Environmental effect of courtyard in sustainable architecture of Iran (Hot-arid regions, meso-climate BWks)  
(Case study: courtyard houses in Isfahan & Kerman)

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ABSTRACT

This paper concentrates on the results of sustainability caused by Courtyard as a climatic element in Iranian traditional architecture of hot-arid regions. Traditional architecture of Iran is perceived sustainable for having sustainable features. It is able to response to environmental problems from a long period. Its features are based on climatic factors as well as local construction materials of hot-arid regions and Courtyard (haye- markazi) is one of this features. Courtyard as one of the determining and organizing factor of traditional architecture in Hot -aired regions involves various aspects. This research uses library documents and Internet sites as well as analysing building plans. Result of this paper;show that considering the experience in traditional architecture of hot-aired regions, it is possible to create an environmental and sustainable architecture.  

Keywords: Sustainable Development, Sustainable Architecture, Hot-Arid regions, Courtyard, Environmental Architecture, Green Architecture, Typology.

1. INTRODUCTION

Sustainability in architecture means conserving constructions for the future, in terms of physical durability planet protect conserving on energy resources. In this case, it seems that sustainability would be based on the introduction productive models in which available materials and resources are used more efficiently, rather than being ignored. Nowadays, the knowledge of building ecology focuses on its capacity to integrate environmental and climatic parameters into design and thus enhances space qualities such as comfort ability. Traditional architecture of Iran is perceived sustainable for having sustainable features. It is able to response to environmental problems from a long period. Its features are based on climatic factors as well as local construction Materials of hot-arid regions and Courtyard is one of these features. Courtyard as one of the determining and organizing factor of traditional architecture in Hot -aired 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 Isfahan, Kerman (Meso-climate BWks) could determine various aspects of environmental and climatically factors in Iranian traditional architecture and provide approaches for contemporary architecture.

2. CLIMATE OF IRAN

2.1 Classification of climate in Iran

"Climate is integration in time of the physical state of the atmospheric environmental characteristic of a certain geographical location. There are different geographical locations in Iran and this provides various climates and every climate has its special characteristics. Iranian researchers, like M. Tavasoli, M. Kasmaee, Dr.H.Ganjee worked on climatic divisions of Iran but the method of Dr.H. Ganjee is the best. He divided Iran based on Koppen’s method. Koppen divided the world based on growing of plants. Microclimates have effect on urban planning and architecture. In a vast country such as Iran, with different climatic zones, traditional builders in the past have presented a series of logical solutions for human comfort. Iran is basically divided into four climatic regions: Mild-Humid Climate-Cold, Climate-Hot-Mild Climate-Hot-Arid Climate.”

2.2 Classification of Hot-Arid climate in Iran:

“This climate consist of the most parts of the central Iranian plateau, receives almost no rain for at least six month of the year, hence it is very dry and hot. In this climate the summer is very hot arid and the winter is very cold and hard. In this area, sky in the most of months of year is without cloud and the weather hasn’t any humidity. Thus temperature is very variety in this region. In the summer, quantity and severe of sun is very much and at day, maximum of temperature is 50-70c but at night, it is 15c-25c. In a vast country such as Iran with different climatic zones, traditional builders in the past have presented a series of logical solutions for human comfort. A principle for the existence of buildings is the need for better environmental conditions. “Early men built houses to keep out the elements-rain, wind, sun and snow. Their purpose was to produce an environment favorable to their comfort and even to their survival.”
What ultimately resulted form the meso-climatic division of hot arid zone of Iran based on a principle proposed by Koppen is the fact that having the accomplished studies in view, one can introduce as follow four meso-climatic classifications for hot – arid zone of Iran: BShs, BSks, BWhs, BWks. Accordingly, the final map to divide meso-climatically the hot – arid zone was drawn as follows. This division will substantially play an important role in selecting more carefully and precisely case study models (figures1-2)

