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A RESEARCH STUDY INTO THE MOST IMPORTANT FLOUR PRODUCTION CENTER OF SISTAN DURING THE SAFAVID ERA (STUDY OF THE ASBAD COMPLEX IN HOZDAR REGION OF SISTAN)

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Abstract: Sistan, one of the ancient regions of Iran, has long been known as the hub of agricultural production due to its fertile soil and the presence of the Helmand River, and has been referred to by various names, such as Asia's Granary and the Breadbasket of Khorasan, throughout history. The abundant wheat production led the ancient people of Sistan to invent and utilize Asbad (the Persian windmill) technology to produce flour. The windmills (Asbads) of Sistan vary in age, ranging from the third century AH to the Qajar era. Typically, during each period, in addition to single windmills (Asbads), a group of windmills (Asbads) existed in one location, serving as the most important flour production center of that era, where the largest and most significant windmills (Asbads) were located. The location of the main flour production center in Sistan during the Safavid era, considered the last glorious period of Sistan civilization, remains unidentified, and no research has been conducted on this issue despite its importance. Therefore, in order to identify the primary flour production center in Sistan during the Safavid period and to study its architectural features, the authors carried out a thorough survey of the region, along with comprehensive documentation of the research topic. Subsequently, they analyzed and compared the collected data and consulted historical sources to achieve the aforementioned objectives. The results indicate that during the Safavid era, the Hozdar complex, dating from the late 9th to the 12th century AH and consisting of five windmills (Asbads), served as the primary hub for flour production in the region. Previously, this position belonged to the Rendeh region, but due to destruction caused by warfare, it was relocated to the Hozdar area in the southern part of the Sistan plain. These windmills (Asbads), which come in two varieties of plans—single and multi-part—are classified into two types: vestibular and vertical-axis windmills (Asbads), with impellers that rotate in a clockwise direction.[1]

Keywords: Sistan, Hozdar, Asbad, Safavid era, Architectural studies.

چکیده: سیستان، یکی از مناطق باستانی ایران، به دلیل خاک حاصلخیز و وجود رودخانه هیرمند، از دیرباز به‌عنوان مرکز تولیدات کشاورزی شناخته شده و در طول تاریخ با نام‌های مختلفی مانند انبار غله آسیا و نان‌دانهٔ خراسان شناخته شده است. تولید فراوان گندم باعث شد که مردم باستانی سیستان، فناوری آسباد (آسیاب بادی ایرانی) را برای تولید آرد اختراع و مورد استفاده قرار دهند. آسیاب‌های بادی (آسبادهای) سیستان از نظر قدمت متفاوت هستند و از قرن سوم هجری تا دوره قاجار پراکنده می‌باشند. معمولاً در هر دوره، علاوه بر آسیاب‌های بادی منفرد، مجموعه‌ای از آسیاب‌های بادی در یک محل وجود داشته که به‌عنوان مهم‌ترین مرکز تولید آرد آن دوران عمل می‌کرده است و بزرگ‌ترین و مهم‌ترین آسیاب‌ها در آنجا قرار داشتند. مکان اصلی مرکز تولید آرد در سیستان در دوره صفوی، که آخرین دوره باشکوه تمدن سیستان محسوب می‌شود، هنوز شناسایی نشده و با وجود اهمیت آن، تحقیقی در این زمینه انجام نگرفته است. بنابراین، برای شناسایی مرکز اصلی تولید آرد در سیستان در دوره صفوی و مطالعه ویژگی‌های معماری آن، پژوهشگران به انجام بررسی میدانی کامل در منطقه پرداخته و مستندسازی جامعی از موضوع تحقیق انجام دادند. سپس داده‌های جمع‌آوری‌شده را تحلیل و مقایسه کرده و با منابع تاریخی مقایسه نمودند تا اهداف مذکور محقق شود. نتایج نشان می‌دهد که در دوره صفوی، مجموعه حوض‌دار، مربوط به اواخر قرن نهم تا دوازدهم هجری، شامل پنج آسیاب بادی (آسباد)، به‌عنوان هاب اصلی تولید آرد در منطقه عمل می‌کرد. پیش‌تر این جایگاه متعلق به منطقه رنده بود، اما به دلیل ویرانی ناشی از جنگ، به ناحیهٔ حوض‌دار در بخش جنوبی دشت سیستان منتقل شد. این آسیاب‌ها، که در دو نوع طرح ـــ منفرد و چندبخشی ـــ وجود دارند، به دو دسته آسبادهای دهلیزی و محور عمودی تقسیم می‌شوند و پره‌های آن‌ها به‌صورت ساعتگرد می‌چرخند.

کلیدواژه‌ها: سیستان، حوض‌دار، آسباد، دوره صفوی، مطالعات معماری.

I. Introduction

The windmill (Asbad) can be regarded as one of the earliest human technologies based on the intelligent utilization of wind power. The abundance of historical sources concerning the windmills (Asbads) of Sistan attests to their antiquity and great significance. Unfortunately, despite this fact, research and studies on the windmills of Sistan have been limited, with most attention focused on only a few specific examples, while important subjects such as the windmill (Asbad) complexes from various periods and the architectural details of each era have not been thoroughly explored.

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Although the earliest windmill (Asbad) in Iran is dated to the 3rd and 4th centuries AH (Mousavi-Haji, 2009: 50–51), historical sources suggest that this advanced wind structure existed prior to the Arab invasion (Ibn Khaldun, 2017: 552). In the earliest historical sources, such as *The History of the Prophets and Kings* (*Arabic: Tarikh Al-Rasul wa Al-Muluk*), references are made to windmills, including a conversation between the second Caliph of Muslims and an Iranian individual about the construction of windmills (Yarshater, 1999: 89–90). Additionally, the operational system of windmills (Asbads) is described in *Nakhba al-Dahr fi Ajaib Al-Bar wa Bahra* (Ansari Dameshghi, 1978: 308–309) and *Al-Hayl* (Bir, 1990).

Although the distribution area of windmills extends across the eastern part of ancient Iran (present-day eastern Iran and western Afghanistan), historical records attribute their origin to Sistan. In *Masalak al-Mamalek*, Sistan is described as a land where the wind blows continuously and where many windmills exist (Ibn Khordadbeh, 1992: 54). In *Ahsan al-Taqasim fi Ma'arfa al-Aqalim*, "the windmills of Saxistan of Poushang in Zaranj fortress" are described as one of the wonders of the East (Moghadasi, 1982: 488).

Furthermore, numerous other historical sources, including *Morrawej Al-Dahaab and Ma'aden al-Jowhar* (Masoodi, 1965: 204), *Surah al-Arz* (Ibn Haukal, 1966: 153), *Ashkal al-Alam* (Jeihani, 1989: 162), *Al-Masalak wa Al-Mamalek* (Estakhari, 1961: 194), *Asar Al-Belad wa Akhbar al-Ebad* (Qazvini, 1967: 36), *Hudud al-Alam Men al-Mashriq el Al-Maghrib* (anonymous, 1993: 319), *Mu'jem Al-Buldaan* (Hamawi, 1995: 190), *Taqwim Al-Buldaan* (Abu al-Fida, 2007: 391), *History of Sistan* (anonymous, 2002: 57), and *Ehya Al-Muluk* (Malek Shah Hossein, 1965: 13), have also documented the existence of windmills (Asbads) in Sistan.

