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AB-ANBAR: İRAN'IN SICAK KURAK BÖLGELERİNDE SU DEPOLAMADA BİR SÜRDÜRÜLEBİLİR MİMARİ YÖNTEMİ

AB-ANBAR: A SUSTAINABLE ARCHITECTURAL METHOD FOR WATER RESERVATION IN HOT-ARID REGIONS OF IRAN

Asst. Prof. Dr. Mahshid MİKAEİLİ

Bursa Technical University, Faculty of Forestry, Landscape Architecture Department, Bursa, Turkey, mahmikaeili@gmail.com, mahshid.mikaeili@btu.edu.tr,
ORCİD ID: 0000-0002-8126-3069

Abstract

The traditional architecture of Iran has always been rational and in harmony with the environment and climate to meet the needs of the people. Iran's vast plateau locate in an arid and semi-arid region of the world. They have also made the best initiatives with the least means without harming the environment. We can say that the Ab-Anbars, which were built in the arid regions of Iran to store water during the rainy season and to use it during the rest of the year, are a climate-responsible architectural design method. In ancient Iranian beliefs, traditions, religion, and culture, water was a holy subject carrying high value as a vital matter for human life. Due to the inefficient annual precipitations, unfavorable distribution of surface water, fluctuation of seasonal streams, and fulfilling water demand: ancient Iranian have provided unique methods for optimizing water utilization. One of the unique ways of optimizing water conservation is using an architectural method, the construction of underground water reservoirs or Ab-Anbar. Ab-Anbar is a roofed underground water cistern. These Underground buildings are historical hydraulic structures for drinking water supply. Today, most of these structures are still functional and are protected by state restoration as historical heritage. Underground water reservoirs have been built in arid regions, cylindrical, sometimes rectangular, and completely buried inside the ground. Access to the water reservoirs is via an underground stairway. In urban open spaces, the roof of underground water reservoirs appears as a dome roof on the ground level. The construction material used for subterranean water reservoirs was brick and a special mortar called Sarooj. Because the Ab-anbar structure is built with very thick walls and below ground level, the water remains cold. They would also build wind towers at the four corners of the water reservoir to ventilate inside the building. Within the scope of this study, the climate-responsible design principles used in Ab-Anbar structures will be examined that emerged in the hot-arid regions of Iran.

Keywords: Underground Water Reservoirs, Climatic Responsible Architecture, Iran.

Özet

İran'ın geleneksel mimarisi her zaman insanların ihtiyaçlarını karşılamak için rasyonel, çevre ve iklim ile uyumlu biçimde oluşmuştur. İran'ın geniş platosu, dünyada kurak ve yarı kurak bölgede yer almaktadır. Ayrıca çevreye zarar vermeden en az imkânlarla en iyi girişimleri gerçekleştirmişlerdir. İran'ın kurak bölgelerinde, yağışlı mevsimlerde suyu depolamak ve yılın geri kalanında kullanmak üzere yapılan Ab- Anbar'ların, iklim uyumlu bir mimarı tasarım yöntem olduğunu söyleyebiliriz. Eski İran inançlarında, gelenekler, din ve kültüründe su, insanın yaşamı için hayati bir madde olarak yüksek değer taşıyan kutsal bir konuydu. Öte yandan, verimsiz yıllık yağışlar, yüzey suyunun elverişsiz dağılımı, mevsimsel akışların dalgalanması ve su talebinin karşılanması nedeniyle: eski İranlılar, su kullanımını optimize etmek için benzersiz yöntemler oluşturdular. Su korumayı optimize etmenin benzersiz yollarından biri, mimari bir yöntem kullanarak yeraltı su rezervuarları (Per. Ab-Anbar) inşa etmişlerdir. Ab-Anbar, üstü kapalı bir yer altı su sarnıcıdır. Bu yeraltı su depolar (Ab-Anbar), içme suyu temini için bir tarihi hidrolik yapılardır. Günümüzde bu yapıların çoğu hala işlevseldir ve tarihî miras olarak devlet tarafından yenileme yapılarak korunmaktadırlar. Yeraltı su depoları kurak bölgelerde, silindir, bazen dikdörtgen biçimde ve tamamen toprağa gömülü olarak inşaedilirlerdi. Su deposuna erişim bir yeraltı merdiveni ile sağlanırdı. Kentsel açık mekânlarda yer altı su depolarının çatısı zemin kotunda kubbe görünümündedir. Yeraltı su depolarında kullanılan yapı malzemesi olarak tuğla ve Sarooj adı özel bir harç kullanılırdı. Ab-Anbar strüktürü çok kalın duvarlar ve zemin seviyesinin altında inşasından edildiğinden dolayı su oldukça soğuk kalırdı. Ayrıca ab-anbarın havalandırması için binanın dört köşesinde rüzgâr kuleleri inşa edilirdi. Bu çalışma kapsamında İran'ın sıcak-kuru bölgelerinde ortaya çıkan iklim uyumlu Ab-Anbar binalarının tasarım ilkeleri incelenecektir.