3. THE ROLE OF COURTYARD IN SUSTAINABILITY OF TRADITIONAL IRANIAN HOUSES

The courtyard in a hot dry climate is usually the heart of the dwelling spatially, socially, and environmentally. Although, the size of the land, to some extent, is influential, the average sizes of the courtyards are generally determined according to the latitude. They are narrow enough to maintain a shaded area during the heat of the day in summer, but wide enough to receive solar radiation in winter. A courtyard can provide security, privacy, and a comfortable place within the house. The courtyard where it is usually planted with trees, flowers and shrubs, not only provides comfortable condition and beautiful setting, but also supplies some shade and increase the relative humidity of the courtyard space. In Yazd and some other cities of the Iranian Plateau, for instance, on the side of the courtyard where maximum shade is provided, there is a large open archway (Iwan) where usually a wind catcher is accommodated directly or indirectly. On the side opposite the open archway where often are rooms with the greater exposure to sunshine in winter. While larger houses have rooms all around the courtyard, smaller ones may have rooms only on three, or two sides of the courtyard shallow pool is often found in the courtyard which may provide more humidity, and cooling physiologically and psychological. The floor of the courtyard is usually tiled with baked square bricks (farshi). The courtyard is frequently cleaned by wetting and sweeping the tiles which further provides cooling by evaporation. “Even without modern, mechanical heating or cooling systems, the courtyard house provides a comfortable living environment through seasonal usage of sections of the structure. The thermal performance of courtyards have been studied by many researchers. (Roaf 1982, Bonine 1980, Givoni 1976, Dunham 1960). The common concept some authors provide is that the air in courtyard is cooler than air temperature above the courtyard mostly in the morning, but their interpretation of this phenomenon is different.

“For instance, provides a general explanation of the performance and explains that as evening advances, the warm air of the courtyard rises and gradually replaced by the already cooled night air from the space above the courtyard. This cool air is stored in the courtyard in laminar layers and can flow into the surrounding rooms. In the morning the air of the courtyard heats slowly and remains cool until the solar radiation falls directly into the courtyard. The warm wind passing above the house during the day does not enter the courtyard but merely creates eddies inside, unless baffles have been installed to deflect the airflow.

“An appropriate explanation however, can be provided by considering the thermal properties of the air and the material of the courtyard. As the thermal capacity of air is very low, the temperature of the courtyard air follows very closely the temperature of the surrounding surfaces. At night, the mass of the walls and floor of the courtyard is cooled by outgoing long wave radiation and therefore, the surface of the courtyard floor and walls will remain cool by the following morning. In this way, the mass of the walls and floor of the courtyard (and not the air deposited in the courtyard) serves as a reservoir of coolness, if it is not too large and well shaded. For this reason one may feel cool in two ways, firstly, the courtyard air is cooled in contact with the surrounding surfaces, and secondly, by losing heat through the surrounding surfaces by radiation which is known as radiant cooling. The courtyard climate can also influence the performance of the wind catcher, because air for the wind catcher is drawn from two areas, from the roof and from the courtyard. It seems that, for the courtyard in the hot arid zones to operate as a source of cooler air for ventilation, they must be well shaded and well ventilated. Otherwise, a non-protected courtyard can increase the heat stress in and around the building.

‘The courtyard climate is similar to the climate on the roof and in one large courtyard (10m x 14 m) measured only at around 2 am to 6am were average courtyard temperatures higher than roof temperatures recorded.’ To examine the thermal behavior of closed non-shaded courtyards, studies were undertaken by Etzion in the Desert Architecture Unit at Ben-Gurion University of the Negev (1991). “It was found that in summer, most of the time the non-shaded courtyard is warmer than the
ambient air and the air inside the courtyard were as high as 7°C. – In winter, the temperatures of the courtyard were somewhat moderated compared to the ambient, but even then in most cases the courtyard was warmer than the ambient air.”

4. ENVIRONMENTAL ANALYSES OF COURTYARD IN THE IRANIAN TRADITIONAL HOUSES

The courtyard in a hot dry climate is usually the heart of the dwelling spatially, socially, and environmentally. The courtyard in a hot, dry climate is usually the heart of the deliberation of specialty of socially, environmentally are architecture. In this article studies are based on different typological imagination of various kinds of traditional Iranian houses are comparatively spread in vast dry-hot climate in this country with aim of comparison the environmental specialties of courtyard architecture from climate aspects. In these studies two aspects physically flesh subsistence biological is analyzed. The base of this article is on analysis and studies of documents like plans, sections, and facades are the examples of Iranian architecture in Traditional texture. In city like kerman and Isfahan, this town are in dry-hot climate. But in every named cities, Minimum three valuable buildings are selected and biological body analyses has been searched on them that the final result will be introduced in this article.

