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Architectural Objectives in Tropical Climates

(Comparing Climatic Patterns in Vernacular Houses of Bandar-e-Lenge and Dezful)

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ABSTRACT: Effects of neglecting climatic patterns in buildings are more intense in severe climates such as tropical. It is resulting an excessive consumption of fossil fuels and consequently environmental pollutions in and after modern era. The objective of this research is to find climate-oriented intentions and solutions in tropical areas and compare them with Dezful and Bandar-e-Lenge vernacular houses to examine how differences in mesoclimates may affect the climatic pattern of buildings. The present study will initially classify the experts' viewpoints on the architectural patterns in tropical climates and prevailing targets, solutions, and will present features of the architecture in such regions. The solutions are tested on vernacular buildings of Bandar-e-Lenge and Dezful. The findings demonstrate that in the above areas, climatic solutions have been used to moderate high temperature and humidity. The local houses in Bandar-e-Lenge are in accordance with both climatic objectives but the houses in Dezful pertain solutions for only high temperature. Results also confirm that the difference can be observed because of the different sub climatic groups they are placed in.

Keywords: *Climate, Architecture, Tropical, Vernacular house, Dezful, Bandar-e-Lenge*.

INTRODUCTION

Man has always attempted to create his living environment consistent with climatic possibilities and limitations of his surroundings. These attempts have yielded a variety of settlement patterns in different climates, and have resulted in emergence of diverse species, each with optimal functioning in the region. Following the modern era, new technologies emerged in mechanical ventilation, heating and cooling systems by which run on fossil fuel that introduced the designers to new possibilities insomuch as buildings grew further dependent on such fuels. In contemporary architecture of Iran, buildings are constructed without due consideration of climatic features regarding the internal and external characteristics and regarding how the given structure is connected to its surroundings. Thus, the structures become uniform without special attention to climatic features. As a result, such similar buildings designed in different climates are not in harmony with their environment, and would not help with adjusting of environmental conditions.

In the climate-oriented house pattern, any particular space obtains its physical features under the influence of the climate, as a result of which, the given ensemble establishes the most desirable connection with its surroundings, and would tend to run on renewable energy supplies. Since climate is in fact one of the foundations of Iranian vernacular architecture (Me'marian, 2007), reading the basis of providing climate patterns for the hot and humid areas of Iran is helpful. Initially summing up the ideas of experts in regional architecture regarding architecture objectives and solutions in hot and humid regions, this research then compares and categorizes them, and studies them in houses in Bandar-e-Lenge and Dezful. Thus, this research has been meant to find out the difference between the Climatic patterns in houses of Bandar-e-Lenge and Dezful, because of slightly difference in their climate zones.

Significance and Necessity of the Research

Productions and consumption of energy and of fossil fuels in particular, has a great impact on the environment. Consumption of fossil fuels counts for emission of the major part of greenhouses gases produced as the result of human activities. Concentration of atmospheric carbon dioxide in the year 2005 measured as 35 percent greater than 150 years earlier (Power and Energy Planning Department, 2009). In 2008, Iran has been the second largest consumer of oil in the region standing next to Saudi Arabia. In the same year, the greatest surge in the consumption of natural gas belonged to the Middle East, with Iran ranking first (Ibid). A comparison of energy consumption rate in the buildings in Iran to its corresponding value in developed countries highlights the considerable difference between the pair of values (Ibid). According to the energy balance sheet published by the Department of Electricity and Energy of the Ministry of Energy, in 2008, one of the major consumers of energy in Iran is the domestic sector with 42 percent of the total consumption of energy (Ibid).

The issues of excessive consumption of energy and use of mechanical cooling and heating appliances in buildings without application of climate-based solutions began by the modern era and have continued to exist in Iran to the date

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due to the low cost of energy carriers. The above statistics indicate that the rate of energy consumption in Iran is considerably higher than the global average, and that the major share of consumption belongs to the residential section rather the productive one. Climate of the tropical regions in Iran is one of the severe climates across the globe. Thus, considering climate components of the region is essential to reduce the rate of energy consumption and increasing the level of comfort. Also south regions of Iran have sub climatic regions that may make differences in architectural patterns. This paper is comparing climatic attributes of Bandar-e-Lenge and Dezful to realize the differences in the architectural patterns due to different mesoclimates they are situated in.

