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WINDMILLS (ASBADS): REMARKABLE EXAMPLE OF IRANIAN SUSTAINABLE ARCHITECTURE

Amin SAEIDIAN [a], Mojtaba GHOLI [b], Ehsan ZAMANI [c]

[a] Associate Prof.; Department of Architecture, Mahshahr Branch, Islamic Azad University, Mahshahr, [IRI]
E-mail address: *amino_saidiano@yahoo.com*

[b] BSc; Department of Architecture, Faculty of Architecture, Jahad Daneshgahi Institution of Ahvaz Branch [IRI]
E-mail address: *maj_stop@yahoo.com*

[c] Dr.; Department of Architecture, Faculty of Art, University of Tarbiat Modares [IRI]
E-mail address: *ehsan.zamani@gmail.com*

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Abstract

The structures such as windmills (Asbads), which are remained from past to add to the knowledge and understandings of the today and future generations, are the indicators of creativity of our ancestors and ancient people. Windmills, dating back to 2800 years ago, are among the oldest examples of using the power of nature by human beings. In Netherland and other European countries, some windmills which are similar to Iranian windmills have been found. Some believe that the art of windmill building was transferred from Iran to the European countries during the Crusade. Because of blowing a type of wind called 120-day wind in Iran, people of Sistan Province made several attempts to exploit the power of this wind. As a result, they invented the Windmills, which are considered as one of the most important inventions of human, to both control and take advantage of the wind power. The present study is of descriptive-analytical type. Data gathering was done in library and by means of fieldwork method. To this end, the Lutak, Neshtifan, and Nehbandan mills, located in Sistan Province, were studied. Following the study of the mill history of Sistan Province and southeast of Iran, the quotations from foreign tourists as well as the stand and the function of the mills in Iran 's architecture were investigated. It is noteworthy that the functional elements of the mills are designed according to the aerodynamics rules. This fact suggests that the builders of these mills were cognizant of the capacity and behavior of the wind to satisfy the daily needs of people. It also is a proof for the updated technology of people of that era and the reason for the continuity and uniqueness of these mills throughout the centuries.

Streszczenie

Struktury takie jak wiatraki (Asbads), które utrzymały się od zamierzchłych czasów, by dla obecnych i przyszłych pokoleń uzupełniać wiedzę i zrozumienie, są wskaźnikami kreatywności naszych przodków, ludzi z czasów starożytnych. Wiatraki zaczęły powstawać 2800 lat temu i są najstarszymi przykładami wykorzystującymi siły natury przez ludzi. W Holandii i innych europejskich krajach znaleziono część wiatraków, które są podobne do tych irańskich. Niektórzy wierzą, że sztuka budowania wiatraków została przeniesiona z Iranu do europejskich krajów podczas Krucjaty. Ludzie z Prowincji Sistan w Iranie zrobili kilka prób, by wykorzystać siłę wiatru. W rezultacie stworzyli wiatraki, które są pojmowane jako jeden z najważniejszych wynalazków człowieka do kontroli i wykorzystania siły wiatru. Prezentowany artykuł to studium opisowo-analityczne. Zebranie danych zrobione zostało na podstawie literatury i przy pomocy metody badania terenowego. Do tego celu zostały przestudiowane młyny w Lutak, Neshtifan i Nehbandan, zlokalizowane w Prowincji Sistan. Dokonane badania historii młynów w Prowincji Sistan i południowo-wschodnim Iranie, obejmowały stan i funkcję młynów w architekturze Iranu. Warto zauważyć, że elementy funkcjonalne młynów zostały zaprojektowane według reguł aerodynamiki. Ten fakt sugeruje, że budowniczowie tych młynów byli świadomi wydajności i zachowania wiatru, by zaspokajać codzienne potrzeby ludzi. To też jest dowód na to, że ludzie tej ery przyczynili się do utrzymania i kontynuacji unikalnych wartości młynów przez wieki, stali się prekursorami obecnych stosowanych struktur wykorzystujących siły wiatru.

Keywords: **Windmill; Asbads; Renewable Energy; Technology.**

1. INTRODUCTION

The word Asyab, which has its root in Pahlavi variety of Persian language, is composed of two parts, as and ab. Asyab means an as which turns around with the power of ab. As, in Persian, means crushing the grain into powder under a millstone [1], and ab is a Persian word, which means water. In Amid Dictionary, as is defined as two rounded and flat stones on each other through which a metal shaft passes. The above stone turns around by the power of men's hands, water, wind, or water steam and, as a result, the grains are ground.

A long time ago, Persian people took a step to exploit the power of nature, by building watermills and milling the grains. Before building watermills, man had to place reliance on his own hands or cattle power to mill the wheat. Thus, the first source of power to mill was the power of hand. After that, man started to use his livestock to do the act of milling. In some parts of Iran, the term Kharas was coined, which was composed of two parts. The first part, khar, means donkey, and the second part, as, means milling. This term was used to show the usage of donkey, camel, cow, or horse to rotate the millstone [2]. Until recently, these kinds of mills were used to extract oil from the seeds [the term extractor or extractor horse is related to this action]. In Yazd City, these kinds of mills were operated with camel to rub henna, and were called Mazari.