4.1 Physical – Environmental criteria for courtyard Analyses

This research lays the foundation of a detailed study as morphologically analyzing the physically formal products of a courtyard which is located in a vast site between different climates in hot – arid area. This in turn, provides a stratum that allows us to measure explicit and implicit characteristics of an architecture having anything to run with climatic aspects. Given the roles, as already explained, that a courtyard plays in developing and regulating the structures particularly housing architecture and as we need to achieve formal models of it, it is necessary to analyze a courtyard among these climates. For that reason, it will be explained in a comprehensive way in this study. It is evident that observing the physical – Environmental criteria for courtyard and analyzing studying models and introducing and employing these details in designing a courtyard as a private open space in our contemporary architecture can lead to a produced sustainable architecture in the said zones.

4.2 Criterion 1: the symmetry between an solid space (occupied space) and a void space (unoccupied courtyard

One of the architectural principles in Iran is how to use a module in the sense of following geometrical science and its discipline. This is largely utilized in the Iranian architecture the same as used in western architecture because they both relatively follow the same module. Module, in the past, was used as an equally micro-measurement device that had to be incorporated at any place proportionate to it. The part architect works (monuments) of Iran in particular in Islamic periods indicate that how much deeply and extensively geometry was employed in different styles of architecture. In past Iranian architecture, any typical linking between various elements was developed on the basis of a negative spatial geometry (courtyard). The geometrical dimensions of this space took up forms from special geometrical morphologies (shapes) such as square and oblong which as a matter of fact are not free from limitations and disadvantages as far as their performances are concerned because it accommodates a definite number of architectural elements. But, having available geometry for a courtyard allows us to have a free hound to develop good forms of facades and how to divide a building in its entirety. This parts of study deals with the ways in which we can consider the area of an occupied their proportions to the total floor area of a house.

4.3 Criterion 2: The Extension direction and rotation angle of a courtyard

Some rotations of this type can be re – known from the positions they take and how much they are available. However, it would be a wall that is entirely parallel to streets. The main reasons for it that can be referred to here are those of (1) climatic orientation, (2) a right angled sequence or quadrilateral is followed by its form as well as (3) the positions of streets and their access roads or paths. As regards older cities with no network pattern for courtyards, the orientations of courtyards are posed based on the observation of equitable diffusion of the light of day on the bodies. Sunlight radiates onto the courtyard to give benefits to humans and plants but what side at a courtyard receives the direct sunlight and what time of a day, where and in what locations the light of day is at its minimum or otherwise are all considered to be optimum comfortable conditions a temperature can provide. The ground lowering or sinking on a level below the surface of the ground a lane has, high walls of an outside fence and the orientation of a house to sunlight which is synonymous to a juxtaposition of a courtyard’s dimensions as focused on the north and south or the orientation of one courtyard’s side to the direction of kaaba can create a structure that provides the most amount of shade daring scorching days in summer and the most penetrating light and heat of sun deep into the rooms in winter. Each front side of a courtyard with sun orientation is special to a definite season but the sequence of room in the living room and wind catcher, three – door rooms, five – door rooms and other special spaces used
during four seasons of year. Also, one can identify and determine the history of their development during different historical progression by considering and looking into different orientations of yards in a city or in a living complex. Over time, the orientations of courtyards have developed into their optimum positions and remained stabilized in their present positions. As for courtyards with their oblong form and shape and their eastern to western extension, the higher facades are situated in northern and southern fronts. This typical orientation prevents the sunlight from radiating directly on higher façade. arches of lesser deep make the openers ready let to blow through them. The shorter front, in turn, the sun’s strong and direct these facades are deprived of daylight in winter. Totally choosing the side in the house is related to direction of street and availability to them. Although the relations are related to analyses of availability but from the main reasons is about climate aspect and from dependence of a right side rectangular and the situation of streets and availability to them. The sun will influence the court yard, the plants and human could use the warmness and light of it. The sides which will accept sprightly influence of sunlight and the best time that court yard has maximum or minimum acceptance of sunlight. So the best time of facilities would be clear.

