research, the weather data in the selected house has been collected through a quantitative research method based on field tests along with anemometer, thermometer, and hygrometer devices, and validation was done to ensure the correctness of the software outputs, and then with the help of Using the CFD method, field data were entered using Cfd Autodesk software, and the models were simulated and evaluated, and finally, the results obtained from the research are presented in tables and graphs.

Research Background

Studies that deal with the category of natural ventilation in historical contexts have increased in recent years. Much research has been done in the field of problems, and applications of wind and air currents. However, the studies that have been done using CFD simulation have been developed mostly due to the progress of computer software and hardware during the last decade. Al-Hinia, Batty & Probert (1993). The survey of the native architecture of Oman shows that the building forms adopted in different regions are specifically related to providing thermal comfort. Oikonomou (2005) compares the measured data under the output of computer software in the traditional buildings of Florina in the summer and winter seasons through simulation. In this way, a complete understanding of the thermal behavior and temperature investigation in traditional houses in the city of Florina is obtained. Antarikananda, Douvlou & McCartney (2006) has investigated the thermal performance of traditional and contemporary buildings in Thailand using a simulation model based on a set of thermal performance criteria of building shape and materials. Ryu et al. (Ryu, Kim & Lee, 2009) have investigated the creation of cold air flow in traditional Korean buildings in a hot and humid climate, in the semi-open space of Daechung to interpret the effects of wind characteristics on thermal comfort. Ramli (2012) has investigated the elements of comfort design by focusing on factors such as building orientation, interior arrangement space, ventilation and natural lighting, window designs, and stack effect on the design. Kristianto, Utama & Fathoni (2014) examined thermal comfort conditions in the interior of Minahasa traditional houses. Houses with terraces, roofs, and floors combined with taller stilts have higher wind speeds compared to houses with only window openings and lower stilts. Bay, Martinez-Molina & Dupont (2022) in his study investigated the relationship between natural ventilation and indoor microclimate in a historic building in San Antonio, Texas. The suggestion of passive cooling using natural ventilation to control and reduce indoor air temperature and relative humidity has been expressed by the CFD method. About climate-compatible architecture and the importance of wind in the design of Bushehr's traditional architecture, studies have been conducted in the past. Among them, Hedayat and Tabaian (2013) introduced the native housing of Bushehr in an article titled "Investigation of the shaping elements and Their Reasons for Existence in the Houses of Bushehr's historical context" and states that the design is based on the flow of wind in this Valuable range in features such as the orientation of the passages, the ratio of the width of the passages to the height of the side walls (transverse section of the passage), the density and height of the building, the filled and empty spaces, the location of the passages and squares, the formation of architectural elements such as Shanashir, roof, Taremeh and it crystallizes with the highest quality. Ranjbar, Pourjaafari & Khaliji (2010) in the article on climate design creations by wind flow in the old context of Bushehr have concluded that the architectural space and details such as room, yard, window, screen, Taremeh, bun, and pre-bun are effective in ventilation and wind speed. Zarei & Beboodi, (2016) in the settlement of Vermal castles of Sistan, by using CFD, found the central courtyard space as a natural ventilator with the passage of the wind flow and found a noticeable reduction in the speed and pressure of the wind movement in the spaces. Salighe and Saadatjoo (2018) have investigated the issue of porosity and terraces and the design of shading forms as the first and most effective step of sustainable design for shading and avoiding the received radiant energy with design builder simulation. Karimzadeh, Mahdinejad Darzi & Karimi (2021 & 2022) have taken into account the knowledge of the thermal performance of the porch about physical proportions and the moderating effect of the porch on the thermal comfort index and average radiant temperature. Salighe and Saadatjoo (2018) compare the effect of terrace-shaped permeability on wind behavior and natural ventilation efficiency in a medium-sized building with CFD analysis. Ventilation evaluation parameters such as average air velocity and average age of air were measured to compare the performance of natural ventilation. Mohammadi, Saghafi, Tahbaz & Nasrollahid, (2017) have researched their thermal comfort using DesignBuilder software by placing semi-open spaces and producing shade, and creating cross ventilation through the implementation of suitable openings in terms of dimensions and number. Cuce, Sherc, Sadiq, Cuce & Besir (2019) evaluate the effects of architectural design on passive ventilation such as direction, room depth, atrium, and solar chimney in school buildings and on potential factors affecting comfort in school buildings such as relative humidity, temperature, Airflow speed, noise, smell, fresh air, and CO^2 are emphasized. Wai Tuck (2021) wrote his doctoral thesis on terraced residential buildings in hot and humid weather conditions to evaluate the performance of all types of buildings and build forms on thermal conditions (air temperature, relative humidity, air speed). Kumar, Kubota Bardhan & Tominaga (2020) used Computational Fluid Dynamics (CFD) with the help of wind tunnel testing to study the effect of ventilation of empty spaces with different sizes, wind catchers, and window sizes. The results show that creating free space can increase natural ventilation in the building's windy units. The smallest size of the empty space showed the highest wind speed. The provision of wind catchers and larger windows increased natural ventilation in the wind deflectors of the building. Xu, Li & Tang (2022) used simulation to improve the internal thermal environment of large semi-closed atriums in hot and humid areas, factors such as transmission and absorption of the ceiling, the area of the upper openings, the ratio of the cross-section dimensions, and the ratio of the top to the bottom of the atrium, were analyzed by simulation and temperature measurement. Table 1 briefly displays the components extracted from past research.

According to the studies conducted in the background of the research, due to the novelty of natural ventilation and the CFD method, there has not been a study yet to investigate the effect of the micro-components of Taremeh on the improvement of internal ventilation in hot and humid climates. Therefore, the non-repetition of the topic and having a new look at the semi-open space, especially the details and form of the Taremeh and the improvement of natural ventilation, justify the necessity of the present study. Also, it can be said that in the review of various experiences about the situation or the internal and external factors affecting the improvement of natural ventilation, the fact is that not many studies have been conducted, and the which have been done are about the discussion of cooling load reduction and quantitative dimensions. Therefore, the role of form and the maximum use of natural wind flow to improve ventilation in critical climates such as hot and humid climates prompted researchers to look at this issue with a different perspective and its achievement will be used in the future as a comprehensive strategy in sustainable development solution to use Taremeh as a functional and useful space.

Theoretical Foundations

• Natural ventilation, how it works, and factors affecting it

Air ventilation is the act of replacing or moving air in a space, which is done to provide fresh air, remove hot and humid air, cool the space, and provide human thermal comfort. In the natural ventilation method, air movement is done through the chimney effect, which is based on the movement of hot air up and the entry of cold air from below instead of it, or through air blinds, where air movement is done through positive and negative wind pressure (Watson & Labs, 2008). The forces that cause natural ventilation are summarized in two general factors (CIBSE, 2005, 10). wind forces and buoyancy. These forces determine the mechanisms of natural ventilation. The shape and location of the building (for example, being in an open or dense environment, being high or low) determine how the building is naturally ventilated. Based on this, three modes of natural ventilation can be considered: one-way ventilation, two-way ventilation, and chimney ventilation. Each of these situations shows how the air inside the building that needs ventilation is related to the airflow outside (Andersen, 2002). Natural ventilation is based on three climatic phenomena, wind speed, wind direction, and

Table 1. Influential indicators and variables investigated by researchers to investigate the natural ventilation of the environment . Source: Authors.

Ventilation evaluation parameters (dependent variable of research)	Factors affecting natural ventilation (independent variable of research)	Researchers
Velocity	Building forms - openings	Al-Hinai et al, 1993
Velocity	Traditional house	Oikonomou, a.2005
Temperature	Building and materials	Antarikananda, 2006
Airflow	Semi-open space	Ryu, 2009
Velocity & air pressure		Zarei & Behboodi, 2016
Velocity	Orientation, opening, type of ventilation	Ramli, 2012
Velocity	Form. Height. Semi-open space	Kristianto, 2014
Velocity. Temperature relative humidity	Passive cooling	Bay et al, 2022
-	Orientation, ratio, mass and void spaces, semi-open space (shanashir, roof, taremeh)	Hedayat, Tabaian 2013
-	Room, yard, window, shanashir, tarmeh, roof	Ranjbar, Pourjaafari & Khaliji 2010
Air pressure and velocity	Form. Geometry, proportions, proper orientation of masses, open spaces	Masoumi, Nejati & Amin Alah 2016
Temperature and wind, thermal comfort, energy consumption	Proportions, semi-open space	Mohammadi et al, 2017
		Xu et al, 2022
Relative humidity, temperature, velocity, noise, odor, fresh air, and co2	Direction, depth	Cuce et al, 2019
Velocity Airflow	Void space, opening	Kumar et al, 2020
Average velocity The local mean age of air Shading Airflow	The semi-open space of the porch, Area, body proportions	Saligheh & Saadatjoo 2018
Air temperature, relative humidity, velocity		Wai Tuck, 2021
Mean radiant temperature		Karimzadeh et al., 2021 & 2022

temperature difference. The following are the most important effective parameters in the performance of natural ventilation that have been discussed in this research. Wind speed: It expresses the distance traveled by moving air molecules per unit of time in meters per second, kilometers per hour, or the old scale of knots (an average of one nautical mile or 1. 85 kilometers per hour). The local mean age of air: It is defined as the average lifetime of air in a certain position inside the space compared to the time when the air entered the space for the first time, and in fact, the local average life of air gives a measure of air freshness.