The windmill (Asbad) played a highly prominent role in the culture and civilization of Sistan. Throughout history, thanks to the fertile soil and the abundant flow of the Helmand River, Sistan consistently produced plentiful wheat harvests, earning it titles such as *Asia's Granary* and the *Breadbasket of Khorasan*. It should be noted that the geological and topographical characteristics of the Sistan plain, coupled with the frequent changes in the course of the great Helmand River, prevented the effective use of watermills in the region.

As a result, the ancient people of Sistan harnessed the power of the constant winds to invent and construct a structure known as the windmill (Asbad), which enabled them to grind their abundant wheat crops. The windmill (Asbad) thus emerged as an important and valuable architectural innovation in ancient Sistan and has attracted considerable scholarly attention due to the flourishing agriculture that served as the region's most significant industry.

Given the fact that Sistan comprised a large central city, along with numerous cities, towns, and villages during different historical periods, the construction of windmills (Asbads) most likely occurred on various scales. According to investigations, windmills were built either individually (as standalone units) in specific locations or collectively in groups within a single site. Places where windmills (Asbads) were constructed collectively were typically regarded as the main centers of flour production during their time. In contrast, powerful lords and emirs of the ruling elite often commissioned single windmills (Asbads) to serve smaller regions, generally situated far from the primary production centers.

According to studies, the Rendeh region was the principal flour production hub in Sistan during the Islamic middle centuries, containing more than seven large and small windmills (Asbads) that fulfilled this role until the 9th century AH (Alaei Moghaddam & Mousavi Haji, 2023).

Unfortunately, due to the Timurid invasion and the devastation of the old city of Zahedan, the central city of Sistan, many key regions of Sistan suffered extensive damage and were even abandoned. In the aftermath of this period, with the transformation of the settlement structure in Sistan, the location of the central city changed multiple times. The destruction inflicted on the northern regions by the Timurids and later by the Uzbeks likely contributed to the relocation of the main settlement center to the southern half of the region during the early Safavid era (Alaei Moghaddam, 2012: 56–57).

Although numerous studies have been conducted on Sistan during the Safavid era and many ancient artifacts have been discovered, there remains a significant gap in research regarding the primary flour production center in Sistan during this period—an area believed to have housed the largest and most numerous windmills of its time. Accordingly, the present study was designed and undertaken with the objectives of identifying and examining the principal flour production center of Sistan during the Safavid period, as well as investigating the architectural characteristics of this center. In essence, this research aims to locate the main flour production hub in Sistan during the Safavid era by analyzing the windmills of that time and exploring their individual architectural features. Although several studies have addressed the windmills (Asbads) of Sistan,

the most comprehensive information regarding their architecture—derived from continuous research and investigation conducted by the authors over the past decade—is presented in this article. Furthermore, the role of the Hozdar region within the production system of the Safavid era is discussed here for the first time.

I.1. Research Questions

In light of the aforementioned topics and with the aim of achieving the objectives of this study, two key questions have been considered:

- After the abandonment of the Rendeh region as the primary flour production center of Sistan during the middle Islamic centuries, to which location was the most important flour production center of Sistan transferred during the Safavid era?
- What are the architectural characteristics of each windmill (Asbad) in the Hozdar region of Sistan, and what differences can be identified among them?

II. The Background of Studies on the Windmills (Asbads) of Sistan

At the end of the 19th century, Brazier-Creagh reported the existence of approximately 36 to 43 windmills (Asbads) in Sistan; however, he did not specify their exact locations (Brazier-Creagh, G.W., 1897: 18–41). Edward Yate (1986: 71) and J.P. Tate (1983: 104) are among the other orientalists who have referred to the windmills of Sistan. These two researchers provided only brief descriptions of a limited number of windmills in the region.

In 2001, the Geography Research Group at the University of Zabol published a 25-page booklet entitled *Sistan, the Origin of Windmills in the World*, which focused solely on the general construction of windmills (Asbads) without referring to any specific windmill (Asbad) (Heidari Mokarrar et al., 2001).

In their article titled *"Asbads, the Oldest Windmills in the World,"* Mahdavinejad, along with Bemanian and Mashayekhi (2011: 50–52), briefly addressed the windmills of Sistan. Despite the quality of their research, these authors mistakenly attributed an image of a circular twin windmill (Asbad) to Sistan, although it does not belong to that region. In the same year, Nima Etehadi, in an article entitled *"Sistan Asbads, a Model Derived from Sustainable Architecture,"* introduced the Asbad of Qala Machi in Hozdar and provided a concise description with a focus on restoration (Etehadi, 2011). Gholami is another researcher who has studied the Machi Asbad and published an article on this subject, suggesting that Iranian architects improved the windmills' vanes by designing small, angular slats adjacent to the main slats (Gholami et al., 2016). Another relevant study, presented at the 5th International Congress on Civil Engineering, Architecture, and Urban Development, analyzed the influence of construction technology and craftsmanship on the formation of windmills (Asbads) in Sistan. This study concluded that, due to a relative decrease in wind speed and energy on the Sistan Plain, architects incorporated features such as additional side vanes on the northern walls and open mouths in the windmill structures to enhance performance (Kazemi and Valibeig, 2016).

Among the most recent studies on the windmills of Sistan is the research conducted by Moslem Mishmastnehi, which has examined the types of windmills (Asbads) in Iran as well as the technology of stone production through several articles. In these studies, Mishmastnehi determined that most of the stones used in the windmills of Sistan are artificial stones manufactured in furnaces within the same region (Mishmastnehi, 2015: 391; Mishmastnehi and Bernbeck, 2015: 89–94; Mishmastnehi et al., 2021: 4–7; Mishmastnehi, 2021: 4–6). The most recent research on the windmills of the Sistan region was conducted by the authors of the present study, focusing on the windmills of the Rendeh region. This investigation was the first to detail the structural characteristics of the windmills in this area and revealed that the windmill complex in the Rendeh region was the largest during the middle Islamic centuries of Sistan, serving as the main flour production center at that time (Alaei Moghaddam & Mousavi Haji, 2023).

III. Theoretical Foundations

The vernacular architecture of each region is shaped by its climate and culture, evolving over millennia and centuries. This type of architecture typically responds to the available resources and environmental constraints of a given area, reflecting an effort to coexist with and adapt to the natural surroundings. Therefore, understanding and studying the ancient architecture of each region—as an integral part of its historical civilization and culture—is a fundamental objective of archaeological and historical research. Architecture represents one of the most significant expressions of human interaction with the environment. Moreover, architecture communicates the function for which a building or structure is designed, while a collection of buildings with diverse functions collectively defines the role and purpose of that complex and its spatial context.

The windmill (Asbad) has experienced various changes and transformations across different regions

from its inception to its final form, and it has not remained static over time. In ancient Sistan, the windmill played a crucial role in harnessing renewable energy, significantly influencing agricultural production, particularly flour milling. Therefore, studying the windmills (Asbads) of each historical period in the Sistan region, along with their spatial organization within settlements, enables the identification of the primary flour production centers of that era.