4.4 Criterion 3: proportions associated to courtyard dimensions
Some ratios (proportions) have been calculated to obtain the physically formal characteristics of selected patterns across the horizon for understanding length – width ratio and along an upright for obtaining height – length ratio and that of height to width.

4.5 Criterion 4: The proportions of physical bodies of courtyard
Courtyard, as an organism and ecosystem is made up of bodies. These bodies can be separated from each other in two major categories. The first category is natural bodies that consist of soil (other minerals), sky, water, plants and human. The second category consists of man – made bodies such as frame, architectural material and human products which a butt each other. This paper substantially shed light on the physical bodies of earth and water that influence considerably the analysis of bio – environment of courtyard.

4.5.1 Earth:
Earth a vantage ground for every architecture in houses of hot – arid climate, has been able in such a way to arrange for a space for it exactly both under and above it self so that it may be able to take advantage of fixed temperature assed and that of fixed humidity which both culminate in a heat– humidity exchange rate supported by environment and their surrounding bodies and finally lead to air current. This section also deals with the surface of earth on courtyard. It will likewise consider the proportions of soil surface to the entire surface of courtyard in studying models.

4.5.2 Water:
Water is a variable that plays and enormous role not only in the space of courtyard but also within the surrounding Limits of a city. It also constitutes a basis on which a city is truly urbanized and houses within it are acclimatized in land where water is valued as a rave gem. The levels and bodies of water that are observed as stagnant and dynamically flowing in courtyards results in a condition under which humidity can be spread up in space and environment can be cooled through this humidity. Water plant, sun and wind are each employed through traditional technology and provide a harmonious set of environment efficiencies water, in two latent and vivid alternatives plays the most important part in developing traditional texture. Spaces for water in their different shapes from the lowest to highest levels of flowing water have different terms such as those: shallow water, ditch of water, garden and grounds. Run – off surf water in its much lower levels does not allow us to gain access to it at higher level. Therefore, a special space is provided in feversishly hot days of summer in order to gain access to run – off water. This space that usually has the same frame of a room is called shallow water. Examples of this water are those that may exist inside a floor laid with brick, a stone – made pond of oblong or hexagonal shape. Its walls are decorated with sills, arches and sometimes platform. At time when the water flowing through subterranean canal does not pass through much lowered depth, another solution is used. In this position, water shows it self off and develops as a pond in the centre of a courtyard area or deep inside the chief courtyard. This deep yard is noted as a garden ditch in a chief courtyard. The water flowing through a subterranean flow back to the original course of the said canal through another stream (brook) once it has been over flown. Therefore, this section discusses the proportions and levels of water and earth as the physical and natural bodies of courtyard in model studies.

4.6 Criterion 5: symmetries of artificial bodies (quad-ruple Elevations of courtyard)
This study examines into the dimensions and sizes of four northern, southern, eastern and western elevations of courtyard in case studies. Also, in this way the proportions related to the levels of four fronts to that of courtyard will be calculated and included in table.
4.7 Criteria 6: The symmetries of openers in artificial bodies (opener in the four elevations)

This section also studies the dimensions and sizes of four northern, southern, eastern and western elevations. Also in this way the ratios related to the relation of opener’s levels in the four fronts to that of total four fronts in case studies.

4.8 The results obtained from the physical-environmental analysis of courtyard in houses with vernacular courtyard in BWs micro-climates

This section deduces the case examples as obtained from environment analysis. For this purpose, it first clearly divides the hot-arid climates of Iran and then it subdivides BSks, BSls, BSks and BWls into four smaller intermediate climates based on Koppen’s standards. It also selects model cities from each intermediate climate considering factors such as the oldness of structure, historical value, renovation value, specified plans and etc. then, three houses with courtyards were also for model studies. Finally it analyzes the courtyards of selected houses based on formal criteria as concern their proportions as introduced and elucidated in previous section. To reach its final conclusion, that is to say, to achieve the same proposed model of correct proportions for designing a courtyard, the paper primarily draws and analyzes all plans by using Auto-Coding software. Then, it formulates all deduced results and outcomes in tables with the aide of Excel software and ultimately it presents a proposed model for creating correct proportions to design a courtyard (as suitably used for each city) and a concerned middle climate. This paper selects from BWks meso-climate three cities such as Isfahan and Kerman as models and also selects out of which three houses with courtyards. In this way, it selects from the city of Isfahan three houses belonging to Charmi, Dehbash and Dr. Alam and from the city of Kerman three houses belonging each to Moradi, Lutfalizadeh and Azimi as models for studies and analyses based on formal-environmental criteria as concern the proportions. It finally presents, some proposed formal models to suit the proportion of courtyard in a climate.

