Assessment of Climatic Parameters in the Architectural Design of Yasuj City Located in Kohkiluye & Boyr Ahmad Province Using Mahoney's Method

Marzieh Mogholi, Hojjatollah Abbassi, Arefeh Zahedi

Assessment of Climatic Parameters in the Architectural Design of Yasuj City Located in Kohkiluye & Boyr Ahmad Province Using Mahoney's Method

INTRODUCTION

Since human's environment is encompassed by atmosphere within which most of his actions and reactions occur, atmosphere variations play a prominent role in his life and activities. Major climatic influence on human's physiology appears through regulation of thermal body system which produces a sense of or lack of relief in different regions and can be of a great functionality in numerous fields such as urbanization, architecture, tourism, medicine and issues related to the determination of a suitable place for the establishment of residential units, rest houses, hospitals, amusement places, etc in which climate is considered as the basis for planning. Thus, in the developmental and constructional planning of a region, climate undertakes a main role and climatology is regarded as the most practical science. This section of current geography has gained a great importance because of high prices of energy all around the world. Construction designers with the help of climatologists employ maximum potential facilities of a region's climate. Exploitation of natural forces in buildings leads to saving of fuel consumption and most important to the enhancement of relief and sanitary qualities of residential areas as well as maintaining environmental health. On the one hand, science of architecture deals with points, directions, surfaces, volumes, sizes, dimensions and landscapes directly and on the other hand, it is involved with places, climates, and locations as geographic subjects in addition to properties and qualities of materials as the issues of construction science. Moreover, it can be said that it shares benefits with widespread realms of other empirical sciences and humanities [1].

Since architectural demands together with the inspiration of an ancient maxim are based on stability, beauty, relief, and health, association of these two sciences is further emphasized because function of climate in human's life is one of the major issues as the focus of numerous experts and construction designers in recent decades. With regard to the definition of climate as dominant weather of a place in a long period, reformation of functionality of climatic potentials in producing some degrees of relief in buildings and optimization of accommodation crave for various techniques the objective of which is reduction of warming and cooling prices with the use of natural currents of energy. In the contemporary era, this geographic issue has undergone a great
attention and significance considering high prices of energy all over the world and construction designers attempt to utilize climatic facilities of a region in the best way.

Therefore, with regard to the above-mentioned problems, climatic and natural potentialities associated with residential optimization and limits of relief in workplaces and life environments were assessed in this research expecting them to be used with an optimal natural energy usage in planning.

**MATERIALS AND METHODS**

**Study area:**

Based on the country's political divisions, Yasuj city is the capital of Kohkiluye and Boyr Ahmad province and the center of Boyr Ahmad Township. It is surrounded by northern Sar Rood rural district at the center, between Bashshar Rivers at South, Mehrian at West, and Dena Mountains at North and East. Yasuj urban area is located within high and folded Zagros mountainous zone. Its limits are encompassed by highly steep and complex topographic zones. Yasuj City is located between Northern latitude 30° 28’ and Eastern longitude 51° 38’ from Greenwich Meridian and has covered an area of 1801 hectares. It reaches Zagros heights from North and East, Bashshar River, and Akbar Abad and Najaf Abad villages from South, industrial complex and Balku Village from Southwest, Mehrian River and Village from West and Northwest, upper sharaf Abad, lower sharaf Abad and middle sharaf Abad.

Based on the establishment of this city on the foot of Zagros mountain chains, its lands and margins include structural features of this mountainous area. The mentioned lands are constituted of parallel anticlines and synclines directed from northwest to southeast. The region includes deep and narrow valleys where only limited parts are constituted of small sedimentary and cultivable plains.

Geological formations of the region are constituted of hard limestone related to jurassic, cretaceous, Eocene and Oligocene periods and Asmari. Modern stones were also observed in several parts.

**Fig. 1:** Geographic location of yasuj city

**Methodology:**

Study method or design can be defined as guidelines or techniques selected by a scholar based on study subject and objective with the use of scientific-logical rules and principles of those methods during his or her study activities.

Research method in the present descriptive study is of an analytical type in which the following methods were used for gathering data.

1) Gathering climatic data from Meteorological Organization
2) Documental and library study in addition to using books, magazines, files, official documents and other written resources
3) Searching through Internet sites for the use of authentic scientific resources of other scientific centers
4) Analyzing and assessing data and information gathered according to basic influential climatic factors on architecture
Mahoney’s indices:

For the first time in 1971, Carl Mahanoy offered several tables in which proper architectural suggestions were presented with regard to climatic conditions. In these tables, efficient relief factors such as temperature, wind, moisture, and radiation are evaluated. Relief circumstances of each meteorological station were determined considering standard limits of temperature and relative moisture obtained empirically.