IV. Research Methodology

The present study is classified as fundamental research in terms of its nature and employs descriptive-analytical and historical approaches methodologically. Data collection was conducted using both fieldwork and archival research methods. Field data comprised detailed surveys, documentation, architectural analysis, and plan drawings of the targeted area. Archival research involved gathering information from historical sources as well as reviewing relevant studies and research findings that align with the objectives of the current investigation, providing essential insights for analysis.

V. Windmills (Asbads) of the Sistan Region

Prior to the aforementioned studies, comprehensive and accurate information regarding the number of windmills in the Sistan region was lacking. The Cultural Heritage Department of Sistan and Baluchistan Province has registered seven windmills (Asbads) on the national heritage list. In the Archaeological Survey Plan of Sistan, although all ancient sites were identified, only six windmills were explicitly introduced without detailed descriptions, while other windmills, part of broader architectural complexes, were not discussed. In his recent research on Iranian windmills, Mishmastnehi reports that approximately 300 windmills currently exist in Iran and Afghanistan, with 12 of them (11 listed in the table) located specifically in Sistan (Mishmastnehi, 2021: 4-6). Based on the authors' investigations over the past decade, 17 windmills and four hills known as Tappeh or Asbad hills have been identified in Sistan, with the northernmost situated in the Qorgori region and the southernmost in the Girdi region. Of these 17 windmills, ten—primarily in the Rendeh region—date back to the middle Islamic centuries (Alaei Moghaddam & Mousavi Haji, 2023), while the remaining seven belong to later periods. These seven windmills include Lutak, Varmal, Machi, the Small Windmill (Asbad), the Big Windmill (Asbad) of Machi, Qala Rostam, and the twin Qala Rostam windmills, with the last five located in the Hozdar region of Sistan. Notably, the only windmills constructed within lordly mansions during the Qajar era are the Lutak and Varmal Asbads, as documented in earlier research by Alaei Moghaddam and Mousavi Haji (2024). Regarding the windmills of the Hozdar region, although they are generally attributed to the more recent centuries, the exact period of their construction and active use remains unclear, a subject that this article addresses.

VI. Windmills (Asbads) of the Town of Hozdar

Hozdar refers to a vast area located approximately 56 km southwest of the city of Zabol and 5 km west of the Zabol-Zahedan asphalt road. Until a few centuries ago, it was known as a high-water-level region of Sistan. Archaeological studies conducted in this area have revealed evidence of settlements dating from the late 4th millennium BC through to the Qajar era (Mousavi-Haji and Mehrafarin, 2008). However, the region is particularly renowned for its extensive urban remains from the late Islamic period.

The town of Hozdar, situated at the center of the Hozdar region, encompasses an area approximately four kilometers by two kilometers. Within this space lie the remains of numerous hills and ancient structures, including the city castle, citadel, various residential units with diverse layouts, campuses, industrial facilities such as furnaces, summerhouses, stables, towers, governmental buildings, tombs, and cemeteries. The city's irrigation was sustained by one of the branches of the Biyaban River (southern Helmand), specifically the Hozdar and Ramroud canals (Alaei Moghaddam, 2019: 66–67). Among the most significant structures in this city are the windmills (Asbads), which have played a crucial role in the production system and the survival of the region. Presently, the historical town of Hozdar in Sistan preserves the remains of five windmills, three of which are located within the inner city, while the other two stand on the western outskirts near Qala Rostam (Fig. 1).

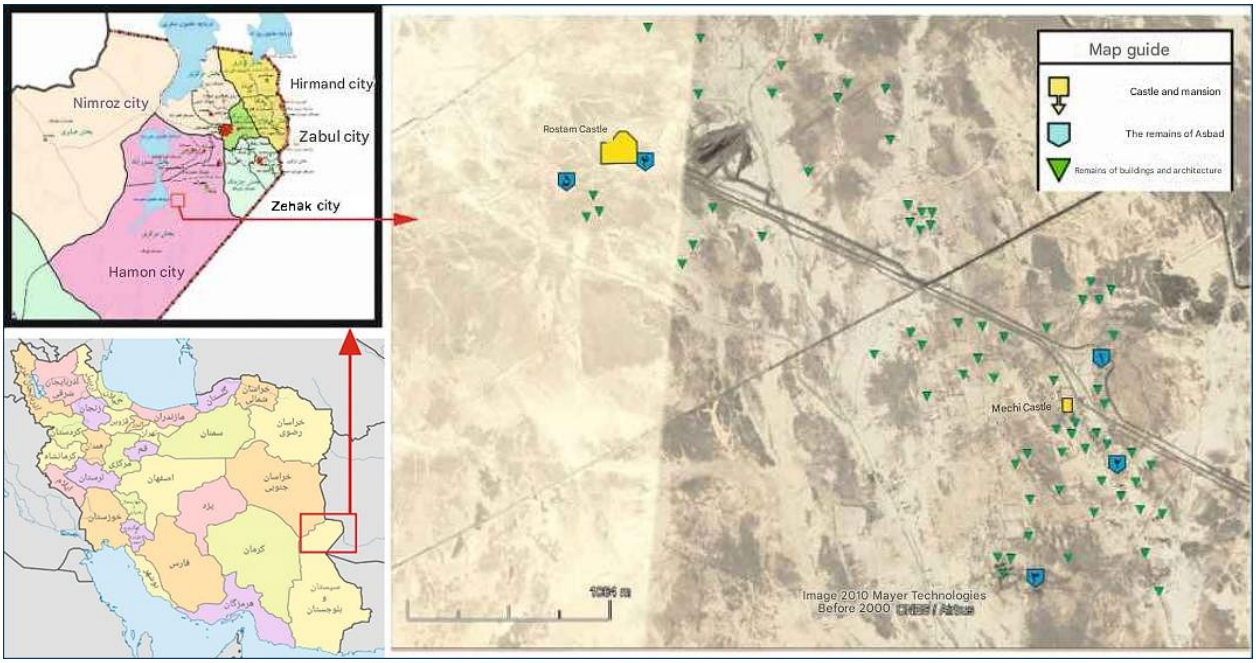

Figure 1: The location of the Hozdar complex and the buildings in it (the authors, 2023)

VI.1. Windmill (Asbad) No. 1

This windmill (Asbad) is situated to the northeast of the Hozdar complex, approximately 270 meters from Machi Castle (Qala Machi). The windmill structure comprises two floors, with its maximum length—from the entrance to the far end—exceeding 26 meters. The width measures 12 meters at the entrance section and narrows to about 9.2 meters in the main body of the building. Access to the interior is provided through a 140 cm-wide portal on the eastern side, leading into a rectangular chamber measuring 670 by 400 cm. This chamber features a domed ceiling with a diameter of 4 meters.

On the western wall of this chamber, directly opposite the entrance, there is a small arched niche measuring 116 cm in width, 150 cm in height, and 92 cm in depth. At the rear of this niche, a recessed space has been created to accommodate objects such as lamps and candles. Additionally, two other niches are located along the southern wall of the chamber, flanking the entrance to the adjacent southern room. The eastern niche measures 36 by 46 cm with a depth of 33 cm, while the western niche is 30 by 60 cm with a depth of 30 cm.