Anahtar kelimeler: Yeraltı Su Depolar, İklim Uyumlu Tasarım, İran.

Introductıon

Today the concept of sustainable architecture means a balanced use of resources. Sustainable architecture aims to create a better living space with balanced use of resources and utilize environmentally responsive design methods. In the concept of sustainable architecture, a building is part of nature. The aim of designing sustainable buildings is the appropriate design of the building and their environment, energy-efficient buildings, utilizing climate-responsible design, the least harm to the environment, and the recycling and reuse of energy and materials during construction. Social equity, economic viability, and protection of environmental values are three components of the sustainable architecture concept. Although the sustainable architecture concept is the subject of today, it is a method applied in historical urban areas, historical buildings, and vernacular architecture for centuries.

Traditional architecture is the unconscious realization and embodiment of the society's culture with the requirements of the people in nature. Throughout history, traditional and vernacular architecture have presented logical climatic solutions to enhance human comfort. Climate condition is a significant factor in the configuration of first settlements. Climate condition in historical settlements creates differences in urban form, buildings' form and function, construction materials, and technical construction methods. All of these factors created the vernacular architecture features or sustainable architecture features.

Iran locates in the hot-arid region of the world. Most parts of the country illustrate hot or semi-hot desert properties with limited water sources and warm climates. Nevertheless, throughout history, people have lived in these areas utilizing sensitive climatic design principles for controlling the climate's condition. Iran's traditional architecture in this area has been constructed based on five design principles. These principles create a basis for climatic responsive design. On the other hand, these traditional design principles are completely comparable with the new idea of sustainable architectural principles.

The aim of the study is to examine the Ab-Anbar buildings (traditional water reservoir buildings) as public buildings in urban open spaces of the hot-arid regions of Iran. The study method is based on a literature review, comparative research, and observation. The conceptual framework is prepared in two parts; the first stage is an examination of the new concept of sustainable architectural principles and then comparative these principles with Iran's traditional architectural design principles. In the second stage, the traditional water reservoir buildings (Ab-Anbar buildings) will be evaluated as traditional sustainable buildings in urban public spaces of hot-arid areas. The final stage of the study will be examined the climate-responsive design principles in traditional water reservoir buildings based on the building form classification, architectural form, architectural material and construction, and architectural elements.

1. Conceptual Framework

1.1. The Concept of Sustainable Architecture

Vernacular architecture, also known as local or regional architecture, is defined as the unconscious realization and embodiment of the society's culture with the requirements of the people in nature (Yousef et al. 2021). Throughout history, traditional and vernacular architecture have presented logical climatic solutions to enhance human comfort. The relationship between humans and nature dates back to the early stages of history. This permanent relationship is the interaction between primitive needs such as nutrition, shelter from climate conditions, and protection from wild nature. Climate condition is known as a significant factor in the configuration of first settlements. Climate effect on historical settlements is a recognized issue that makes the difference between the settlement's form, the direction of the roads, buildings' form and function, vernacular construction materials, and vernacular technical construction methods. These factors are recognized as characteristics of vernacular architecture or sustainable architecture of regions.

From an ecological point of view, sustainable architecture is a vital approach that is needed today. The concept of sustainable architecture means the balanced use of resources. The purpose of sustainable architecture, environmentally friendly architecture, or eco-architecture is to create a better living space with balanced use of resources and utilize environmentally responsive design methods (BNA, 2021).

