Abstract— One of the most important parts of traditional architectural structural building in Iran that have a significant impact on the urban landscape and architecture, are domes. In the natural architecture of the central plateau region, establishing a spiritual and material relationship between the environmental conditions and the use of arched ceilings, such as domes over the centuries has become an important feature of the place. In this paper, as an example of the masterpieces of the ancient Persians, the efficacy of such ceilings in ab-anbar with windcatcher has been investigated. The ab-anbar as one of the infrastructures has a great position in the Iranian civilization and is spread almost in the frontline across Iran. Ab-anbar space does not disclose and all of them have a vent for air. Confined space makes the possibility of access to storage inside difficult, additionally, it makes the water very hot, so on sunny days the storage inside is very hot. Therefore, all the ab-anbar has air vents on the storage roof. The vent and the windmill cause the coolness and the salubrity of the water in addition to the ventilation inside the tank. In this paper, we firstly discuss the function of the ab-anbars and then we study the function of ab-anbar with windcatcher under different velocities using computational fluid dynamics. For this purpose, first the geometric modeling and mesh structure is done in software GAMBIT and then we investigate the flow patterns in this type of ab-anbars with using FLUENT software.

Keywords—Ab-anbar with windcatcher, Computational Fluid Dynamics, Different winds Velocity, Fluent, k-ε.

I. INTRODUCTION

The rain rate in Iran, except northern region and the Caspian Sea beach, is very low in other regions. For this reason, in most of the vast plains of Iran, significant efforts have been made for access to the water and tens of kilometers of canals have been dug utilizing the Iranians' abilities. In addition to constructing of canals and dams, Iranians have paid attention to store the winter water for its usage in the warm seasons; for this purpose they have founded ab-anbar. Ab-anbar means 'water storage' in Persian.

Ab-anbar plays a significant role in the life of a particular situation, as well as the culture and beliefs of the people of this country, in addition to their important role in everyday life of people. The relationship between water and religious ritual has continued after the advent of Islam in Iran; so the temples of Anahid replaced with glorious places out of cities. The ab-anbar in the desert cities has been the center of many villages and towns and neighborhoods and they are the largest and most significant architectural units in many neighborhoods.

Construction technology and architectural style of the ab-anbar constructions have special credit because the manufacturers of these units were very careful about the main issues such as the water pressure on the bottom of the ab-anbar, lined, ventilation, purification and water pollution prevention. The decorating art of external view of the ab-anbars especially the front entrance and in some cases, the selection of interesting poems for the main entrance show that these constructions have a close and strong relationship with many features and the spirit of the inhabitants.

The reasons of collecting water and keeping the water in the ab-anbar can be classified as follows:

A) evaporation of water in direct contact with the sun's heat and airflow
B) deterioration of water outdoors
C) water warming due to sun radiation
In arid and desert regions, the ab-anbar is filled with rainwater or seasonal streams. The water is usually stored in winter and is used in summer. Such facilities are dependent on subterranean reservoirs. The build of ab-anbar, its purification and isolation conform to scientific and engineering principles. The physical and chemical methods are used for purification. These methods include: the deposition of waste material, adding a certain amount of salt for analyzing, the microbial degradation by chlorine, the disinfection by calcareous compounds and the use of smell bags of coal.

The most popular ab-anbar is the Sishbadgiri and the Amirchaqmaq ab-anbars in the city of Yazd, the largest single-domed ab-anbar in the city of Qazvin, and the ab-anbar in the city of Gerash Fars. Gerash and Qazvin have dozens of ab-anbar in Iran, and many of them still remain. Ab-anbars of Qazvin -which tourists visit them- are Sardare Bozorg, Haj Kazem, Sardare kuchak, Molaverdikhani, Zananebazar, Masjed Jame. Figure 1 shows new and old ab-anbar. [1]