4.8.1 The results of formal environment analysis of houses with courtyard in the city of Isfahan.

Result obtained from the analysis of six formal criteria related to proportions in model studies on houses belonging to Charmi, Dehbash and Dr. Alam are:

**Creation 1: The Symmetry Between an Solid Space (Occupied Space) and a Void Space (Unoccupied Court Yard):** In the models that were studied it was found that on an average the area of house on northern part is about 126 m² and that of southern part about 251 m² and that of eastern part 271 m² and that western part about 344 m². The ratio of clearly unpopulated space (courtyard) to the whole surface area is about 37% and that of occupied (living) space to the whole surface area is 63%.

**Criterion 2: The Extension Direction and Rotation Angle of a Courtyard:** All models display that the extension direction of north eastern to south western is with a mean proportion of 1/3 and rotation angle of 0-5 west to the axis of north southern.

**Criterion 3: Proportions Associated to Courtyard Dimensions:** In models that have been studied if was found that, the surface area of courtyard is about 400 m² and its proportion about 1/3 and the form of courtyard is oblong and there is and analogy longitudinal latitudinal.

**Criterion 4: Proportions for Natural Bodies of Courtyard Such as Water and Earth:** In models studied, it was learned that the surface area of water is about 46 m² and its proportion to the surface of courtyard about 10% and the earth area about 84 m² and its proportion to the surface of courtyard about 20%.

**Criterion 5: Symmetries of Artificial Bodies (Quadruple Elevations of Courtyard):** In models that have been studied, it was learned that the area of northern front is 148 m² and that of southern front 91 m² and that of eastern and western 128 m². The ratio of northern front surface to that of courtyard are about 37% and the surface of southern front to that of courtyard about 33%, the surface of eastern and western fronts to that of courtyard is about 23%. It is observed that the widest front surface concerns that of northern and the narrowest of it concerns that of southern.

**Criterion 6: The Symmetries of Openers in Artificial Bodies (Opener in the Four Elevations):** In models that have been studied, it was found that the areas of openers in northern fronts are 33 m² and those of southern about 26 m² and those of eastern and western 53 m². Also the ratio of northern front openers to courtyard is about 22% and that of southern about 28%, that of eastern and western about 39%. It is observed that the widest surface of openers concern the eastern-western front and the narrowest of it concern the southern fronts.

![Isfahan](image)

**Table 1:** Formulas for computing the area of courtyards in Isfahan

<table>
<thead>
<tr>
<th>Formula</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>W=a</td>
<td>Width</td>
</tr>
<tr>
<td>L=1.32 a</td>
<td>Length</td>
</tr>
<tr>
<td>AC=1.32 a²</td>
<td>Area of Courtyard</td>
</tr>
<tr>
<td>AE1, E2 =0.53 a²</td>
<td>Area of E1, E2</td>
</tr>
<tr>
<td>AE3, E4 =0.42 a²</td>
<td>Area of E3, E4</td>
</tr>
<tr>
<td>AOE1, E2 =0.11 a²</td>
<td>Area of Openers</td>
</tr>
<tr>
<td>AOP, E1, E2</td>
<td>Area of Openers in Courtyard</td>
</tr>
<tr>
<td>A(ERT) =0.26 a²</td>
<td>Area of ERT</td>
</tr>
<tr>
<td>A(WAT) =0.16 a²</td>
<td>Area of Water and Earth</td>
</tr>
</tbody>
</table>

**Fig 3:** Proper proportions of designing Courtyard in Isfahan
4.8.2 The results of formal environment analysis of houses with courtyard in the city of Kerman:

Result obtained from the analysis of six formal criteria related to proportions in model studies on houses belonging to Moradi, Lotfalizadeh and Azimi are: CREATiON 1: THE SYMMETRY BETWEEN AN SOLID SPACE (OCCUPIED SPACE) AND A VOID SPACE (UNOCCUPIED COURT YARD). In the models that were studied it was found that on an average the area of house on northern part is about 176m² and that of southern part about 99m² and that of eastern part 106m² and that western part about 142m². The ratio of clearly unpopulated space (courtyard) to the whole surface area is about 43% and that of occupied (living) space to the whole surface area is 57%.