Mahoney’s method includes a series of tables. In table 8.2, main climatic data is registered the same as monthly maximum and minimum averages of temperature, relative humidity, and amount of precipitation. Accordingly, variation limits and averages of such information as fluctuation averages of temperature and relative humidity as well as humidity group is determined for each month.

In this method, at first, daily and nightly relief limits of each month were obtained with regard to annual average of temperature and humidity group and then thermal conditions of the days and nights of each month of the year were determined through comparison of averages of monthly maximums with daily relief limits and averages of monthly minimums with nightly relief limits. Afterwards, indices were offered for the whole year regarding climatic thermal conditions in each month and recorded data. Later, with regard to the whole indices, significant information of designing such as building orientations, spacing between buildings, air current, constructional components of buildings, and protecting buildings against rainfall was offered. Finally, suggestions related to building details such as doors and windows dimensions, situations, and protection against external conditions, constructional components of buildings and external details were introduced. One of the main objectives of establishment of houses is protecting them against difficult environmental conditions such as cold and hot weather, swift winds and dust storms, heavy rainfall, extreme radiation, protection against attacks of wild animals, etc.

Little attention is focused on the establishment of houses in a mild, suitable climatic condition and if necessary, it is carried out with the least investment.

For instance, less expense is spent on this task in equatorial regions while in Middle East warm and dry deserts, houses are built with thick and highly resistant walls against wind erosion so as to protect humans against sandstorms and high radiation of the Sun.

Donnell Watson and Kent Lenz have explained theoretical and executive principles of utilizing energy for optimal use of climate in buildings. These principles for the use of climatic potentials for relief provision and weather control include: using heat from the Sun, reducing thermal current conduction, decreasing penetration of outside air, reducing thermal absorption from the Sun, applying air ventilation, using radiative coldness, utilizing evaporative chilliness, and using air rigidity conduction.

Simple architectural techniques for the accomplishment of the above-mentioned principles in buildings include: using windbreakers, plants and water, internal and external free space, conservation of construction by ground, solar walls and windows, shadows against sunlight and natural ventilation.

Features of indices suggested in Mahoney’s method:

A) Indices related to humid conditions:

H1: This index is representative of a condition in which daily heat is incessantly accompanied by high relative humidity of groups 2, 3, and 4 and round-the-clock temperature variations less than 10°C. At this climatic condition, tangible air current would be necessary to produce a feeling of relief.

H1 = hot day + RH4
H2 = hot day + RH2, 3 + temperature variations of less than 10

H2: This index is representative of a condition with suitable limits of temperature and high relative humidity. With the humidity group 4, one would have an uncomfortable feeling while air current would be appropriate in such a condition.

H2 = suitable day + RH4
H3: This index is representative of a condition in which rainfall penetration into the building causes disturbance. With this condition, whenever there is a high rate of precipitation, usually over 200 mm, it is necessary to take actions for the whole building design against possible risks.

H3 = monthly precipitation over 200 mm

B) Indices related to a dry condition:

A1: This index is indicative of a condition in which there occurs a high temperature variation, over 10°C. Days are hot with low relative humidity. Humidity groups include 1, 2, and 3. Temperature variation causes discomfort and necessitates the use of construction materials with average to high heat capacity in building designing.

A1 = hot day + temperature difference of more than 10 + RH1, 2
A2: This index is in fact indicative of a condition with warm nights and low relative humidity. Relative humidity groups 1 and 2 cause discomfort within building space. With this circumstance, sleeping in open air could be considered as the only way to get rid of warmth.

A2 = hot night + temperature variation more than 10 + RH1, 2
A3: This index is indicative of circumstances in which daily temperature is lower than the least temperature of relief limits in Mahoney’s index. As a result, coldness causes disturbance and the only way to avoid it is the use of energy for warming internal building spaces.

A3 = months with cold days

Table 1: Mahoney’s evaluation

<table>
<thead>
<tr>
<th>Group</th>
<th>Relative humidity average %</th>
<th>Annual temperature average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;20°</td>
<td>20-30</td>
</tr>
<tr>
<td></td>
<td>Day</td>
<td>Night</td>
</tr>
<tr>
<td>1</td>
<td>34</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>31</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>25</td>
<td>24</td>
</tr>
<tr>
<td>4</td>
<td>27</td>
<td>21</td>
</tr>
</tbody>
</table>

Table 2: Detailed suggestions of Mahoney’s architecture

<table>
<thead>
<tr>
<th>No.</th>
<th>Indices of thermal conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A3</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1-12</td>
</tr>
<tr>
<td>3</td>
<td>0-3</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>4-12</td>
</tr>
<tr>
<td>6</td>
<td>3-12</td>
</tr>
<tr>
<td>7</td>
<td>6-12</td>
</tr>
<tr>
<td>8</td>
<td>0-2</td>
</tr>
<tr>
<td>9</td>
<td>2-12</td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>0-2</td>
</tr>
<tr>
<td>12</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>0-2</td>
</tr>
<tr>
<td>14</td>
<td>3-12</td>
</tr>
<tr>
<td>15</td>
<td>6-12</td>
</tr>
</tbody>
</table>