II. FUNCTION AND STRUCTURE OF THE AB-ANBAR, AND TYPES OF AB-ANBAR CONSIDERING THE FUNCTION AND STRUCTURE

Private Ab-anbars: ab anbar in urban or rural areas are generally built under the building or under the surface of the courtyard. The ab-anbar tanks are usually cubic or rectangular and have a flat roof or a roof cradle. If the tanks in this type of ab-anbars were built under the house yard, water would be pumped by a manual pump with a bucket through a valve in the ceiling or near the ceiling. But if the tank was built under the building, water would be available through water tap facilities. These tanks have mainly a fan or a windcatcher for ventilation that extends to the roof of the building [2]. The water capacity of this ab-anbar is sufficient for three to four years for a building (Figure 2).

General Ab-anbar: These ab-anbars are often quite large buildings and their builders were rulers or rich men, who provided the cost of them from their property or from the public property.

A) Urban Ab-anbars: They were mostly built in neighborhoods or near the religious, educational, welfare and trade centers. The surviving ab-anbars of this kind show that they have a higher capacity than the other types, and they provided the water supply of urban areas for months. Because of the importance of these buildings, the builders paid attention to choose of materials’ type and quality of the buildings. In addition to the necessary parts and components, the builders used large entrance, vestibule, wide stairs, and a variety of decorations. Among the most famous ab-anbars in Tehran, Seyed Ismail, Saheb Ivan, Baba Norouz, Yuzbash, Seyed Vali, Emamzadeh Yahya, Gholi Khan, Chel Tan and Kocheh Ghariban schould is pointed. Gholi and Sorkheh ab-anbar in Semnan, Haj Kazem and Sardar Bozorg ab-anbar in Qazvin, Hoz Loghman, Hoz Mirza Nazer, Bala kucheh and Chel Payeh ab-anbar in Mashhad, Seyed Hosseyn Dekhan ab-anbar in Kashan are considered as famous examples of this type of architecture.

B) Rural Ab-anbars: they were built mainly in the central square in the village. These ab-anbars were very simple architecture, and were built with the existing materials in place without any ornamentation or decoration. Haj Seyed Hossein ab-anbar in Khonk Village and Do Rah ab-anbar in Rahmat Abad village in Yazd province can be pointed out as the known examples of these ab-anbars.

C) Castle Ab-anbars: This is simple ab-anbar and is a covered tank. The tank is relatively small and deep and is built as a well in the center of ab-anbar. Some of them were connected to the building of castle in order to collect and storage of the rainwater that can be on roofs and courtyard of the castle. The architecture of the ab-anbar inside the Caravan can be the effect of this kind of ab-anbar. So it can be studied in this group. These constructions were usually built in the form of covered tanks in courtyard.

D) Midway Ab-anbars: These ab-anbars were usually built along the caravan routes. They have cylindrical tanks and a
dome cover, and they have also some rooms for rest and for pray for travelers. As the examples of these ab-anbars, Hoz Biland Vazir ab-anbar on the way of Yazd to Mashhad and Haj Hosseyn Memar ab-anbar on the way of Yazd to Tehran can be noted.

E) Ab-anbars of desert: These ab-anbars were usually built in dry deserts for livestock watering. The water tanks were usually rectangular and their walls were approximately two meters above the surface of the earth.

The ab-anbar has two staircases, one for Muslims and another for Zoroastrians. Soil surrounding the tank is acted as the tank water bars and its dome. As we know, water-tank space in ab-anbar wasn’t disclosed and all of them have a valve for ventilation. Disclosed space may prevent access into the water, furthermore it makes the water very hot. So on sunny days, the disclosed space in the tank may be very hot. Therefore, all the ab-anbars have air vents on the tank roof or windcatcher. The ab-anbars of the central desert of Iran mostly have two, four or six windcatchers around the tank (Figure 3). The valves and windcatchers cause the coolness of the water in addition to ventilation. In this paper, we firstly study the function of the ab-anbar using computational fluid dynamics, and then the function of ab-anbar with windcatcher at different velocity.