MATERIALS AND METHODS

The method of analysis and resultant in this article is quality based and answer to questions are found by data gathering from chosen samples, classification, analysis and finally choosing related data and integrating them. Data gathering in introduction of vernacular house patterns are conducted by use of theoretical studies and analysis of houses available documents. In addition, the climate analysis is conducted by use of weather statistics of the towns. Research framework is defined while considering climatic objectives and architectural aspects of hot and humid regions based on experts opinion. Finally, the climatic patterns of vernacular houses of selected towns will be analysed and compared based on their level of response to climatic objectives according to research framework.

Comparison of Climate Attributes in Bandar-e-Lenge and Dezful[1]

Southern region of Iran has one of the most sever climates in the world, therefore considering climatic characteristics is essential in urban planning and designing in this area. Bandar-e Lenge and Dezful are listed among the towns in the southern region of Iran. Like other towns of the region, It is expected that they have the same climate and the same climatic patterns in vernacoular houses. Careful climate classification is the first and the most important activities in sustainable development in all regions. Koppen method is one of the most known and applicable systems of climate classification in the world. Koppen-Trewartha method is a modification from Koppens system with non-structural changes. By comparing the climate attributes of synoptic stations situated in the Dezful and Bandar-e-Lenge, with definitions of boundaries in Koppen-Trewartha method, two Climate groups are seen in these regions. They are as follows: tropical wet-and-dry type with dry summers (As) for Bandar-e-Lenge and subtropical type with hot and dry summers (Csa) for Dezful (Nikghadam and Mofidi Shemirani, 2012).

Studying the weather statistics of Bandar-e-Lenge station shows (Fig. 1 and 3):

Very hot summers (Max. mean daily temperature 34 degree centigrade) and moderate winters (Min. mean daily temperature 18 degree centigrade);

High relative humidity in both summers (max. 82% in 6:30) and winters (Min. 54% in 18:30);

97% of annual precipitation in winter and dry summers. Annual precipitation equal to 13.9 mm;

Situated in North West coasts of Persian Gulf;

Wind direction from south and southwest from May to November (7 months) and from south, from April to September (6 months).

Studying the weather statistics of Dezful station shows (Fig. 2 and 4):

Very hot summers (Max. mean daily temperature 36 degree centigrade) and cold winters (Min. mean daily temperature 11 degree centigrade);

Low relative humidity in summers (min. 18 in 18:30) and high relative humidity in winters (Max. 90% in 6:30);

93% of annual precipitation in winter and dry summers. Annual precipitation equal to 20.9 mm;

Situated in South East of Dez river;

Wind direction from south west from May to September (5 months).

Comparing the weather statistics and climate classification, shows some differences in Bandar-e-Lenge and Dezful, such as Dezful has cold winters, low relative humidity in summers, almost 1.5 times more precipitation, and less windy months than Bandar-e-Lenge. In addition, Bandar-e-Lenge in coastal areas of Persian Gulf has the benefit of sea breezes at nights and days. The difference between the temperature in summers and winters is more in Dezful than bandare lenge. The Fig. 1 to Fig. 4 Show the difference in two weather features of Bandar-e-Lenge and Dezful.

Architectural Features Influenced by Climatic Attributes in Hot and Humid Climate

In this part, perspectives of scholars about climatic architecture and its objectives, solutions and features in hot and humid climate are collected, compared and categorized as the research framework, in order to be tested on the houses of Bandar-e-Lenge and Dezful.

In these regions, men try to avoid the heat and radiation of the sun as it is seen in the tropical and subtropical regions (Fathy, 1986). They minimize the solar heat in the building and maximize the nighttime cooling (Givoni, 1998). Also built high so that each level provides a protective layer for the level underneath. Central courtyard is replace with narrow holes which make ventilation and lighting possible (Roof et al, 2007; Hyde, 2000), and create vaster shadowy surface. Outer, more exposed rooms facing the courtyard can protect the inner spaces from the sunshine and heat. In these regions, as one move to the lower floors, the heat is as well decreased, and the minimum temperature belongs to the basement (Roof et al., 2007). Some of the techniques have been used in vernacular houses in hot humid climates in experts' opinion are as follows:

Stretching the building in south-southeast direction (Kasmaee, 2003). Considering direction of the rooms and doors, and inclusion of belvedere and porch (Givoni, 1998).

