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Explanation of the structure of *Pahl* port windbreaks with a square cross-section in order to achieve a sustainable development model

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Abstract

Passive thermal comfort methods have replaced active methods in Iran's architecture over the past century, resulting in increased energy consumption costs, environmental crises, and considerations. Thus, sustainable architectural features in hot and humid climates are essential to increase energy consumption in today's world. One of the prominent examples of energy optimization in the architecture of hot and humid climates is the wind towers in Pohl port. Investigating and understanding wind towers' behavioral patterns can effectively achieve sustainable architectural solutions. The present study aimed to assess the typology of wind towers in Pohl port as an example of traditional architecture based on sustainable development patterns and to identify the most energy-efficient type of wind tower. This was an applied study in terms of purpose. The research methodology was a computer simulation, and the required data were collected through the library and field method. DesignBuilder software was used to perform a quantitative analysis. Initially, the historical houses with square-plan wind towers were selected. Then, 21 houses were evaluated based on their physical characteristics and categorized into three main groups. The results indicated that the square plan wind towers with three openings exhibited superior performance than the wind towers with two or four openings. Moreover, the study demonstrates that cooling output from the square plan wind towers with three openings is important in reducing energy consumption in Pohl port's hot and humid climate.

***Keywords**:* Sustainable architecture; Energy optimization; Vernacular architecture,; Wind towers; Pohl port

1. Introduction

In recent years, the energy crisis and air pollution in big cities have become severe issues. According to the statistics, over 50% of the world’s population lives in urban areas. This number is likely to increase to 80% in the future. Although large and dense cities are desirable places in terms of production and innovation, the rapid increase in population poses a serious challenge for governments (Harrison and Donnelly, 2011, p. 341).

The lack of access to natural elements is one of the most significant disadvantages of urbanization. Due to human-centered activities, the connection between humans and natural elements is weakened, and welfare, health, and living environments are threatened (Hall & Pfeiffer, 2000, p. 57). Cities consume 60-80% of the world's energy despite occupying less than 2% of the earth's surface (Nel et al., 2017, p. 87). The growing trend of the population and consequent demand leads to an increase in resources, costs, emission of pollutants, and intensification of climate change and the global warming phenomenon.

Since ancient times, architects have evaluated the relationship between the architectural and urban fabric with the wind flow and tried to find a suitable design for the use of solar energy. The traditional architecture of Iran is different depending on different climates. The climate adaptations that the residents of this region have developed over the years have provided them with thermal comfort.

The vernacular architecture of Iran has unique features, and besides aesthetic and cultural issues, it plays an important role in environmental issues. According to studies, the vernacular architecture of Iran provides promising solutions to facing climate challenges and meets the needs of residents using natural and inexpensive methods. The traditional architecture of Iran has strong and adequate support in terms of sustainability, art, and culture (Mahdavinejad and Javanroudi, 2011, p. 71). The majority of Iran has a hot climate, so one of the primary objectives of architects is to meet the space cooling demand. In the past, empirical knowledge was used to improve life without the use of mechanical methods. To this end, a wind tower is one of the most important cooling elements in Iranian architecture, providing natural ventilation in hot and dry and hot and humid regions through the use of renewable wind energy.

Wind towers in Pohl port were evaluated in this study. The proper design of architectural elements results in less nonrenewable energy loss. Using a climate-friendly architectural method, it is possible to understand traditional architecture concepts better, analyze traditional solutions, and fully introduce them to today's engineers. As part of these methods, the comfort level provided by the traditional building in each climate is evaluated and determined. This type of energy optimization has been discovered through the knowledge of vernacular architecture and the centuries-long experience of architects. The use of the architecture of

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the past cannot meet today's climate change and the needs of people; consequently, the aim of the present study is not to repeat the architecture of the past. This study aimed to investigate the characteristics, techniques, architectural concepts, and thermal comfort performance of several types of wind towers in Pohl port to find the optimal type of wind tower.[K1]

2. Research Questions

1- How do wind towers work in Pohl port's hot and humid area?
2- Which type of wind tower performs better in terms of energy optimization?

3. Research Method

In terms of purpose, this was an applied study, and in terms of methodology, it was a quantitative in terms.methods study.
In the present study, the computer simulation method was utilized to investigate the concepts and indicators of sustainability in a hot and humid climate. The research was based on experimental studies and fieldwork on a square-plan wind tower in the Pohl port residential buildings. Data were collected using library resources. The following selected samples were found using the field method, and their plans were drawn. Due to the collection of quantitative data through field collection and library studies, it has been used. After preliminary studies and observations, a case sample was selected and evaluated. Variables related to climate and environment are taken by meteorological data and entered into the software, then the desired house is modeled. Modeling has been done in Design Builder software.