The anteroom, or entrance chamber, leads to the *Askhaneh*—the room housing the millstone—through a large archway measuring 330 cm in width, with side walls 120 cm thick. The *Askhaneh* itself measures 900 by 520 cm. Inside this space, structural elements include stone-bearing walls, a western corridor, an eastern roofed corridor, and a northern chamber located behind the millstone. The bearing section of the stone is constructed of adobe and consists of two parallel walls on the east and west sides, and a perpendicular north wall, measuring 56 cm, 70 cm, and 170 cm in thickness, respectively, with a height of 130 cm. These walls form a rectangular cavity with dimensions of 107 cm in width and 160 cm in length, which served as the base on which the millstone was placed.

The western corridor, 120 cm wide, likely functioned as the initial flour collection area. The eastern corridor, measuring 124 cm in width and 325 cm in length, is covered by a gabled roof. This corridor leads to the space behind the millstone, which further connects to the northern room through an entrance 100 cm wide.

The northern room is oriented along an east-west axis and measures 630 by 120 cm. At the eastern and western ends of its southern wall, it connects to two corridors running north-south, each extending the full length of the Askhaneh with a maximum width of 160 cm. These twin corridors, commonly found in many windmills of Sistan, served a dual purpose: structurally, they reduced the load imposed by the thick walls, thereby enhancing overall strength and stability; functionally, they likely provided additional side storage space when needed.

The entrance room leads to the southern room of the windmill through a door 110 cm wide. This southern room measures 670 by 350 cm and features two niches on the south side, as well as two niches on each of the east and west walls. The windmill's opening spans 12 meters in width, with the eastern wall measuring 142 cm thick and the western wall 122 cm thick.

The upper section of the opening connects to the windmill's second-floor space, known as the *Parehkhaneh*—the vane chamber that houses the windmill's vanes. Besides the main eastern and western walls, the vane chamber includes a centrally positioned slanted wall designed to direct and intensify wind pressure. This wall plays a crucial role in enhancing the wind wheel's speed and power.

At the center of the vane chamber's floor, there is a hole for the vertical axis of the windmill's vane, through which a wooden shaft passes, linking the vane to the millstone below (Figs. 2 and 3).

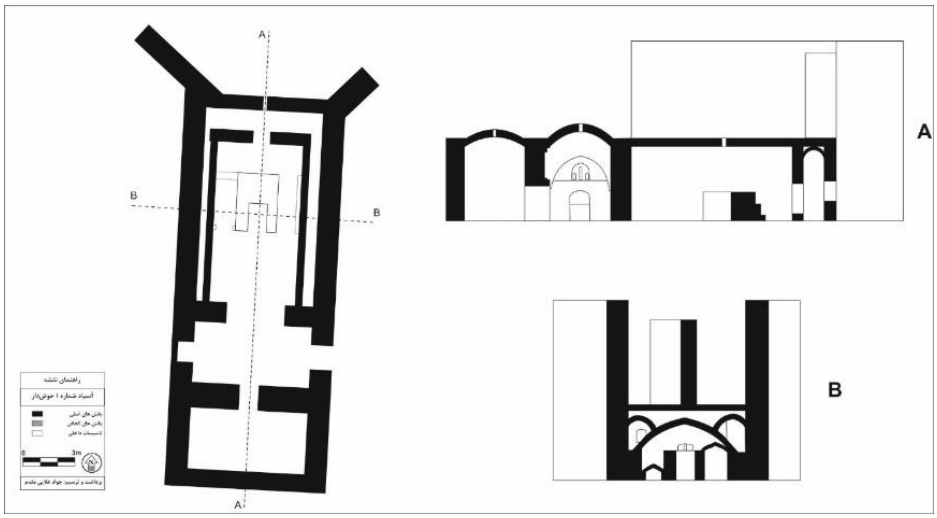

Figure 2: The plan and cross-sections of the windmill (Asbad) No. 1 of Hozdar in the north of Qala Machi (authors, 2023)

Figure 3: The windmill (Asbad) No. 1 of Hozdar (authors, 2023)

VI.2. Windmill (Asbad) No. 2

This windmill, which is the smallest and likely the latest example constructed in Hozdar, is located in the northeast of the complex, approximately 400 meters southeast of Qala Machi. Including the opening walls, the length of this tower is 11 meters; excluding them, it measures 8.7 meters in length. The windmill's opening is about 9 meters wide, while the main building itself is 5.7 meters wide.

The design and structure of this windmill are simple, consisting of a rectangular mill chamber (*Askhaneh*) on the first floor and a vane chamber (*Parehkhaneh*) on the second floor. The entrance to the building, located on the south side, is 120 cm wide and opens into the rectangular Askhaneh, which measures 7 by 3.7 meters.

The southern part of this room does not contain any additional structures, but in the center, the side platforms supporting the millstone are present. To the west of this platform, there is a closet-like platform

measuring 230 by 85 cm, with its northern side blocked and a 50 cm wide opening on the south side.

Unlike other windmills, there is no trace of a wind flow opening on the north side of this room. Instead, a small niche has been created near the ground, measuring 70 cm wide and 87 cm high.

The eastern arm of the opening is 295 cm long, and the western arm measures 350 cm; both are connected to the side walls of the Parehkhaneh. At the center of the vane chamber, a guide wall is built to intensify wind pressure on the vanes (Figs. 4 and 5).

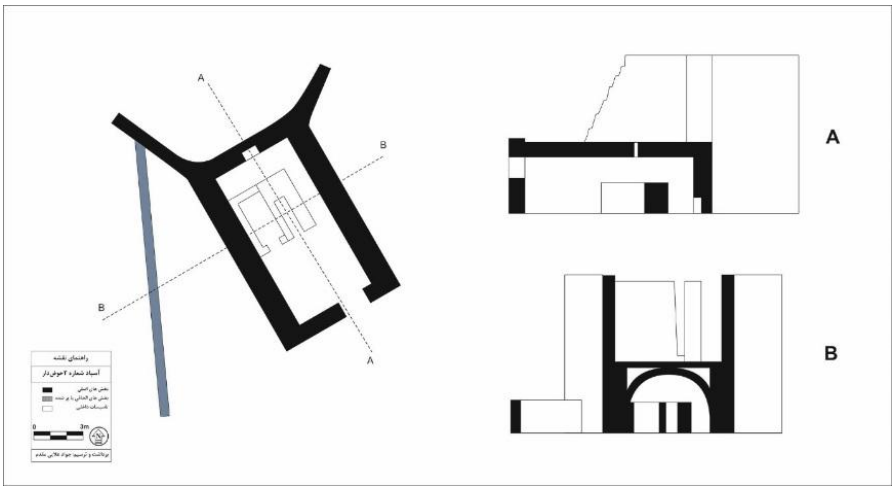

Figure 4: Plan and cross-sections of the windmill (Asbad) No. 2 of Hozdar (small Asbad) in the southeast of Qala Machi (authors, 2023)

Figure 5: The windmill (Asbad) No. 2 of Hozdar (Small Asbad) (authors, 2023)

VI.3. The Windmill (Asbad) No. 3

This windmill is located 850 meters south of Qala Machi and has been renovated in recent years. The overall dimensions of the tower, including the opening walls, are 11 by 34 meters.

The entrance to the building, which is 145 cm wide, is positioned in the middle of the eastern side and opens into a rectangular room measuring 890 by 350 cm. This room is connected on the north side to the *Askhaneh* through a 510 cm wide arch. It also connects to a nearly rectangular storage room via a 215 cm wide arched entrance, and to the south through another passage.