Considering east-west direction, minimizing the width of eastern and western sides (Koch-Nielsen, 2002; Hyde, 2000)

Making shade by creating the vastest possible shadows and using wide shades in order to protect the house against the sun and rain, also using roofs in order to keep the sunshine out (Rapaport, 1996). Using deep porches (Hyde, 2000), and hanging and protruding balconies to cast vast shadows on the walls (Fathy, 1986). Outer walls are normally shadowed by awnings, belvederes, and latticed wooden windows (Roof et al., 2007).

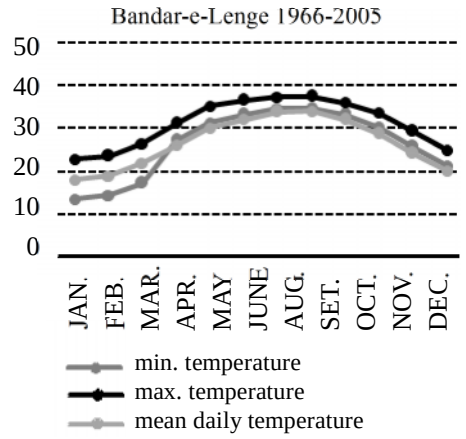

Fig. 1: Temperature in Bandar-e-Lenge.

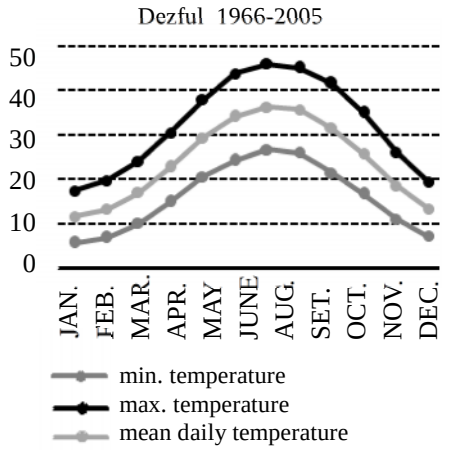

Fig. 2: Temperature in Dezful.

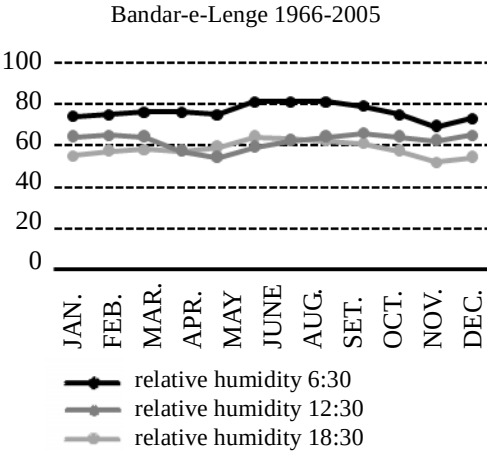

Fig. 3: Relative humidity in Bandar-e-Lenge

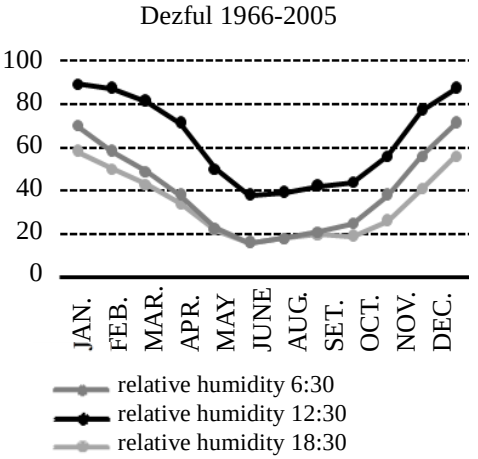

Fig. 4: Relative humidity in Dezful

Using light-weighted materials considering minor thermal changes (Hyde, 2000) and porous materials for walls (Koch-Nielsen, 2002), also materials with minimum thermal capacity and maximum ventilation through linear and narrow and fragmented parts and thin walls (Rapaport, 1996). For example using wood and straw in the building in such a way that they allow the air current into the house (Fathy, 1986). Using the materials with bright colors (Koch-Nielsen, 2002; Kasmaee, 2003),

utilizing natural ventilation depending on the season (Kasmaee, 2003) by using vast plans (Givoni, 1998) and the free, scattered and extended style (Koch-Nielsen, 2002) to facilitate natural ventilation even in the sunshine, also windows that face the prevailing winds in the summer (Hyde, 2000). Using increased height of the rooms for cooling the space (Tahbaz and Jalilian, 2008; Qobadian, 1994) and reducing the temperature and dampness by the air current and high ceilings (Rapoport, 1996).