- **Taremeh typology**

A typology refers to a type of classification in which several different objects are organized according to one or a set of common characteristics. Various researchers have discussed the typology of the building and architectural elements of Bushehr. Raisi (2006) studied the morphology of Bushehr courtyards, and Hedayat and Eshrati (2017) studied the typology of Shanashir and Taremeh (2019). In the architecture of Bushehr, the creation of blinds and ventilation is of great importance, and the wind is considered the most important climatic factor in the architecture of Bushehr, and it seems that most of the architectural elements in this valuable context serve the wind (Moghimi, Kiani Borazjani, Amirzadeh, Bahraini & Qanawati, 2018). In the case of this research, which was formed by focusing on the Taremeh element, the field and library studies and investigations conducted on 29 historical buildings with Taremeh in Bushehr show that Taremehs can be divided into three types, “inner”, “outer”, “middle”, based on the place of installation in the building. the most used example of which is the inner Taremeh (Table 2). Also, in terms of shape, Bushehri Taremeh can be divided into four categories: linear (rectangular), L-shaped, U-shaped, and four-sided, and the rectangular linear type is considered the dominant type. The dominant direction of the Taremeh is towards the south and west, and in all the buildings of the coastal wall, at least one Taremeh has a view of the sea, which emphasizes the role of the climate and the sea in the direction of the Taremeh. The Taremeh are often wide and open from one to three sides. The floor is often rectangular; the length is equal to the length of the adjacent room or the whole elevation. The width of the Taremeh is between 2 and 5 meters, the height of the shelter is about 1 meter, and they have a sunshade with a height of 100 to 120 centimeters.

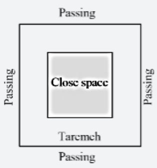
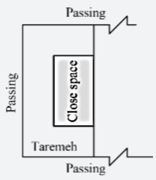
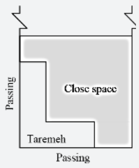
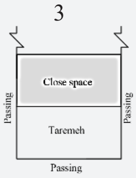
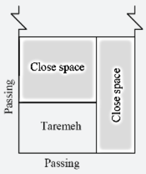
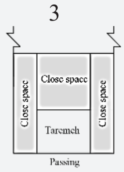
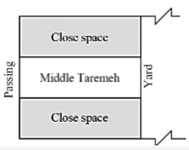
Research Method

The present study is interdisciplinary and mix-method includes qualitative and quantitative parts. In the phase of identifying the effective components, qualitative methods were used, and in the simulation and data analysis phase, quantitative methods were used. At first, by collecting data from library sources and field observations of Bushehr houses, the preliminary data about architecture, housing, and Taremeh space in this climate was completed and the parameters affecting the quality of natural ventilation of indoor air were identified. Then using an experimental strategy, tests were performed and independent variables were determined. The Taremeh and its spatial characteristics including dimensions and size (length, depth), the effect of the room and openings (with and without opening), the number and distance between the columns, and the way of placement on different sides of the yard (linear, L-shaped, U-shaped and 4-sided) as independent variables, and the airflow quality of the room and yard including two components of airspeed (Velocity) and age of air (Local mean age of air) were considered as dependent variables (Fig. 1).

After the typology of Bushehr houses, according to the dominant form of the houses, 9 types can be investigated. (Table 3), after simulating all kinds of types with regards to having more favorable ventilation quality, type number 2 (vertical rectangular room - vertical rectangular courtyard) which has 8 meters of mass on the sides, with non-aligned inlet and outlet openings in the second height level has been selected for the simulation (it should be mentioned that the types of species, height levels and thickness of the mass have already been simulated and its result, which is species number 2, has been used to continue the simulations).

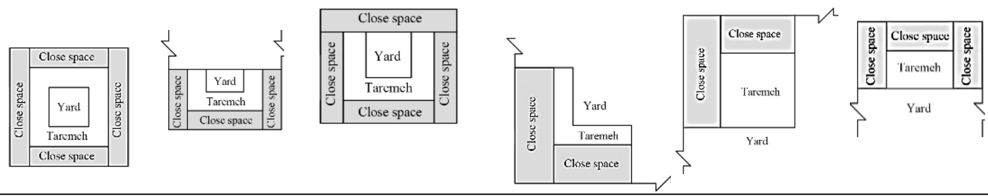
The different modes of Taremeh are in three types, outer, middle, and inner, according to the location, and the inner and outer modes include four linear, L-shaped, U-shaped, and 4-sided types in terms of forms. All these species were simulated with the help of Computational Fluid Dynamics or CFD and using Autodesk CFD 2018 software, and then the geometry of the room and the mesh network around and inside the room were analyzed. It was considered for field data collection and software validation of the Dehdashti building (second-floor spaces, courtyard, and roof), which was confirmed after applying the experimental data by simulating the accuracy of the software. From the point of view of the goal, this research is placed in the applied research group. The simulation steps are as follows: first, the three-dimensional volume of all species was created in AutoCAD, then it was converted in the Autodesk CFD 2018 software by determining the boundary conditions in the wind tunnel, and after running the software, the contours were extracted, categorized and reported for comparison and analysis. Wind tunnel simulation was performed by applying two components of velocity in meters per second and age of air in meters per hour. Extraction

Table 2. Taremeh typology: outer-middle-inner. Source: Hedayat & Eshtarti, 2019.

Case (mansion)	**Sort by directions**		**Sorted by plan**					**Place of establishment**
Tejaratkhane Irani- bilyard- amirieh- nozari- hamal bashi- malek.	Number	Direction	Number		General shape			**Outer**
	3	south	7	rectangular		linear		
	2	west	2	linear				
	6	South & west	2	Trapezius				
	1	North & west	2		L shape			
	1	North & east						
	1	North West South	2		U shape			
	1	East North South						
	1	4 sides	1		4 sided			
			sort by enclosure					
4 sided Three open sides & one closed side	U shape Three open sides & one closed side		L shape Two sides open & two sides closed	Three open sides & one closed side	Linear Two sides open & two sides closed	One open side & three closed sides	plan Enclosure	
1	2		2	3	4	3	Number Diagram	
								
Case (mansion)	Sort by direction				Sort by plan			**Middle**
Alavi- Hafte- Haj Rais- Jaafari	number	direction		number		General shape Linear- rectangle		
	5	South		9				
	3	North		2				
	1	West		2				
			Sort by enclosure					
		Two sides open and two sides closed 9				Enclosure Number Diagram		
								
Alavi- Rafiee- Azin- Gaafari- Nozari	Sorted by direction					Sorted by plan		**Inner**
	Number	Direction		number		General shape		
	6	South		13		Linear- rectangle		
	3	West						
	2	East						
	2	North						
Tabib		North & west		1		L shape		
	1	South		6		U shape		

Rest of Table 2.

Case (mansion)	Sort by directions		Sorted by plan		Place of establishment
Amirieh- Rostami- Hamal Bashi- Zende Pey	1	East West 4 sided			
Tabib- Haj Rais	2	4 sided	2	4 sided	

sort by enclosure						
4 sided	U shape		L shape	linear		Plan
One open side & three closed sides	Two sides open & two sides closed	Three open sides & one closed side	Two sides open & two sides closed	Two sides open & two sides closed	One open side & three closed sides	Enclosure
2	2	4	1	1	11	Number
						Diagram

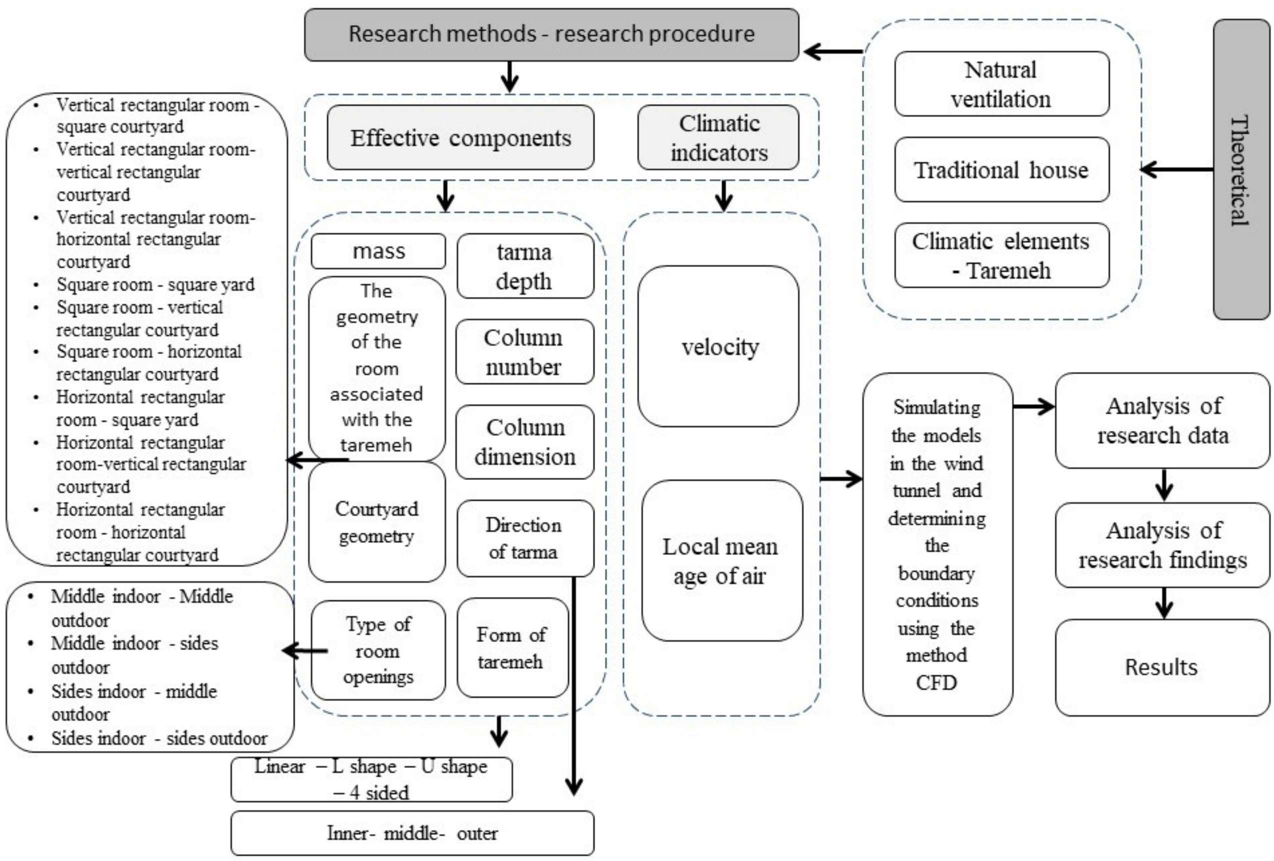
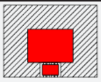
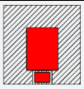
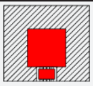
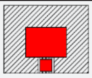
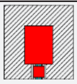
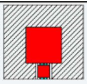
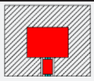
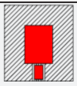
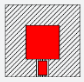


