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Review Article

EXPLORING PATTERNS OF SUSTAINABLE ARCHITECTURE AND ENERGY MANAGEMENT IN TRADITIONAL WATER STORAGES

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ABSTRACT
Although in the modern world, sustainability and sustainable development are newly proposed topics, by looking at the sustainability of traditional Iranian architecture we find that sustainability has long been considered in Iranian culture. Iranians were also meticulously careful about dealing with the environment to meet their needs and made the best use of the least facilities without harming the environment, and showed creativity in responding to their needs. In fact, Iranian architecture takes advantage of all facilities and surrounding areas. This productivity does not undermine and destroy the natural environment, and at the same time strengthens the surrounding nature. Understanding and detailed study of the water storage constructions and their characteristics and comparing them with the principles of sustainability would help sitaute them in sustainable architecture and energy management as a pattern. This study addresses sustainable patterns of energy management in water storages. This research is a qualitative study and data collection tools were objective observation and library resources and documents.

***Keywords**: Sustainability, Energy Management, Water Storage, Principles of Sustainability*

INTRODUCTION
Due to technological advances in extraction of groundwater energy resources which can help satisfy the eating and cooling needs, people were increasingly driven towards the use of these resources and gradually the traditional methods, and solutions consistent with nature were forgotten and technology which should have been used as a tool, were considered as aims. This technology- based attitude has played a considerable role in endangering the environment and awareness of this made the issues related to the sustainability important.
Our predecessors, however, were very conscious in dealing with the environment to meet their needs and made the best use of the least facilities without harming the environment and showed creativity in responding to their needs. In the past Iranian architects took advantage of all facilities and surrounding areas. This productivity not only did not undermine and destroy the natural environment but also strengthened the surrounding nature (Haeri, 2009).
A large part of Iran climate is hot and dry with little rainfall. Meanwhile correct understanding of climatic and local – geographic characteristics makes the traditional society to devise innovative methods such as water storage as a consistent element with climate to compensate for the vital problem of water shortage. As a result, water storage was considered in seasons in which atmospheric precipitation is higher for use than other seasons (Memarian, 1993). With understanding and a detailed study of the water storages and their characteristics, and comparing them with the principles of sustainability, we classify water storages as sustainable buildings.
The present study, therefore, first focuses on sustainable architecture and principles of sustainability, and then through a comparative approach compares the principles of sustainable architecture and water storage. The research is qualitative descriptive-historical study. The data under study were the traditional architecture of the desert and arid climates. Data collection tools were library sources including documents, maps and first-hand data such as opinions and objective observations.

LITERATURE REVIEW

Significant researches have been conducted on water storages, among which GholamHossein Memarian's valuable book, "A journey into Water storages of Yazd, University of Science and Technology Publication, 1993" can be cited. Pirnia, Varjavand and Ghobadiyan also have provided valuable works in this field, but the present study emphasizes on stability of the patterns in water storages.

SUSTAINABLE ARCHITECTURE AND SUSTAINABILITY PRINCIPLES

The application of concepts of sustainability and sustainable development in architecture created new topics such as sustainable architecture or green architecture and environmental or ecological architecture, all with the same sense and a common purpose which imply an architecture compatible with the environment. The use of non-renewable resources should be reduced to achieve sustainable architecture and efforts should be made to enrich the natural environment. An architecture is sustainable in a system when systematic and coordinated management accomplishes high efficiency in using of renewable resources, avoiding contamination and compatibility with the environment. Architecture should be like a pomegranate tree, like a machine in nature, and be compatible with nature to strengthen the nature (Iravani, 2006).

Some of the principles that should be considered to include a building as a sustainable architecture are as follow: energy conservation, compatibility with climate, compatibility with the site, holism, using of renewable energy sources, using of local materials, reducing energy consumption and improving human health, understanding of the environment and environmental impacts, respecting users, considering needs of residents, reducing use of new resources of materials, using natural materials, using ecologically safe materials, using recyclable materials and materials which do not create pollution (retrieved from http://www.arch.hku.hk/research/BEER/sustain.htm).

WATER STORAGE

Water storage was one of the initiatives of the Iranians from the far past which was used to save water and was not just for hot and dry areas. It is also used in some northern cities such as Gorgan, Sari and around the Persian Gulf (Memarian, 1993). Water as a holy and vital element had always a significant role and what made it more important was heat and drought in many areas. Iranian people never have surrendered to limitations and shortcomings, rather they have tried to cope with the environment creatively and what have made them creative and innovative is this attitude and the way they deal with obstacles.