Using building vast porches with high ceilings where the major part of daily activities take place (Tahbaz and Jalilian, 2008) and provide spaces for activity in semi-open areas as the indispensable part of living spaces (Givoni, 1998).

Windows are made smaller . Wood or stone lattices cover the windows also in order to control the sunshine and let the air in at the same time (Fathy, 1986; Tahbaz and Jalilian, 2008). Minimizing the number of ceiling windows (Hyde, 2000) and omission of windows that facing the sky in order to minimize the heat absorption from the sun (Hyde, 2000; Koch-Nielsen, 2002). Using tall windows (Qobadian, 1994). In the areas near the sea, there is no basement in buildings due to the damp soil (Tahbaz and Jalilian, 2008). Using wind catchers which face the sea and placing the main living spaces on the upper levels in order to make use of air current are conventional (Tahbaz and Jalilian, 2008). Using central courtyard (Qobadian, 1994). Elevating the floors in order to create air current underneath (Rapoport, 1996; Koch-Nielsen, 2002).

The aforementioned opinions altogether suggest that climate patterns in hot and humid areas are principally the functions of two main objectives: first, creating shadows and minimizing the sunshine and heat that enters the building, and second, using the natural air current; using prevailing winds and local breezes in order to create air current and ventilation. These two solutions originate from the dominant characteristics of hot and humid regions: extremely high

temperatures (i.e. where the average temperature of the coldest month of the year is above 18.3°C.) and high humidity. Such regions are situated in the hottest, most humid areas on the Psychometrics Chart, which, according to the comfort conditions set by Olgyay, are well above the comfort level against the wind and humidity (Kasmaee, 2003). Scholars have proposed similar solutions and physical characteristics to reach the desired objectives. These similar solutions and characteristics are categorized in Table 1.

RESULTS AND DISCUSSION

Climate Pattern of Houses in Bandar-e-Lenge

In the houses of Bandar-e-Lenge, the plans are vast and narrow at all sides. The walls are either single-layered or double or multi-layered made of succession of narrow, connected, and porous layers. This is made to expose all the spaces to the air current. All the spaces have windows facing the central courtyard, and the rooms on the first floor have openings facing the sea in order to create air current. The rooms are internally connected with several openings by which make the structure of the plan into a porous structure to enjoy the current of air in all seasons.

In all plans, wind catchers that face the coast are included in order to enjoy the sea breeze, and there are openings between the rooms with wind catchers and those adjacent to them. The walls are made of brick and adobe, while the ceilings are made of wood and straw. Living spaces have east-west alignment, and have the smallest number of openings towards the east and west. The orientation of house is in the most houses toward the sea, so they can enjoy the sea breeze and the winds from, south, south east and south west. Wherever the size of plots has allowed, north and south courtyards are added, or the house has been located in the center of the courtyard while observing the privacy. Houses are elevated so they are protected from the dampness in the ground and they can also open to the sea breeze. Vast porches that face the south protect the back spaces against the extreme sunshine Among the unique features of houses in Bandar-e-Lenge is porosity of brick and adobe walls, which makes heavy-weighted walls into those with the possibility of letting the air current through. Also, the corridors around the rooms act as a protective layer against the sunshine and facilitate the air current and ventilation. Fig. 5 is illustrating the air current and protected spaces from sunshine in Fekri house in Bandar-e-Lenge. Tones in the plans mark the order of the rooms in successive layers as each room or porch acts as a buffer for the room on its back to reduce the heat, and this way, the heat reaches the following inner spaces with delay. As a result, inner spaces are always cooler. The arrows show one of the presumed directions of the air current in the plan of one of the mentioned houses.

Climate Pattern of Dezful Houses

In the houses of Dezful, the main part of the building is situated in south west facing north east and the plan is stretched north east to south west in order to avoid direct sunshine. Semi closed spaces such as porches and corridors are situated always at southeast and southwest, facing north. The less important functional spaces are placed at north sides if necessary. All the spaces are deep and thick so the deepened parts of the rooms are protected of direct radiation of sun.