4. Literature Review

About 9% of oil and its products are consumed by Iran’s population, comprising 1% of the world population (Rubin and Paridson, 2002, p. 8). Buildings account for 40.6% of total energy consumption (Energy Balance Sheet 2011). Socioeconomic programs such as urbanization development, lack of construction, and the rise in land prices and horizontal structures are the primary causes for the disconnection of contemporary architecture from its traditional counterpart and the disregard for physical and climatic factors (Bolouhari et al., 2020, p. 91).
Knowing the region's wind speed and intensity can help designers optimize this natural resource. Iran's traditional architecture has a solid foundation and is adapted to each region's culture and climate. Today, despite the various technologies, no traces of them can be found (Ghasemi Esfahani, 2014, p. 15). Modern architects favor applying the advantageous rules of vernacular architecture to new projects. The detailed structure of local buildings should be checked to achieve these principles.
Using passive thermal comfort in traditional Iranian architecture in accordance with climatic conditions has formed identifying forms and patterns. Using the active thermal method, population growth, depletion of natural resources, and environmental crises limited hydroelectricity energy production in hot and humid climates over the course of the twentieth century (Rostampour et al., 2020, p. 154). Despite having a simple mechanism and utilizing clean, renewable, readily available, and inexpensive energy, wind towers are still functional.
Even though the wind tower, one of the architectural symbols of the country's hot and humid regions, can greatly assist in building construction and energy conservation, it is no longer utilized.
Mahdavinejad and Javanroudi (2011) conducted a study entitled “comparative evaluation of airflow in two kinds of Yazdi and Kermani wind-towers.” Gorji Mahlabani et al. (2020) evaluated the combined wind tower systems with cooling and heating systems to improve the design and increase energy efficiency. Bolouhari et al. (2020) conducted a study on the wind towers of Yazd titled “Learning Traditional Architecture for Future Energy-Efficient Architecture in the Country.” Sadeghi et al. (2021) investigated the thermal performance of wind towers in hot and dry climates (Isfahan) and reported that the potential of energy consumption reduction strategies in the case sample was proven through computational fluid dynamics (CFD) simulations.
Suzan Roaf (1988) conducted a study entitled “the wind catchers of Yazd.” Beharinejad (1981, 1985, 1994) investigated wind towers, and Yagoubi (1991) analyzed the performance of three wind towers in three cities. Saadatian et al. (2012) conducted several studies on wind catchers from different aspects. Montazeri et al. (2018) evaluated the effect of the outlet opening on the performance of the wind catcher based on three parameters: air flow rate, age of air, and air exchange efficiency. This data is generated using precise modeling with software and CFD output based on valid wind tunnels and climate conditions. The information was obtained via simulation with CFD software based on wind tunnel calculations and Pohl port's climate. McGrath et al. (2021) investigated the natural ventilation of residential buildings by modeling the buildings and using the accurate climate data of the region. Vidra (2021) investigated climate challenges and opportunities in the West of Sub-Saharan Africa.

4.1. Pohl port's geographical location

Pohl port is located in the province of Hormozgan, approximately 5 km from the wharf. This is the only location 2 km from Qeshm Island. Pohl port is open to the sea from the south and surrounded by a mountain (salt mine) and a shallow river to the north and east, respectively. The meteorological data of Pohl port station in Hormozgan province shows that the temperature (>30 ˚C) and humidity (>80%) of this port are higher than the thermal comfort standard (Meteorological station of Iran Ports and Maritime Organization). Consequently, natural ventilation can be used to adjust the thermal conditions during the hot months of the year.
In order to create natural ventilation in this climate, it is necessary to use the building envelope and outdoor airflow entering the indoor area. The wind tower, the empty spaces on the ground floors for airflow, and ventilated roofs are used in traditional and modern architectural designs in hot

and humid areas. The wind tower, a passive ventilation system, not only reduces energy consumption and building costs but also provides a clean environment and climatic comfort for people by reducing the heat generated by electric cooling devices and ensuring proper and constant ventilation.

The physical solutions for creating natural ventilation in the building are divided into three types: physical measures in the roof, physical measures in the facade of the building, and a combination of both (CIBSE, 2005, p. 15-20). Common natural ventilation strategies include wind towers, solar chimneys, one- or two-sided ventilated windows, double-skin facades, and an atrium with a stack effect (Allard and Ghiaus, 2005, pp. 28-36). Since the warm air tends to rise upwards due to its lightness, the roof is very important in natural ventilation. In addition, the air currents passing through the roof surface are stronger and more stable.

Natural roof ventilation is appropriate for low-rise and enclosed buildings with low airflow, as well as buildings with significant surrounding noise and air pollution (Mehari, 1996). Since residential buildings in Pohl port are often low-rise and enclosed, natural roof ventilation is more appropriate. Wind catchers of buildings in hot and dry or hot and humid regions effectively regulate the temperature by directing the airflow and utilizing the energy of the wind.

The wind catcher is the most significant physical element in the architecture of hot and humid climates. In traditional architecture, the wind tower was used for air conditioning. Although it seems that the prevalence of the air conditioning system has led to the cessation of wind tower construction, its structural form is still used as a symbolic element in current projects (Behnejad et al., 2012, p. 26). The wind towers, a passive cooling system, not only cool the interior but also exhaust the layer of air that contains the hottest air. The wind catcher's accurate and correct performance demonstrates that its designers employed the principles of thermodynamics, aerodynamics, heat transfer, material strength, and thermal human comfort in its design (Sadeghi et al., 2021, 35).

A wind catcher has been used as a cooling and ventilation system for many centuries in the central plateau of Iran and the Persian Gulf, the Middle East, and North Africa (Yarshater, 1989, p. 22). A wind catcher consists of certain functional components, including a chimney, channel, and shelf. The chimney is the lower part of the wind catcher, which removes the airflow inside the wind catcher and transfers the air inside the wind catcher channel. The channel is the highest point of the wind catcher, located above the chimney, and it leads to the shelf. The main function of the channel is the transfer of air. The shelf is the upper and most important part of the wind catcher. This component uses wind to circulate fresh air within the building while simultaneously utilizing suction to evacuate hot air. The shelf consists of three parts: roof, separating blades, and air inlet opening (Abusaba and Khodakarmi, 2011).

Fig. 1. Sample images of wind turbines in Pahl Harbor, Photographer: Munira Sharifi

4.2. Features and details of the windbreaker

The windproof skeleton is made of a load-bearing wall that extends in the form of a tower on the floors of the building and starts from a height of 2.5 meters from the floor of the room and is extended by a column or a side wall and is connected to the side wall or a column at the 4 corners of the wall on the ground floor with the help of two cross braces. transfers The base level is usually 2.5 to 3 x 3 meters and the height is between 5 and 6 meters above the roof level, and due to the heat of the air in most of the year, in order to create a stable comfort zone in the houses, there is a wind room to bring the wind down from the heights. be guided and collide with the surface of the residents' bodies. The dryness of the land surface and the direction of the prevailing wind flow during the day from the land to the sea and vice versa from the sea to the land at night, thus always creates the air flow in the building. Each windshield is made up of specific physical components that vary greatly in detail. Dr. Memarian Badgir is made of parts including: oven, stem, string and chain, shelf and string and chain.