Sustainable architecture; is a harmony between nature and architecture. Sustainable architecture is not the design and use of high-tech building products but also an established balance between the natural and artificial environment (Broadbent and Brebbia, 2006). In the concept of sustainable architecture, a building is part of nature. Therefore, the objective in the appropriate design of the building and its environment are; climate-responsible design, the least harm to the environment, and the recycling and reuse of energy and materials during construction (Acres, 2015; USGBC, 2016).

Sustainable architectures include some values such as aesthetics, ecological protection, and creating a balance between social, political, and ethical values (İbrahim, 2010). Sustainable architecture is a responsive design and application method for the environment via using the architect's imagination and technical knowledge. Sustainable architecture emerges based on logic as a combination of sustainable, durable, long-lasting, and environmentally friendly materials (López, 2006). The aim of sustainable buildings is to manage natural resources effectively and design environmentally friendly and energy-efficient buildings (İbrahim, 2010).

Social equity, economic viability, and protection of environmental values are known as the three components of the sustainable architecture concept. In addition, there is a binary relation between sustainability components. Figure 1 illustrates three components of sustainable architecture and the relations between them.

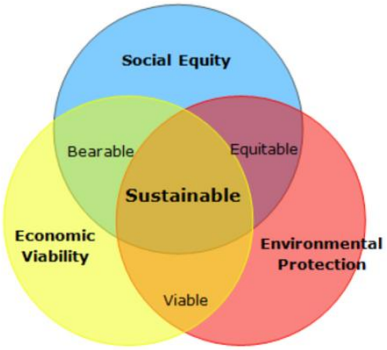

Figure 1: Sustainable architecture components

Sustainable architecture includes the concept of efficiency, beauty, settlement, and construction costs. Sustainable architecture is an environment-oriented design approach consisting of five main titles (Ghani, 2012). These:

- Healthy environmental design,
- Energy efficiency,
- Use of ecological construction materials,
- Building form,
- Well design.

Although the concept of sustainable architecture is the subject of today, it is a method applied in historical urban areas, historical buildings, and vernacular architecture for centuries. In settlements, the sun, wind direction, topography, use of local materials, and the production of construction techniques have always been at the forefront of adaptation to environmental and climatic conditions. Based on sustainable architectural design principles, it is significant to

establish climate-responsible design in the urban fabric and living spaces. The purpose of sustainable architectural design is to use design methods compatible with the natural environment and climate for human comfort. In the designing process should be considered the local climate, construction material selection, and building construction technic compatible.

1.2. Iran's Traditional Architecture Principles

In the studies conducted by Köppen (1936) and Olgyay (1962), they created climatic classifications on a world scale. According to Köppen's classification (Ghiai et al. 2020), there are five different climate types in the Iran plateau; hot desert, cold desert, hot semi-arid, cold semi-arid, and hot Mediterranean Continental Climate types (Figure 2).

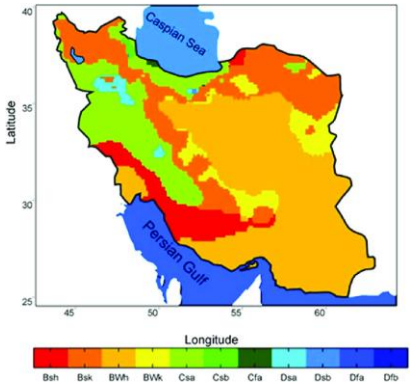

Figure 2: Iran climate classification map by Köppen-Geiger (Ghiai et al., 2020)

According to Figure 2, most parts of the country are located in hot desert climates. These areas show climatical features with limited annual precipitation, low humidity, warm-arid, and limited water resources (Geography Dünyası, 2021). So there is a decrease in the number of settlements in these areas. However, the margins of the desert areas have a milder climate in comparison to the central areas. Nevertheless, throughout history, people have been living in the margin areas due to the applying sensitive climatic design principles for controlling the harsh climates condition. According to Pirnia (2005), Iran's traditional buildings in this area have been constructed based on five design principles (Figure 3). These principles are;

1. Human scale,
2. Introversion,
3. Independence / Autonomy,
4. Purposefulness (Avoiding Emptiness),
5. Structure and Modulation.