Table 1: Objectives, solutions and features of buildings in tropical climates.

Objective	solution	Physical characteristics of building	
Regulating the high humidity	Use of natural air current, prevailing winds and local breezes	Direction	Choosing the direction of the building and windows to face good winds
		Physical characteristics in the height and on the surface	Designing vast, narrow and scattered plans Tall windows in the majority of surfaces Using wind catchers that face the coast in the areas in the vicinity of the sea Moving living spaces to the upper levels in order to make use of good winds
		Materials	Omission of basement in the areas near the sea; creating air current underneath the building Using highly porous materials
Combination of shadow and ventilation		Using latticed walls against wide openings and around the roof Deciding the direction of openings towards the sunshine and privailing winds	
Regulating the temperature and moderating the severe sunshine	Creating shadow and minimizing the influence of solar radiation and heat on the interior	Direction	Stretching the structure in east-west direction; minimum surface for east and west sides
		Physical characteristics in the surface and height	Placing the building in the shadow Using awnings and making the roof into an awning Addition of shadow makers such as porches and belvederes Using wide and roofed porches Conditions of seasonal use of any of the four sides of the structure Great height of rooms Omission of ceiling windows
		Materials	Using materials of low thermal capacity

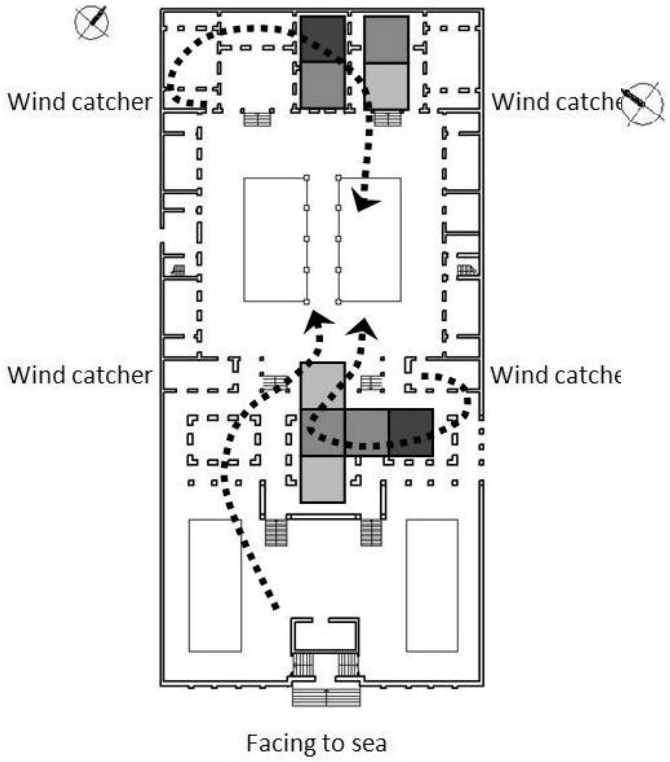

Fig. 5: Plan of the ground floor, Fekri House, Bandar-e-Lenge
The plan is adopted from
(Source: Iranian Ministry of Housing and Urban Planning, 1993)

Fig. 6: Plan of the ground floor, Ghalmbor house, Dezful
The plan is dopted from
(Source: Iran Cultural Heritage Organization of Khoosestan, 1999)

The temperature of inner parts is always lower. Fig. 6 is illustrating the Ghalambor house in Dezful and its deep spaces with protected layers.

The material of thick walls and vault ceilings are heavy-weighted to delay the transition of heat, so the rooms would become cooler in the hours of high temperature. The ceilings are high so the heat gets to higher levels and the lower space will become cooler. The windows are of the minimum number and smallest as possible. They are only faced to courtyard to have a share from cooler atmosphere of microclimate of courtyard. The connected rooms one after another helps the temperature become lower in deepened rooms.

Houses of Dezful have no wind catchers because there is no high relative humidity in summers so the ventilation is not essential as in Bandar-e-Lenge. In addition, Statistics shows there is no wind with appropriate speed in long period in Dezful to be used as a cooling strategy in hot seasons. As a substitute in Dezful using ground floors named Shabestan and Shavadan is conventional, in two depth of ground, to protect residents from extreme heat in summer because of the temperature balance of earth in depth. In Dezful the houses are mostly in two levels apart from basements. The tall walls protect the space of courtyard from direct sunshine.