Table 1

Definition of the main components of wind deflectors

Wind deflectors	
Shelf	The top part of the wind deflector, which includes channels for air flow
stem	The part of the body that is placed between the shelf and the roof
blade	Brick and clay elements that divide the wind channel into several smaller channels
The main blade	The walls that continue to the center of the tower and divide the windbreak into several small channels.

Sub blade	The walls do not continue to the center of the tower and have the role of wind vanes
Open and closed pores	In the windbreak view, any space that is placed between two tiles, the open hole allows air to pass, and the open hole allows air to pass, and the closed hole does not allow this.

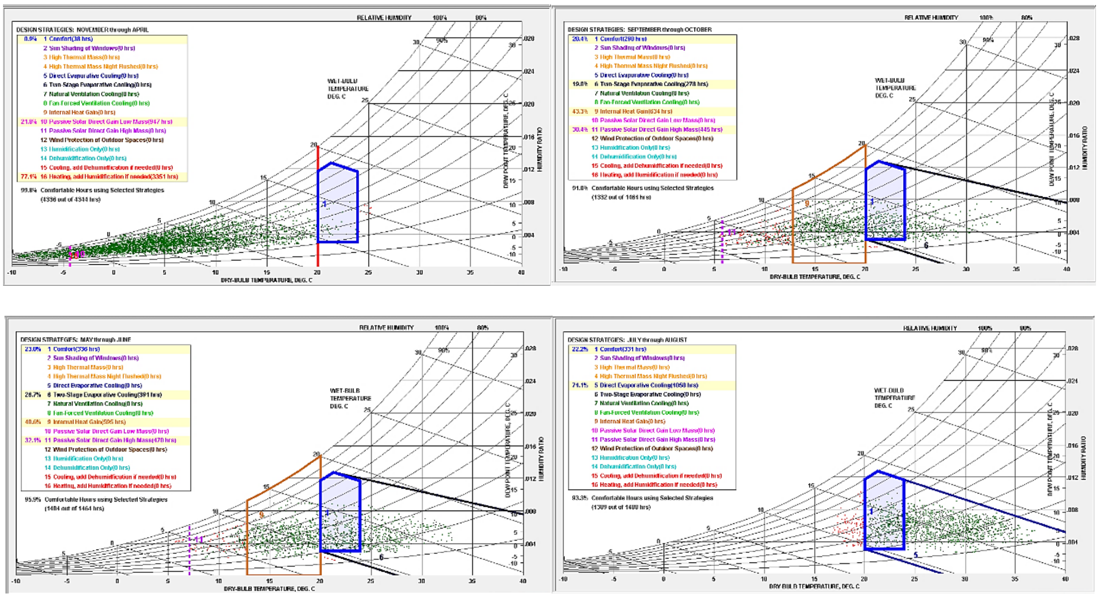


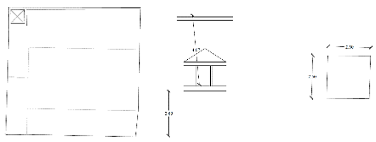
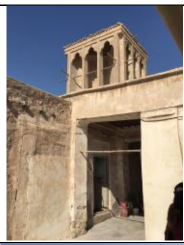
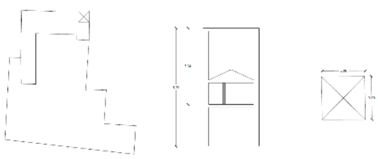
Fig.2. Display thermal comfort graph for 12 months of the year

5. Results and Discussion

5.1.Analysis of findings

According to the assessments, the wind catchers of Pohl port are four-sided with square or rectangular plans. Approximately 27% of Pohl port wind catchers are of square plan type. The present study randomly selected 21 wind towers with a square plan. Each of these wind catchers located in a neighborhood of Pohl port was named according to the name of the houses. Wind towers with a square plan can be divided into three main categories regarding the number of openings: one, two, and three. Table 1 shows each type of wind tower.