Asbads can only be found in a limited number of areas in Iran, because using such mills requires constantly blowing and powerful winds. Since the winds in the southern part of Iran have these required features, windmills were used for many years in there. However, with the advent of mechanical mills, called fire mills by native people, using the old windmills was ceased. Now, only a few of these windmills are used in the southern areas of Iran. While, today, only one or two series of the mills arranged near each other may be used, they remind us of the time that the nature and its energies were employed in the best way.

2. ORIGIN OF WINDMILLS (ASBADS)

Some evidences on the construction of Asbads have been found in the literature remained from the emergence of Islam. Masoudi, famous historian, says:

…Omar did not permit anyone from Ajaman to enter Madina. MoghayarIbn-e-Shaei wrote a letter to Omar and said: I have a servant who is painter, carpenter, and metal worker and is useful for people of Madina. Moghayar continued to say that if Omar allows him, he would send the servant to Madina. Omar permitted him to do that. Moghayar took two dirhams a day from the servant. The servant's name was Abdullah. He was a Magian from Nahavand town. So, he lived in Madina for a while. Abdullah went to Omar's mansion and started to complain about the tax, which he should pay to Moghayar. Omar responded: what can you do? The man said: painting, carpentry, and metal working. Omar said: The tax that you pay is not more than what you do. Abdullah murmured and exited the mansion. Another day, Abdullah passed the place in which Omar sat. Omar said: I heard that you can build a mill which works with the wind. Abdullah bounced back: I would build a mill for you that all people keep speaking about it. When Abdullah went, Omar said: This man is threatening me [3].

The author of "history of Sistan" wrote:

…and they rotate the windmills to mill the wheat. They ground the wheat with windmill or watermill. They have made such mills to draw well water from underground or to water the farms … they make many uses from winds… [4]. In addition, Seven Hedin, who had a journey to Iran deserts, late at 19th century, points to the existence of windmills [5]. He encountered an array of windmills in Nehbandan. He compared these mills with those of Meigun. Velayat zadeh, a historian and geographer who has recently visited the windmills, stated: In the downstream of Khaf and Zouzan, windmills have eminent value, above the doors and walls, in the design of the building. They demonstrate appraised and fruitful gains of the past [6].

Ghodsi, in Ahsan al-Taghvim fi Marefate Aghalim [the best book to know the lands] book in 375 Hegira penned about the wonderful land of Sistan: …Sagastan windmills and its sand dunes are wonderful [7]. Ibn-e-Hoghoul, also, has written about Sistan as: In Sistan, powerful winds blow and, for this reason, the windmills were built to crush the wheat into powder [8]. Abou Eshagh Estakhri, in his Masalek va Mamalek [religions and regions] book, states:

Sistan is a tropical city. It has date trees. It has no mountain. In winter, no snow falls. Powerful winds continuously blow. The mills are built for the winds [9].

In Asar al-Belad va Akhbar al-Belad [Ages and news of the lands] book written by Ghazvini, it is mentioned that: …The whole land is sandy and lutaceous. No rest, the wind takes. The rotation of the mills is

rather by the winds than water [10].

According to Piccoloskian, most of the Iran's towns or cities had mills in Parthian and Sasanid dynasties. They had strict rules for using these mills, payment of the millers, and the goods [11]. Jan Naar, in his book, points to a kind of windmill that was used in China to draw well water and is still used in some cities [Fig. 1]. This type of windmill, though has vertical axis, is completely different from those of Persian lands in structure. This is because the sails are situated in an open area and a wind-directing system is not mounted on the sails [12]. Ali Balad Kabashi in Great Encyclopedia of Islam book has cited from Ghazvini and habibi's book of The history of Afghanistan after Islam that Khorasan Province to be on par with Sistan in using and constructing mills [13]. But the point is that, in most of quotations from historians, windmills are recounted as the unique feature of Sistan Province. This fact simply indicates that there were other mills in other lands, but they were not considered a typical characteristic of that land. In the records of a tourist in Ghajarid dynasty about the eastern part of Iran, the names of the cities and towns that had windmills is successively mentioned, but the exact number of these cities is not clear. This means that the tourists reacted to the windmills at the first time they saw them and wrote about them in their registers. Then, they attached an image or a picture of the windmill to their register. Seven Hedin, Colonel Mc Gregure [14], Sir Persy Sikes [15], and Colonel Charlse Pitt [16] as well as others who traveled to the eastern borders of Iran reported more than one or two towns with windmills.

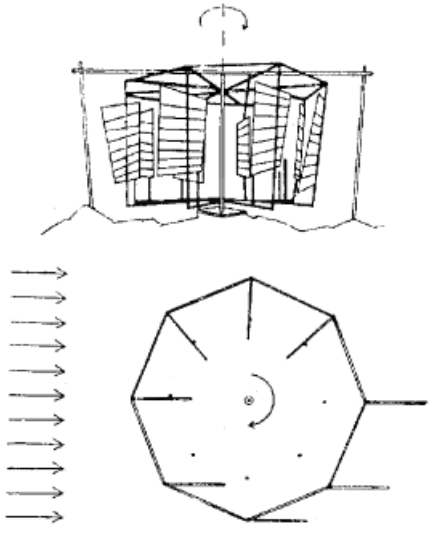


Figure 1.
Chinese windmill with vertical axis [17]

Jeihani, Ibn-e-Hoghoul, Ghazvini, and Yent, who investigated more about people of Sistan and their cultures, perceived the people of Sistan to have a great culture and to cope with their daily demands by using wind and water powers.

