

INVESTIGATE AND COMPARISON PHYSICAL PATTERNS OF COURTYARD IN IRAN'S COLD AND HOT-ARID CLIMATES (CASE STUDIES: TABRIZ AND YAZD)

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ABSTRACT

Central courtyard is one of the ancient patterns in Iranian architecture which organizes the architectural space and provides the environmental quality. The features of the courtyard, varies under the influence of the environmental conditions and is different from a region to another one. In other words, housing as one of the most important elements of the vernacular architecture, has been constructed in various physical patterns, in different climates, while observing the principle of adapting with the environment. The main issue in the present study is to investigate the adaptability of the courtyard element with climatic conditions. In order to investigate the climatic features of the courtyard in the housing of cold and hot-arid regions of Iran, Tabriz and Yazd were chosen as two cities located in the mentioned areas. Having reviewed the climatic characteristics of the two areas, and also by investigating the physical features of the courtyard in the mentioned cities, the researchers determined the climatic analysis criteria. The criteria were selected according to the common physical features in the selected climates including the form and orientation of the courtyard, the proportion of the courtyard dimensions and its elements, the proportion of the courtyard area and the building mass, and the proportion of the courtyard facades dimensions. In order to analyze the climatic structure of the courtyard, 20 sample houses with courtyards, were selected from the two cities, and were evaluated according to the 9 determined criteria. The results of the climatic analysis in the two climates showed that the dimensions and proportions of the courtyard and its elements in the two different climatic areas had changed and these changes were done for adapting with the environmental conditions.

Keywords: *Courtyard, Climatic Structure, Cold Climate, Hot-Arid Climate*

INTRODUCTION

Environmentally sustainable design integrates supply factor and demand factor efficiencies through low energy technologies and passive design strategies in building. The use of passive design strategies aims to minimize energy demand in buildings and the rational use of energy. Passive systems are essential and the use of passive climate control can reduce energy use in building. The natural energy sources such as passive solar, ventilation and daylight are considered essentially energy sources. Buildings make use of natural energy in the environment and its free running capability to control indoor climates of buildings for climatic comfort (FerrerForés, 2010). Courtyard as one of the main elements of vernacular architecture can be effective in providing the environmental welfare as a microclimate. The houses with courtyards in various areas of Iran are constructed in various forms, affected by the environmental factors. Hence, in this study, instances of houses with courtyards in two different cold and hot-arid climates that both have crucial seasonal conditions, are analyzed, based on the climatic criteria. The results of the analysis will show the courtyard's physical structural differences in the two climates and also the extent of adaptability of these forms with different environmental conditions.

Iranian Courtyard Houses

The courtyard housing typology has been in existence for almost as long as humans have been constructing their own dwellings. Examples of early courtyard houses have been traced back as far as 3000 B.C. In Iran and China (Bridson, 2012). Courtyards are utilized in almost all building types, in all periods of history of architecture, in every part of the world as an organizing element of building design. Houses, palaces, monasteries, mosques, schools, governmental and private administrative buildings to

name a few. So far as the traditional houses are concerned the genesis of the courtyard house is traced back to 7000 BC in Çatalhöyük/Anatolia and 10.000 BC in Beijing/China (Eyüce, 2012).