HISTORY

Iranians since ancient times due to lack of water in most areas valued water and established great temples to worship the guardian god of water, Anahita (Nahid). One of the oldest examples of Water storage in Iran was obtained besides the Choghazanbil area, related to the second millennium BC during Elamite civilization flourishing era (Varjavand, 1978). There are many remains of Water storage and waterways in the palace of Persepolis from the reign of the Achaemenid (Memarian, 1993).

On the northwest wall of the Duruntash in which Choghazanbil temple is located a Hydraulic structure was built that a substantial part of it was unearthed intact. Some people regard this structure as the oldest water treatment plant on earth. A small tank of water in the inner side of wall and a large tank of water behind the wall to a volume of 350 cubic meters, outside the city, are made which were connected through brick waterways (KhajehAbdullahi, 2004). In the Islamic era, the critical role of water storages in the context of cities especially in desert fringe cities and low-water region of Iran, the evolution of designs and constructions, and their artistic and ornaments dimension (especially at the entrance and additional inscriptions to them) are so remarkable that some examples of these architecture phenomena are paralleled with some of the great mosque, palace, tombs and other monuments of Islamic architecture in Iran in terms of artistic, cultural, technical and historical value (Varjavand, 1978).

DIFFERENT TYPES OF WATER STORAGES

Different types of Water Storages by location (Memarian, 1993):

- Dessert- agricultural water storages These water storages had been built in the desert so that farmers in the warmth of spring and during cultivation and harvesting used the water of these storages and besides them usually temporary shelters were also built for farmers to rest.
- Rural- urban water storages In many cases, in terms of performance the architecture of rural and urban water storages are not different. Only in a few villages the form of rural water storages are simple compared to that of urban water storages. Water storages usually were built in center of neighborhoods and manufacturers had been trying to build them next to the mosques, Hosseiniehs and markets.
- Midway water storages These water storages watered thirsty and tired travelers and were located near inns and shelters.

DIFFERENT PARTS OF WATER STORAGES

1- Tank
2- Access route
3- Bottom-valve
4- Entrance and forecourt
5- Windward

Tank

It is a cylindrical shape to save water in it which is embedded in the earth and because of static problems (to prevent the water pressure on the body) is located within the ground and is the main part of a water storage (Pirnia, 1992). For constructing the tank the ground was excavated about 15 to 35 meters and depending on the tank cover the architectures implemented the plan (Emamia, 2006).
The floor of the water storage was laid concrete. Pirnia (1992) stated that to resistant the floor of water storage and to prevent deformation of it the bottom layer was covered with a layer of lead. Agha Mohammad Khan removed the lead on the bathroom floor of Ali Mardan Khan, located in Ganjali Khan Kermani Square, for example, and made bullets with it.
Typically, after excavation the floor was laid a concrete and then the bricklaying process was started. The thickness of the wall was three bricks and the thickness of concrete behind it was about one meter.Walls and the floor was covered with black ash mortar. (Memarian, 2005).
Water storage tanks were often spherical and domed and in some cases they were conical or flat so the roof surface could be used. In the tropical region of the country the outside wall of the dome was covered with a white mud to absorb less sunlight. This white mud had good resistance against humidity and because of its white color prevented excessive warming of water in the tank.

Access route

Access to the water was possible through a staircase, although in the case of desserts, water storages were located in sloppy lands. Given lack of direct contact with the water and preventionof water pollution, the staircase method was more sanitary. Naturally, the number of steps of water storages changes with the depth of access route, and depth of the route was also proportional to the depth of the tank. As a result, the number of steps depended on the height of the tank and the water storage depth was lower than the staircase landing. Due to the urgent need for saving water, the height of a water storage reached to about 16 meters. For example, Shah AbulQasim water storage in Yazd has 76 steps (Memarian,1993) and Kashan water storages have 45 to 80 steps (Emamian,2006). Providing enough light for staircases were also taken into consideration and by opening part of the route or creating open large vertical channels, the light would be shed on staircase path. Some water storages in Yazd had two staircases, one for Muslims and one for Zoroastrians.