Table 2
Typology of A

<table>
<tr><th>Row</th><th>Name of typology</th><th>The number of openings</th><th colspan="2">House names</th><th>Frequency percentage</th></tr>
<tr><td rowspan="2">1</td><td rowspan="2">A-1</td><td rowspan="2">Two openings</td><td>Qibla-6
</td><td></td><td rowspan="2">23.80%</td></tr>
<tr><td>Qibla-8
</td><td></td></tr>
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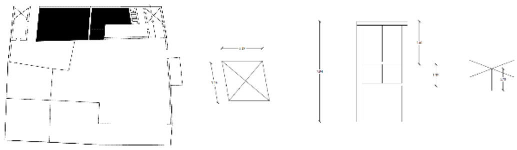
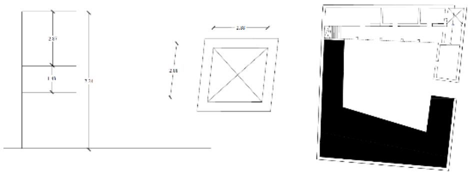
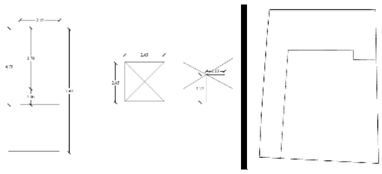
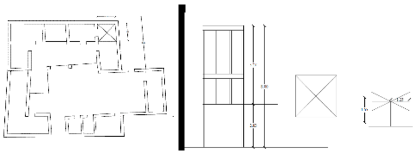
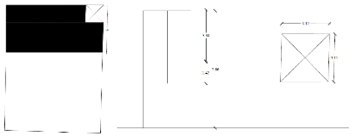
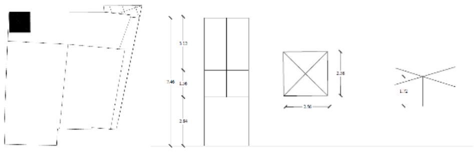
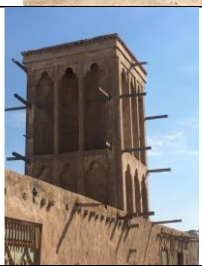
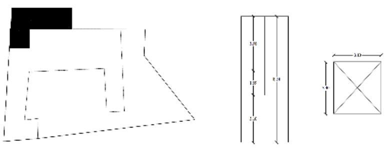
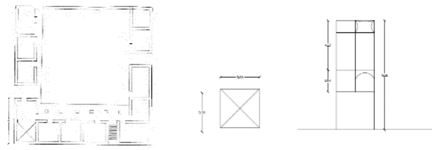
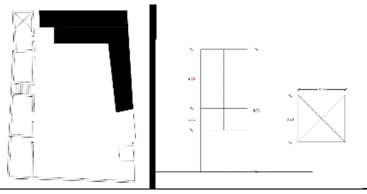
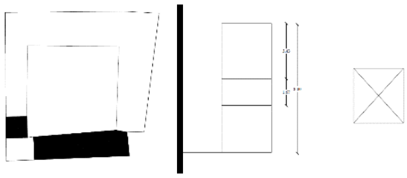
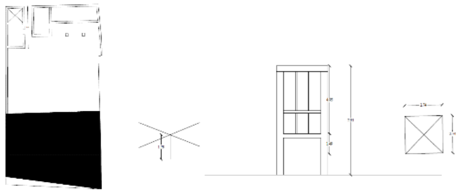
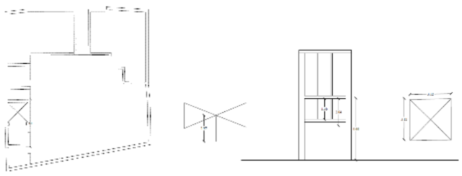
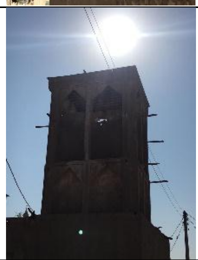
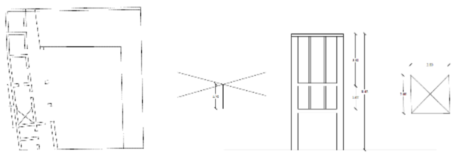
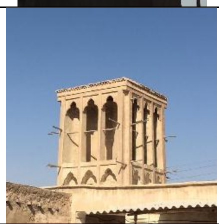
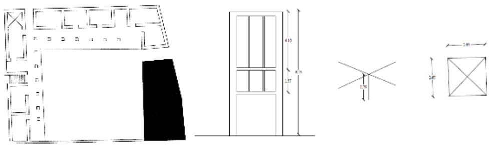
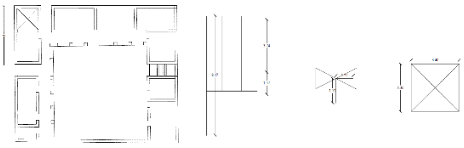
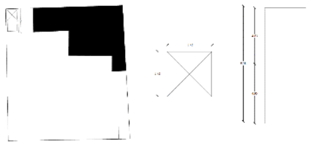
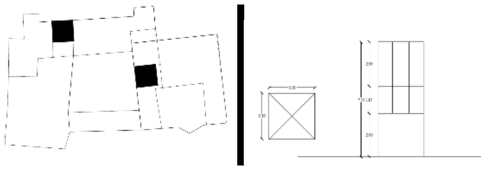
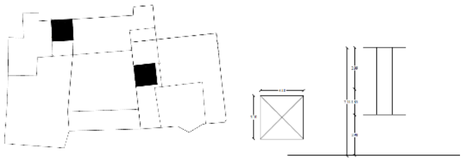
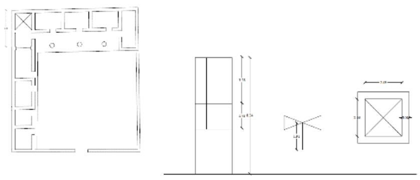
			Moghayeri-6 		
			Korchi Chi-5 		
			Khorno-9 		
2	A-2	Three openings	Korunai-6 		33.33%
			central Mosque-9 		
			Korchi Chi-2 		
			Mughalishah-8 		

			Bavard-2 		
			Bavard-4 		
			Khorno-11 		
3	A-3	Four openings	Qibla-5 		42.85%
			Qibla-9 		
			Qibla-10 		
			Kirtai-8 		

			Mughalishah-5 		
			Baward-3 		
			Khorno-1 		
			Khorno-2 		
			central Mosque-5 		

Type A-1 are square-shaped wind catchers with two openings. This type exhibits the lowest frequency among all wind catchers of Pohl port. The dimensions of these wind catchers vary from 2.5 to 3.19 m. Wind catchers of this type are located in the corner of the plan, most of them on the western front. Table 2 shows the general characteristics of type A-1 wind catchers.