The *Askhaneh* is a rectangular space measuring 505 x 910 cm along the north-south axis. The southern part of this space has no architectural elements. In the middle of the northern side are sturdy platforms designed to support the millstone. On either side of the platform, there are two closet-like spaces with arched roofs, each entered from the south side, measuring 130 cm and 145 cm wide. Both are closed at the northern end and were probably used for storing flour.

What is particularly noteworthy about this windmill is its end section, which distinguishes it from other examples in the Hozdar region and Qala Rostam. In this case, the space at the end of the Askhaneh—at the same

level as the stone platform and its side corridors (about 2 meters above the floor)—has been filled in to create a mezzanine. This mezzanine was accessed via a staircase located to the east of the eastern corridor.

From here, the mezzanine leads to a rectangular space measuring 162 x 820 cm at the north end of the windmill, reached through an entrance 95 cm wide in the center of the north side. This room also connects to the side corridors via two entrances at the eastern and western ends of its southern side, measuring 115 cm and 70 cm wide, respectively. Each corridor is about 10 meters long, with widths of 115 cm and 85 cm.

The windmill's warehouse is an almost square room measuring 650 x 680 cm, located to the south of the entrance room. It has two windows, one on the east side and one on the west. Before the restoration work, traces of a blocked entrance were visible on the south wall, but this has since been concealed by the interior thatching. This entrance originally led to a space further to the south, of which only parts of the walls remained until 2016. Following the restoration, this southern section, measuring 890 x 400 cm, now has a separate entrance on the eastern side.

A narrow arch runs through the middle of this area, dividing it into two equal parts, east and west. At the far end of the north side of this room, there is a low corridor measuring 7 meters in length and 1.5 meters in height, whose function remains unknown.

The side walls flanking the windmill's opening measure 670 cm on the east and 660 cm on the west and are connected to the main walls of the *Parehkhaneh*. The main walls, about 100 cm thick, run parallel to each other in a northwest–southeast direction. Between these two walls is the central guiding wall of the windmill, which adjusts the direction of the wind striking the vanes and increases the wind's impact (Figs. 6 and 7).

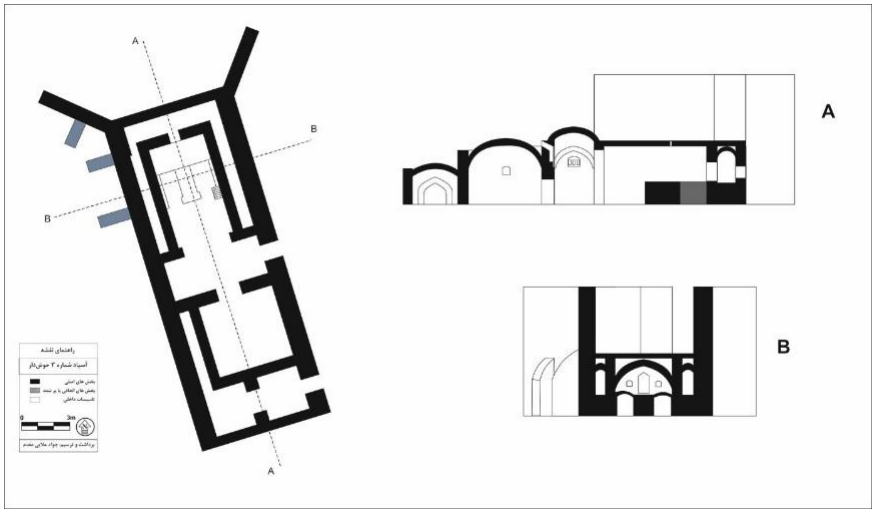

Figure 6: Plan and cross-sections of the windmill (Asbad) No. 3 of Hozdar in the south of Qala Machi (authors, 2023)

Figure 7: The windmill Asbad No. 3 of Hozdar (authors, 2023)

VI.4. The Windmill (Asbad) No. 4

This windmill is located southeast of Qala Rostam and to the west of the Hozdar complex, which is why it is known as the Qala Rostam Asbad. The overall dimensions of the windmill, including the louvered opening, are 13 x 31 meters. The main entrance, 115 cm wide, is positioned in the center of the eastern side and opens into a rectangular space measuring 325 x 890 cm with a pitched roof. This room provides access to other parts of the windmill through three entrances.

The southern entrance opens into a nearly square room measuring 590 x 585 cm, with a width of 180 cm and a domed ceiling. From the southwest, this entrance room leads into an L-shaped hallway that is 195 cm wide.

The northern arched entrance, 300 cm wide, opens into the Askhaneh. This space measures 840 x 555 cm and includes a central platform flanked by two corridors with arched ceilings. The central platform, currently 2 meters wide and fully integrated, was originally constructed as an open space in the middle where the millstone was placed.

The eastern and western corridors, both recently renovated, are 165 cm and 175 cm wide, respectively.

At the northern end of the Askhaneh, a mezzanine—similar in design to the one in the windmill (Asbad) No. 3—provides access to the northern space of the windmill, which measures 125 x 880 cm. This area is reached via an entrance 80 cm wide located in the center of the north wall.

On both sides of the southern end of this room are entrances measuring 90 cm and 85 cm wide, which lead into the eastern and western corridors. These corridors extend the full length of the Askhaneh.

The walls flanking the windmill's opening, which served to channel the wind into the vane chamber (Parehkhaneh) on the second floor, measure 520 cm in length on the east side and 740 cm on the west side, with a thickness exceeding 130 cm.

As with other windmills in the region, the vane chamber itself is designed as a corridor-like space, distinguished by a wind inlet configured as an open corridor (Figs. 8 and 9).