3. WINDMILL FUNCTION

According to the historical documents related to Sistan, indigenous people gained advantage of wind power in different aspects of their life, including grinding the wheat [according to Masoudi] and drawing well water according to Yent [18]. The mills were also used to ventilate house air. That is, they had a function similar to that of the wind catchers in the central cities of Iran. However, it is not clear whether the wind catchers are as old as windmills or not.

According to Ghazvini [19], Ansari [20], and Ibn-e-Hoghoul [21], wind power was used to carry sand and to deposit the garbage. Yent in Sistan book has mentioned the method of using wind power. Following the study of historian books on the way of using wind power in Sistan, we conclude that the people of Sistan were familiar with the basic principles of aerodynamics. They called these rule geometrics. Ibn-e-Hoghoul in Sovarat al-Arz [The pictures of the earth] writes: In here, people preserve their land against the danger of sand tornados, by using the experience of their antecedents [22].

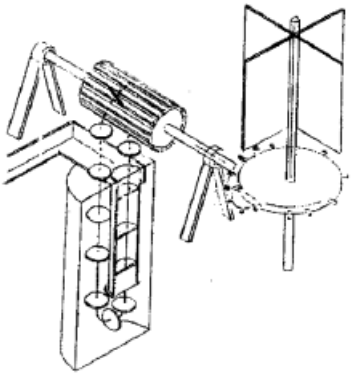
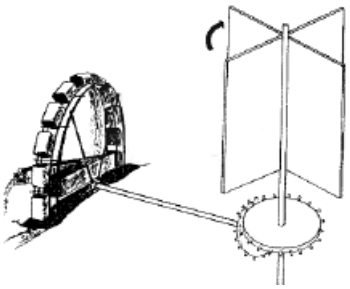
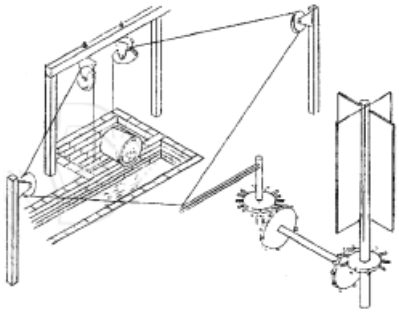
3.1. Windmills, like the wind catchers, air conditioned the house

Yent in his book, by considering the structure and location of the windmills near the houses, reasoned that the windmills were used to ventilate the house. He also writes about the windmills of Palangi ruined buildings as: In the northwestern part of Iran or so, the walls were in front of and along with the house fences and were extended along an angle to not only keep the sails but also direct the wind toward the house. This point suggests that the windmills were used for two purposes: firstly, to crush the wheat into flour and secondly to ventilate the rooms and keep the rooms cool [23].

3.2. Drawing well water and milling the wheat

In Hodud al-Alam men Mahsreghe al Maghreb [boarders of the world from east to west] book, it is mentioned that: ... a region in Sistan, which is called Zarang by the native speakers and is tropical, no

Table 1.
Sample of the windmills which were used to draw well water [27]

An imaginary picture of a combination windmill and chain wheel	An imaginary picture of a combination of windmill and gavgard	An imaginary picture of a combination of windmills and two-buckets
		

snow fall and, thus, many mills are built in the path of the wind. It is a situation unique to Sistan and nowhere else [24]. People have built sails on the mills for the wind to rotate. Other mills have sails which are rotated by wind or man's hand to draw well water and cultivate the farms. Where the amount water is not enough, people make use of winds [25]. The tools which, by the windmills, drawn the well water were chain pump, gavgard, and the well wheel. [Table 1] shows the way that well water is drawn with the chain pump [26]. The main application of the windmills was to mill the wheat and grains. Today, by the reason of their slow operation, these mills are not used anymore.

4. SUSTAINABLE ARCHITECTURE OF THE WINDMILLS

Windmills are made of two stories. On the top or house of as [the tool that mills the grains], lateral curved walls direct the wind to the sails, which are fixed on the windmill. There are more than 1000 windmills in Khorasan and Sistan Provinces which are on the way to be completely destroyed.

The body and walls of this structure are, like a tower, situated in the middle of the building. They move three sails of eight sails of the polygonal structure of the windmill. The rest of the sails, which are not in the wind direction, do not inhibit the circular movement of the sails. The sails are mounted on a vertical mast. In the sails, the mast rotates in the hole of a horizontal lumber and the end of the mast, which is inside the mill, moves the runner stone on the bed stone. The above room, depending on the direction of the wind, has two walls toward north and south. The entrance of the room is located on the north side of the top room and occupies a half of the north side. The entrance is located at the place that the wind blows to the sails. The exit is located in the south, in which the distance between east and west is completely open. The above room has no roof and the opening is funnel-form. Thus, two sides of the opening of the wall are diagonally located toward the wind direction and, as a result, the wind strikes the sails powerfully. Ground floor of the system is a place where the wheat, flour, and other tools are collected. One of the prominent characteristics of windmills is that the sails, though being light and built by rustic building materials, are covered by canes to avert the structure destruction by the termites.

4.1. The original model of windmill

Ansari Dameshghi [28] had drawn the oldest image of the structure of a windmill in Sistan. In his book, Dameshghi had drawn many pictures of the interesting and wonderful places of Sistan. Hence, the major changes made on the original model can be found. The picture [Fig. 2] that Dameshghi provided is different from what we see as today's windmills. In that time, the windmill's sails were positioned at the bottom with the millstone on them. It was, in fact, another model of watermill which benefitted from wind rather than water.