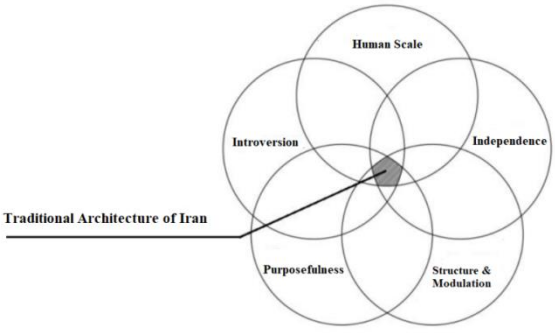

Figure 3: Design principles applied in Iran's traditional architecture (Adapted from Pirnia, 2005).

In addition, besides these designing principles, traditional architecture utilizes geographical location, bio-ecology, and climatic conditions. In buildings, human comfort is provided via building orientation, building form (introversion), central courtyard system, benefiting from the sun's rays or being protected, roofs and coverings, wind traps, windows, materials, and colors (Kasmaee, 2003).

This research has prepared a comparison between sustainable architectural principles and Iran's traditional architectural principles. There are similarities between Iran's traditional architectural principles and sustainable architecture even though they belong to different periods. Figure 4 transpired the common concept and similarities. Due to this diagram, in today's terms, it is possible to say that the climate-responsible designing or sustainable architecture design approach has been utilized in the traditional architecture of Iran for centuries.

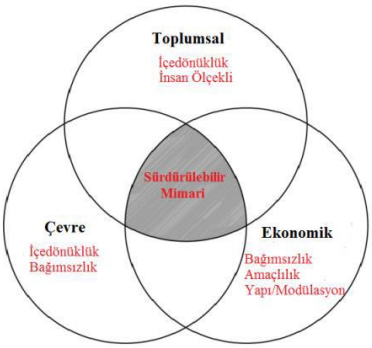

Figure 4: Comparative sustainable architectural principles and Iran's traditional architectural design principles (Mikaeili, 2021)

2. Ab-Anbar Architecture

Water is the most significant source of life, and daily demands of water supply have always been one of the most necessary concerns of humans. Especially the issue's importance is apparent in areas with limited water sources and hot-arid regions. Ab-Anbar is an underground water reservoir building in the historic architecture of Iran. The past architects of Iran found an intelligent method by utilizing climate-responsive methods and sustainable architecture to store water. They applied climatic designing principles in designing the Ab-Anbar building. Ab-Anbar is a Persian word that means water reservoir. The function of Ab-anbar buildings is to have reserved rainwater and keep cool water for use by people. Ab-Anbars buildings in each region are in harmony with their environment and natural limitations.

Today many historical Ab-Anbars are persisted in some regions of Iran. These buildings have been constructed on city squares, neighborhood areas, bazaars, social complexes, villages, private houses, and even on passing routes of caravans outside the city (Mikaeili, 2012). Ab-Anbars are known urban public open spaces elements and created the city image in the urban landscape as landmarks or nodes, increasing the readability and perceptibility of the urban areas.

The capacity of these traditional public water reservoirs depended on the population of the settlements. The underground water channels or Kariz[1] (Qanat) provided the Ab-Anbar's water. Figure 5 presented some views of the traditional building of Ab-Anbars. Due to the climatic zone of Iran in Figure 2, traditional water reservoir buildings will be investigated in hot-arid and hot semi-arid regions. The investigation is based on the Ab-Anbar types, architectural elements, construction materials, and construction technic.

[1] Karis (later called Qanats in Arabic) is man-made a combination of below and above-ground channel systems used to bring water to a settlement or fields from a natural source, say an aquifer, mountain spring, or lake. The system originated approximately 3,000 BC in what is now Iran (Zoroastrian Heritage, 2023).

Figure 5: Several views of Ab-Anbars with badgirs towers (wind-catchers)

Ab-Anbar Classification: Today many historical Ab-Anbars are persisted in some regions of Iran. Each of them is in harmony with their environment and natural limitations. The classification of Ab-Anbars is prepared due to its location, function, and building form. The Ab-Anbar can be classified into two groups:

1- Public Ab-Anbars are located in public open spaces of a city or village. These groups are known in the urban area based on the dome roof and entrance gate. These groups are public open spaces were bulk and accessible to all. The water of qanat and precipitation were the water source of this group.