Fig. 1. Structure and theoretical framework of the research. Source: Authors.

Table 3. Dominant residential patterns in Bushehr houses for simulation. Source: Authors.

9	8	7	6	5	4	3	2	1	Type
									Plan
Horizontal rectangle	Horizontal rectangle	Horizontal rectangle	Square	Square	Square	Vertical rectangle	Vertical rectangle	Vertical rectangle	Room
Horizontal rectangle	Vertical rectangle	Square	Horizontal rectangle	Vertical rectangle	Square	Horizontal rectangle	Vertical rectangle	Square	Courtyard

and display of data in the form of graphic images were done in the form of a horizontal section (plan) from a height of 150 cm from the floor of the room and a vertical section from the center of the room. A graphic display of airflow makes it easier to understand how the wind moves.

- **Geographical context (weather information)**

The dry temperature of the Bushehr port is shown in Fig. 2. The maximum temperature, minimum temperature, and average temperature for each month are shown in Fig. 1. The average highest temperature in the period from July 1 to August 31 is 36 degrees Celsius, and from January 1 to February 28, heating is needed during the day and night. According to Fig. 1, from November 1 to December 31 and from March 11th to March 31, heating is needed at night and comfortable conditions are established during these months. During the nights and days from July 1 to August 31, cooling is needed, and during the nights of the rest of the year, comfort is maintained and the weather is warm during the days. The average relative humidity in Bushehr Port is between 60% and 70% (Fig. 3).

Ambient wind speed information in Bushehr was extracted based on fifty years of weather data (taken from the official site Energyplus.com) and checked with weather tool software according to Fig. 4.

- **Validation**

Validation of software, airflow network modeling using data measured on site (Dehdashti's building) by precise digital wind, temperature, and humidity measuring devices (Table 4) and matching them with the model simulated in the software and all climate information on September 21, 2021, and

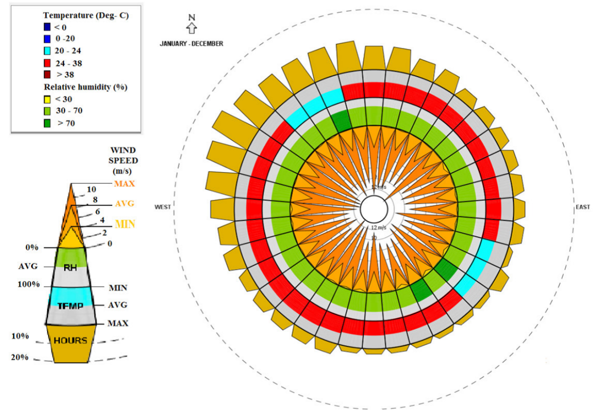


Fig 2. Temperature chart in the months of the year in Bushehr city. Source: Authors.

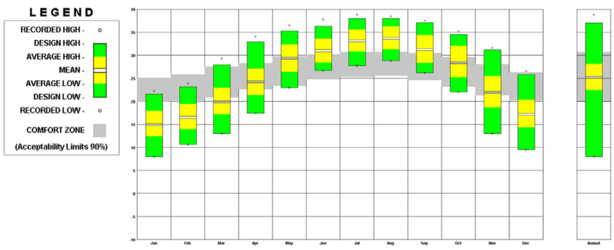


Fig 3. Wind rose of Bushehr. Source: Authors based on Climate consultant software, version 6.

they were measured at a height of 1. 5 meters (for a standing person) in 4 spaces (two rooms located on the second floor, the yard and the roof).

The results show that there is little discrepancy between the collected model data (Dehdashti Building) - (Fig. 5) and the simulated model, which indicates its high power and reliability. The simulation results and the numbers obtained from the experimental tests (Fig. 6) are comparable and a very small difference (about 0.5%) was seen, which is less than 10% and acceptable according to the ASHRAE standard.

- **Boundary conditions**

To perform the tests, all the models have been

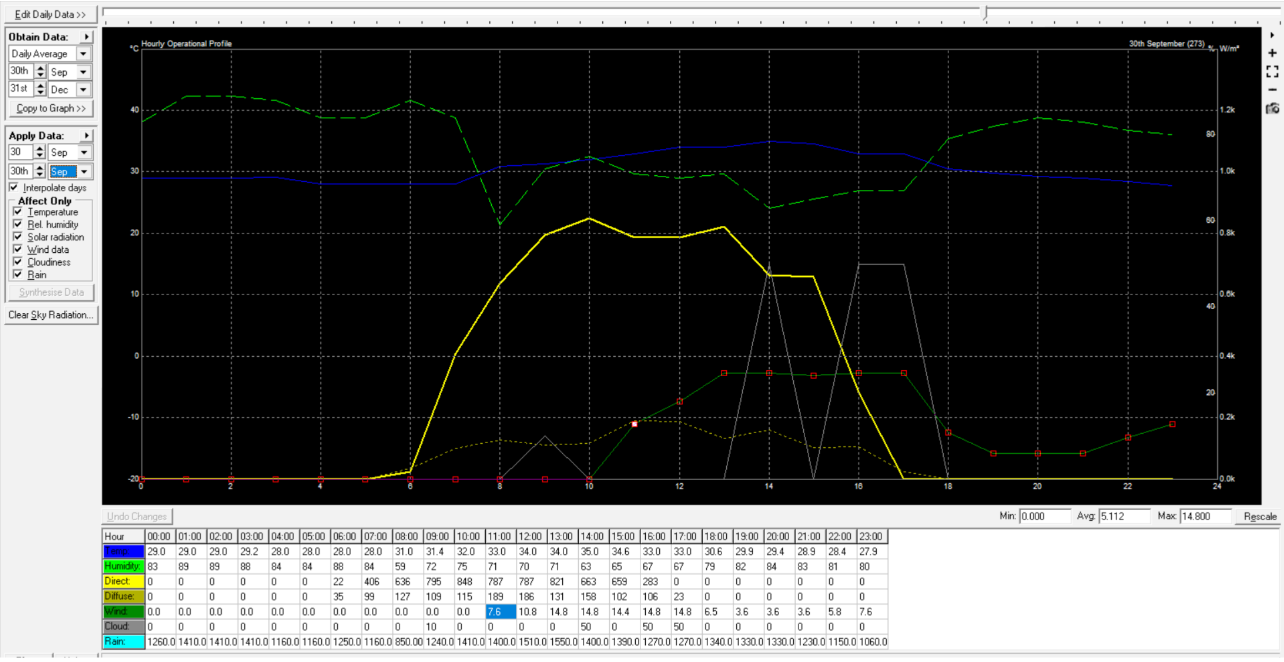
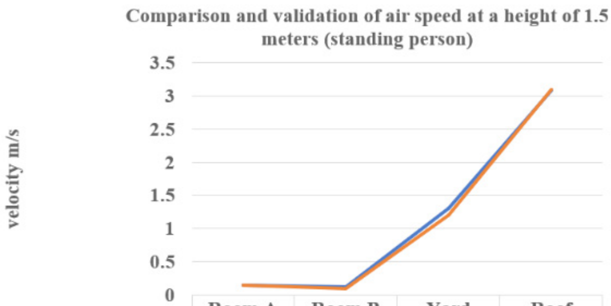


Fig. 4. Wind speed based on weather tool software. Source: Authors.

Table 4. Specifications of measuring equipment for collecting data. Source: Authors.