Table 3
Physical characteristics of type A-1

Building Number	The dimensions of the wind tower (m)	The area of the wind tower (m2)	The area of the wind tower room (m2)	The ratio of the wind tower area to the wind tower room (%)	The total height of the wind tower from the ground (m)	Wind tower shelf (m)	Wind tower stem (m)	Wall pier (m)
Qibla-6	2.50*2.50	6.25	-	-	6.95	4.05	-	-
Qibla-8	3.10*3.00	9.30	-	-	8.2	5.3	-	-
Mughiri-6	3.19*3.19	10.17	21.81	5	7.94	3.4	1.7	0.44
Korchi Chi-5	2.88*2.88	8.29	19.92	4	7.24	2.87	1.43	0.40
Khorno-9	2.45*2.45	6.00	16.56	4	7.69	3.79	1.00	0.40

Type A-2 are square-shaped wind towers with three openings. The dimensions of these wind towers vary from 2.56 to 3.43 m. This type of wind tower is frequently positioned at the corner of a plot and between the west and north. Table 3 shows the general characteristics of type A-2 wind catchers.

Table 4
Physical characteristics of type A-2

Building Number	Dimensions of the wind tower (m)	The area of the wind tower (m2)	The area of the wind tower room (m2)	The ratio of the wind tower area to the wind tower room (%)	The total height of the wind tower from the ground (m)	Wind tower shelf (m)	Wind tower stem (m)	Wall pier (m)
Cartaei -6	3.4*3.4	11.56	34.10	3	7.50	3.4	1.2	0.45
central Mosque -9	3.12*3.12	9.73	25.86	4	7.66	3.34	1.42	0.40
Korchi Chi-2	2.56*2.56	6.55	-	-	7.46	3.12	1.56	0.40
Mughalishah-8	3.4*3.4	10.54	-	-	8.24	3.56	1.59	0.40
Bavard-2	3.26*3.26	10.62	25.46	4	9/16	4/12	1/84	0.44
Bavard -4	3.20*3.26	10.43	25.40	3	8.52	4/10	1/52	0.40
Khorno-11	3.43*3.43	11.76	24.97	5	8.00	3.43	1.67	0.49

Type A-3 wind catchers are square and have four openings. The frequency of this type is the highest among all square-shaped wind catchers. These wind catchers range in length from 2.63 to 3.72 m. Less than half of these structures are located on the north side, while the majority are on the west side. In addition, most of these wind deflectors are located in the plan's corners. The general characteristics of type A-3 wind catchers are detailed in Table 4.

Table 5
Physical characteristics of type A-3

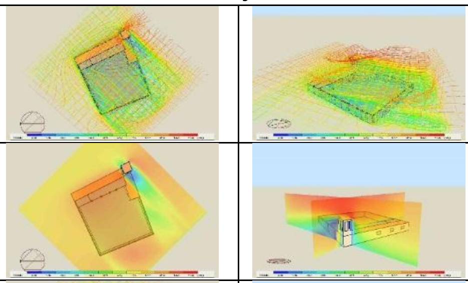
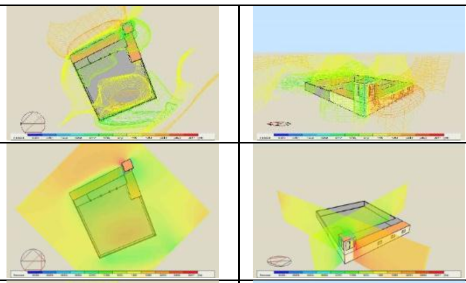
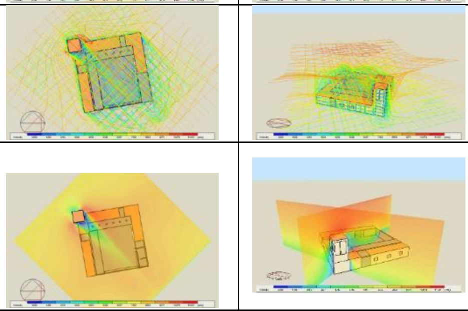
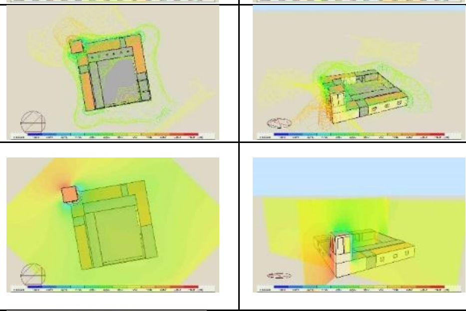
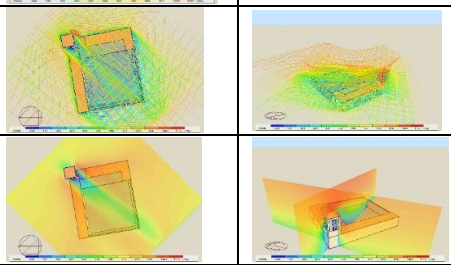
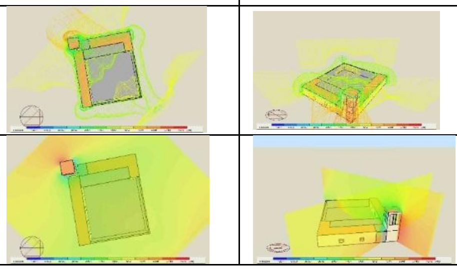
Building Number	Dimensions of the wind tower (m)	The area of the wind tower (m2)	The area of the wind tower room (m2)	The ratio of the wind tower area to the wind tower room (%)	The total height of the wind tower from the ground (m)	Wind tower shelf (m)	Wind tower stem (m)	Wall pier (m)
Qibla-5	2.74*2.74	7.50	22.19	3	7.95	4.95	1.50	0.50
Qibla-9	3.12*3.12	9.73	22.96	4	8.3	3.64	1.56	0.43
Qibla-10	2.80*2.80	7.84	20.94	4	8.48	3.81	1.67	0.50
Cartaei -8	2.67*2.67	7.12	24.53	3	8.73	4.13	1.57	0.50
central Mosque -5	2.63*2.63	6.91	15.14	4	8.24	3.28	1/78	0.50
Mughalishah-5	3.40*3.40	11.56	31.65	3	8.47	3.74	1.57	0.42
Bavard-3	3.72*3.72	13.83	24.99	5	9/58	4/63	1/95	0.40
Khorno-1	3.1*3.1	9.61	29.51	3	7.74	2.99	1.85	0.40
Khorno-2	3.21*3.21	10.30	22.82	4	7.27	2.78	1.59	0.35

Using DesignBuilder software, three types of wind towers were chosen and modeled. Finally, the model of the wind tower that maximizes thermal comfort and performance was selected and implemented. To this end, the CFD model of wind towers was analyzed based on climatic conditions and openings in terms of various parameters. This research determined the air tower's inlet and outlet openings, speed, and positive and negative pressure. These variables directly affect the efficiency of the wind catchers.