2- Private Ab-Anbars locate in the underground level of personal houses. These groups have flat, unseeable roofs from the outdoors and are smaller than the public type. The water source of this group is only Kariz's water (Daiiallahet et al., 2014).

Ab-Anbar architectural elements and functioning: The tank of Ab-Anbar is a circular or rectangular pit in a depth of 10 to 20 m, covered by a dome roof and accessed by a stairway leading down to its entrance (Saeidian, 2013). The main objective of ab-anbar construction is to provide a waterproof cistern for a large volume of water while allowing for proper ventilation and access. Figure 6 illustrates the architectural elements of Ab-Anbars which settled in public open spaces. In historical cities, silhouettes are visible only in domes ve badgir towers of Ab-Anbar in public open spaces.

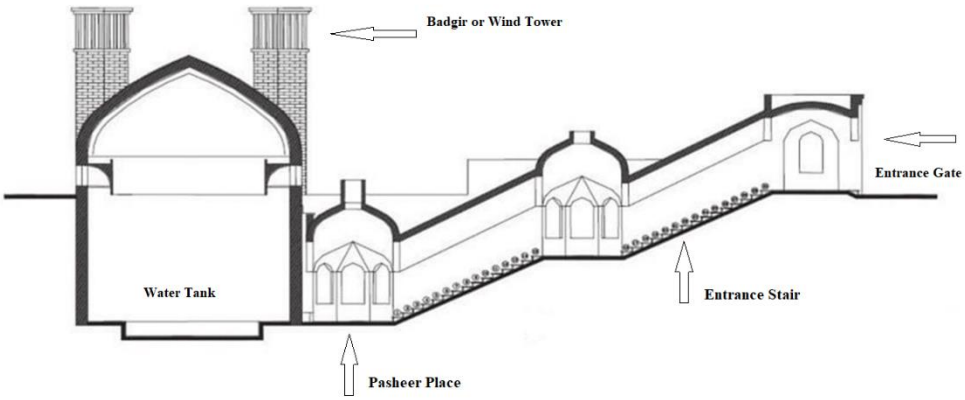

Figure 6: Architectural Elements of Ab-Anbar (Adapted from ICQHS, 2023)

The architectural elements of An Ab-Anbar consist of:

1-Water tank: A water reservoir that is cylindrically or square-shaped and below the ground surface. The water flows to the tank via underground canals.

2- Roof: A dome roof built over the reservoir, which keeps the water cool.

3- Badgir: Badgir or wind tower is a vertical channel for bringing in the air current inside the building in order to protect the water from spoiling and saving cool.

4- Entrance Gate: A decorated gate as an entrance place connected to underground stairs.

5- Pasheer: The meaning of the Persian word Pasheeer is a platform with a faucet, which people use for taking water from the reservoir (Saeidian, 2013).

Ab-Anbar construction: The construction technology has been embodied in Ab-Anbar structures is unique. The buildings needed to be strong to resist the water's high pressure and the region's massive earthquake. Construction on the underground was an answer to these demands. On the other hand, this system helps to gather the underground water of Kariz flowing to the ab-anbar tank by gravity. In designing of Ab-Anbar has been using seasonal temperature changes and isolation in the ground. Water was kept cool and clean by using traditional architectural techniques. During the winter, the water accumulates in the reservoir, and in the summer, the dome roof decreases the heat of the water and ventilates inside the building. Badgir or wind towers are built on the edge of the dome roof, directly on the upper part of the water cistern wall, and connected via a duct to the Ab-anbar chamber (Gholami, et. al. 2015, Daiiallah et al., 2014). Badgir or wind tower is a high tower on top of the roof that works with the thermal air convection method. Wind catchers rely on local weather, microclimate conditions, and wind direction. Wind catchers vary dramatically in shape, including height, cross-sectional area, and internal sub-divisions and filters. The construction of a wind tower depends on the prevailing wind direction at that specific location. Fresh air enters via these ducts inside the Ab-Anbar chamber, circulating and keeping water cool (Mikaeili, 2021). The upper layer of water evaporates and exits from the reservoir with the air flowing in the air trap. A barrel-vaulted ceiling covered this stairway. The water of Ab-anbar remains cool since the cistern is built at the underground level and insulated by very thick walls (Mikaeili et al., 2012), (Figure 7).