Resolution	Precision	Range	Environmental Parameters	Equipment image	Equipment
0.1 °F / 0.1 °C 1.97 fpm / 0.01 m/s	±0.9 °F / ±0.5 °C ± (19.7 fpm + 5 % of mv) (0 to 394 fpm) / ± (0.1 m/s + 5 % of mv) (0 to 2 m/s) ± (59.1 fpm + 5 % of mv) (394 to 2953 fpm) / ± (0.3 m/s + 5 % of mv) (2 to 15 m/s)	-4° to 140 °F / -20 to +60 °C 0 to 5906 fpm / 0 to 30 m/s	temperature Wind speed		Hotwire anemometer. testo 405i
		0% 100 %	relative humidity		Klima logger

created with the same boundary conditions based on the wind tunnel standard (Fig. 7) in comparison with each other, which is the same as the conditions considered for validation. The pressure coefficients of the wind flow on the building have been extracted as a function of the wind direction and the geometry of the building. At first, the modeling was evaluated using AutoCAD design software, then Autodesk CFD software. After creating the models, mesh networking is defined, a grid study was done for showing the independence of the network, and the high density of nearly 2 million meshes was considered (Fig. 8). Of course, it is possible to change these conditions in the Autodesk CFD software in the next stages of the analysis. The boundary conditions of the openings are considered unrestricted and free to determine the correct operation of the openings under high-pressure or low-pressure conditions. Since at this stage, checking the speed and pressure of the flow is enough to compare the models, and also the fluid used is air and not ideal gas, the energy equation was considered passive. The flowing fluid



	Room A	Room B	Yard	Roof
velocity in experimental test	0.15	0.12	1.3	3.09
velocity in simulation	0.14	0.1	1.2	3.1

Fig. 5. Interior of Dehdashti's building. Source: Authors.

Fig. 6. A comparison of airspeed between simulation and experimental test for validation. Source: Authors' Archive.

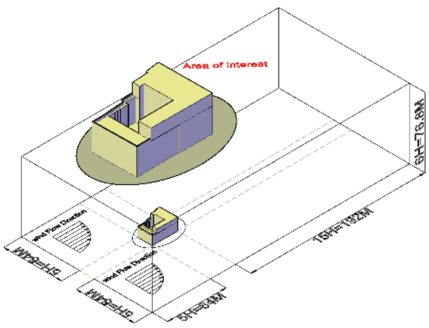


Fig 7. Wind tunnel dimensions. Source: Authors.

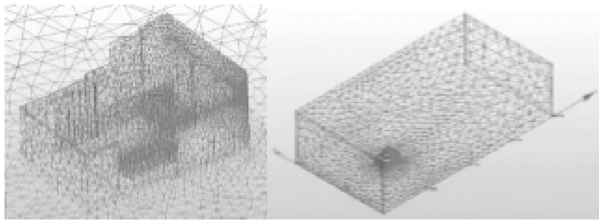


Fig 8. Mesh used for simulation. Source: Authors' Archive.

is incompressible with an inlet velocity of 7.[6] m/s (wind speed at the site) and a pressure of 101325 pascals. In choosing the viscosity model according to the flow conditions; The k-epsilon turbulence model was used. Continuity equations, momentum, and epsilon k-, governed the flow, and the error range for solving these equations was 04-le the number of repetitions of the equations was considered 5000, and they converged after 1000 to 1500 repetitions. Velocity vectors, dynamic pressures, and pressure differences created around and inside the model were used in the analysis of the models. The angle of the wind hitting the building is 90 degrees perpendicular to the grid. Brick materials and an ambient temperature of 33. 2 Celsius (temperature taken on site) were considered.

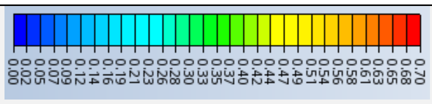
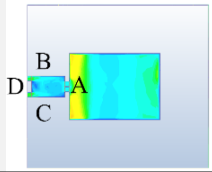
Findings and Discussion

To simulate each of the Taremeh types (inner, middle, and outer), a set of qualitative components of natural ventilation (velocity and age of air), as well as general air circulation and direction of wind movement, should be considered, besides the basic components of architecture including dimensions and size (length, depth), enclosure, the impact of the room and the openings (with and without opening), the number and distance between the columns and the way they are placed in the different sides of the yard (linear, L-shaped, U-shaped and 4-sided) have been measured. It should be noted that all the simulations of this stage have fixed and identical conditions, except in cases where a change in conditions is specifically announced. Air quality contour diagrams are according to Table 5.

- **Inner Taremeh**

To measure the factors affecting the quality of

Table 5. Name of the sides and contour color legend for air quality. Source: Authors.

The local mean age of air	Velocity	Name the sides
		

natural ventilation of the semi-open space, it is first necessary to check the wind circulation in the courtyard, semi-open space, and around the mass without any additional elements such as openings and columns. As a result, the simulation was performed according to mode A in Table 6 for all four different modes of the Taremeh form. A comparison of the way of wind circulation in the yard space in type number 2 (without open space) and the addition of semi-open space in the basic state (internal Taremeh) in different states shows:

- Linear Taremeh: although the airflow speed of the yard in one-way mode is lower than the basic mode, compared to the other three modes, it has the highest air flow speed. Wind circulation is less in the middle area and more towards the walls.
- L-shaped Taremeh: with the addition of semi-open space to sides B and D, the speed of the wind flow on the opposite side and attached to the corner of side C is very high, although it is generally slower than the linear mode.
- U-shaped Taremeh: in this case, two high-pressure air centers are formed in the middle of the yard, which has the highest speed, but the distance between them shows a lower speed. This range in the courtyard and semi-open space on side D has a higher speed than side A.
- 4-way Taremeh: like the U shape, it shows the same air movement pattern but lower speed.

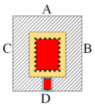
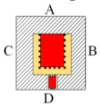
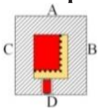
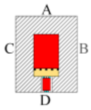
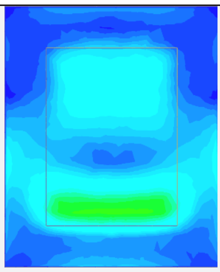
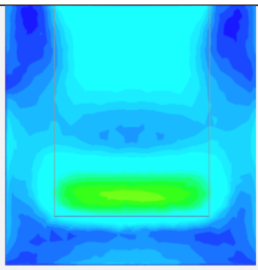
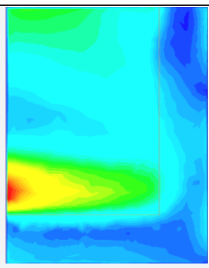
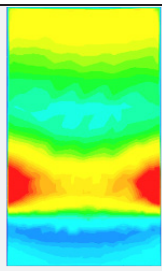
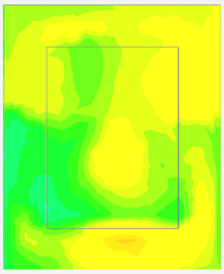
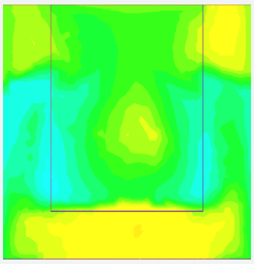
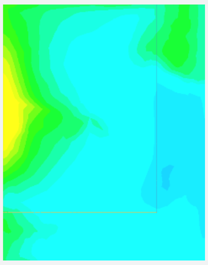
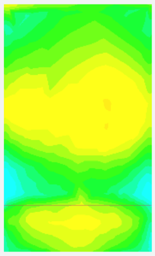
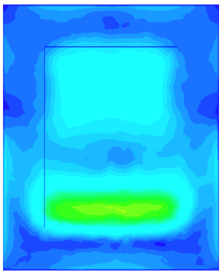
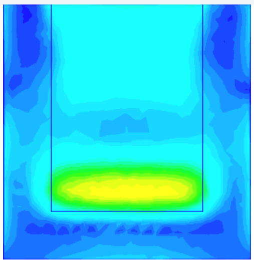
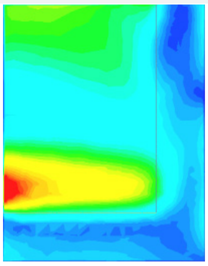
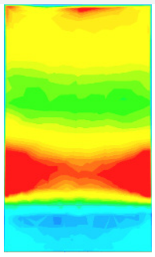
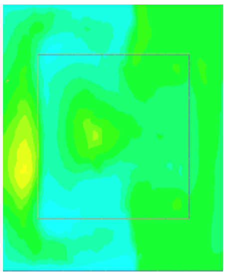
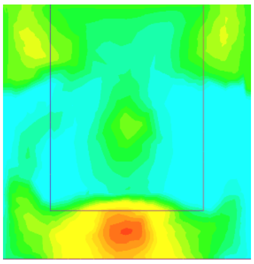
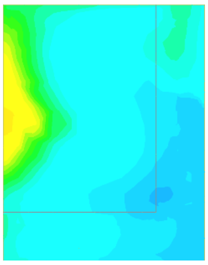
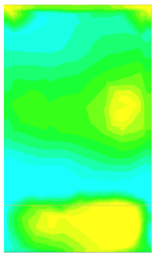
- **Mass**

By increasing and decreasing the thickness of the yard mass, the speed and quality of natural ventilation will be different. It can be said that the importance and impact of mass changes are far more than other components. To measure how and the extent of this effect, a comparison is made in Table 6 between the two cases “A” where the area of the yard is fixed and a semi-open space with a width of 3. 5 meters is added to the mass area, and case “B” where the area of the yard is still constant, but the area of the Taremeh is part of the yard. The findings show that the way of wind circulation is almost the same in both cases “A” and “B”, but in case “B” due to the thickness of the mass being less, the speed of the airflow is somewhat higher and the life of the air is less. Also, the contours of air life show that with the addition of Taremeh to different sides of the yard, the age of air in “B” is less than “A”. In general, the linear Taremeh in mode “B” is the most optimal and the 4-sided Taremeh in mode “A” has the longest age of air and the worst air quality (Table 6).