Bottom-valve

Bottom-valve is a section in large brass valves connected to water storage tank. In this part there was a pit which was built under the valve to enable people to easily remove water from the pit. bottom-valvearea was constructed right after the last step of the stairs and was usually an area of about 15-30 square meters (Memarian,1993). A bottom-valve may resemble a half octagonal, square or quadrilateral. The combination of square and half octagonal shapes were also used (Emamian, 2006).

Sometimes this small space had platforms to sit on, and its coolness and air conditioning provided suitable place to stop and have a chat during the summer. At the corner of this space, there were wells or wastewater channels, waste water, or the cleaned water removed through the channel in storage tank. Sometimes a ventilation channel on the ceiling helped the air conditioning of bottom-valve area. What is important is that the lowest valve of the water storage should be placed about one meter above the bottom of the tank to collect inside the valve sediments and mineral deposits in the water tank.

Entrance and forecourt

The entrance leads to water storage and stairs. The entrance of water storages in addition to its primary function as a communication space in terms of visual and cognitive communication, is an interface space and a bridge between the water storage and urban space, representing the social and architectural identities of water storage.

Windcatcher

Windward was used to keep water cool and clean. Windward circulated the air inside the tank using natural and free wind energy and kept water cool. In water storages in which there were no windcatchers, ventilators were installed on the ceiling to flow the air. These arrangements were used even in water storages without windcatchers.

The direction of the windcatcher shelf was adjusted according to the wind direction. In this case, the windcatcher to the wind direction played a sucking role and took cool air into the tank and the windcatcher against wind direction carried the air out of the tank and as a result windflaw caused the air and water remain cool (Memarian, 1993).

In some cases the windcatcher was like a circular aperture, up to 50 centimeters in diameter and a height of about 20-30 feet from the roof surface of water storage, and was built like a stokehole. It was used to ventilate the water storage air including a bottom-valve area and the staircase and to provide enough light for the water storage. The number of windcatchers of the water storage varies from one to six. In some places, water storages had no windcatcher but instead they had wind-tunnel. In some places by using a windcatcher, water in the tank was so cool thatit was difficult for the teeth to tolerate its coldness (Pirnia, 1992).

Water storage materials

Technologies of the building and construction methods in water storage buildings have a specific validity because the architects of these units would carefully consider main points such as: the amount of water pressure to the bottom and all sides of the tank, plastering of the inside part of the water storage, ventilation, filtration, water pollution prevention, and many other issues (Javadi, 1984).

Materials used in the construction of the impounding part was made up of mortar. The raw material for mortar is lime, while for strengthening and retrofitting of buildings, lime is important for water disinfection. Two types of bricks were used in the construction of water storage: raw and Kiln-baked bricks, and black-ash mortar and cement. Generally,, these combinations made a strong building. There were special light yellow bricks called *water storage bricks* for the back part of water storage that were only used for water storage construction (Pirnia, 1992).

To fill water storages, water usually was brought from the mountains, was filtrated through sandy ponds, and was conducted to the water storage. The cleanliness of the tank was very important and it was done very carefully. There was a place under the tank to discharge sludge and it usually demanded several strong people were used to do it. They wore fluffy dresses for cleaning and getting into the tank and evacuated sludge with a rope and wheel-wells from an embedded hole. Lime and salt was poured into the water to prevent putrescence, so a layer was created on water and if the layer was torn, water would be putrefied and was unusable (Pirnia, 1992).

After filling, and when the tank was filled with water, some salt and a little lime were added to it. Neighborhood residents believed that the harvesting and using water in a newly filled water storage is not permitted. In this period, the water in the tank would filtrate itself; in this way, larger bacteria and aquatic organisms eat small bacteria till larger bacteria and aquatic organisms perish from hunger. Lime and salt would help water disinfection, and gradually minerals were deposited in water bacteria and other organisms' bodies came at the surface and a layer was formed. This layer prevented absorbing air into water. During two to three weeks these interactions result in c learing, lightening and relative filtration of water. This method provided clean water to residents. The main causes of putrescence including air, light and heat were away from the building (Emamian, 2006).