Ansari points to the picture saying:

…What you see is a picture of a windmill and the above as well as the below rooms. It is like a khamas, as it has two rooms above and four openings for the

beneath room, like a cornet which has four rooms. The structure of the openings is in the form that their smaller side is toward wind path and the bigger side is positioned toward the forge. From the two openings that are located toward forge, one with tighter opening is toward the forge mouth and the other toward inside the forge. In this way, from whatever direction that may come, wind enters the rooms very powerfully. When the wind enters the room, it strikes the column or mast, which is similar to spindle. The mast has six to twelve sails, which are covered by skin. The skin coverings are put on the sails in a way that every sail [blade] has skin and cane coverings, from which the air passes and pushes the sails forward. Then, the air goes to the next sail [29].

This is probably the oldest complete description of the windmills. Even, Mousavi in Moravej al-Zahab, which is mostly relied on by the foreigner researchers, did not offer such a complete description. By reading the records of Ansari Dameshghi, we

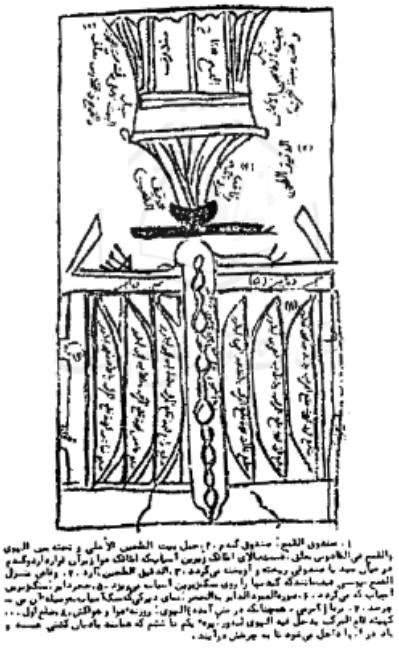


Figure 2.
Original model of the windmills, according to Ansari Dameshghi [30]

conclude that:

4.2. Windmills today

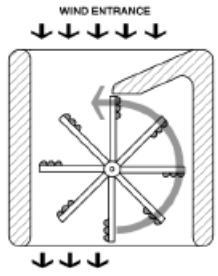
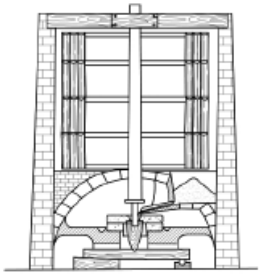
The original windmills had vertical sails and, according to the reports, were built around seventeenth century. They had about six to twelve sails, which were covered by the leaves of the date trees. Their function was milling the grains or drying them [31]. Following Ansari [who traveled to Sistan in 727 Hegira], Seven Hedin, a Swedish scientist in 1328 Hegira, wrote about what he saw in Iran; the barren regions, windmills of Meigun, Nehbandan, and Tabas, and he attached some photos of his observations to his record, when passing from Iran on his way to India. Hedin, in his book about Iranian desert, described Meigun town as: Meigun has a ruined castle and, in the rural area, there are two windmills with special appearance. In the middle of June, northeaster blows and lasts for two months. The blow of the wind is stronger at night. The wind, like a tower, passes through the columns and walls of the mills, which are made of stone and clay brick. The wind moves three of eight sails of the mill. The rest of the sails which are not in the wind direction stand still, but do not inhibit the movement of other sails. The sails are mounted on a mast, which is placed in a vertical position. On the top, the mast rotates in the hole of a horizontal piece of wood. At the bottom, the mast moves the runner stone on the beneath one. The whole system is simple but sensible. Such system can only be used wherever the wind is constantly blowing [32].

According to Hedin, in 1328 Hegira, the structure of the mills was very similar to those of Falarag, Neshtifan, etc. Most of the mills were built on the top of the hills and few on the plane. The above room had two walls toward north and south. On the north side, opening was located. The side walls of some of the mills were paralleled and in some other they were curved so that they were harmonized with the direction of the sails. The openings were located in the north wall. The north wall occupied half of the north side of the room and its opening was structured in a way that the wind struck the sails, when it entered the mill. In the southern part of the mill, an outlet was designed. In most of the mills from Khaf to Nehbandan, the distance between east and west sails is open and has no roof. To prevent too much stress from occurring on the sail and to protect the sails against excessive pressure of the wind on the opening, some lumbers were mounted on the wall. The lumbers could decrease the wind pressure, when necessary. The opening width of the mills in Khaf was 1 meter. In windmill, the beginning of the opening is funnel-form. Thus, one side of the opening is diago-

nally positioned in the wind direction and directs the wind into the opening. As a result, the wind hits the sail with more pressure. But the windmill of Nehbandan, Khonicsefil, Shousef, and Khaf, had simple openings, without any diagonal wall to direct the wind.

The outlet of the Neshtifan mills is 4.1 meters wide. The difference of width of opening and that of the outlet caused the creation of a vacant part at the back of the sails. The wind speed, according to the frequent tests, is about 21 kilometers per hour in the opening and 18 kilometers per hour in the outlet. The difference between the old mills and the current ones is that the old mills had the millstone on the top of the wind wheel, but the current ones have the millstone below the sails [Table. 2].