- **The dimensions of the columns**

The simulation was carried out along the side D (southern part), by determining the distance between the columns as a constant 80 cm, the number of columns from 5 to 11, and the dimensions of the columns from 260 to 12. 72 cm. The analysis of the wind circulation in Table 7 shows that by reducing the number of columns and increasing the dimensions of the columns, on the one hand, the speed of airflow in the Taremeh space decreases, and on the other hand, by reducing the ratio of semi-open space to the mass (columns), the velocity in the yard increases. In general, the wind flow moves around the smaller columns, but for the columns with larger dimensions and due to the reduction of the distance between them, a corridor is created to guide the wind. This is especially true for a Taremeh with 5 columns. Although the overall pattern of wind rotation in the courtyard space is not affected, with the increase in the dimensions of the columns

Table 6. Measurement of mass in the inner Taremeh. Source: Authors.

Type		4 sided	U shape	L shape	Linear
	Form				
A: Taremeh was added to the mass and yard	plan (velocity)				
	Plan (age of air)				
B: Taremeh is a part of mass	plan (velocity)				
	Plan (age of air)				

behind the columns from the courtyard side, a high-pressure part is created on the first and second floors. In addition, with the increase in height, the speed of airflow increases in all modes.

The comparison made in Table 8 shows that with the addition of room and openings in "B: with room and opening" mode, communication is established between the yard, semi-open space, and outside volume. Due to the nature of the wind tunnel, the airflow path of the room is from the outside of the space to the inside of the room and the Taremeh. As a result, despite the general similarities in velocity and age of air with "A: No room and opening" mode, it has a different wind circulation method. In this case, due to the movement of the wind from the side of the room to the (Taremeh) space, causes

Table 7. Measuring the dimensions of the columns in the inner Taremeh in linear form. Source: Authors.

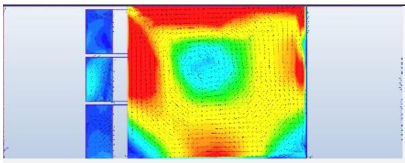
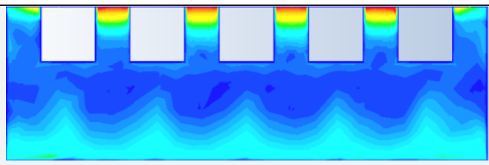
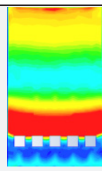
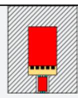
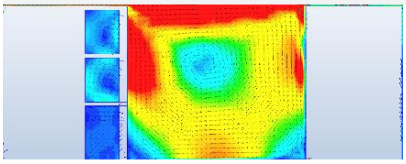
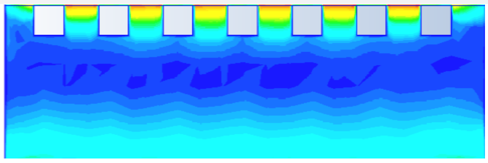
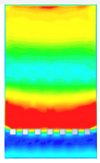
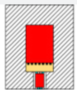
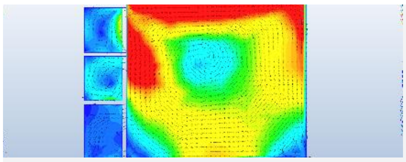
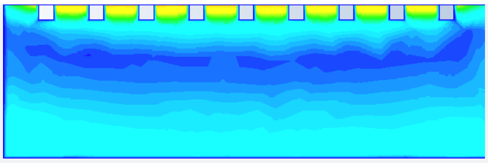
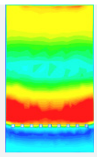
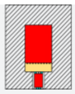
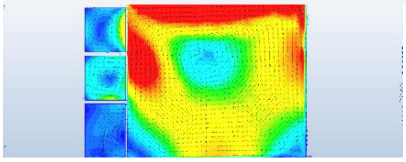
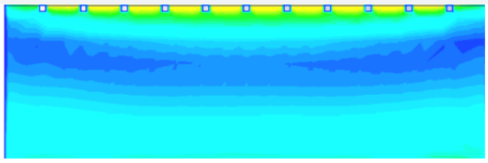
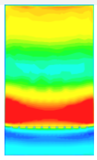
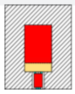
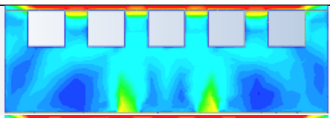
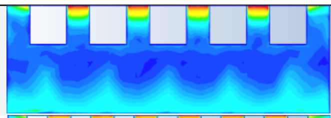
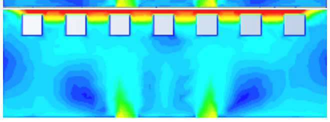
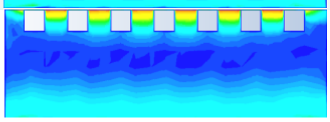
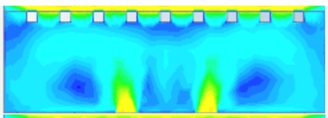
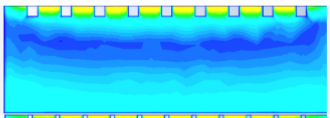
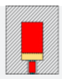
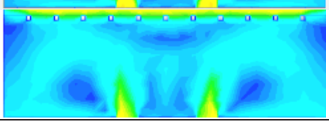
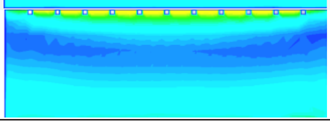
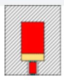
Section of Building	Taremeh plan	Yard plan	Column dimension (centimeter)
			 5 (124*124)
			 7 (66*66)
			 9 (33*33)
			 11 (13*13)

Table 8. A comparison of the dimensions of the columns in the inner Taremeh in linear form. Source: Authors.

B. Taremeh plan (mentioning room and openings)	A. Taremeh plan (without mentioning room and openings)	General form And column number
		 5
		 7
		 9
		 11

more air circulation and the non-uniformity of the wind movement path and provides better air quality. Also, with the increase in height in all modes, the speed of the airflow increases and the life of the air decreases.

- **The distance between the columns**

According to Table 9, the analysis of the flow of wind circulation in "A" mode shows that, with the increase in the number of columns and the decrease in the distance between the columns, both the speed of the airflow in the semi-open space decreases, and due to the decrease in the ratio of the semi-open space to the mass, the flow speed The air rises in the yard. Although a limited wind is created in the distance between the columns, the wind speed decreases in the space of the Taremeh. Analysis of the flow of wind circulation in state "B" shows that, with the addition of room and openings, there is a connection between the inside and outside space. As a result, individual wind islands are formed at a lower speed. Although the overall pattern of wind circulation in the courtyard space is not affected, however, with the increase in the number of columns behind the columns from the courtyard side, a high-pressure area is created on the first and second floors. Also, with the increase in height from the ground floor to the first and second floors, the speed of velocity in Taremeh increases in all cases.

- **Depth**

Regarding measuring the effect of depth on the quality of natural ventilation in a semi-open space, Table 10 examines the velocity for the inner Taremeh in a linear form (without room and opening). The simulation was performed for a linear Taremeh with 4 columns 80x 80 with a distance of 156 cm, for depths of 2 to 5 meters. In "A" mode, with the dimensions and the distance between the columns remaining constant and the depth increasing, the velocity decreases significantly. Due to the absence of openings, the velocity at the end of the space and attached to the D side wall has the lowest velocity and acts as one-way ventilation. The wind rotates in this space and is the least in the corners and under the ceiling. However, in mode "B" and with the addition of a room and openings to this space, the air quality improves significantly. Also, with the increase in height, the velocity of Taremeh increases.

- **Form of the Taremeh**

According to Table 11, at this stage, it is necessary to compare several effective components in a combined manner. For this purpose, the simulation of velocity and age of air was performed for all 4 types of the 3.5-meter-deep, with room and openings, and 8-meter thickness of mass. The analysis of the findings shows that by adding more sides to the semi-open space, the speed of the airflow in the yard is reduced and distributed in the semi-open space. As a result, the linear Taremeh has the highest and the 4-sided Taremeh has the lowest velocity in the yard and semi-open space.

- **The middle Taremeh**

All middle Taremehs are open on both sides and closed on both sides. In this part, it is necessary to examine the "depth" of the Taremeh as the most important physical element affecting it. For this purpose, in Table 12, the simulation of air quality components for the middle Taremeh in the modes "A: with openings and room" and "B: without openings and room" for widths of 1, 2, and 3 meters were done. The analysis of different modes shows

Table 9. Comparison of the distance between the columns in the inner Taremeh in linear form. Source: Authors.