CRITERION 2: THE EXTENSION DIRECTION AND ROTATION ANGLE OF A COURTYARD: All models display that the extension direction of north eastern to south western is with a mean proportion of 1/3 and no rotation angle to the axis of north southern.

CRITERION 3: PROPORTIONS ASSOCIATED TO COURTYARD DIMENSIONS: in models that have been studied it was found that the surface area of courtyard is about 154m² and its proportion to 1/3 and the form of courtyard is oblong and there is analogy longitudinal latitudinal.

CRITERION 4: PROPORTIONS FOR NATURAL BODIES OF COURT YARD SUCH AS WATER AND EARTH: In models studied, it was learned that the surface area of water is about 11m² and its proportion to the surface of courtyard about 9% and the earth area about 3m² and its proportion to the surface of courtyard about 6%.

CRITERIons 3: SYMMETRiES OF ARTIFICIAl BODiES (QUADRUPLE ELEVATIONS OF COuRTYARD: In models that have been studied, it was learned that the area of northern front is 72/7m² and that of southern front 74m² and that of eastern front 62m² and western front 54m². The ratio of northern front surface to that of courtyard are about 54% and the surface of southern front to that of courtyard about 55%, the surface of eastern front to that of courtyard about 61% and western fronts to that of courtyard is about 43%. It is observed that the widest front surface concerns that of eastern – western and the narrowest of it concerns that of eastern.

CRITERIONS 6: THE SYMMETRIES OF OPENERS IN ARTIFICIAL BODIES (OPENER IN THE FOUR ELEVATIONS): In models that have been studied, it was found that the areas of openers in northern fronts are 14m² and those of southern about 18m² and those of eastern about 18m² and western about 14m². Also the ratio of northern front openers to courtyard is about 20% and that of southern about 26%, that of eastern about 28% and western about 25%. It is observed that the widest surface of openers concern the northern front and the narrowest of it concern the eastern fronts.

<table>
<thead>
<tr>
<th>Kerman</th>
</tr>
</thead>
<tbody>
<tr>
<td>W=0.13* (a^2)</td>
</tr>
<tr>
<td>L=1.4 (a)</td>
</tr>
<tr>
<td>AC=1.4* (a^2)</td>
</tr>
<tr>
<td>AE1, E2 =0.72* (a^2)</td>
</tr>
<tr>
<td>AOP.E1, E2 =0.19 *a²</td>
</tr>
<tr>
<td>AE3, E4 =0.77 a²</td>
</tr>
<tr>
<td>AOP.E3, E4=0.9 a²</td>
</tr>
<tr>
<td>A (ERT)=0.8 *a²</td>
</tr>
<tr>
<td>A (WAT)=0.13 *a²</td>
</tr>
</tbody>
</table>

Fig4: Proper proportions of designing Courtyards in kerman

5. CONCLUSION

Finally, then cities and three houses with courtyards from each were chosen from amongst climates and were analyzed with physical – environmental criteria related to proportions. The following results were obtained from the analysis of six formal criteria concerning the proportions to nine studied models such as houses in Isfahan and Kerman: Result obtained from the analysis of six formal criteria related to proportions in model studies in Meso-climate BWks: CREATiON 1: THE SYMMETRY BETWEEN AN SOLID SPACE (OCCUPIED SPACE) AND A VOID SPACE (UNOCCUPIED COURT YARD). In the models that were studied it was found that on an average the area of house is about 1065m². The ratio of clearly unpopulated space (courtyard) to the whole surface area is about 40% and that of occupied (living) space to the whole surface area is 60%.

CRITERION 2: ORIENTATION AND ANGLE OF ROTATION ON COURT YARD IN PROPORTION TO NORTHERN AND SOUTHERN AXES: As the models show, the extended direction of courtyard depends on suitable and unsuitable winds which variety in any area. CRITERION 3: PROPORTIONS ASSOCIATED TO COURT YARD DIMENSIONS: in models that have been studied if was found that, the surface area of courtyard is about 27/8m² and its proportion about 1/35and the form of courtyard is oblong and there is and analogy longitudinal latitudinal. CRITERION 4: PROPORTIONS FOR NATURAL BODIES OF COURT YARD SUCH AS WATER AND EARTH: In models studied, it was learned that the surface area of water is aboutm² and its proportion to the surface of courtyard about 10% and the earth area about m² and its proportion to the surface of courtyard about 13%.

