Wind tower a natural cooling system in Iranian traditional architecture

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ABSTRACT

This paper is a synopsis of the results of a research on form of wind towers. Wind tower is an architectural element in traditional architecture of Iran. It can be seen in cities with hot-dry and hot-humid climates. This analysis demonstrates wind towers' characteristics with emphasis on their morphology.

1. INTRODUCTION

Wind tower is a key element in traditional architecture of Iran. It is seen in settlements in hot, hot-dry and hot-humid climates. They look like big chimneys in the sky line of ancient cities of Iran. They are vertical shafts with vents on top to lead desired wind to the interior spaces and provide thermal comfort. This architectural element shows the compatibility of architectural design with natural environment. It conserves energy and functions on the basis of sustainability principles.

The result of this research shows that traditional architecture can give ideas to enrich modern architecture. In traditional architecture of Iran, climate, local materials and renewable energy resources have been used. Wind tower shows the harmony of human built environment with nature. Traditional building techniques were normally well adapted to the climate. However, the modern way of life and imported western technologies have often replaced the established traditions in the design of the buildings. There examples which reflect the way people organize their environment in various forms. This paper shows different forms of wind towers adopted by people in different situations. Wind towers are described in terms of their function, structure, details, components, ornaments and form.

2. HISTORY AND DEFINITION OF WIND TOWER

Wind is one of the important elements for studying the climate. One of its important users is the provision of comfort in hot region. This is because the wind current creates a difference in pressure on the exterior walls that has an effect on the natural ventilation and interior air temperature of a building. For architects, the wind is an important factor in the design of a building. They consider the wind's effect on the thermal comfort through convection or ventilation and the penetration of air in interior spaces.

Wind has been given much attention in urban design, and in particular in cities with hot weather such as Yazd, it is to be seen clearly from the images of the city. The effect of the wind on building forms is recognized through the use of formal features such as wind towerwhich provides for the best use of the wind for the comfort of the occupant. Thus, along the northern shores of the Persian Gulf and the sea of Oman, architects have known how to make effective use of the sea breeze. They have achieved this by designing the wind towerwith an opening towards the breeze for the maximum use of natural ventilation.

Wind towers as their name implies, are ventilation tools used for obtaining natural cooling. They have been used for centuries in countries with hot-arid climates, particularly in Iran. Wind towers in the central cities of Iran are known as "badgir" which literary means wind

catcher. Wind towers not only appear on top of ordinary houses but also can be seen on top of water cisterns, mosques. The first historical evidence of wind towers dates back to the fourth millennium BC. An example of a simple wind tower was found in Iran by a Japanese expedition in a house from the site of Tappeh chackmaq some eight kilometres north of Shahrood and the southern slopes of Alborz Mountains in north eastern Iran. Wind tower comprises a tower with one end in summer living quarter of the house and the other end rising from the roof.

Wind tower is divided into several vertical air passages by internal partitions or shafts. The shafts on top terminate in to opening on the sides of the tower head. The flow in side the wind tower is in two directions, up and down. Namely, when the wind blows from one direction the windward opening will be the inlets and the leeward opening will be the outlet and vice versa.

3. ORIENTATION AND FUNCTION OF WIND TOWER

The orientation of wind tower generally means the positions of the wind tower flank based on the four main geographical directions. It is determined in view of function, use of wind power and the desired direction in which the wind blows. There are one-directional wind towers in Meibod, they are facing to the desired wind and in some cases one directional wind towers act as air suctioning and the air flow turned its back to the wind to locate itself in a negative pressure region to cause warm air in interior to blow out of the house. The desired wind currents in Yazd blow from the north-west. The long sides of wind towers are, therefore, oriented towards the north-west for maximum usage of the wind to provide cooling for buildings. In coastal regions like Bandar Lengeh, buildings have an east-west orientation. Sea breeze that blows during both days and nights but the most desirable wind blows from the east to the west.

Wind towers are therefore, built with a four-directional orientation in order to use all of the desirable winds from north to south and from east to west (Figs. 1 and 2). Orientations of wind towers are different according to the blow of main desired wind.