5.2. External CFD analysis

External CFD includes velocity and pressure contours. According to the results of the air velocity contour in the wind catcher's outer space with different types, the lowest air velocity was related to the southeast and the northwest front, respectively. Northeast and southwest fronts have the highest air velocity compared to other fronts. Table 5 shows the images related to the velocity contour of different types of wind catchers. The value of the velocity contour increases from blue to red in the graphs.

Table 6
Images of the contour of the velocity and external pressure of wind catchers

Type	Name windward	Velocity contour	Pressure contour
A-1	Korchi Chi-5		
A-2	Bavard-2		
A-3	central Mosque -5		

The results showed that the highest and lowest velocity was related to type A-2 and A-1, respectively. According to the results, the northwest front was the only front with positive pressure. Other fronts exhibited negative pressure. The highest and lowest pressure was related to type A-3 and A-1, respectively. Table 6 shows the numerical value of the wind catcher's velocity and pressure contours on different fronts.

Table 7
Comparison of velocity and external pressure contours of wind catchers

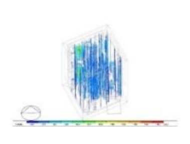
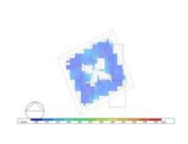
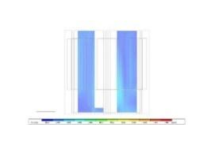
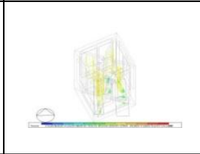
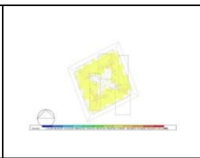
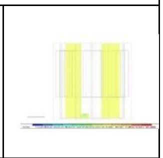
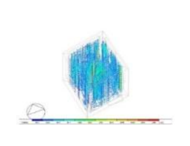
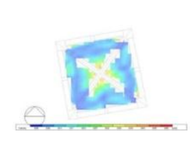
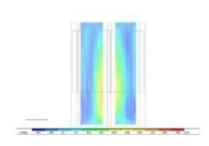
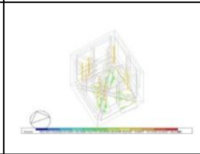
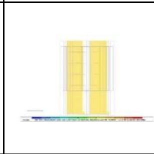
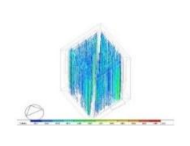
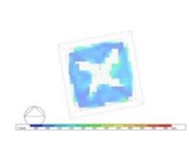
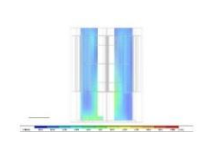
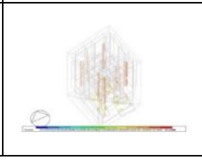
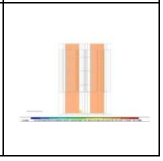
Type	Northeast		Northwest		Southeast		Southwest	
	Velocity	Pressure	Velocity	Pressure	Velocity	Pressure	Velocity	Pressure
A-1	8.17	-27.47	3.06	28.65	1.02	-8.43	7.15	-27.47
A-2	10.79	-41.68	5.39	33.33	1.08	-20.25	9.71	-41.68
A-3	9.60	-39.56	4.27	37.40	1.01	-28.57	8.53	-39.56

The optimal inlet and outlet are determined by evaluating the velocity and pressure contours. Since suction occurs optimally in locations with zero air velocity and positive air pressure, this location is ideal for an inlet opening. Places with high air velocity and negative pressure are suitable for exiting and exhausting air. Because the greatest amount of negative flow and air traction occurs at this point, the output window should be considered. The northwest, northeast, and southwest fronts had the highest and lowest pressures, respectively. In these two fronts, most wind catchers exhibited comparable pressure behavior.
The lowest and highest air velocity, related to the type of A-3 and A-3, respectively, were assessed to determine the optimal inlet opening. According to the definition of the optimal point for airflow entrance, the A-3 type wind catcher demonstrated the optimal and most suitable flow entry point. In terms of the air exhaust, the highest velocity and the most negative pressure were observed in the type A-2 wind catcher. Consequently, A-2 and A-1 can be considered to possess the optimal air output. In addition, the northeast front was the most suitable for air exhaustion. Furthermore, the northwest and southeast fronts were the best for air entry.

5.3. Internal CFD

Internal CFDs were evaluated in the body and room of the wind catcher. The body of the wind catcher was initially evaluated. In the wind catcher, the air velocity contour was zero, whereas, in types A-2 and A-3, it increases in the middle section. A-3 was associated with the highest wind pressure. The contours of velocity and pressure within the body of the wind catcher are depicted in Table 7.

Table 8
Images of the velocity and internal pressure contour in the body of the wind catcher

Type	Name of the wind tower	Velocity contour			Pressure contour		
A-1	Korchi Chi-5						
A-2	Bavard-2						
A-3	central Mosque -5						

The results indicated that the air velocity inside the wind catcher was zero and in the range of 0.3 to 0.11. The lowest and highest velocity was related to type A-1 and A-2, respectively.