The forms which remain stable in the course of the history of architecture can be called “generic forms” as they possess some general virtue. However, these generic forms sometimes completely vanish and reappear again in some point in the future (Norberg-Shulz, 2013). The buildings with courtyards in Iran, and especially the houses as such, in the way to reach a complete central courtyard form, passed a period like six thousand years, and in each historical era, the courtyard has had one or more functions (Memarian, 1996). The important and effective factors in the formation of various architectural spaces can be generally classified in two main groups: first, the material and environmental factors; and second, the cultural and historical factors. The material and environmental factors involves the constructional materials, natural environment and economic factors. The effect of these phenomena on the formation of various architectural places especially the settlement areas was so considerable in the past traditional world, as one can easily regard the variety of the architectural styles in the ancient civilization in harmony with their natural environmental characteristics. The effectiveness of material and environmental factors was not the same on various constructions, because cultural and ritual buildings, besides being impressed by the environmental factors, were highly effected by the historical and cultural factors; despite the fact that how the settlement places were formed, were affected by the natural environmental phenomena, more than anything else (Soltanzade, 2011). The patio house was developed to achieve privacy in the outdoor space and good orientation of the rooms. Privacy is the key quality of the courtyard house. The courtyard is the center of the dwelling and facilitates outdoor activities. The courtyard looks inward into the space it surrounds (FerrerForés, 2010). The courtyard, in addition to integrating the architectural elements, creates a scaling relationship with them; which forms either from the building entrance towards other spaces in the courtyard, or it connects the main sections of the house, by establishing main summer and winter enclosures in different aspects (Memarian, 1996). Courtyard house it is also a climatic device: in summer the courtyard becomes a second living room and facilitates outdoor activities, in winter the house it looks inward onto the private courtyard which is an enclosed room. It is an open room sheltered from the wind and protected from the neighbors (FerrerForés, 2010). Courtyard is one of the Iranian traditional architecture elements, which all of the spaces in a building are located around this open and rectangular area. This spatial structure has both social and environmental function, which provides private space, while acting as a source of light, fresh air and heat (ChoSoolyeon, 2013). The courtyard could be defined as a room without a roof, which is the core of the house. From the standpoint of the weather, the patio is an outdoor space, but from the topological point of view is clearly an interior space bounded and protected, a concave space (FerrerForés, 2010).

The organization of different spaces while considering the effective factors has ever been one of the most important functions of the courtyard in house designing. Regarding the impact of the solar rotation on the different aspects of the house, the architects determine each aspect for each season and hour. Considering this issue, the aspect facing the sun was determined as the winter settlement; the aspect back to the sun, was determined as the summer settlement (in some hours of the day), and the western aspect was determined for the cold winter days (Memarian, 1996). The courtyard house acts as a temperature regulator and as an open space within a building. The archetype of the courtyard house have been considered to offer a substantial potential for utilizing passive strategies for indoor thermal comfort and has been adapted in subtle regional variations to the climate variations (FerrerForés, 2010). Building geometry, enclosure, orientation, density of the building context and access to wind flow can produce considerable architectural implications in modifying the microclimate of the courtyards. The courtyard offers a specific microclimate area between the outdoor and indoor environments of the building. From the climate design viewpoint, the courtyard layout allows larger areas of internal passive zones, which can benefit from natural ventilation and daylight (FerrerForés, 2010). There are various geographical areas in Iran, which brings about different climatic conditions, where each climate has its own special characteristics. Nevertheless, the geographical dimensions are also significant, but in general, the average dimensions of the courtyard are determined while considering the latitude and altitude. Therefore, the

courtyards will be narrow enough to preserve a shading area during summer days, and at the same time, they will be wide enough to receive the sunlight in the winter. The courtyard can provide a secure, private and peaceful place in the house. Furthermore, the courtyards with a small garden where the trees, flowers and bushes are planted can bring about a beautiful environment, besides proving peace and serenity.

The building with courtyard form is one of the most common vernacular forms, and the instances of such form can be observed from the hot-arid regions to mountain areas and also the southern hot and humid areas. However, there is a brief difference between the central courtyard buildings in the hot-arid regions with the same buildings in mountain areas (Ghobadian, 2006). The courtyard pattern in the cold and hot climates acts completely different. The type of houses with courtyards is naturally suitable for the hot climates. Because in these areas, the aim is to keep the building from the direct exposure of sunlight. The small courtyard, are kept in shades by the high walls, protuberance of the roof edges, and tree leaves. By sharing the external walls with the neighbor houses, sunlight is minimized in the vertical levels. The thick walls and small windows, keep the internal space cool. In other words, the housing design makes it possible to have two-way ventilation and the shady courtyard and the porches, facilitate living outside home. The plants and the fountains are also used to cooling the weather in the courtyard. In the hot and humid areas, the house with a courtyard is a proper design for ventilation.

Features of Courtyard in Cold Climate

Courtyard as one of the determining and organizing factor of traditional architecture in cold regions involves various aspects. Knowing different features (material, window, symmetry, orientation and etc) in environmental design of Iranian houses, along with examining and comparing case studies in some Iranian cities like Tabriz,... could determine various aspects of environmental and climatic factors in Iranian traditional architecture and provide approaches for contemporary architecture (Shokouhian, 2007). In cold climates, the archetype of courtyard can be used for letting the sunlight into the house. Thus, the rooms can have big windows for receiving the southern light, without violating the privacy of the house. In general, we can divide the courtyards in these areas, into internal courtyards and external ones. In some houses, we can see both types of the courtyards: an internal courtyard, besides an external one. In cases where there is only one type of courtyard, this courtyard has more characteristics of external courtyards (Kaynejad, 2011).