Comparison of Architectural Patterns in Bandar-e Lenge and Dezful

Comparing architectural features of Bandar-e-Lenge and Dezful shows fundamental differences mostly based on the differences in climatic attributes of these two regions. Fig. 7 shows the schematic formation of houses in Bandar-e-Lenge and Dezful. The clearest difference is in using basements in Dezful in two levels and conversely elevating the house from ground in Bandar-e-Lenge. Also rooms with windows on opposite sides to simplify the ventilation in Bandar-e-Lenge and conversely the rooms with windows on the side toward courtyard in Dezful to use the cooler air in microclimate of the court yard. Some more differences are mentioned in Table 2. Evaluating the features shows in Bandar-e-Lenge because of existing appropriate wind in most of the year, and also high relative humidity, the solution are oriented to use of the air current and natural ventilation. However, in Dezful the solutions are expressing a struggle to protect the house from extreme heat in summer.

Fig. 8 shows the differences between semi open spaces such as verandas and corridors in two samples. The difference again is emphasizing on the importance of air current in connected semi open corridors in Fekri house in Bandar-e-

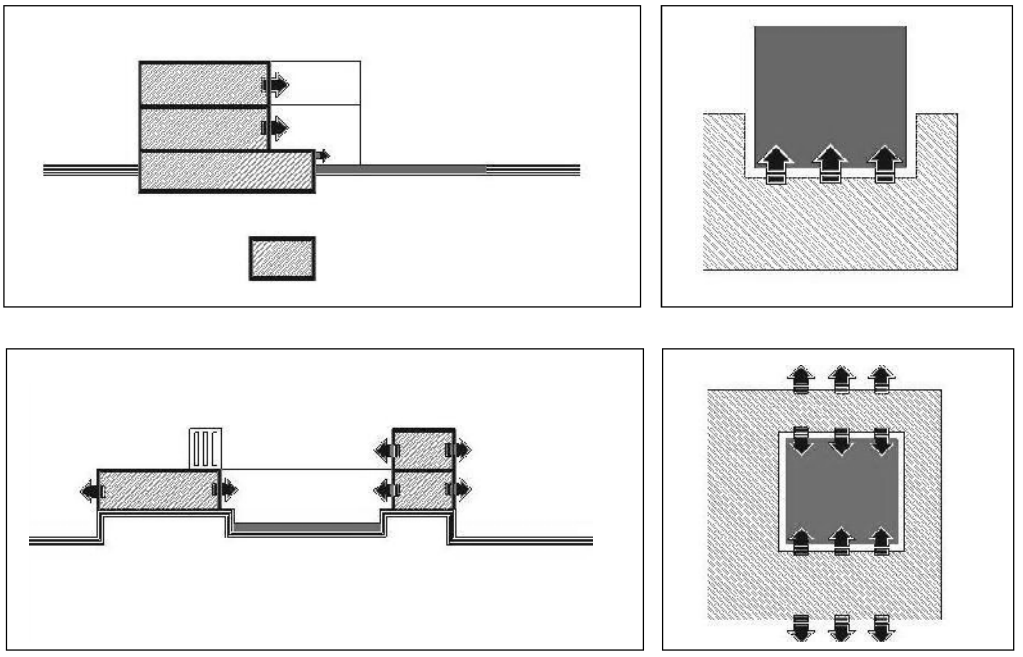

Fig. 7: Comparison the schematic formation of houses in Dezful (up) and Bandar-e-Lenge (down)

Table 2: Comparison the features of buildings in houses of Bandar-e-Lenge and dezful

Physical characteristics of building	
Bandar-e-Lenge	Dezful
Facing to south, using the sea breeze	Facing to north, avoiding direct sunshine
Vast and narrow plan	Thick and deepened plan
Porous layers	Massive layers
Elevated ground floor	Using deep and shallow basements
Upper levels, using the prevailing wind	Upper levels, Protecting ground floor from heat
Interconnected rooms, facilitating air current	Interconnected rooms, avoiding heat in depth
Semi open porches face to wind from south	Semi open porches face to north, avoiding direct sunshine
Windows toward both courtyard and outside	Windows only toward courtyard
Using wind catchers to all directions	No method is applied
Ceilings from wood and straw	Ceilings from brick and adobe
Both court yards out and in the middle of the building	Court yards, mostly open to north

Lenge and importance of protecting the house from direct sunshine in Ghalambor house in Dezful. It also indicates the use of different levels and composition of spaces in geographical directions in two samples. The semi-open corridors in Bandar-e-Lenge are facing the sea in south and the semi-open spaces in Dezful are facing the north.