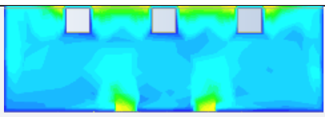
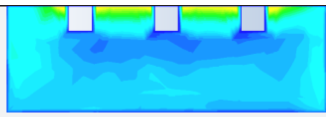
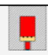
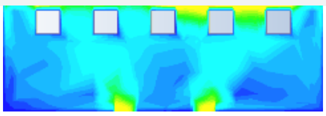
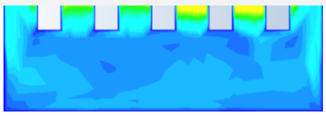
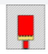
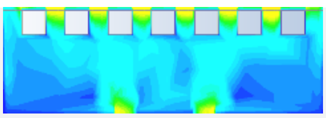
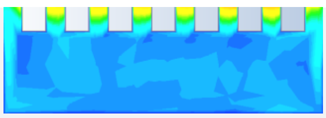
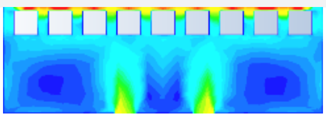
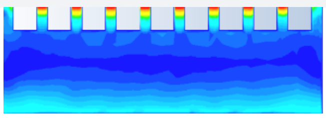
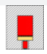
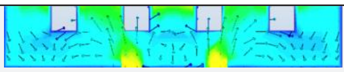
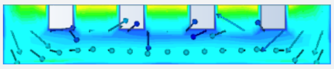
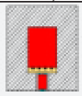
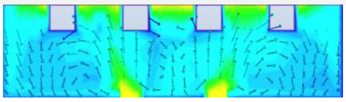
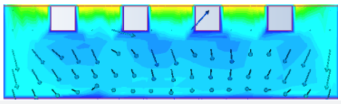
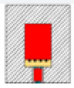
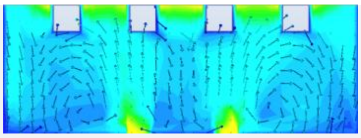
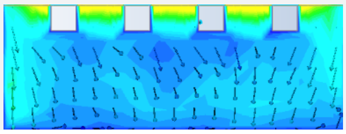
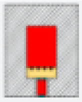
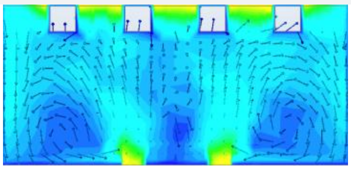
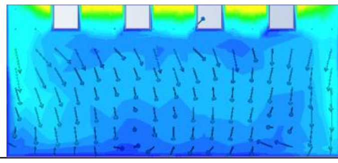
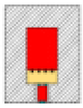
B. Taremeh plan (mentioning room and openings)	A. Taremeh plan (without mentioning room and openings)	General form And column number
		 3
		 5
		 7
		 9

Table 10. The effect of depth on velocity in the inner Taremeh in linear form. Source: Authors.

B.Taremeh plan (mentioning room and openings)	A. Taremeh plan (without mentioning room and openings)	General form depth (meters)
		 2
		 3
		 4
		 5

that, according to the direction of wind movement, the general pattern of wind circulation is the same. For a width of one meter, due to the creation of a long corridor with a small width, a wind tunnel is created, where the case without opening is better than adding room and opening. Also, with the increase in the width of the Taremeh, the velocity decreases to some extent, but the difference is insignificant.

- **Outer Taremeh**

- Depth measurement

At this stage, it is necessary to measure the effect of the width of the outer Taremeh. For this purpose, simulation was done for three forms: linear, L-shaped, and U-shaped for widths of 2 and 5 meters. The findings of Table 13 show that the linear Taremeh with a width of 5 meters has the highest and the L-shaped Taremeh with a width of 5 meters has the lowest velocity. Although in all cases, the velocity has decreased to a certain extent compared to the case without the Taremeh, it can be said that the addition of the outer Taremeh has provided optimal air quality both in the semi-open space and in the room.

- **Effect of Tarmeh form**

First of all, it is necessary to check the general pattern of wind circulation in the semi-open space in the form of an outer Taremeh without openings and columns. For this purpose, the simulation of 4 different types of the outer Taremeh around the mass (Table 14) and 2 types around the room (Table 15), with a width of 3/5meters, was done. The findings of Table 14 show that, in general, the addition of outer Taremeh has significantly improved the air quality of the outdoor semi-open space. On sides B and C, the wind moves parallel to the direction of the wind tunnel and along the semi-open space, and has the highest velocity and the lowest age of air. The speed of airflow in side D in linear form is less than the L-shape, less than the U-shape, and almost the same as the 4-sided. The age of air of side D is at its highest value in linear form, followed by U-shaped and 4-sided forms with much better ventilation, and finally, the L-shaped form has the lowest age of air and the best ventilation. In general, side D in the L-shaped form has the most optimal ventilation due to the highest velocity and the lowest age of air, and in the linear form, the worst ventilation includes the lowest velocity and the highest age of air. In addition, the velocity of the semi-open space is the highest on side A facing the wind and the lowest on side D

Table 11. Measuring the impact of the inner Taremeh's form. Source: Authors.

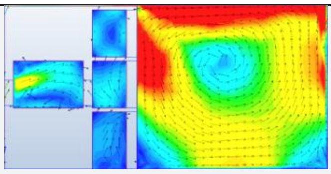
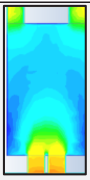
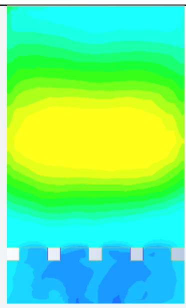
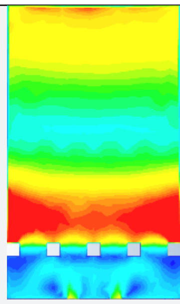
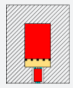
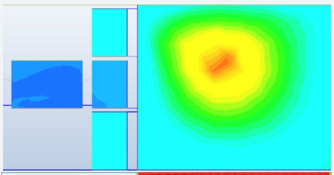
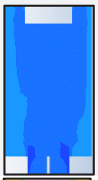
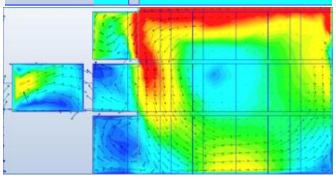
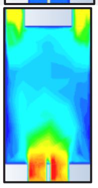
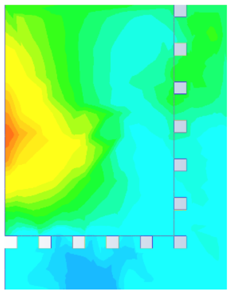
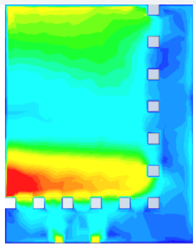
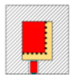
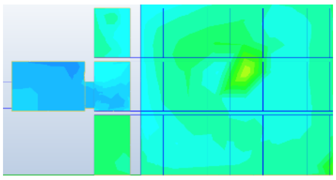
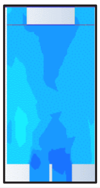
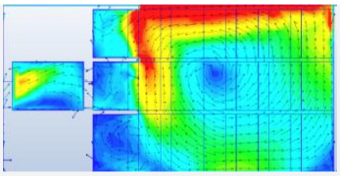
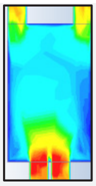
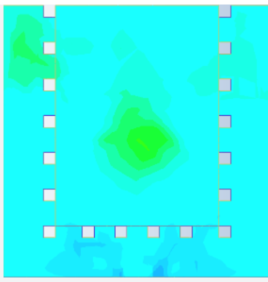
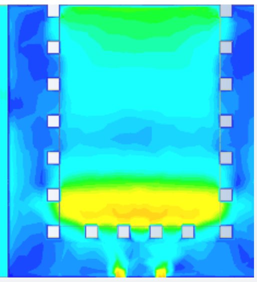
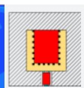
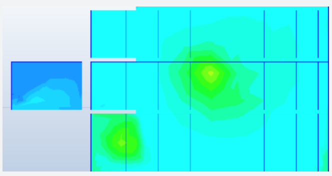
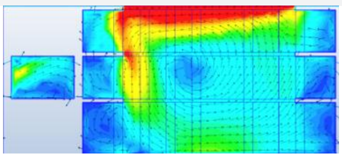
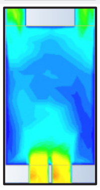
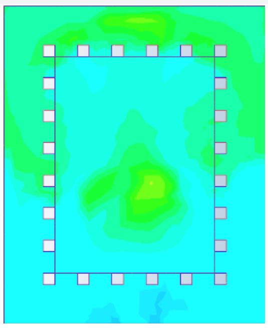
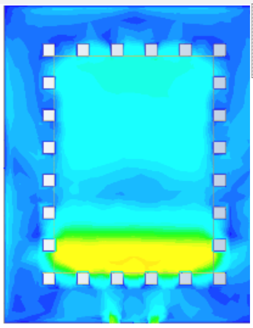
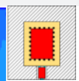
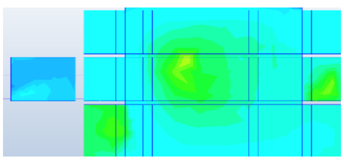
Parameters	Section	Room Plan	Taremeh Plan (Age of Air)	Taremeh Plan (Velocity)	Form
Velocity					 linear
Age of air					
Velocity					 L shape
Age of air					
Velocity					 U shape
Age of air					
velocity					 4 sided
Age of air					

Table 12. The effect of depth on velocity in the middle Taremeh. Source: Authors.