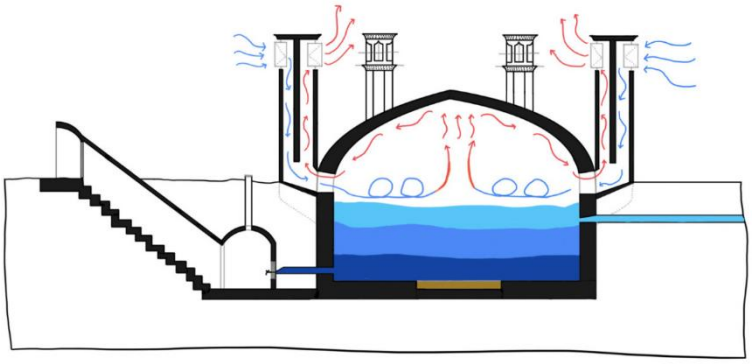

Figure 7: Badgir ventilation system in Ab-Anbar (Bauten Entdecken, 2023)

The Ab-Anbar's construction material: The construction material consisted of baked brick with special lime mortar. The walls of Ab-Anbar's tank build burly and thick with superb insulators, preventing the warming and freezing of the stored water. The thickness of the water cistern's walls, commonly nearly or more than two meters, has been built using specially baked bricks called Ab-Anbar's-Brick. The special mortar called Sarooj is an Iranian special traditional water-resistant mortar used in bridges and ab-bars. It was prepared of sand, clay, egg whites, lime, goat hair, and ash in specific proportions, depending on the location and climate of the city. Clay and limestone were mixed in a six-to-four ratio to make a stiff mix and knead for three days. A portion of furnace slags from baths is combined with cattail (Typha) fibers, egg, and straw, and fixed, then beaten with a wooden stick for even mixing. Egg whites can be applied as a water reducer as needed (Gholami, et. al. 2015). After preparing the cistern pit, the bottom of the tank is covered with lime mortar. Following the mortar hardens, the builder erects the walls of the tank, made of baked brick or stone. The construction bricks are soaked in water before being laid. (Yousef, et al., 2021).

Conclusion

Throughout history, different civilizations have made an effort to adapt to the natural environment where they lived. Adapting to the natural environment is recognized by location choice, water

resources, use of natural topography, and utilizing climate-responsive design in the building. The ancient architects have noticed and applied responsive climatic design, using sustainable construction methods, durable and long-lasting local materials, building form, and roof construction methods in traditional architecture. Recently one of the interesting architectural issues is sustainability in architecture to reduce environmental damage and protect natural resources. Sustainable architecture aims to convince a balance between architecture and the natural environment by utilizing climatic responsible designing methods. In the scope of sustainable architecture is a balance established between the natural and artificial environment by using vernacular architecture methods. Sustainable architecture design principles include building orientation, building mass, utilizing renewable energy sources, natural ventilation, climatic responsible landscape design, and water management. Although the concept of sustainable architecture is a current issue, it employed as a method used in architecture for centuries to adapt to environmental conditions.

The focal point of the study is the sustainable architectural concept in Ab-Anbar traditional public building in Iran's urban open spaces of historical cities. The traditional architecture of Iran has developed based on the needs of people and environmental conditions like the most traditional architecture in the World. Iran's traditional buildings have formed as a result of thousands of years of evolution according to the environmental conditions and climate. The use of sustainable architectural methods in traditional architecture establishes a quadrilateral relationship with the human-environment-settlement society. In this study, the utilization of sustainable architecture methods in traditional Ab-Anbar buildings has been compared to similar characteristics in new sustainable buildings:

- Natural ventilation, providing airflow by utilizing a wind-catcher (badgir),
- Reducing internal heat production and transmission gain in hot seasons,
- Minimizing solar energy gain,
- Reduction of external surfaces,
- Climate-responsive landscape design and use of water sources
- Utilizing vernacular construction material in an economical way.

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