The general form of the external courtyard is a rectangle that in some cases has extra parts and cuts on its sides. The external courtyard is mostly located in the southern side. In cases where the house has also an internal courtyard, the external courtyard is located on the northern side of the house. The external courtyard is oriented and stretched generally north-south, in the direction of the main axis. The external courtyard can be classified in case of body and on the basis of the number of constructed aspects, into following types:

Type A: In this type of external courtyards, the courtyard is confined only on one side with the built aspect and there is a wall on the other three sides.

Type B: In this type, the courtyard is confined on two sides with the built aspects and on the other two sides, walls are built. The two built aspects have facades and the side bodies are like a wall which can be simple or have arches.

Type C: In this type, the courtyard is confined on three sides with the built aspects and there is a wall only on one side. The side walls have arches (Kaynejad, 2011).

The courtyards are generally located in a lower level than the entrance, and this difference and gap is resolved by using steps; however, in some houses, this problem is tackled using a slope corridor leading to the courtyard.

Also, in some cases, this height difference has been shaped as a soffeh (A kind of terrace in old Iranian architecture which was located higher than the courtyard level, with an area where all the family members could get together and take advantage of the fresh air and the view of the night sky in summers) on the southern side of the courtyards, which leads to the courtyard with some steps. In most courtyards, a central pond can be seen which has many forms. In order to reaching the courtyard from outside the house, one can use spaces such as the entrance, the vestibule and the corridor (Kaynejad, 2011).

Features of Courtyard in Hot-arid Climate

The courtyards in the hot-arid climate of Iran, is a complete instance of introversion. In this area, the environmental courtyard is completely different with the outside space. The courtyard is an important element in organizing the various spaces in different seasons. The pond and the plants inside the courtyard, compensate for the shortage of weather humidity. All the openings and entrances of the rooms open towards the courtyards and the courtyard is regarded as the connecting space among all the house sections (Ghobadian, 2006). Residential architecture of these regions is an expressive sample of ecological architecture. Old architecture in hot and dry region is in accordance with regional factors such as desired and undesired winds, humidity, sun, etc. Planning each of the solid and void spaces like courtyard with tall and shading walls, enclosed spaces, porches, rooms in different directions, corner rooms with wind-catcher and pond, basement and roof is for special hours of day and night of cold-average and hot season. A person can change his/her living space in harmony with regional changes. In addition to this, all traditional buildings of Iran, both in architectural and constructional fields, are planned in a way to have maximum of sun radiation during winter and maximum of shade during summer to use natural ventilation and to provide peace and comfort for the house residents (Ahmadkhani, 2011).

The shape of the courtyard is a stretched rectangle. Based on the general area of the house and the needed spaces, the courtyard dimensions have also changed and the courtyards are divided into internal and external ones. In these houses, the winter settlements, occupy the northern and western spaces, and according to the role of the courtyard and regarding the hall facing the courtyards, the houses are divided into a total classification of houses with one courtyard and houses with multiple courtyards (Memarian, 1996). The houses with one courtyard are grouped to following types:

The types located on the southern side which have only one hall and also have a room on the winter side
The types on the southern side which have a space on one side of the hall and on the facing side also have a room and a corridor.

The types on the southern side which have two spaces on two sides of the hall and on the winter side have a combination of three spaces.

The types on the southern side with a hall at the center, and two other spaces on each side, and on the winter side, on each side of the winter rooms, there are also two spaces (Memarian, 1996).

In bigger houses of this area, the spaces are organized in multiple courtyards that according to the location of these courtyards in relation to one another, the following classification can be the result:

The main axes of several courtyards are parallel to one another too.

The main axes of two or more courtyards are parallel but not next to one another.

The main axes are perpendicular.

A combination of the three above axes can be seen (Memarian, 1996).

The entrance way to the courtyard, have been designed in several ways in these houses. The most common way is connection via the vestibule. It is possible that the house has several entrances to the courtyards or the access may be possible through the vestibule and several entrances. The internal and external courtyards have connection via several ways: this connection can be possible through the ground floor level or via the different corridors or via the underground (Memarian, 1996).