Evaluation of the velocity and pressure contours determines the optimal inlet and outlet. Inlet openings are suitable in locations with no air velocity and positive air pressure. Locations with high air velocity and negative pressure are ideal for air exits and exhaust. The type A-3 wind catcher was the most efficient for air intake and suction. The output of type A-1 wind catchers was superior to that of all other types.

Table 9
The contour of velocity and pressure in the body of the wind catcher

Type	Velocity	Pressure
A-1	0.03	235
A-2	0.11	233
A-3	0.06	324

The internal CFD of the wind tower room was evaluated based on an expanded list of criteria. Initially, the velocity and pressure contour in the room of the wind tower is discussed. The contour of velocity and pressure in various types of wind towers is displayed in Table 9. The velocity contour in the room of the wind tower was close to zero, which corresponded to the openings. The minimum wind velocity within these structures was zero. The peak velocity near the openings reached 1.02 m/s. The mean wind velocity in various types of wind towers ranges from 0 to 0.23. The types with the lowest and highest velocity values were A-1 and A-3, respectively. All rooms had a pressure contour of zero, so the openings in the wind tower rooms were determined to be the optimal location for air exhaust. As the wind speed increases in these openings, they can be considered a more efficient air outlet.

Table 10
Images of velocity and pressure contours in the wind tower room

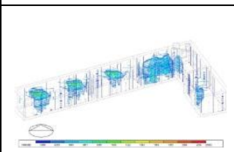
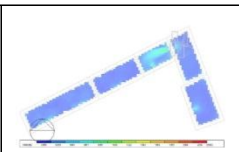
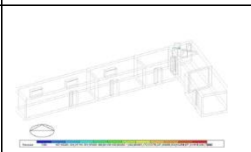
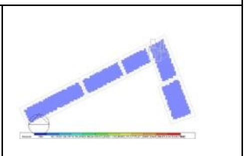
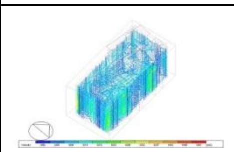
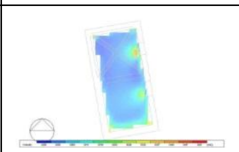
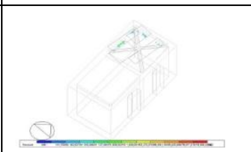
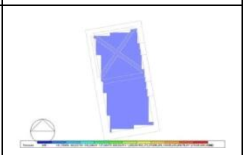
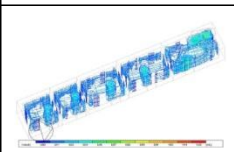
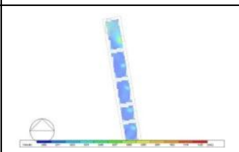
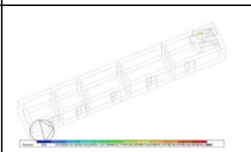
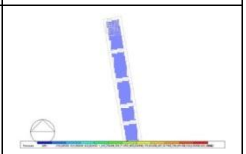
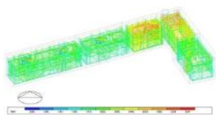
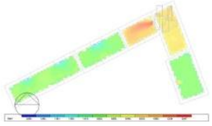
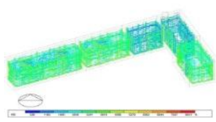
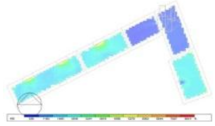
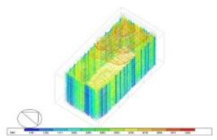
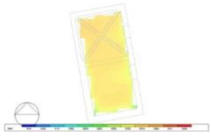
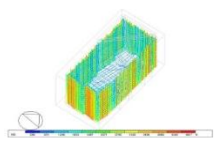
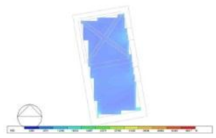
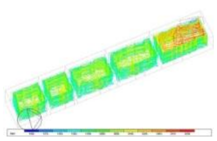
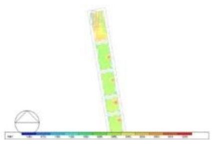
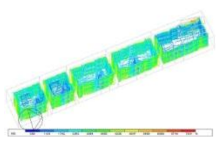
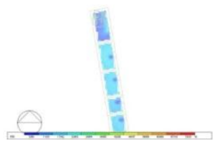
Type	**Name of the building**	**Velocity contour**		**Pressure contour**	
A-1	Korchi Chi-5				
A-2	Bavard-2				
A-3	central Mosque -5				

Table 10 shows the thermal comfort index and the dissatisfaction percentage of residents with wind catchers. The results revealed that the thermal comfort index in the wind catcher room was high compared to other rooms. Furthermore, the percentage of dissatisfaction in all wind catcher rooms was zero. The percentage of dissatisfaction in rooms adjacent to the wind catcher without opening was significantly increased.

Table 11
Images of thermal comfort index and percentage of dissatisfaction in the wind catcher room

Type	**Name of the building**	**Thermal comfort index**		**Dissatisfaction percentage of people**	
A-1	Korchi Chi-5				
A-2	Bavard-2				
A-3	central Mosque -5				