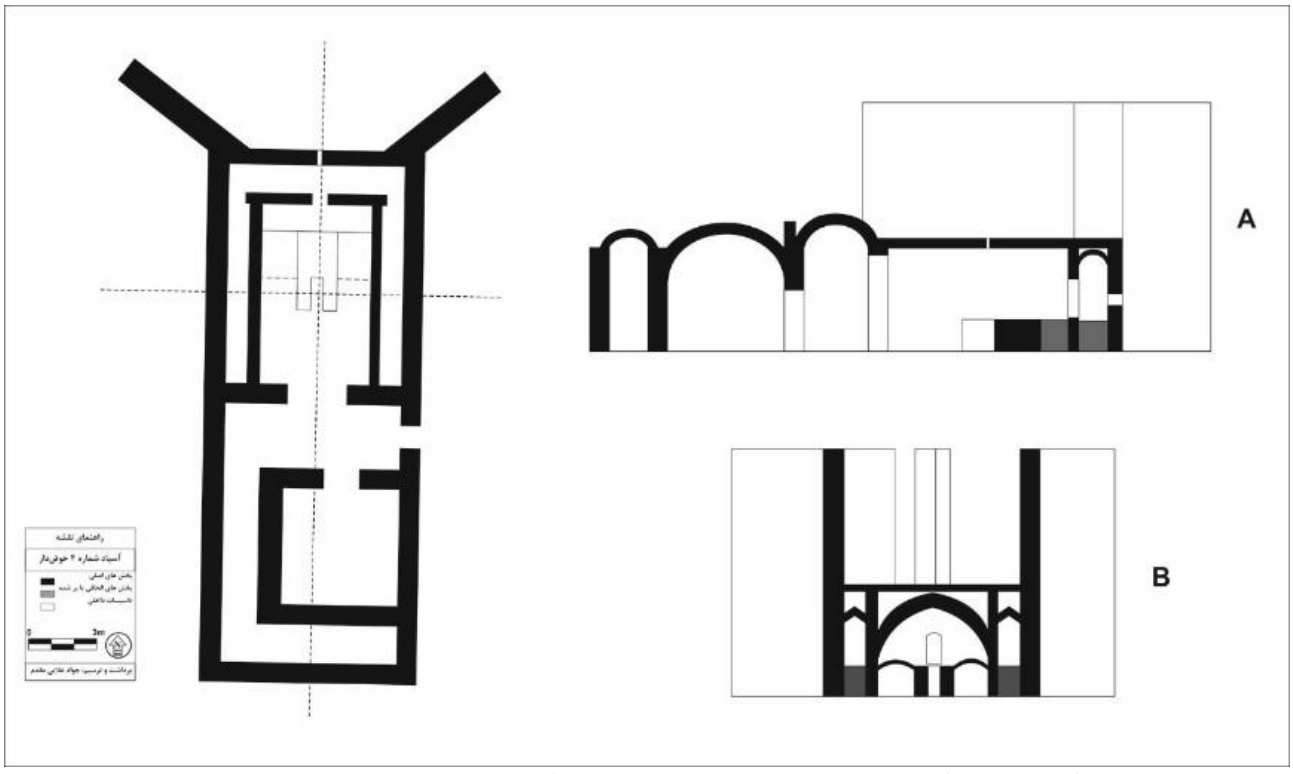

Figure 8: Plan and cross-sections of the windmill (Asbad) No. 4 of Hozdar in the southeast of Qala Rostam (Authors, 2023)

Figure 9: The windmill (Asbad) No. 4 of Hozdar (authors, 2023)

VI.5. The Windmill (Asbad) No. 5

This windmill is located 240 meters southwest of Qala Rostam and is known locally as the Twin Asbad due to its distinctive configuration. The overall dimensions of the windmill, including the openings, are 19 × 19.5 meters, consisting of two sections—eastern and western windmills.

The eastern windmill is the larger of the two and features two entrances, each 115 cm wide, situated almost directly opposite one another on the southern sides of the eastern and western walls. These entrances open into a room measuring 420 × 785 cm. On both sides of the eastern entrance are platforms 60 cm high.

This room connects to the Askhaneh through a vaulted entrance 305 cm wide. The Askhaneh itself measures 530 × 820 cm and occupies the center of the northern half of the millstone bearer's platforms. These platforms are 87 cm wide, with a 70 cm gap between them where the millstone was positioned.

Flanking the platforms are two arched-roof corridors, each 140 cm wide. The Askhaneh connects to the northern room of the Asbad via a 70 cm wide entrance. This adjacent space measures 150 × 790 cm and links to the windmill's southern side corridors, each approximately 100 cm wide.

At the end of the western corridor, a staircase provides access to the vane chamber **(**Parehkhaneh**)** of both windmills.

The architecture of the western windmill is simpler in design, with access to its only interior space provided by an entrance 110 cm wide. The Askhaneh measures 4 × 10 meters and features a central platform for placing the millstone, as well as two short side corridors. The millstone platforms are approximately 60 cm wide and are spaced 78 cm apart.

In the southeast corner of this Askhaneh, a simple platform has been constructed beneath an arched recess.

The vane chamber (Parehkhaneh) in the Twin Windmill (Asbad) of Qala Rostam is similar to other vane chambers found throughout the region. The only notable distinction is the height difference between the two sections: both the alcove wall and the roof of the western windmill are lower than those of the eastern windmill (see Figs. 10 and 11).

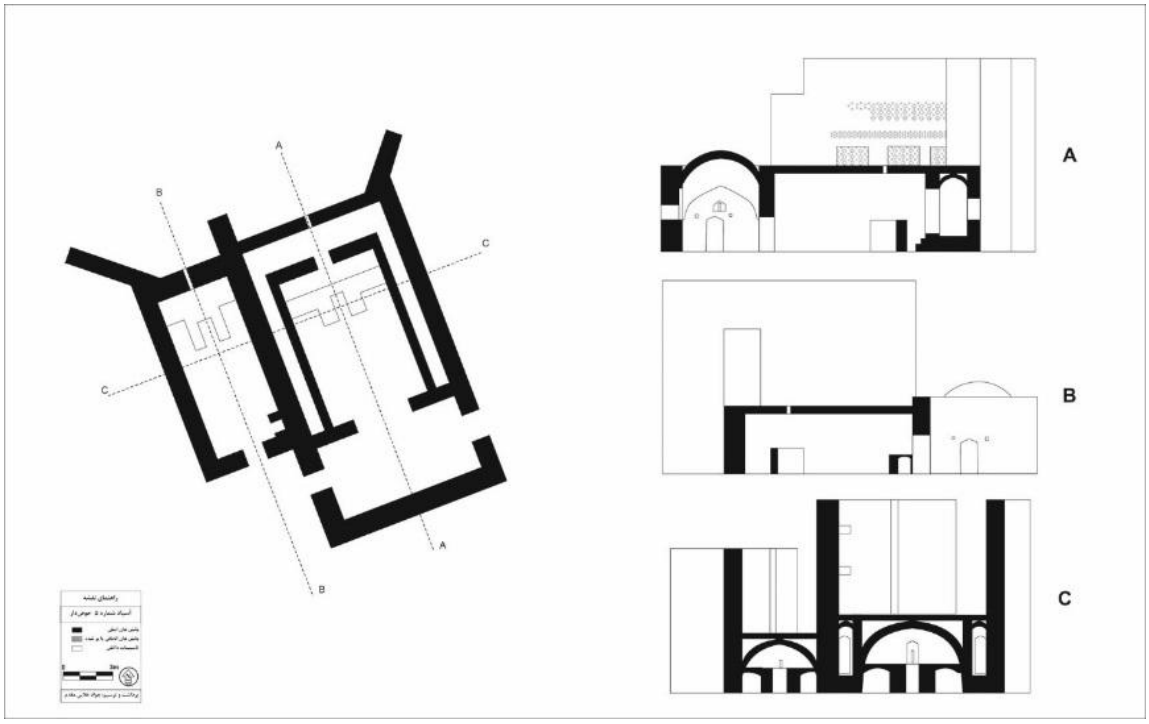

Figure 10: The windmill (Asbad) No. 5 of Hozdar in the southwest of Qala Rostam (authors, 2023)

Figure 11: The windmill (Asbad) No. 5 of Hozdar (authors, 2023)

VII. Decorations of the Safavid Windmills (Asbads)

The decorative elements in the windmills of the Hozdar region in Sistan are primarily restricted to beehive motifs. These patterns, present on all windmills except the small windmill (Asbad No. 2), consist of geometric shapes such as rhombuses and trapezoids. They also feature vertical and rectangular frames arranged adjacently by carving shallow recesses in square, rectangular, cruciform, and semi-cruciform forms on the exterior surfaces of the main walls (see Fig. 12). This restrained ornamental approach emphasizes subtle geometry and texture rather than elaborate adornment.