Climatic Analysis of Courtyard

Central courtyard as a pattern in Iranian architecture is the most important space in buildings with different land such as homes. Organizing different spaces according to the effective factors has been the most important function of courtyard in buildings design (Mahdavejad, 2013). All traditional buildings of Iran, both in architectural and constructional fields, are planned in a way to have maximum of sun radiation during winter and maximum of shade during summer to use natural ventilation and to provide peace and comfort for the house residents. The houses of courtyards with indicators like thick walls, porches, underground, wind catcher, vault and dome, are clear examples of architect understanding of environmental conditions (Ahmadkhani, 2011).

However, all the mentioned characteristics are under the influence of the environmental conditions and vary from area to area. In other words, housing as one of the most important elements of the vernacular

architecture, has been constructed in various physical patterns, in different climates, while observing the principle of adapting with the environment. These characteristics and differences can be supposed as the variables and criteria for climatic analysis, in vernacular housing of the different cities and climates. In order to investigate the climatic features of the courtyard in the housing of cold and hot-arid regions of Iran, Tabriz and Yazd were chosen as two cities located in the mentioned areas.

Table 1: Climatic characteristics of Tabriz and Yazd [13]

	Tabriz	Yazd
Average of mean daily temperature in c.	12.6	19.2
Average of minimum temperature in c.	7	11.9
Average of maximum temperature in c.	18.2	26.6
Average of relative humidity in percent	53	21
Average of minimum relative humidity in percent	63	20
Average of maximum relative humidity in percent	71	46
Annually total of precipitation in mm.	283.8	59.2
Annually total of sunshine hours	2796	3244.9