SUSTAINABLE PATTERNS OF WATER STORAGES

- In water storage buildings, construction technologies, architectural styles, and attention to environmental climate issues to provide clean cool and accessible water to all residents were notable, and what water storages resting in the heart of hot desserts are wonders of the world. They represent careful and discerning local architects and builders of these buildings who have carefully considered main concerns such as the amount of water pressure to the bottom and all sides of the tank, plastering of the inside part of the water storage, ventilation, filtration, water pollution prevention, and many other issues(Hosseini, 2009).
- Water storages provide their energy from the site.
- Ventilators and windcatchers are used to ventilate and circulate air in the water storage, using natural and free energy of wind
- Water storages are compatible with the site, the context, and regional climate in which they are located, and has evolved and formed through changing conditions.
- In Iran Vernacular Architecture architects have always tried to get their needed materials from the nearest places, thus the building have been made more quickly and more compatible with their surrounding nature. At the time of renovating, also, materials are always available (Pirnia, 1992). This method is considerable in water storage formation.
- In the construction of water storages, the use of indigenous materials such as clay, mud and brick cistern is quite remarkable. It is worth noting that due to the principle of self-sufficiency in Persian architecture, this method has been always considered. According to the environmental conditions with high amount of soil and low amount of water, the use of mud and brick materials is very reasonable and environmentally compatible. Limited need to water for clay molecular connection is matched with low water conditions.
- Minimal manipulation of the environment has occurred. Clay is generated with little change in and maximum harmony with its surroundings, and it is also the most economical materials. In making materials, the use of bed soil of structure without leaving traces of soil or waste and low consumption of water, which was in subterranean usually at a depth of about one floor, causes much of needed materials be provided from the construction site to a minimum energy consumption and illegal additives. This is one of the most important indicators of sustainable architecture, because materials extraction from nature, reshaping of environment, changing the nature of the materials in the factory and transporting them to the site typically consume largest amount of energy and create most pollution to the environment. In this case all these points have been removed (Ahmadi, 2005).

• Indigenous technology and sophisticated techniques of construction and transportation of Materials have been used in the construction of water storage. Regarding abundant soil in plan place and low consumption of water, about 10% for humidification, there is no pollution due to changing nature of the materials (Ahmadi, 2005).

• Water storage have emerged with limited, simple, inexpensive and available facilities at their local conditions.

• Cooling process of water in water storages is carried by means of natural and inexhaustible energy resources.

• Water storage tank locates in the heart of the earth so minimal heat exchange takes place and through windward, directed wind flow energy is used to ventilate and cool the water and the air.

• Materials used in the water storages are easily recyclable in nature and do not create any kind of pollution and loss.

• In the summer mud brick dome cover stores sun's heat during the day and returns the heat to environment during the night- because mud brick materials have high thermal capacity and gradual accumulation of heat and conductivity properties- thus the heat is kept away from water because of spaces created by the dome. As a result cool water is available in hot desserts.

• The use of deep earth energy is another significant specification of water storage. The remarkable thing is that the earth not only gives off heat energy but also is a good place to save energy. Locating a building under the ground solves many needs and problems related to climate. Thus, the tank which is located under the ground causes minimum energy fluctuations due to the energy of deep earth.

• Earth is a huge reservoir of energy. This energy can be employed for human welfare. Atmospheric conditions and temperature fluctuations have very little effect on underground structures and the Earth's crust, such as a retaining, protects the building against changes. Storms and wind cannot penetrate into the ground and earth's crust, as a great thermal insulation, prevents the heat transfer into the ground. As a building is in the greater depth of the earth, temperature changes are lower, because the soil thickness is greater. Temperature is almost constant from the depth of 6.1 m into the ground and is equal to the average annual temperature of the outside (Ghobadian, 2003)

CONCLUSION

The legacy of our predecessors in the form of vernacular architecture is a precious asset. Through study and understanding of this architecture style, it becomes obvious that creators of these buildings provide a sustainable architecture. This architecture does not impose any harm and damage to the environment and is amazingly compatible with the environment. This architecture is the result of a long experience of the coexistence of man and nature and tries to coordinate its environmental, climate and natural environment. Traditional architecture of Iran does not seek to overcome or ignore nature or to benefit from it. In traditional architecture, special attention is given to climatic factors and design, and construction of buildings are based on climate conditions. In this architecture, each building is designed and implemented on the basis of its cultural, social, historical, physical, climatic, and specific circumstances of the context and the building is a consistent member of ecology and a harmonic component in its environmental atmosphere. Iranian architecture does not seek benefit from the environment and always tries to accommodate and adapt itself with conditions and changes limitations into facilities and opportunities.

Water storages are clear evidence of the importance of sustainable patterns of vernacular architecture. Therefore, along with technologies usually imported from the West, we can rely on Eastern capitals and seek to recognize and benefit from Eastern vernacular architecture.

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