A Wind tower is a formal structural element

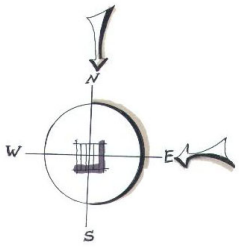


Figure 1: Orientation of wind towers in Bandar Lengeh.

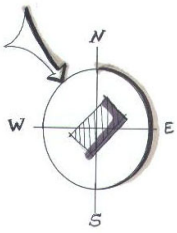


Figure 2: Orientation of wind towers in Yazd.

in Iranian architecture that is used to convey the wind current to the interior spaces of buildings in order to provide living comfort for occupants. In Iranian architecture a wind tower is a combination of inlet and outlet openings.

The tunnel provides cool air for the building while serving as a conduit through which the stuffiness within the building is conveyed through its shaft. There were wind towers in Bam which were destroyed by earthquakes; they weren't directly connected to the living hall. They were built away from the house. An additional underground tunnel links the base of the wind tower to the basement.

In most wind towers, especially the four sided types, the tower is divided by partitions. One of the shafts operates all the time to receive the breeze and the other three shafts work as outlet air passages. They convey the stuffiness out of the living space through the “flue” (chimney) effect. The chimney effect is based on the principle that the air density increases with the increase in temperature. The difference in temperature between the interior and exterior parts of a building and between different regions creates different pressures and result in air currents.

The average relative humidity in moisture in hot and dry regions is low and it is necessary more humidity there for wind towers are used to provide living comfort through the use of the air current and evaporation. Through the wind tower, the air current first passes over a stone pond and fountain after entering a building, thereby bringing humidity to the other spaces in the building (Fig. 4).

In some places, mats or thorns are placed within the wind tower, and users pour water on them in order to increase the humidity and the

coolness of the air flow. The hot weather in Yazd has the potential effect of causing water to evaporate easily to develop cooling in the living spaces and relative humidity in the air, thereby reducing the heat and dryness.

It is clear that there is usually high humidity in hot and humid regions because of their being in vicinity of the sea. In these regions, wind towers reduce the temperature of the weather only through the movement of the air they facilitate, not through increased humidity (Fig. 3). The level of humidity in this region is already high and an increase in the humidity would make living conditions troublesome.

A wind tower in a hot and dry region brings about comfort by evaporation and air motion but a wind tower in a hot humid region only moves the air and conveys the wind into spaces. Different function and shapes were designed for different climates (Figs. 5 & 6).

4. CATEGORIES BASED ON FUNCTIONS

The tower head may have vents on one, two or four sides that face the predominant wind direction to accommodate wind in suitable directions. Wind towers are often described by the number of directions in which they face; such as one directional (yek-tarafe), two directional (do-tarafe), four directional (char-tarafe), and eight directional (hash-tarafe).

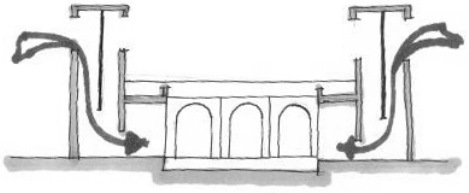


Figure 3: Function of tower in hot and humid.

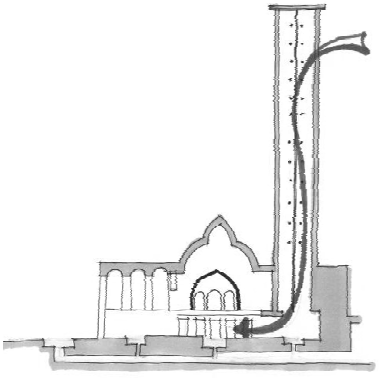


Figure 4: Function of tower in Yazd.

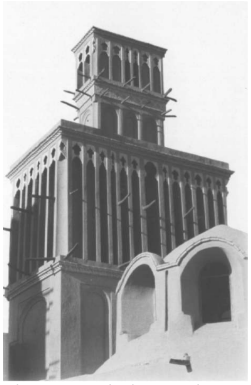


Figure 5: Wind tower in Abarghoo.