Table 2.
Today's model of the windmills [33]

Schematic view of windmill	Schematic plan of windmill
	

This mesh has holes to keep the air in and push it forward. Then, the air fills in the next sail and pushes it forward, too. Next, the third sail rotates the steel axis. The rotation of the steel axis moves the millstone and crushes the corns. This type of mill can be found on the high hills or in the areas which water is scarce but blow of the wind is strong and continuous [34].

5. THE SEASON OF USING WINDMILLS

In Sistan land and Khaf planes, located in Zouzan plane, a type of wind, called 120-day wind blows. This fact made the people of the area invent a tool to benefit from the wind. The advantage of this wind is that it blows very regularly and with steady speed. It blows from northwest, west, and southwest, about 4 months a year, May, June, July, August [35].

In summer, a low pressure center with 775 millimeters pressure is extended from the center of Asia continent to Siberia. This stream covers the eastern part of India, Middle East, Arabia Island, and north of Africa. At the same time, In Indian Ocean, there is a high pressure center with 765 millimeters pressure which causes the creation of the air streams, developed from Indian Ocean to Asia, and monsoon winds. In summer, two high pressure centers are developed near Atlantic Ocean, one with 757 millimeters pressure near Iceland and Gruen land and the other with 765 millimeters pressure near Asour Island. The second one is of less importance. Part of the stream, which is developed in this region, is extended to east. It is directed to north on Caspian Sea and along the borders and Shouni Mountains and then to Sarakhs town, in which this wind is called Chahchahe [36].This wind moves from Khorasan to Gonbadad and Ghaenat, in which it is called Farah baad or Baad-e-Gheis. After that, it moves toward Sistan, in which it is called Levar. Next, it moves to Zahedan city, in which it is called Baade-e-Nashi [37].

A branch of this stream moves from Caspian Sea toward Turkmenistan and then to the east borders of Iran. In summer, this wind blows strongly from east borders of Iran and is called 120-day wind. In Ghaenat and Gonbad towns, this wind is called Baad-e-Rast [Right Wind]. According to the official reports, the speed of this wind is about 36 kilometers per hour and sometimes it is about 70 or 90. This wind, because of its high speed and power, is used in the mills. According to Sven and other historians, the basis for designing the windmills was this powerful wind [38].

6. PARTS OF WINDMILLS

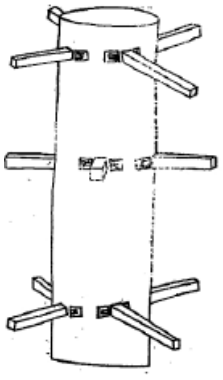
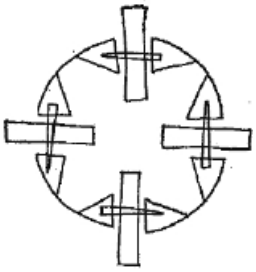
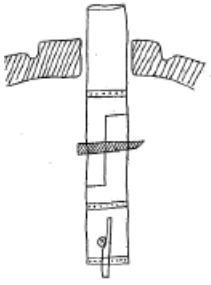
With regard to the structure, windmills are very simple. Windmills are composed of integrated elements, failure of each are causes the failure of the whole system. Iranian, in Sistan, chose a name for each part of the windmill. Different parts of the windmill are made of natural materials and are reusable. Each of these parts is built to do a specific function in the integrated system of the windmill. These parts are as follows:

1. Bridge is defined as the pieces of three logs, whose their leaves are removed and which lost their tree façade and turned into lumbers.
2. Sarpol or kharpol is defined as a log of 45 centimeters width, 4 meters length, and 30 centimeters diameters. It is anunified and smooth lumber, which rests on the wall by means of its two ends. From its middle, sarpol is attached, by a wooden axis, to the windmill. Its function is to prevent the lateral movement of tirpol.

3. Tirpol is defined as a rounded log of 8 meters length, 35 meters diameter, and 101 centimeters circumference. The diagonal of tirpol at both top and bottom is identical. As finding a tree with such size is impossible, tirpol is built in three parts which are locked together. Then, a connector is passed through it, so that it prevents the lateral movement and, probably, dislocation caused by the wind. Tirpol is made of pine timber, which indigenous people call Naju.
4. Arm [also called Bazu or Bahou by native people] is defined as a series of lumbers of 175 centimeters length and diameter as well as 7 centimeters width. From one end, it is connected to the sail and from the other end to the end of tirpol. Each arm is the connector between tirpol and the sails and transmits the forces, made by the rotation of the sails, to the tirpol and, in this way, causes the tirpol to rotate. Each sail has 6 to 7 arms and the arms are mounted on the joints of the tirpol in a way that prevents the bridge from breaking. Arms also make the tirpol stronger and firmer.
5. Sail is defined as a piece of lumber of 14 centimeters width and 1 centimeter thickness. The reason for selecting thin planks was to lighten the weight of the sails, for the sails to be rotated by the summer wind. The approximate length of each sail is 6 meters. There are four or five cut-out windows in the each sail. The width of the sail is identical to that of the opening.
6. Support [also called poshtiban by the native people] is defined as a set of lumbers of 74 centimeters length, 6 meters width, and 1 centimeter thickness, which are pinned to the sails with nails. The aim of using this set was to strengthen the connection of the arms to the sails in order to prevent them from unhooking from the sails.
7. Two-folded lumber is a type of lumber of 140 height and 7 to 10 centimeters whose ends are two folded. This lumber starts to function when the mill is to stop moving [Table 3].
8. Cane of wind [also called neibad by the native people] is defined as a series of canes, which are woven together. They are used to stop the mill.
9. Port is defined as the distance between the sails. The distance is 62 centimeters. To prevent the sails from falling down, they are connected together with the use of a wire or rope.
10. Porkhogandom [or porkhonamak] is located inside the mill and near the millstone and is composed of two parts; the above part is a container for the wheat and the below part is the place for pouring salt, which by passing from an opening to the duct enters a passage to millstone.
11. Millstone