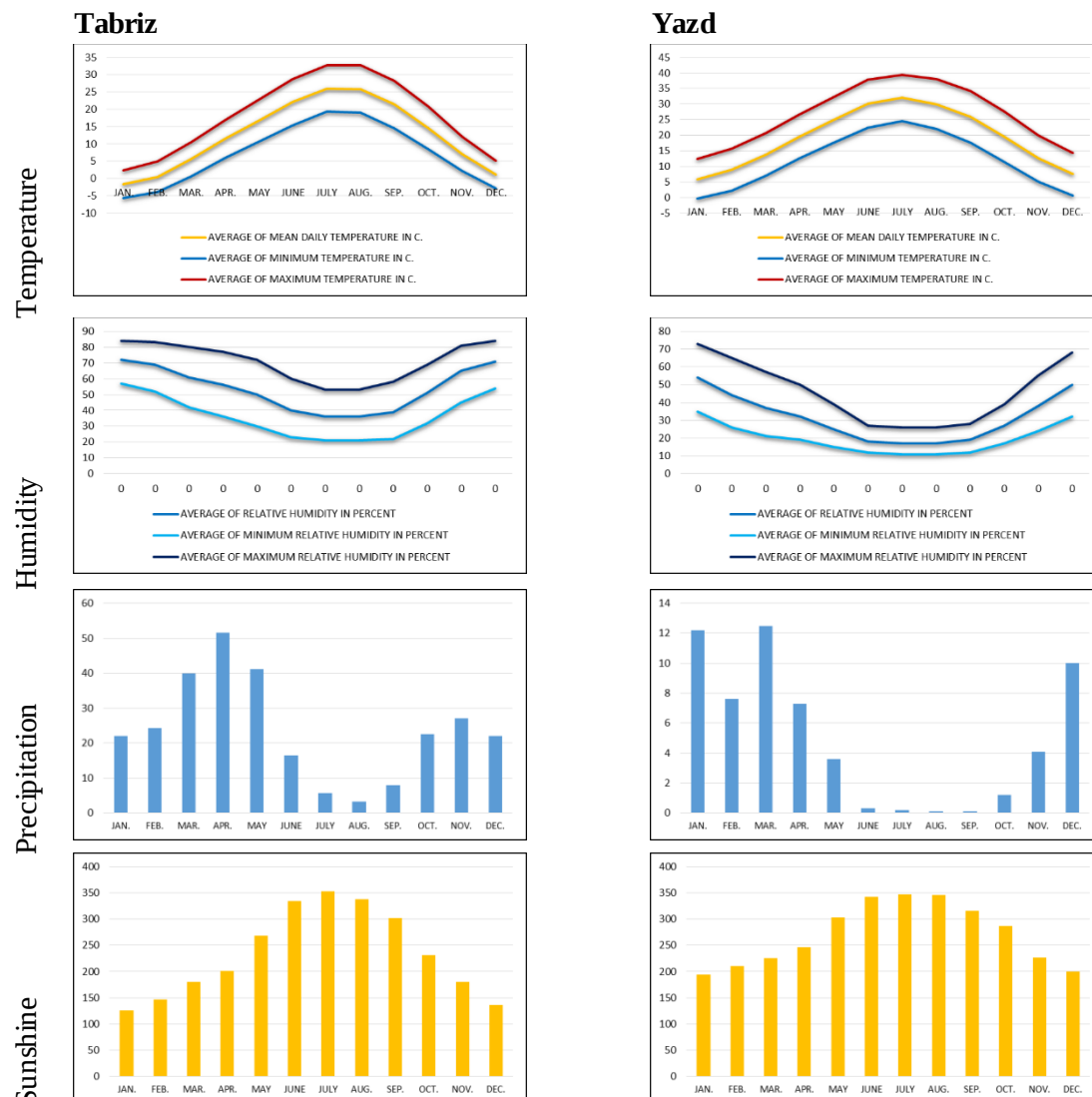


Figure 1: The climatic characteristics graph of Tabriz and Yazd

The main reason for choosing these two cities was the prominent climatic characteristics in the mentioned areas. Also, the variety of the observable forms and types and accessibility to the related documents and maps, was the other reasons for selecting Tabriz and Yazd. The climatic characteristics of these two cities are shown in Table 1 and Figure 1.

Considering the fact that the purpose of the present research is to study the climatic structure of the courtyard in two different climates, it is expected that the climatic change can bring about differences in the physical features. Therefore, the analysis criteria are selected according to the common physical elements which are affected by the environmental conditions. In this regard, 9 criteria have been considered for the analysis of the physical structure of the housings which are as follows:

Table 2: The climatic analysis results of the courtyard in Tabriz and Yazd houses

	Houses of Tabriz	Houses of Yazd
Courtyard Form	courtyard with building mass in the 2 opposite or adjacent sides	courtyard with building mass in 4 sides
Courtyard Orientation	Northern-Southern	Northeastern-Southwestern
Building Mass Location in Courtyard	North-South East-West	Northeast-Northwest- Southeast-Southwest
Courtyard Wide to Courtyard Length	1:1.2	1:1.4
Water Area to Courtyard Area	1:22.3	1:7.3
Green Space Area to Courtyard Area	1:3.6	1:6.4
Courtyard Area to Building Mass Area	1:1.1	1:2.2
Building Mass Area in North Side	1:1.7	
every Side to Total South Side	1:6.3	
Building Mass East Side	1:1.9	
West Side	1:3.5	
Northeast Side		1:4.1
Southeast Side		1:7.1
Northwest Side		1:4.7
Southwest Side		1:3.0
Courtyard Facade Height to Facade Wide North Side	1:2.3	
South Side	1:3.7	
East Side	1:4.3	
West Side	1:4.4	
Northeast Side		1:2.2
Southeast Side		1:3.2
Northwest Side		1:3.2
Southwest Side		1:1.9

Courtyard Form: This criterion, investigates the pattern of building location in relation to the courtyard. Various forms involve the courtyard with the building mass on one side, courtyard with building mass in the two opposite sides, courtyard with the building mass in the two adjacent sides, courtyard with the building mass in three sides, and courtyard with building mass in four sides.

Courtyard Orientation: This criterion assesses the orientation of the courtyard in relation to the geographical orientations.

Building Mass Location in Courtyard: Here, the location of building mass is studied affected by the orientation of the courtyard in various instances.

Courtyard Dimensions Proportion: This criterion compares the ratios of the length and width of the courtyard in various samples.

Water Area and Courtyard Area Proportion: This criterion shows the ratio of the courtyard area and the water (pond) area.

Green Space Area and Courtyard Area Proportion: This criterion shows the ratio of the courtyard area and the green space (garden) area.

Void and Mass Proportion: This criterion shows the ratio of the courtyard area and the building mass area; or in other words, it deals with ratio between the void area and mass area.

Building Mass Areas Proportion: the evaluation of this criterion determines the ratio between the building mass areas on different sides to the total building mass area.

Courtyard Facade Proportion: This criterion, investigates the ratio between the width and length of different aspects of the courtyard (Ahadi, 2014).