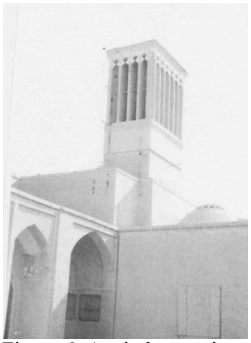


Figure 6: A wind tower in Yazd.

4.1 The one directional towers (yek- tarafeh)

These towers generally face north-west or north. They have a sloping roof and one or two vents only. Otherwise they are commonly described by the direction in which they face such as "shomali" or north facing. The survey of wind towers Roaf (1988) reveals that 3% of the wind towers were unidirectional in Yazd.

4.2 The two directional towers (do- tarafe)

The tower, in a simple example, is divided in to two shafts by a vertical brick partition. It has only two vents. They are often called by direction, such as north-south towers. Roaf's survey indicates that 17% of the towers are in this kind and all are made on the ordinary houses.

4.3 The four directional towers (chahar- tarafe)

Studies indicate that this is the most popular wind tower. They have four main vertical shafts divided by partitions. More than half of the wind towers in hot and dry region have been of this kind, as reported. They are so common locally called Yazdi. All of wind tower in hot humid region are four sided type.

4.4 The eight directional towers (hasht- tarafe)

According to the Roaf survey (1988) only 2% of the wind towers of Yazd are in this kind. They are most common on water cistern. The greatest

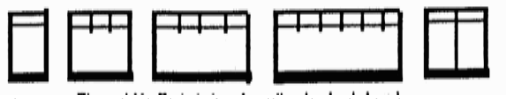


Figure 7: Typical plan of one directional wind towers.

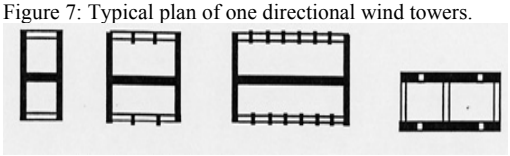


Figure 8: Typical plan of two directional wind towers.

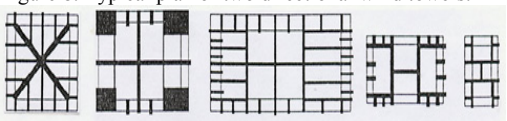


Figure 9: Typical plan of four directional wind towers.

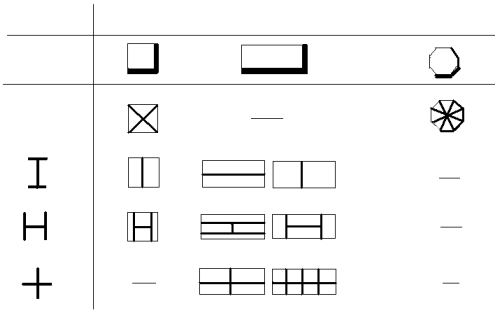
wind tower on top of bagh-e dolatabad has an octagonal plan.

5. CATEGORIES BASED ON FORMS OF PLANS

Forms of the plan were reported square, rectangular and octagonal. The square form is the type used in the four directional wind towers in Yazd. (Fig. 9) The rectangular forms consist of one, two, four directional wind towers. Eight directional wind towers are those with an octagonal plan. There are enormous range of size and dimension from 0.40 x 0.80 m to 5 x 5 m. in plan and the ratio between widths to length is 1:2 of which, is reported.

Partitions are component in wind towers to divide it in to several shafts. They are built of mud brick. These partitions form a plane grid of vents ending to a heavy masonry roof on top of the tower. Partitions can be classified in to group: main partition and secondary partitions. Main partitions continue to the center of the tower, forming a separate shaft behind the vents. These partitions often start between 1.5-2.5 m above the ground floor level. The patterns of the partitions vary from tower to tower, but the most commons are in forms of I, H and diagonal. Secondary partitions remain as wide as the external wall, about 20-25 cm. A shaft can be subdivided by a number additional partitions performing either structural or thermal role. These can separate the tower, respectively in two or four shafts. Wind towers could be categorized according to forms of the plan and patterns of the partitions (Table 1).