    The millstones of Khaf town were supplied from a rocky area near Neshtifan Castle, which is 18 kilometers far from south of Khaf. Some experts lived in this region whose only job was to supply the millstones. In fact, the millstones were changed when their thickness reached 10 to 15 centimeters. The normal thickness of the millstone is 30 to 45 centimeters. The bed stone, in comparison with the runner stone, because of having less movement has less erosion and, as a result, longer lifetime. As it was mentioned above, the millstone was replaced depending on its function and the extend

Table 3.
The elements and main parts of the windmills [authores]

The connection of bahou [arm] to tirpol	The bottom of tirpol	Tirpol, which is composed of three parts
		

of wearing. However, they normally were changed every 5 to 10 months of working [Fig. 3].

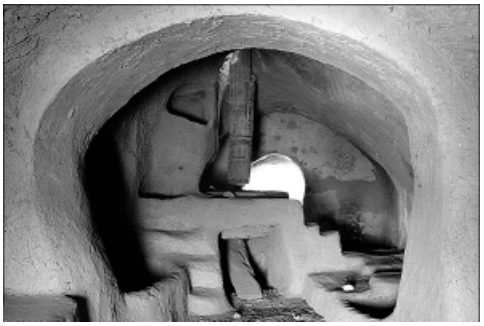


Figure 3.
Example of millstone of the wind mills, on its way to destruction [authors]

7. THE OPERATION OF WINDMILL

A giant system with 48 arms, 32 sails, and 8 ports was operated on a higher place. The whole body is held by a kharpol. The wind passes through wind catcher gate and reaches the corners of the eight-folded port, and moves the wheels and sails. This is because the end of mast is attached to the runner stone. As a result, the millstone is rotated with the rotation of the mast. When the runner stone is rotated, a small piece of wood called laklaki shakes. The movement of laklaki shakes the dulbareh of the mill. Dulbareh, by horizontal movement, direct the wheat from the porkhorigandom to the middle hole of the stones. Remember that the higher speed of the wind, the higher speed of rotation of millstone and, as a result, the more wheat the laklaki and dulbareh can carry out to the stone.

By removing the stones, the flour, which is the outcome of wheat crushing, pours out around the millstones and becomes prepared to be collected. In the hole underneath the stones, a very old system is situated, which can stop the stones by the operation of the lever. A tool called takhtomoushete from inside of the windmill slows down the movement of the stones. Immediately after that, the wheels and sails are stopped by another lever and the whole work stops [39].

Figure 4.
The wind, passing the wind catcher gate, reached the corners of eight-folded ports and moved the wheel and sails [ghader agheli]

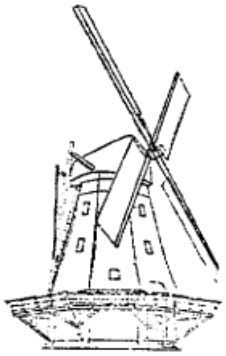
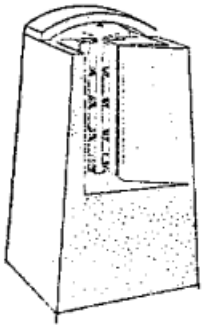
8. SPREADING THE WINDMILL TECHNOLOGY THROUGHOUT HISTORY

Some researchers and historians, while have no evidence for their claim, maintain that the windmills originally came from other countries into Iran. In the third version of the book social history it is written: Chinese and Iranian, who lived in Tarim, learned the construction of this type of mill from Chinese. This technology has been transmitted to the world, following the invasion of Arab to Iran [40]. Some other historians say the opposite. That is, they believe that the windmills, following the invasion of Mongol, were taken to the eastern borders of Iran by Iranian [41]. This second idea is the likeliest to be true, because transmitting a technology in that era was done by trading with other tribes or by dominating the tribes on each other.

The tourists such as Marco Polo and Ibn-e-Batouteh traveled to China, passing Silk Road. They stayed in China for a while. Their reports on the way of life, the status, and social features of the towns are available but did not point to the existence of such technology in China. In addition, the windmills can only be designed in places where the wind blows constantly in a certain direction. Therefore, using such mills without being completely familiarized with the region and its climate was not possible.

According to the historian and geographer reports, technology of windmill was transmitted from Iran to India and China, passing Silk Road. Then, it was

Table 4.
The evolution of the windmills throughout the history [43]

The recent wind turbines of Europe in 20th century	American windmills in 19th century	Netherland windmills in 1100 AD	Iranian windmills in 200 BC
			

transmitted to France and Portugal, passing Spain. The point is that some small changes were made in its appearance and design. Sistan, which was known as grain store, with this technology became known as the land of windmills. Windmills generally found their place in other countries. It can be said that they were Iranian windmills which were taken to the European countries, by the Muslim conquest in Al-Andalus. Also, following Crusade, European took this technology as a gift to their countries, but this type of windmills in Europe was replaced by famous mills of Netherland, which had better output. It can be, however, said that Iranian windmills endured until the late nineteenth century in Poland [42].