Considering the fact that the vernacular houses of each area have the most climatic and environmental adaptability, some of the vernacular houses with courtyards of the two mentioned areas, will be investigated as the samples, in terms of the building's age, traditional materials and the use of climatic architecture strategies. The other criterion in selecting the samples is having definite span of the construction and its elements. Therefore, the houses that do not have definite span and components or their span or elements cannot be measured are removed from the samples. In this regard, 10 houses from Tabriz and 10 houses from Yazd are selected. The selected houses are investigated considering the physical features and are analyzed according to the determined criteria.

The purpose of this analysis is to classify the houses in case of climate in the studied region. One of the main results of the climatic studies is the classification of the case studies. The data classification also makes it possible to compare the groups according to the samples features and the analysis criteria. Table 2, shows the analysis results of the selected samples.

Comparing the analysis results according to climatic criteria in cold region and hot-arid region, the physical structure of the courtyard in these areas are determined. Since the quantitative criterion are expressed as proportions, comparing these criteria in the houses of these two climates, can determine the courtyard's physical structure of these areas, which are briefly as follows:

The prevalent form in the cold climate houses (Tabriz) consists of a building mass on two sides opposite or adjacent the courtyard, whereas in the hot-arid climate (Yazd), on all four sides of the courtyard, the building mass is seen.

The building mass location in the cold climate in most cases is on the northern and southern side, and in in other cases, it is on the northern-western or northern-eastern direction. However, in hot-arid climate, the building mass location is on all four sides of the courtyard.

The stretching direction of the courtyard in the cold region in north-south and in the hot-arid climate, it is northeast-southwest.

The proportion of the courtyard sides shows that the courtyard shape in both areas is rectangular, but in the hot-arid climate, the courtyard is more stretched.

The water area and courtyard area ratio shows that this ratio in hot-arid climate is thrice more than that of the cold climate.

The green space area and courtyard area proportion shows that this ratio in the cold climate is twice more than that of the hot-arid region.

Comparing the water area and the green space area of the two climates shows that in the hot-arid climate, the water area is a little more than the green space area. However, in the cold climate the green space area is seven times more than the water area.

Comparing the building mass area and courtyard area proportion shows that in the cold climate, the areas of building mass and the courtyard are close. Whereas in the hot-arid climate, the building mass area is twice more than that of the courtyard. The maximum proportion of the building mass area in the cold climate is on the northern side and after that, the highest proportion of the building mass areas are on the eastern, western and southern sides. In this regard, the maximum proportion of the building mass area in the hot-arid climate is on the southwestern side and after that, the highest proportion of the building mass areas are on the northeastern, northwestern and southeastern sides.

Courtyard façade dimensions proportion shows that in the cold climate, the lowest façade is on the western side and the highest façade is on the northern side. However, in hot-arid climate, the facades on the northwestern and southeastern side has the lowest height and the southwestern façade is the highest. Comparing this proportion in the two climates shows that generally the height of the courtyard facades is more in the hot-arid climate.

Conclusion

Comparing the dimension, proportions and the relations of the architectural elements in different climates shows the difference in the different areas, which consequently reveals the adaptability of the building with the environmental conditions of each area. The physical structure study of the courtyard in the two case studies shows that the courtyard elements are formed or changed according to the climatic needs of each area. The results of the climatic analysis of the courtyard in cold and hot-arid regions can be expressed as follows:

Comparing the courtyard form and several building mass location on its different sides shows that the different seasonal conditions changes the residential function location in both climates.

The north-south orientation in the cold climate and the northeastern-southwestern orientation in the hot-arid climate show that the courtyard's structure in both climates has been shaped according to the sunlight direction.

The more water area in the hot-arid climate, compared to the cold climate shows the importance of the pond in providing the humidity of the courtyard in this region.

The small building mass and courtyard areas in cold climate, refers to the heat requirement in the crucial season of the year (winter). The vast building mass on the side facing the sun (northern side) in the cold climate shows the adaptability with the seasonal condition and the use of sunlight in the extremely cold and long winters of this region. However, the vast building mass on the side back to the sun (southwestern side) is in order to use the shades of this side in the very hot summers of this region.

The height difference on different courtyard sides of the two climates shows the importance of sunlight on the northern area in the cold climate and also it reveals the need for a vast area of shading in the courtyard in hot-arid climate.

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