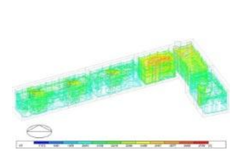
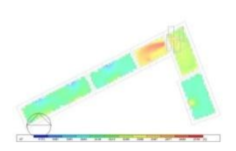
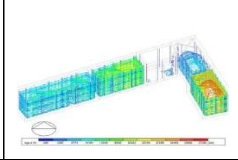
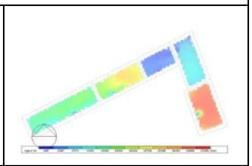
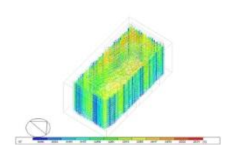
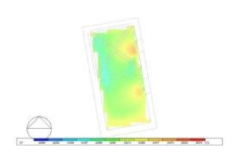
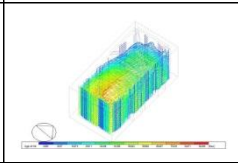
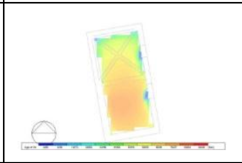
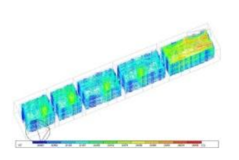
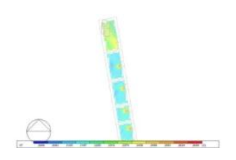
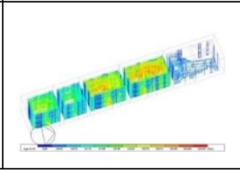
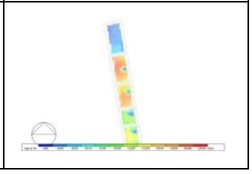
Type A-3 wind catchers provided the least thermal comfort, while type A-2 wind catchers provided the most. Minimum thermal comfort ranged between -0.35 and -0.66, and maximum thermal comfort ranged between 0 and 0.04. In wind catchers, the average thermal comfort ranged between -0.11 and 0.24. The minimum and average level of user dissatisfaction among all wind catchers was 5%. The maximum level ranged between 8.71 and 17.24%. The type with the highest and lowest levels of dissatisfaction was A-3 and A-2, respectively.

Table 12
Comparison of the thermal comfort index and the percentage of dissatisfied individuals in the wind catcher room

Type	Thermal comfort index			Dissatisfaction percentage of people		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
A-1	-0.46	-0.23	0	5%	5%	11.83%
A-2	-0.35	-0.19	0.04	5%	5%	8.71%
A-3	-0.66	-0.24	-0.03	5%	5%	17.24%

The room's temperature beneath the wind catcher was significantly lower than that of the other rooms. Even though there is an opening to the adjacent room in type A-1, very little heat enters this room. The temperature of a room beneath a wind catcher depends on factors such as placement direction, type of rotation, placement position, and wind catcher condition. Several variables, including openings, orientation, and environmental factors, influence the temperature of the wind catcher room.
The minimum and maximum temperature in the wind catcher room varied between 21 and 22 and between 23 and 26, respectively. The highest temperature was related to the room under the type A-1 wind catcher. The mean temperature in the wind catcher room varied between 22 and 24. The lowest temperature was related to type A-2. Air age is the rate at which air changes one point per second. As air age decreases, air circulation in a region increases. The age of the air in the wind catcher room was less than that of the air in the surrounding rooms, indicating continuous air movement. The lowest and highest age of the air was related to type A-3 and type A-2, respectively.

Table 13
Images of the RealFeel temperature and air age in the wind catcher room

Type	Name of the building	The real feel of temperature		Air age	
A-1	Korchi Chi-5				
A-2	Bavard-2				
A-3	central Mosque -5				

6. Summary and Analysis of Results

The present study determined the optimal type of wind catcher for a building based on modern technology and contemporary human needs. The investigation of the velocity and pressure inside and outside the wind catcher and the definition of the best inlet and outlet revealed that the best inlet and outlet were associated with wind catchers of types A-3 and A-1, respectively. The highest thermal comfort index value in the wind catcher room was associated with type A-2, whereas the highest percentage of dissatisfaction was linked with types A-1 and A-3.

Table 14
Comparison of thermal comfort index and dissatisfaction percentage in the body and room of wind catchers

Type	Thermal comfort index	Dissatisfaction percentage of people
A-1	-0.23	11.14%
A-2	-0.19	10.79%
A-3	-0.24	11.14%

The lowest and highest temperatures in the wind catcher room are related to type A-2 and type A-1, respectively, as shown in Table 14. The amount of air circulation in the wind catcher room can be ascertained by determining the age of the air in this space. The airflow increases as the age of the air decreases. The highest flow was associated with type A-1, while the lowest flow was associated with type A-3.

Table 15
Comparison of the temperature of the body and the air age in the wind catcher room

Type	Air temperature			Air age		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
A-1	21.3	23.98	24.57	0	67.74	101.61
A-2	21.57	22.61	24.17	0	58.54	75.27
A-3	22.5	23.74	24.99	0	20.4	67.19

The performance of three distinct types of wind catchers in Pohl port is displayed in Table 15. Type A-2 performed the best in terms of thermal comfort, percentage of satisfaction, room temperature, and air age.

Table 16
The optimal performance of wind catchers in terms of various factors

Type	Best input	Best output	Thermal comfort	User satisfaction percentage	The temperature of the wind tower room	Air age
A-1		*				*
A-2			*	*	*	*
A-3	*					

Type A-2 wind towers had a square plan with three openings and were located in the west and north geographical direction. The dimensions of these types of wind towers varied from 2.56 to 3.43.

7. Conclusion

It is possible to create natural ventilation of the hot and humid area only through the use of outside air flow inside as well as the building shell. The design of the wind deflector is a type of passive ventilation system that, in addition to reducing energy consumption and building costs, is a step towards keeping the natural environment clean by reducing the heat produced by electric cooling devices and increasing the climatic comfort of people through proper and constant ventilation.
About 27% of Pahl Port windbreaks are of square plan type. 21 wind deflectors with a square plan were randomly selected. Wind deflectors with a square plan can be divided into three main categories, one opening, two opening and three opening, in terms of the number of openings.
The studies conducted on the wind deflectors of Pahl Port show that of the three different types, the A-2 wind deflector has the best performance in terms of thermal comfort, satisfaction percentage, room temperature and air age in this area.
The use of clean energy is one of the best practices of energy consumption in the direction of growth and expansion of sustainable architecture.

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