Windmills with vertical axis or, in other words Iranian windmills, reached China in Mongol age [thirteenth century]. At that time, Iran was, by means of Silky Road of eastern borders, connected to Far East countries. This path between Iran and China passed through various valleys and reached the North and was extended through some towns, which today are located in Turkmenistan and Tajikistan. From there, it reached the current north borders of China. That is, the path begun from full of water valleys of Afghanistan to Seihun and Jeihun coasts and ended in dry and barren deserts and poulterer and belligerent people. Windmills with vertical axis were also developed in Islamic period. In Egypt, they were among the main sources of crushing sugarcane.

9. EXAMPLES OF WINDMILLS

It is evident that the regions such as Falarag, Laj, Barabad, Tizab, Shangan, Neshtifan, Lutak, and many other regions of Khaf town and Sistan province had various windmills whose number was rather high. But now, they became obsolete by the pass of time. In this section, three types of windmills, Lutak, Neshtifan, and Nehbandan are introduced. The history, architecture, and specific features of these windmills are also, presented.

9.1. Lutak windmills

The Lutak windmills were found 62 kilometers far from the southeast of Zabol city, in other words, 5 kilometers to the north of archeology base of Shahr-e-Sukhte [The Burnt City]. The emergence of this type of windmill dates back to Sasanid period.

According to windmills plan, this structure was made of two floors. The ground floor had three rooms, one of which was milling house. Milling house consists of water container and a place to put the millstone as well as two other rooms, which are store or service rooms. On the first floor, only wind wheel existed [Fig. 5]. The building materials of this structure were adobe and thatch. The thick walls of the structure signal the structure old history.

The above room is built in north to south direction and in the northern side of the room, the opening is built. The opening is placed where the wind, when entering the room, hit the sails. In the southern part, there was an outlet so that the distance between eastern and western walls is open. The above room lacks

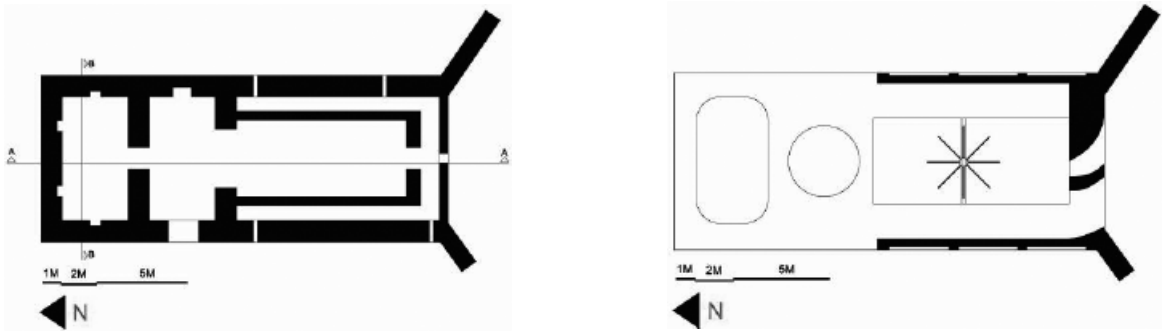


Figure 5.
Configuration of SSVA strengthening

roof. The opening of the mill is funnel-form and its two sides are diagonally positioned in the wind direction. In this way, the wind is directed into the entrance and, as a result, strikes the sails with more pressure. A typical characteristic of Sistan windmills was that their sails were covered by canes. This allowed the mills to stay light and, at the same time, impregnable against wear and tear as well as termite.

The decoration of the structure includes its decoration of eastern and western walls. These walls are beautifully decorated with set-backs and juts, which are made with adobe brick [Fig. 6].

Figure 6.
Set-backs and juts of east and west wall, which add to the beauty of the structure [authors]

9.2. Neshtifan windmills

Neshtifan with 10 degrees and 60 minutes longitude as well as 24 degrees and 26 minutes latitude is located 20 kilometers far from Khaf town, in the margin of flat grounds ended in desert. It is in a gentle slope of one of the alluvia of Kalshour River. It is ended to Bakhzar Mountain in north, Abasabad, Mohammadabad, and Behdadian towns in south, Barabad and Sungan towns in east, and Kalateha lands in west. Neshtifan had 40 windmills, most of which are ruined now. The development of windmill in Neshtifan in Khorasan Province dates back to Safavid dynasty. Neshtifan town was developed from northwest to southeast and falls plum on the direction of 120-day wind. As the older parts of the city are lower in height in comparison to the other parts, the northeast winds have higher speed in the rural area of the towns. This fact affects the obtained energy of the wind by the windmills. Neshtifan windmills, which are located 15 to 20 meters above the ground surface on the high hills of the town, are built in a multi-storied form to gain the wind power. That is, two to four mills were built in a higher floor and another two to four mills were built in a higher floor. The reason for this form of arrangement lies in the slope of the hills on which the windmills are built. Neshtifan windmills are arranged in two rows with 100 meters in between the mills. The first row consists of 14 windmills and the second 19 windmills. Based on the remained windmills, it can be said that the Neshtifan windmills had 6 to 12 vertical sails, which were covered by pieces of cloth or leaves of date tree.