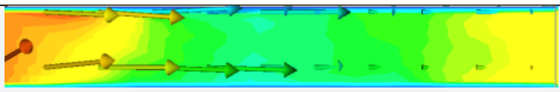
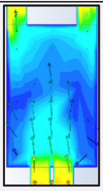
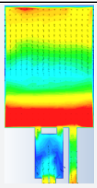
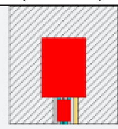
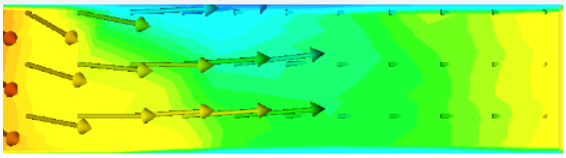
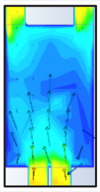
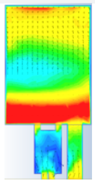
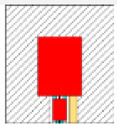
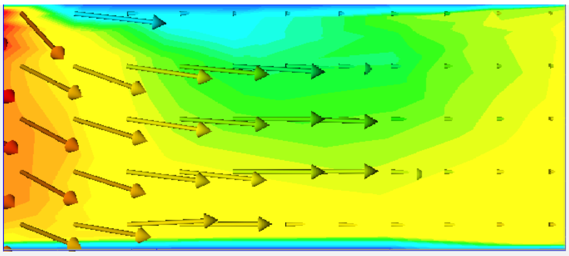
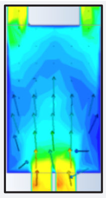
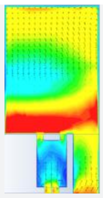
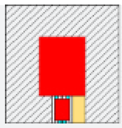
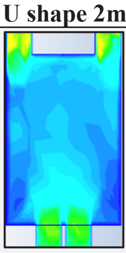
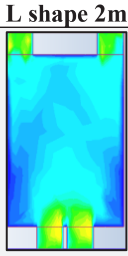
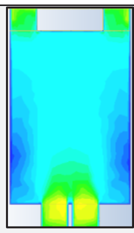
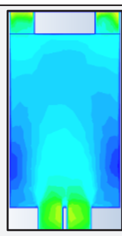
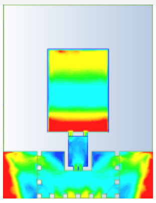
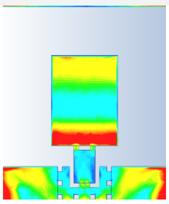
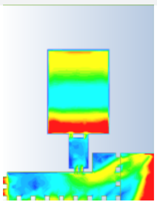
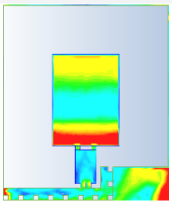
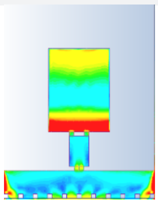
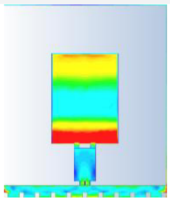
Taremeh Plan	Room Plan	Total volume	General plan, width (meters)
			 1
			 2
			 3

Table 13. Measurement of the width of the outer Taremeh - velocity (width of 2 and 5 meters). Source: Authors.

U shape 2m	U shape 2m	L shape 5m	L shape 2m	Linear 5m	Linear 2m	place
						Plan of room
						volume

facing the wind at all height levels. Wind circulation and air quality components in all 3 floors and all 4 forms almost follow the same pattern (except for the second floor on the windward side).

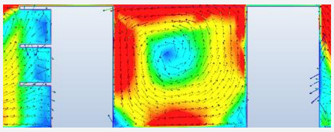
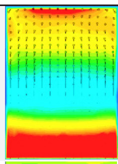
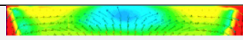
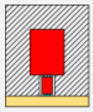
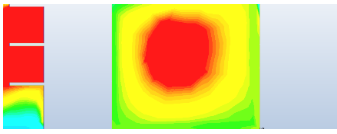
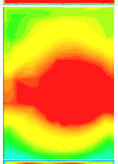
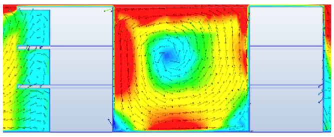
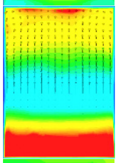
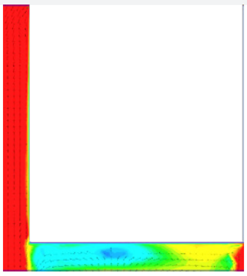
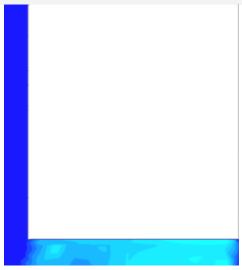
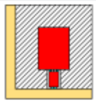
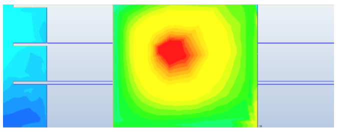
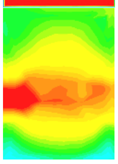
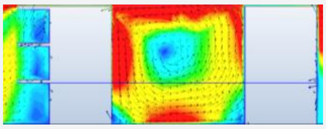
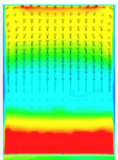
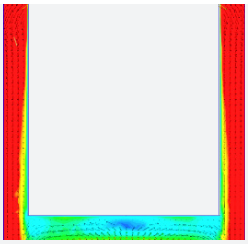
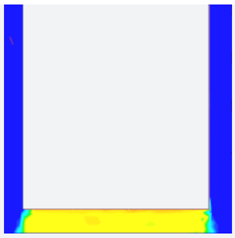
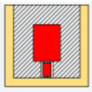
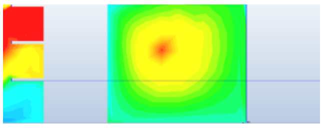
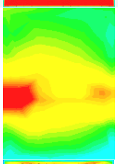
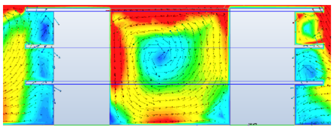
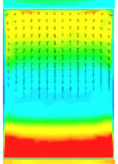
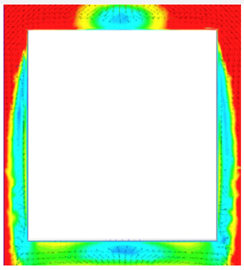
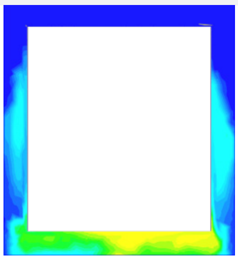
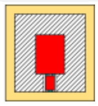
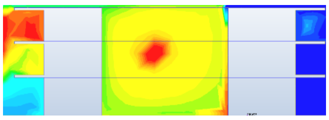
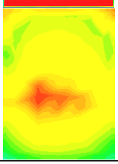
The findings of Table 15 show that the addition of a semi-open space around the room on side D has improved the velocity and age of air in the semi-open space and room. Also, with the addition of a room and an opening in the second height level, the air quality in the semi-open space of this floor has become better than other floors.

In general, the addition of the outer Taremeh in all directions (except for the 4-sided form) has increased the quality of room ventilation and also created a favorable air quality in the semi-open space itself, and it is only 4-sided type that faced the decrease in velocity. In other forms, the addition of semi-open space has almost not reduced the room space.

Conclusion

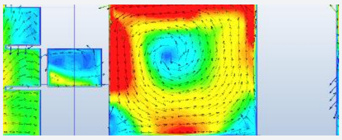
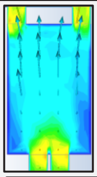
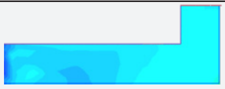
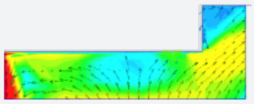
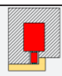
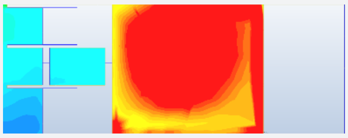
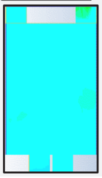
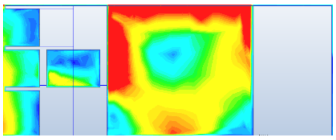
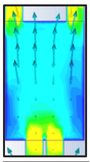
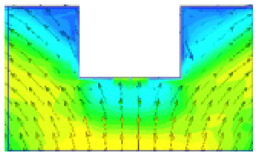
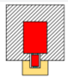
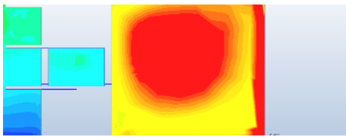
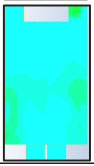
The purpose of this research in measuring the

Table 14. Measuring the form of the outer Taremeh: velocity & age of air (for the state without room and opening, 3. 5 meters wide). Source: Authors.