CRITERIONS 5: SYMMETRiES OF ARTIFICIAl BODiES (QUADRUPLE ELEVATIONS OF COuRTYARD: The ratio of northern front surface to that of courtyard are about 49% and the surface of southern front to that of courtyard about 33%, the surface of eastern front to
that of courtyard about 43% and western fronts to that of courtyard about 44%. The ratio of widest front surface to that of courtyard are about 41% and the surface of length front to that of courtyard about 43%.

CRITERIONS 6: THE SYMMETRIES OF OPENERS IN ARTIFICIAL BODIES (OPENER IN THE FOUR ELEVATIONS): the ratio of northern front openers to courtyard is about 25% and that of southern about 24%, that of eastern about 30% and western about 33%. It is observed that the widest surface of openers to the front is about 25% and the length surface of openers to the front is about 31%.

Table 1. Proper proportions of designing courtyards in Kermanshah and (BWks).

<table>
<thead>
<tr>
<th>Meso-Climate BWks</th>
<th>Kerman</th>
<th>Isfahan</th>
</tr>
</thead>
<tbody>
<tr>
<td>W=(a)</td>
<td>L=1.35 a</td>
<td>L=1.35 a</td>
</tr>
<tr>
<td>AC=1.35 (a^2)</td>
<td>AC=1.4 (a^2)</td>
<td>AC=1.35 (a^2)</td>
</tr>
<tr>
<td>AE1, E2=0.58 (a^2)</td>
<td>AE1, E2=0.72 (a^2)</td>
<td>AE1, E2=0.33 (a^2)</td>
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<td>AOE1, E2=0.18 (a^2)</td>
<td>AOE1, E2=0.19 (a^2)</td>
<td>AOE1, E2=0.01 (a^2)</td>
</tr>
<tr>
<td>AE3, E4=0.55 (a^2)</td>
<td>AE3, E4=0.77 (a^2)</td>
<td>AE3, E4=0.42 (a^2)</td>
</tr>
<tr>
<td>AOE3, E4=0.14 (a^2)</td>
<td>AOE3, E4=0.9 (a^2)</td>
<td>AOE3, E4=0.17(a^2)</td>
</tr>
<tr>
<td>A (ERT) =0.18(a^2)</td>
<td>A (ERT) =0.8 (a^2)</td>
<td>A (ERT) =0.26 (a^2)</td>
</tr>
<tr>
<td>A (WAT) =0.14 (a^2)</td>
<td>A (WAT) =0.13 (a^2)</td>
<td>A (WAT) =0.16 (a^2)</td>
</tr>
</tbody>
</table>

6. FINAL RESULT

A courtyard in a house lets the light of day and air current radiate and flow into its surrounding rooms. In domestic hot – arid areas, the courtyard operates in three usual cycles to use at a maximum rate the daily changed front during summer days. In cycle 1, the night cold air descends into the courtyard and fills the surrounding rooms. Under this condition walls, roots, columns, ceilings and furniture get cool at night and remain so far a long time. The courtyard loses its warmth by radiating it towards sky. This courtyard with this condition can be use as a sleeping site at night in summer. During the cycle 2 around midday when the sun shines directly on the surface of courtyard, the existing cool air of the courtyard and rooms ascends upwards. This causes the heat to exit there and comfort is gained. During cycle 3 the surface of courtyard and the surrounding of house become warmer and all cool air as exists within the house begin to diffuse by the evening. Therefore the role a courtyard plays as factor to provide micro – climate must be taken into consideration because it is exceeding effective to regulate and develop building especially housing structures.

REFERENCES


NOTS

This article is a part of writer’s Ph.D thesis: Soflaee, Farzaneh, 2006, “Environmental Analyzes of Courtyard in the Sustainable Architecture of Hot-Aired Region”, Islamic Azad university, Research & scientist Branch, Tehran, Iran.