Table 1: Categories of wind towers based on plan.



Partitions divide tower to small shafts to increase air motion according to “Bernoly effect”. It express that air rate will be increased when air pass from narrow section. Such an arrangement provides more surfaces in contact with the flowing air, so that the air can interact thermally with the heat stored in the mass of these partitions. They act climatically in spite of aesthetic aspects. They work as fins of cooler window or fins of radiator because mud brick partitions give back stored heat during night and they are prepare to absorb heat. Warm wind contact with mud brick partitions there for its heat transfer to partitions after that wind with less heat enter to space.

6. MATERIAL, COLOUR, TEXTURE AND HEIGHT

The construction materials used for wind towers depend on climate. The choice of materials is made to ensure that the wind tower operates effectively as a passive cooling system. Wind towers in hot dry are built either of mud brick or more commonly of baked brick covered with mud plaster. Mud brick (adobe) passes heat at long time, because soil has got uncompressed volume and mud makes from water and soil.

After evaporating, there is made empty pit. It causes that heat and cool can not arrive in molecules of soil and mud brick or adobe. Mud plaster (kah_gel) is mixture of wet earth with fine or chopped coarse straw. These construction materials give the wind tower a coarse texture. The mud plaster covering the facade of a wind tower has a light colour and there for reflects rays well.

Wind towers in hot humid are covered with (gach) plaster and (sarooj) this type of covering

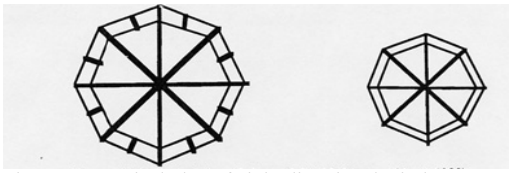


Figure 10: Typical plan of eight directional wind towers.

resists moisture. Vapor in the air in this region sits on the surface with temperature less that dew point in the environment. If there are high penetration on walls and surfaces of building, these drops penetrate in wall for the osmosis pressure or absorption of materials. It causes demolition of surfaces. It pushes salts of materials out of surfaces. The texture of wind towers is polished with a white colour, which also ensures that the wind towers do not absorb rays. It provides more operation in climatic function.

Wind towers trap the desired wind currents and transport these to interior spaces. To fulfil this purpose, a wind tower is designed to raise above roof the building. To enable its serve its function effectively through the appropriate utilization of wind currents, the ratio of its length and its width to height is important. Height of Wind tower in hot dry and hot humid is different. Height of wind towers in hot dry regions is more than hot humid regions. When the air current is closer to the land surface, it is warm because of the effect of the sunshine on the ground. Thus in a hot and dry region, because of the low temperature and a higher wind velocity at greater heights, wind towers are built higher to enable them to trap such currents. The residential regions in hot humid are built near to the beach. In the hot and humid regions, the temperature on the land surface is low and desired wind and breeze or current is at a lower level thus wind towers in such areas do not rise very high at their highest, they rise only one level above the roof. Since building levels in central plateau of Iran are also below the ground level, wind towers are designed to service two interior spaces in different levels: the basement space and the reception hall on the ground floor used in summer. Water surface in Bandar Lengeh is higher because of the proximity of the sea. Thus there are no basements in the buildings in this region. (Fig. 11) Here the transportation of wind currents at their minimum temperature is an important design objective for wind towers.

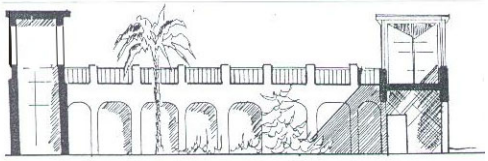


Figure 11: Section of a house in Bandar Length.