Parameters	Section	Yard plan	Taremeh plan (velocity)	Taremeh plan (age of air)	Form
Velocity					linear 
Age Of Air					
Velocity					 L shape
Age Of Air					
Velocity					 U shape
Age Of Air					
Velocity					 4 sided
Age Of Air					

indicators related to the semi-open spaces in the historic houses of the central courtyard to benefit from natural ventilation and achieve architectural solutions, the results of the comparative tables about the internal Taremeh show that with the increase in the overall volume of the building, due to the addition of the Taremeh between the yard and mass, the quality of ventilation in the yard and room decreases. By reducing the number of columns and increasing the dimensions of the columns, as well as when the dimensions of the columns are fixed and the distance between the columns increases, the velocity decreases in Taremeh, but it increases in the yard. In all cases, with the increase in height,

Table 15. Measurement of the effect of the outer Taremeh's form on the air quality of the room (Taremeh width: 3. 5 meters). Source: Authors.

Parameter	Section	Room Plan	Tareme Plan (Velocity)	Taremeh Plan (Age Of Air)	Form
Velocity					 L shape
Age Of Air					
Velocity					 U shape
Age Of Air					

the velocity in the yard increases, and the age of the air decreases. With the addition of the room and the openings on the D side, the connection between the courtyard, the semi-open space, and the outside volume is established and the quality of ventilation is improved. Finally, the inner Taremeh in linear form has the highest and the 4-sided Taremeh has the lowest velocity in the yard and semi-open space. Around the middle Taremeh, the results show that, for a width of one meter, due to the creation of a long corridor with a small width, a wind tunnel is created, in which the case without opening is better than the addition of room and openings. Also, with the increase in the width of the middle Taremeh, the velocity decreases to some extent, but the difference is insignificant. Regarding the outer Taremeh, the results show that the addition of semi-open space around the room on side D has improved the velocity and age of air in the semi-open space and room. Also, with the addition of a room and openings in the second height level, the air quality in the semi-open space of this floor has become better than other floors. In general, the addition of the external Taremeh in all directions (except for the 4-sided form) has increased the quality of room ventilation and also created a favorable air quality in the semi-open space itself, and it is only in the 4-sided mode that we are faced with a decrease in the velocity. In other forms, the addition of semi-open space has almost not reduced the room space.

Reference list

• Al-Hinai, H., Batty, W. J. & Probert, S. D. (1993). Vernacular architecture of Oman: Features that enhance thermal comfort achieved within buildings. *Applied Energy*, 44(3), 233–258.

• Andersen, K. T. (2002). *Naturlig ventilation i erhvervsbygninger, By og Byg, Statens Byggeforskningsinstitutt Horsholm*. Denmark: Alborg University.

• Ansari, A. (2013). Introducing The Historical Context of Bushehr Port. *Sarvestan*, (6), 15-26.

• Antarikananda, P, Douvlou, E. & McCartney, K. (2006). *Lessons from traditional architecture: Design for a climatic responsive contemporary house in Thailand.* In Proceedings of the 23rd Conference on Passive and Low Energy Architecture- PLEA2006-, Geneva, Switzerland.

• Bay, E, Molina, A Martinez, Dupont, W. (2022). Assessment of natural ventilation strategies in historical buildings in a hot and humid climate using energy and CFD simulations. *Building Engineering*, 51 (1), 104287.

• CIBSE, Chartered Institution of Building Services Engineers. (2005). *Natural ventilation in nondomestic buildings.* London: Chartered Institution of Building Services Engineers.

• Cuce, Erdem, Sherc, Farooq, Sadiqc, Hamad, Cuce, Pinar Mert, Guclu, Tamer, Besira, Ahmet (2019). Sustainable ventilation strategies in buildings: CFD research. *Sustainable Energy Technologies and Assessments*, (36), 100540.

• Hedayat, A., Eshrati, P. (2017). Typology Of the Form and Placement of Shanashir in Vernacular Architecture of Bushehr Port, Iran. *Reasearch In Islamic Architecture*, 3(13), 20-60.

• Hedayat, A. & Eshrati, P. (2019). Typology Of Tarmeh in The Historic City of Bushehr. *Housing and Rural Environment*, 39(172), 106-119.

• Hedayat, A. & Tabaian, S. M. (2013). The Survey of Elements Forming Houses and Their Reasons in The Historical Fabric of Bushehr. *Architecture in Hot and Dry Climate*, 3(3), 35-52.

• Hedayat, A. & Ziaei, M. (2011). *Analysis of the Role of Wind in The Formation of Bushehr's Historical Texture,* Second National Conference on Wind and Solar Energy, Hamandishan Energy Kimia Office, Tehran.

• Karimi, B. (2012). Persian Gulf Architecture the Effect of Bushehr Old Tissue on The Culture and Architecture of The Persian Gulf Countries (Case Study: Al-Bastakiyeh Neighborhood in Dubai). *Hoviatshahr,* 6(11), 85-96.

• Karimzadeh, J, Mahdinejad Darzi, J. & Karimi, B. (2021). Climatic Performance of Traditional Houses in The Old Texture of Shiraz Using the Thermal Comfort Approach Case Study: The Iwan (Veranda). *Iranian Architecture Studies,* (20), 89-115.

• Karimzadeh, J., Mahdinejad Darzi, J. & Karimi, B. (2022). The Effect of Physical Proportions on The Thermal Performance of Porches in The Historical Fabric of Shiraz Based on The Improvement of Thermal Comfort Index. *Architecture and Urban Planning,* 15(36), 27-52.

• Kristianto, M. A., Utama, N. A. & Fathoni, A. M. (2014). Analyzing Indoor Environment of Minahasa. Traditional House Using CFD. *Procedia Environmental Sciences,* (20), 172-179.

• Kumar, N., Kubota, T., Bardhan, R. & Tominaga, Y. (2020). CFD analysis of airflow in voids for better cross ventilation in midrise buildings in hot and humid climates. *Building Simulation Conference Proceedings,* (6), 3879-3885.

• Masoumi, H. R., Nejati, N., Ahadi, A. (2016). Learning from the Heritage Architecture: Developing Natural Ventilation in Compact Urban Form in Hot-Humid Climate: Case Study of Bushehr, Iran. *International Journal of Architectural Heritage*, 11(3), 414-432.

• Moghimi, V, Kiani Borazjani, K, Amirzadeh, F, Bahraini, D. & Qanawati S. (2018). Investigation Of the Optimal Orientation of Tarameh in Relation to The Wind Flow in Traditional Buildings of Bushe*hr. Tourism and Sustainable Development Research,* 4 (7), 27-36.

• Mohammadi, A, Saghafi, M. R., Tahbaz, M. & Nasrollahi, F. (2017). Potentials of Vernacular Climatic Solutions (VCS) in Energy Efficiency of Domestic Buildings in Hot and Humid Climate: The Case Study of Bushehr, Iran. *Space Ontology International Journal,* 6(3), 59 – 76.

• Oikonomou, A. (2005). *Winter thermal comfort in 19th century traditional buildings of the town of Florina, in north-western Greece.* In Proc. 22nd PLEA Conference, Beirut-Lebanon.

• Raisi, I. (2006). Morphology Of the Central Courtyard in The Houses of Bushehr. *Shaarestaan*, (13&14), 7-11.

• Ramli, N. H. (2012). Re-adaptation of Malay House Thermal Comfort Design Elements into Modern Building Elements – Case Study of Selangor Traditional Malay House & amp; Low Energy Building in Malaysia. *Energy & Environment*, (3), 19–23.

• Ranjbar, E., Pourjaafar, M. & Khaliji, K. (2010). Climatic Design Creations in Accordance with The Wind Flow in The Old Context of Bushehr. *Bagh-e Nazar*, 7(13), 17-34.

• Ryu, Y., Kim, S. & Lee, D. (2009). The influence of wind flows on thermal comfort in the Daechung of a traditional Korean house. *Building and Environment*, 44(1), 18–26.

• Saligheh, E. & Saadatjoo, P. (2020). Impact of Building Porosity on Self-Shading and Absorbed Solar Heat Reduction in Hot and Humid Regions. *Naqsh-e Jahan,* 9(4), 257-271.

• Shahi, A. &Takapoomanesh, Sh. (2006). Sustainability Pattern in The Old Residental Fabric of Boushehr, *Architecture and Construction,* 7(10), 130-135.

• WAI Tuc, N. G. (2021). *Effectiveness of passive cooling strategies of indoor thermal conditions for terrace house under hot and humid climate.* Unpulished Phd Thesis. Razak Faculty of Technology and Informatics, Universiti Teknologi Malaysia.

• Watson, D. & Labs, K. (2008). *Climate Design Efficient Building Principle and Practice* (V. Ghobadian & M. Feyz Mahdavi, Trans.). Tehran: University of Tehran. [in Persian]

• Xu, F, Li, Ch. & Tang, H. (2022). Influence analysis of space configuration on cooling load of a large semi-closed atrium in hot and humid region. *Building and Environment,* (225), 109670.

• Zarei, M. E. & Behboodi, N. (2016). Investigating The Speed and Pressure of The Wind in The Central Part of Varmal Castle Settlement in Sistan, Using CFD Simulation Method. *Research in Islamic Architectur*e, 4 (10), 94-110.

HOW TO CITE THIS ARTICLE

Ghahraman Izadi, N.; Taghipour, M.; Eskandari, H. & Movahed, Kh. (2023). The Role of the Effective Parameters of Taremeh in Improving Natural Ventilation in the Courtyard Houses of Bushehr in the Historical Context. *Bagh-e Nazar*, 20(125), 23-44.

DOI: 10.22034/BAGH.2023.385984.5336
URL:https://www.bagh-sj.com/article_178203.html?lang=en