CONCLUSION

One of the reasons for excessive use of fossil fuels and the subsequent environmental pollution is non-consistency of houses with the appropriate climate model of the given city and their dependency on mechanical systems. Meanwhile, the interaction between architecture and climate has been brought to perfection in the vernacular architecture of Iran, and particularly that of extreme climates such as the tropical region in the south. The present research shows that to the experts, the objective of architecture in hot and humid regions has been to moderate the most significant climactic components of the region, i.e. the high humidity and temperature. Pursuit of this objective has yielded solutions for creating shadows and minimizing the effect of sunshine on the interior of the buildings as well as using the natural

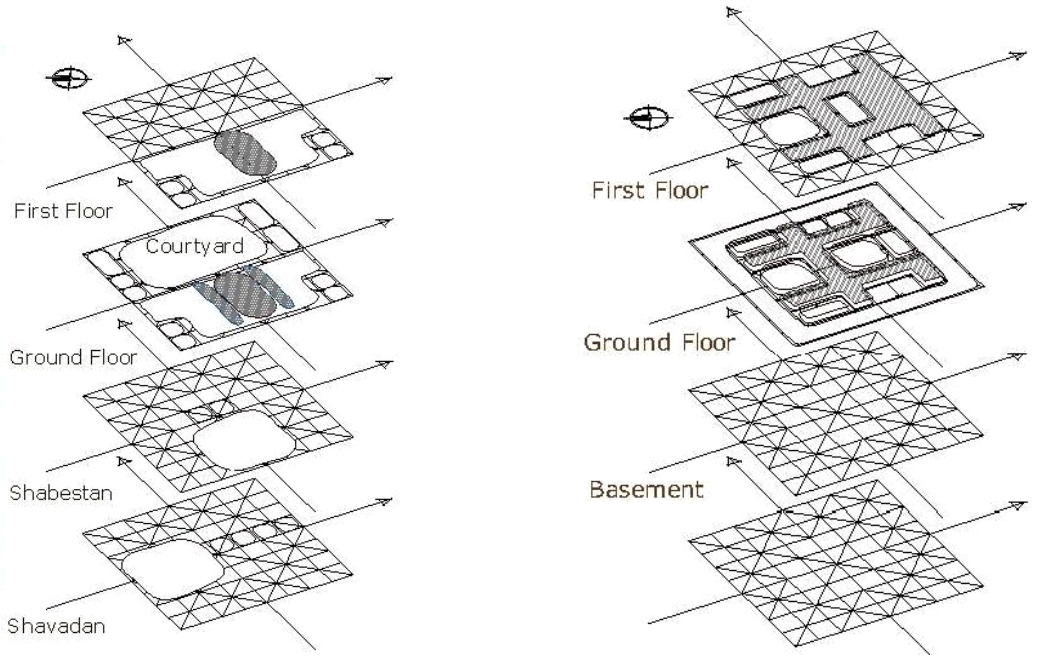

Fig. 8: Composition of open spaces and semi open spaces in different levels in houses of Bandar-e-Lenge (right) and Dezful(left)

air current, prevailing winds and local breezes. Characteristics resulted from such solutions define the configuration of architecture in this region.

Although both Bandar-e-Lenge and Dezful are placed in southern Iran but are in different sub climatic regions with different characteristics. Studies shows the architectural features are formed by the solutions based on climatic objectives in these two cities. Because of different climatic attributes the architectural features has became different.

The climatic patterns and aims are different in houses of Bandar-e-Lenge and Dezful even if they have followed the same manner in shapes. Comparing the houses in Bandar-e-Lenge and Dezful shows multiple differences. The most objective of Dezful houses is protecting the inside of house from heat and sunshine when characteristics of houses of Bandar-e-Lenge shows the respect to facilitating wind current through the house. The study shows even small differences in climate attributes in mesoclimates had been caused main differences in feature of architecture.

ENDNOTES

1. Weather statistics used in this part are retrieved from official site of Iran Meteorological Organization in 2011: http://irimo.ir/english/statistics/synopH/index1.htm

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