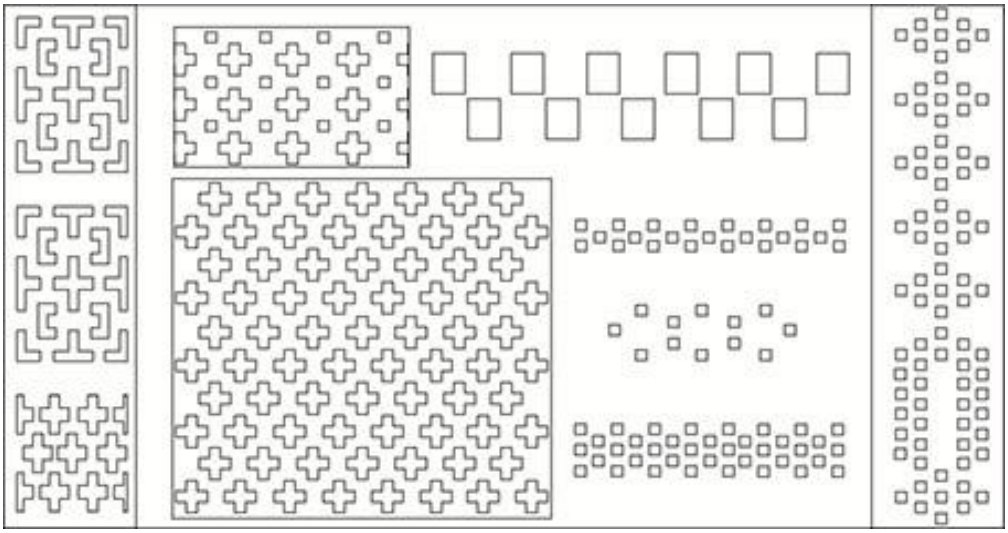

Figure 12: The different types of decorations used in the windmills of the Hozdar region (the authors, 2023)

VIII. Structural Investigation of Windmills (Asbads) of Hozdar

The windmills of the Hozdar region can be classified into two types based on the number of openings they feature: single and twin windmills. Specifically, in this region, there are four single-type windmills and one twin-type windmill.

All the windmills in the region consist of two floors. The first floor comprises the roofed part of the building, while the second floor includes the roofless part, known as Askhaneh and Parehkhaneh, respectively. In all windmills, the first floor features a common space, considered the main room, which contains architectural elements such as a millstone platform, a hallway or corridor, and a ditch (Kondak). In addition to this room, other spaces can be found in some windmills, including side corridors, the northern room featuring a lower louvered window (Darbad), the anteroom (entrance room), storage rooms and corridors, the miller's room, and the entrance stairs to the Parehkhaneh. Therefore, the windmills can be categorized into single-part and multi-part types. The Small windmill (Asbad) (Figs. 3 and 4) and the western part of the Twin windmill (Asbad) (No. 10 and 11) are single-part types, while the others are considered multi-part windmills.

The second floor, or the "Parkhaneh" section, characterized by the lateral main walls and the "wind guide" wall, is the place where the wind vane is located. An interesting feature of these windmills, which is characteristic of the windmills of Sistan, is the presence of an air inlet duct in the form of an open corridor and the "Darbad" (wind conductor). This is why they have been known as corridor windmills (Asbads). The advantage of this corridor is more effective wind guidance and increased wind power. The increase in wind speed resulting from the creation of wind corridors and the "Darbad" in the windmills of Sistan has been demonstrated in the modeling attempts conducted so far (Gholami et al., 2017).

Some architectural features of the windmills of the Sistan region include symmetrical composition and a regular structure based on quadrilateral geometry (square and rectangular) and circles (observed only in windmills No. 3 and 4). The interior of windmill (Asbad) No. 2 and the western windmill in the twin windmill can be accessed directly from the south side, while in other windmills of the Hozdar region, the interior can be accessed indirectly through the entrance room. The ceilings of the various spaces in the windmills of Hozdar include a barrel vault, a coved vault (a quadrangular vault), a Kolumbo, and a dome. A squinch (Filpush) has been used to create the dome. The ceiling of the windmill space is double-walled, which forms a barrel vault on the inside and appears flattened on the outside by the construction of lateral vaulted corridors and an all-around ceiling. The entrance arches are multi-layered and simple.

IX. Structural Direction and Orientation of Hozdar Windmills (Asbads)

All windmills of the Sistan region face north, but they differ from each other depending on the degree of deviation from the north-south ridge. The windmill of the Hozdar region has a variable structural direction, ranging between 4 degrees east and 31 degrees west. Accordingly, three windmills in the Hozdar complex have Isfahani Orientation, while the other two windmills, despite the minor shift to the east, can almost be considered to have straight Orientation (Table 1).

Table 1. Structural direction and Orientation of Windmills (Asbads) in the Hozdar region of Sistan (authors, 2023)

Name of windmill (Asbad)	No. 1	No. 2	No. 3	No. 4	No. 5
Type of windmill (Asbad)	Single Corridor-type	Single Corridor-type	Single Corridor-type	Single Corridor-type	Twin corridor-type
Interior	Multi-part	single-part	Multi-part	Multi-part	Multi-part-single-part
Structural direction	4 degree eastern	32 degree western	17 degree western	1 degree eastern	21 degree western

X. Age of Windmills (Asbads) of the Hozdar Region

In order to determine the age of the windmills in the Hozdar region, two methods can be used: typological comparison of surface pottery samples and historical sources. Based on the typological comparison of surface pottery samples from the windmill collection of the Hozdar region (Fig. 13), including samples with specific dates found in various sources and museums, it has been determined that most of these pottery samples date back to the period from the 9th to the 11th centuries AH, corresponding to the Safavid period (Table 2).

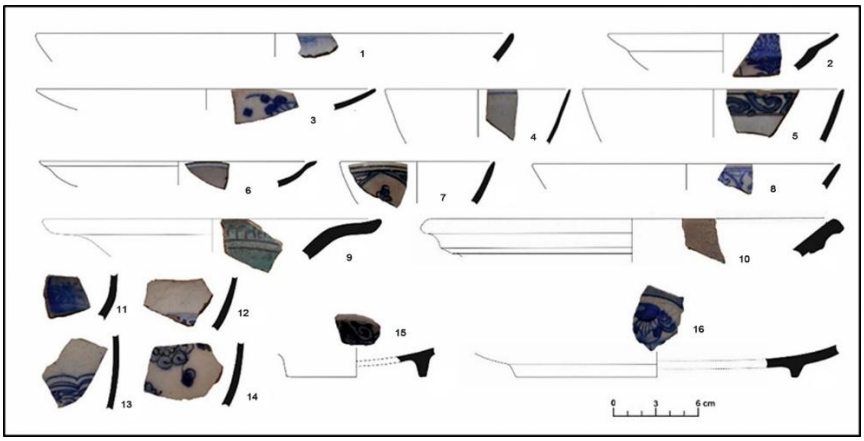

Figure 13: Examples of typical pottery of Hozbad Windmills (Asbads) (the authors, 2023)

Table 2: Typological comparison and relative chronology of the pottery of Hozdar Windmills (Asbads) (authors, 2023)