The building stuff of these windmills is clay brick which is filled in with thatch. Each windmill in Neshtifan consists of two parts, lower and upper. Lower part, which is in the roof of the structure, includes the wheel and sail. The height, width, and the diameter of the windmill wheel are 5, 1.5, and 3.5 respectively. This wheel is mounted on a heavy and firm kharpol. The kharpol is located on an adobe wall, of 5.5 meters length and 2.3 meters width. The firm mast of kharpol is situated on a hole, called kalosi, which is in the middle of kharpol [Fig. 7]. Lower part of the windmill a room is built with

12*4.5 meters dimensions, which has a type of cross-sectional covering and is mounted on the windmill horizontal wall in a semi-circle form. This part includes a millstone, which has two lower and upper stories [Fig. 8], porkho or the wheat container and dulbareh, which directs the wheat from the container to the middle hole of the millstone.

On the facade of Neshtifan windmills, no decoration can be seen. In other words, the only aim of building such structure was to crush the wheat and grains. The view of the giant wheel and sails is aesthetically pleasing.

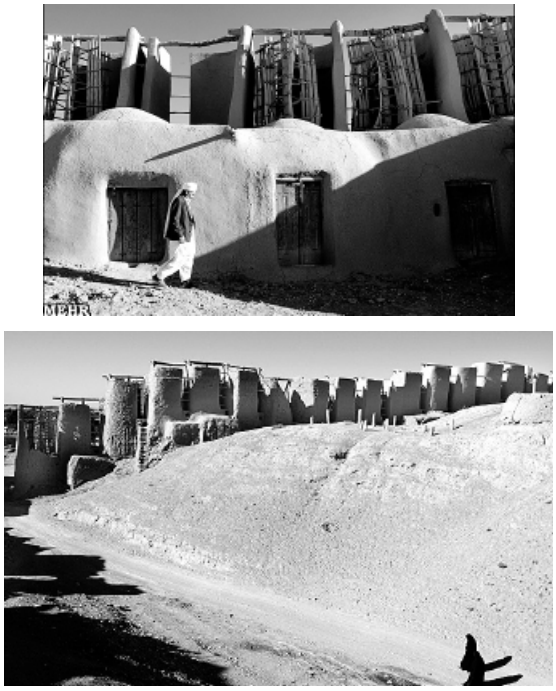


Figure 7.
The Neshtifan windmills are built in a multi-storied form to exploit the wind [authores]

10. CONCLUSION

Considering the nature and use its potential powers have got the long history in the eastern countries, so that the numerous examples of minimum energy consumption and Renewable Energy usage are recognizable in their historical past. Based on the studies on the local windmills known as Asbads, located in the eastern part of Iran (the southern part of Khorasan and Sistan), Wind power, known as Renewable or Eco-friendly Energy in the contemporary age, plays the pivotal role in the historical and cultural traditions of this country. The study mainly shows that Asbads as the traditional mechanical machines, used for the wind power transmission mechanism can be utilized again in the contemporary era, developing its overall mechanism or constructional materials. Such an action is considered as an innovative step toward overcoming the nature, but this time not to destroy it but to keep it for the following generations. Based on the research provided modeling, Asbads mechanism in transmission of wind kinetic energy to the energy needed for the agricultural activities such as gridding the wheat or barley can be simply applied in the contemporary era. The utilization of Renewable Energies plays the pivotal role in the environmental protection in the contemporary age, so that many countries have given the priority to such energies in their national programs, seeking the efficient methods or strategies to achieve such ambition. The study shows that the issue has been considered in Iran Plateau from the early ages. The recognition of windmills utilization experience in the eastern region of Iran and especially the southern part of Khorasan province and Sistan shows that the use of wind energy has been adapted to the daily needs of residents. Based on the study main achievement, such a power

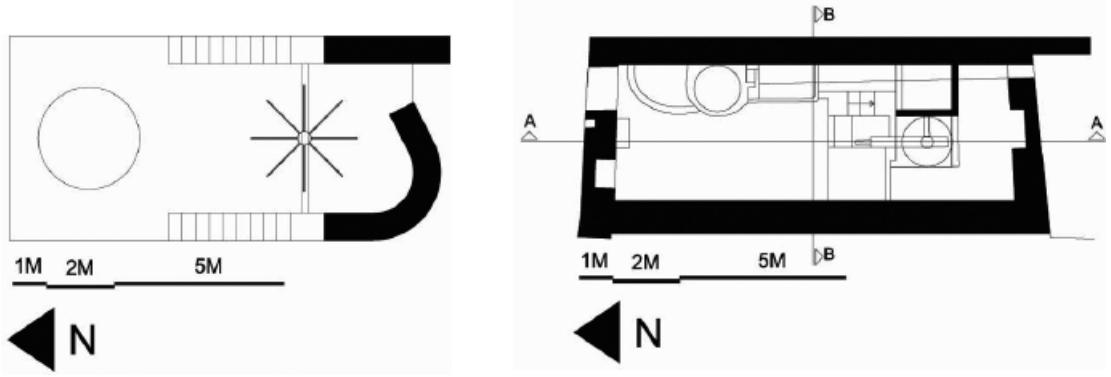


Figure 8.
The plan of ground and first floors [authors]

transmission mechanism can be applied in the contemporary age even in other countries to replace the energies derived from the fossil fuels with the wind energy as a *Renewable and Eco-friend Energy*.

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