![Fig. 2 (A) Abdol Razagh Khan ab-anbar plan in Khan neighborhoods Center in Kashan established in the year 1193 AH. (B) Plan of Shish Badgireh ab-anbar in Yazd.](image)

![Fig. 3 The image of the construction of the windcatcher on the ab-anbar.](image)

### III. Numerical Modeling

There are three methods to solve problems related to fluid mechanic: empirical, analytical and numerical methods. The progress of numerical methods in various Sciences in recent decades was remarkable. Due to the high cost of the empirical methods and the weakness of analytical methods to solve engineering problems, nowadays most researchers use numerical methods.

To study the pattern of air flow passing through ab-anbar with windcatcher, the geometry of the structure was generated in GAMBIT software using existing maps (Figure-4). As shown in Figure 4, we use velocity inputs and pressure outputs as boundary conditions. Then we study this geometry in the FLUENT software. FLUENT software is a program for fluid flow modeling and heat transfer in complex geometry. This software is based on limited volume method which is a strong and appropriate method in computational fluid dynamics methods. [3],[4]

In this paper, we chose k-ε as the turbulence model. k-ε model is a relatively complete and common model but very expensive which is used to describe turbulence. It is useful for description of the transport properties of turbulence by the average flow, turmoil, production and depreciation. In this model, two transport equations (partial differential equation PDE) are solved: one for the turbulent kinetic energy k and the other for the turbulent kinetic energy depreciation rate ε.
In the standard k-ε model, the transport equations (1) and (2) are applied that are used for ε and k in the FLUENT software [5]

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_i}(\rho k u_i) = \frac{\partial}{\partial x_i} \left[ \frac{\partial}{\partial x_i} \left( \alpha + \frac{\alpha_t}{\sigma_k} \right) \frac{\partial}{\partial x_j} \right] + G_k + G_b$$

(1)

$$\frac{\partial}{\partial t}(\rho \varepsilon) + \frac{\partial}{\partial x_i}(\rho \varepsilon u_i) = \frac{\partial}{\partial x_i} \left[ \frac{\partial}{\partial x_i} \left( \alpha + \frac{\alpha_t}{\sigma_k} \right) \frac{\partial \varepsilon}{\partial x_j} \right] + C_{1s} \frac{C_3}{k} (G_k + C_{3s} G_b) - C_{2s} \rho \frac{\varepsilon^2}{k}$$

(2)

$$k = \frac{1}{2} \left( w^2 + v^2 + w^2 \right)$$

(3)

K = kinetic energy (per unit mass) is related to the turbulent, \( \alpha_t \) = turbulent viscosity. The equations are included five fixed values which are adjustable:

Gk = turbulent kinetic energy term due to velocity gradient is average.

Gb = turbulent kinetic energy term is due to buoyancy.

In order to study the flow pattern in ab-anbar, three different modes are considered. In the first mode \( V = 2 \) m/s, in the second mode \( V = 5 \) m/s and in the third mode \( V = 10 \) m/s. The results are given in figures 5 to 8. In Tables 1 to 3, the minimum and maximum values of the velocity are given in X and Y directions in 3 assumed modes.
According to the results and figures, in the points of the structures in the first mode \((V = 2 \text{ m/s})\) velocity rate, velocity in the direction X and velocity in the direction Y are 2.48, 1.44 and 2.48. In the second mode \((V = 5 \text{ m/s})\) velocity rate, velocity in the direction X and velocity in the direction Y are 2.61, 1.50 and 2.55, and in the third mode \((V = 10 \text{ m/s})\) velocity rate, velocity in the direction X and velocity in the direction Y are 2.74, 1.56 and 2.66 (tables 1 to 3). So the wind with different velocities in some parts of the structure is resulted the dramatic increase in the velocity rate, velocity in the direction X and velocity in the direction Y. This issue represents the optimum function of this type of ventilation system for inside the ab-anbar. The flow pattern also confirms the issue.

### IV. CONCLUSION

According to the results and figures, in the points of the

### REFERENCES