Pottery No.	Form	Age	Comparison source
1	bowl	Safavid	Carsewll, 1979, 58
2	chalice	Safavid	National Museum of Iran, Astan Sheikh Safiuddin Ardabili
3	bowl	11th-12th centuries AH	Fehervari, 2000, 286, no.348
4	chalice	Safavid	Nazari Gashkinani, 2013, 92
5	bowl	9th-10th centuries AH	Nazari Gashkinani, 2013, 126
6	bowl	Safavid	Ansarinia, 2016, Image 5
7	Chalice	11th century AH	Akbari, Sadeghi, 2014, 83
8	bowl	Safavid	Sarmadi, Torki, 2010, 113
9	bowl	late centuries	Nasri, Aslani,
10	laver	-	-
11	-	late centuries	Malekpour Shahraki, 2013, 89, sample 37
12	-	Safavid	Allen, 2004, 67
13	-	Safavid	Nazari Gashkinani, 2013, 78 and 6
14	-	Safavid	Malekpour Shahraki, 2013, 121
15	bowl	Safavid	Malekpour Shahraki, 2013, 95, sample 67
16	bowl	Safavid	Koniei, 2008, 112

This dating can be confirmed based on historical sources. Although the historical sources do not directly refer to the windmills of this region, it can be inferred that their age corresponds to that of the city itself, since they are part of the historical city of Hozdar. As described in *Ihya al-Muluk*, Hozdar was a prosperous and fertile region in the 9th and 10th centuries AH, known as one of the most populated areas of Sistan.

Between 880 and 1042 AH, the northern and central regions of Sistan experienced significant destruction due to the Timurid invasion and subsequent attacks by the Uzbeks. This led many kings, nobles, and a large portion of the population to relocate to southern Sistan, including Hozdar. Due to these events and the area's productivity, the Hozdar region began attracting greater attention from the 9th century AH onwards, leading to the establishment of extensive settlements.

After that, in the early 11th century AH, when Malek Shah Hussain visited Hozdar, the region was governed by Raeis Hossein Ali and Raeis Shamsuddin. Despite the damage caused by the Uzbek attack, approximately 300 households lived in Hozdar Castle (ibid: 382).

By the end of the Safavid period, the Hozdar region, like other parts of Sistan, was in poor condition. The last period of relative silence in the Hozdar region dates back to the Qajar period. Following multiple wars that resulted in significant destruction, the Raisi tribe gained control over this region in the second half of the 12th century AH (Rais al-Zhakrin Dehbani, 2009: 54 and 285).

Until a few decades ago, there was an inscription in Qala Machi of Hozdar containing a historical record related to the lunar year 1130 (1717 AD and 1096 Hijri Shamsi) (Ahmadi Karviq, 2015: 202).

According to historical sources, it can be stated that the urban structure of the Hozdar region dates back to a period after the 9th century AH, and the city continued to exist despite frequent fluctuations until the early Qajar era. Therefore, it can be argued that the age and operational period of the windmills in this city also fall within this timeframe.

XI. Study of the position of the Hozdar region in the flour production system of Sistan during the Safavid era

After the mid-Islamic centuries and the destruction caused by the Timurid invasion, followed later by the Uzbeks, most cities, towns, and related facilities in northern Sistan suffered extensive damage. During this period, the Rendeh complex—the most important and largest flour production facility in the Sistan region during the middle Islamic centuries (Alaei Moghaddam & Mousavi Haji, 2023)—was destroyed, creating an urgent need to find a new center to sustain the region's primary production function: flour production.

Furthermore, prior to the Safavids' control, northern Sistan had been plagued by insecurity and destruction due to frequent Uzbek attacks, which forced kings and nobles to relocate to the southern region (Malek Shah Hossein, 2004: 133-137). This suggests that the main center of flour production during the Safavid era should be sought in southern Sistan.

According to the evidence presented here, among all the windmills (Asbads) in Sistan, only those in the Hozdar region can be attributed to the Safavid period. Moreover, the only cluster of windmills from this era collectively located within a single settlement is found in the Hozdar region. Considering this, it can be argued that the primary flour production function in Sistan was transferred to the Hozdar region during this time.

Hozdar is a fertile area that is also mentioned in historical sources (ibid: 132). Additionally, during the successive wars of the 9th and 10th centuries AH, a large portion of Sistan's population migrated to this region and other southern parts, establishing it as a major population center in Sistan, as evidenced by numerous material evidence, ruins, and ancient buildings and castles from this era.

XII. Conclusion

As stated earlier, this research was conducted with the aim of "identifying and studying the most important flour production center of Sistan during the Safavid era and investigating its architectural features." To achieve this goal, two main questions were considered:

After the abandonment of the Rendeh region as the primary flour production center of Sistan in the middle Islamic centuries, to which location was the most important flour production center of Sistan transferred during the Safavid era?

What is the architectural structure and style of different types of Safavid windmills (Asbads) in Sistan like?

In response to the first question, it should be noted that after the mid-Islamic centuries and the destruction of the main cities, villages, and key facilities such as the Rendeh windmill (Asabad) complex in northern Sistan—caused by repeated attacks from enemies, particularly the Uzbeks—most of the population of Sistan and its ruling kings migrated to the southern regions, namely Hozdar, Tarqoun, Ramroud, and Shileh (Malek Shah Hossein, 2004: 133-137). Therefore, the most important flour production center of this period

should be sought in the southern part of Sistan. According to investigations, the only location in southern Sistan with a collection of windmills is the Hozdar region. Studies have revealed that these windmills date back to the Safavid period, and thus they can be considered the most important flour production facilities in Sistan during that era.

In response to the second question, it can be stated that the construction style and layout of the Hozdar windmills (Asbads) closely resemble those of the older windmills in northern Sistan, specifically the windmills of Zahedan-e Kohneh (4th to 9th century AH) and Rendeh (5th to 9th century AH). The main differences lie in their size and the absence of a dedicated external space in each windmill. In other words, all these windmills belong to the vestibular and vertical shaft type, with their vanes rotating in a clockwise direction. Their plans include both multi-part and single-part configurations. In the multi-part examples, alongside the Askhaneh and Parkhaneh spaces, other elements such as the entrance room, storage rooms, side corridors, staircases, and the miller's room are also present.

Some architectural features of the windmills (Asbads) in the Sistan region include symmetrical composition and a regular structural design based on quadrilateral geometry (squares and rectangles) and circles (observed only in windmills No. 3 and 4). The interior of windmill No. 2 and the western windmill of the twin windmill set can be accessed directly from the south side; however, in other windmills of the Hozdar region, access to the interior is indirect and through an entrance room. The ceilings of the various spaces in the Hozdar windmills include barrel vaults, coved vaults (quadrangular vaults), Kolumbo, and domes. A squinch (Filpush) technique has been used to support the domes. The windmill space features double-walled ceilings that form a barrel vault on the interior and a flattened shape on the exterior by means of lateral vaulted corridors and an encompassing ceiling. The entrance arches are multi-layered yet simple in design.

Finally, the Hozdar Windmill (Asbad) complex can be regarded as the last large-scale windmills of the Sistan region. The number and size of these windmills clearly demonstrate that their flour production capacity far exceeded the needs of the agricultural lands in the Hozdar area. This implies that wheat produced in many villages and towns across Sistan during the Safavid era was brought to this region for milling. In other words, Hozdar served as the final major center for flour production by windmills in Sistan.

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