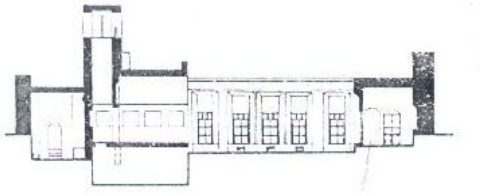


Figure 12: Section of a house in Yazd.

Survey shows that over 60% of all wind towers are less than 3 meters high above the roof parapet level and only 15% rise above 5 meters high. The higher towers carry the potential for structural failure, particularly in the head of the towers, which are weakened by a number of vents.

Shafts of wind tower in hot dry regions are longer than shafts in hot and humid regions. Firstly, because wind towers in hot dry areas serve to basement floor, and this service is not needed in hot humid regions. Secondly, the height of wind from the earth has also a role in determining the height of wind towers. If desired wind current is in low levels, wind towers must receive it in low height. Longer shaft also increases wind speed during the shaft.

7. STRUCTURE AND ORNAMENT

Body of wind towers soar to receive winds in the height. Open vents reduce resistance in front of horizontal forces there for it is clear importance of structural elements. Mud brick and timbers are used in the construction of wind towers (Fig. 13). Since a wind tower rises above a building, it needs elements to support it. The wind towers are built of mud brick or more commonly of baked brick and timbers. The main structure of a typical wind tower consists of a tower, several vents and partitions (Fig. 14).

Timber beams are used to support partitions at various levels and to fasten the structure together in order to increase the shear resistance of the tower. The beams are left to project out of

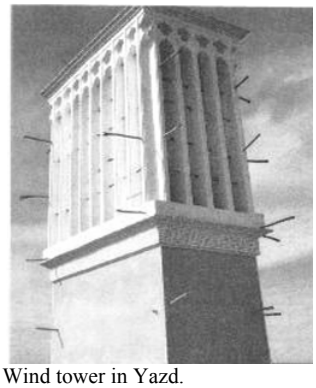


Figure 13: Wind tower in Yazd.

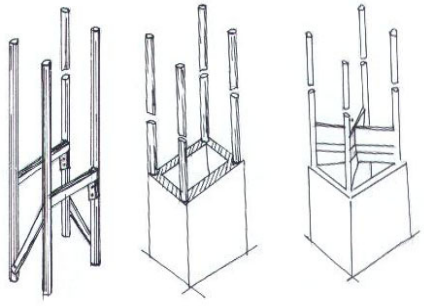


Figure 14: Structures of wind towers.

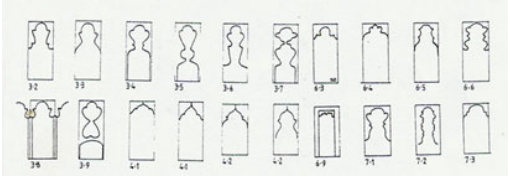


Figure 15: Examples of vent head details (Roaf, 1988).

the structure to provide a ladder and scaffolding for building the tower and for use during subsequent maintenance. Main and subordinate partitions are accounted as an element to support wind towers more.

There are two kinds of ornamental features in wind towers, which may be considered notable among Iranian ornamental architecture. The first comprises ornamental elements that are added to the body of the wind tower for aesthetic reasons. The second consists of ornamental elements that serve as functional elements. Features of the wind towers of Yazd that may be referred to as ornamental elements include the gach feature placed at the end of the fins in different shapes in a variety of arches. Each architect used a different type of arch according to his personal preference; it can thus be said that this type of ornamentation was his signature (Fig. 15). Such features are just for decoration and serve no other function. For example, brick rows are sometimes placed on the top and bottom part of the head of a wind tower, thereby probably creating a shadow effect on the body of the wind tower. These differences in ornamental elements are in now way connected with the climatic conditions and functional problems existing in these areas, but are rather a reflection of cultural features and effects.

8. CONCLUSION

In respect to the growing need for environmentally responsive architecture from one side, and from another side, the shortcoming in provision of electricity in many small cities and villages in Iran, the use of traditional wind towers are recommended. In large cities, in low and medium rise buildings, with new mechanism and some skills, the natural cooling systems can be renewed.

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