Based on latest estimations, most humans are sensitive to weather and its variations. This sensitivity is revealed in various reactions and can be spread with the occurrence or reinforcement of different types of diseases. The mentioned sensitivity depends on age, gender, social status, health condition, and seasons of the year. Moreover, geographic conditions of different regions, especially geographic locations as well as uneven lands provide the background of different climates and would cause a great influence on physical and mental human structures accompanied with their reactions. On the one hand, not only weather and variations of atmospheric systems but also climate which is the product of dominant type effects of atmospheric systems on a region produce an influence on human beings and provide the background for different bio-climates.
Adaptation of architectural climatic conditions of Yasuj City with Mahoney's method:

Using Mahoney's method and two groups of the following table, the impact of climatic conditions in the formation of buildings and several architectural details were assessed. Results obtained by this index are as follows:

According to Mahoney's table 1, it was recognized that the days of six months of the year (Dey, Bahman, Esfand, Farvardin, Ahan, Azar) are cold, those of two months of the year (Ordibehesht, Mehr) are mild, and those of four months of the year (Khordad, Tir, Mordad, Shahrivar) are warm. Thermal air conditions of the nights of two months of the year (Tir, Mordad) are mild and those of the rest months are cold.

Table 3: 1st Mahoney’s table

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Dry</th>
<th>Bahman</th>
<th>Esfand</th>
<th>Farvardin</th>
<th>Ordibehesht</th>
<th>Khordad</th>
<th>Tir</th>
<th>Mordad</th>
<th>Shahrivar</th>
<th>Mehr</th>
<th>Ahan</th>
<th>Azar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly maximum average</td>
<td>9.1</td>
<td>9.2</td>
<td>3.4</td>
<td>18</td>
<td>24</td>
<td>34.1</td>
<td>34.2</td>
<td>35.1</td>
<td>32.4</td>
<td>26</td>
<td>19</td>
<td>11.2</td>
</tr>
<tr>
<td>Daily high relief</td>
<td>28</td>
<td>28</td>
<td>28</td>
<td>28</td>
<td>28</td>
<td>31</td>
<td>32</td>
<td>30</td>
<td>30</td>
<td>28</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Daily low relief</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Monthly minimum average</td>
<td>-1.4</td>
<td>-1.7</td>
<td>1.8</td>
<td>5.4</td>
<td>10.2</td>
<td>13.9</td>
<td>175</td>
<td>18.1</td>
<td>14.4</td>
<td>9.5</td>
<td>5</td>
<td>1.1</td>
</tr>
</tbody>
</table>

After identification of thermal conditions and circumstances of relief or lack of relief of different months, dry or wet conditions of each month were designated and the results were represented in Mahoney’s table 2. Based on this table, index R was selected for all months of the year which is indicative of a condition in which a feeling of discomfort is created and relief is produced due to high temperature variations (more than 10°C) and low relative humidity. With regard to the above-mentioned cases, it is necessary to pay a great attention to building designs and use of construction materials with average to high thermal capacity. Index R2 was selected for the months (Tir, Mordad, Shahrivar). This index is indicative of a condition in which a feeling of discomfort is created and choosing to rest in open air is necessary for relief. Index R3 was selected for six months of the year (Dey, Bahman, Esfand, Farvardin, Ahan, Azar) which is representative of cold climatic condition. The only way to protect against this condition is the use of energy for warming internal building spaces.

Table 4: 2nd Mahoney’s table

After identification of thermal conditions and circumstances of relief or lack of relief of different months, dry or wet conditions of each month were designated and the results were represented in Mahoney’s table 2. Based on this table, index R was selected for all months of the year which is indicative of a condition in which disturbance is produced due to high temperature variations (more than 10°C) and low relative humidity. With regard to the above-mentioned cases, it is necessary to pay a great attention to building designs and use of construction materials with average to high thermal capacity. Index R2 was selected for the months (Tir, Mordad, Shahrivar). This index is indicative of a condition in which a feeling of discomfort is created and choosing to rest in open air is necessary for relief. Index R3 was selected for six months of the year (Dey, Bahman, Esfand, Farvardin, Ahan, Azar) which is representative of cold climatic condition. The only way to protect against this condition is the use of energy for warming internal building spaces.

Table 5: The degree of adaptation of architectural climate with Mahoney’s suitable conditions for the architectural texture of Yasuj city

Generally, the following suggestions for Yasuj climatic conditions are offered based on Mahoney’s tables:
1) It is better to establish buildings in north-south direction.
2) It is better for the building complex to be consolidated.
3) It is better for the spacing between buildings to be determined based on Sun shades, not wind shades.
4) It is better for doors and windows to have an area of approximately 25 to 40% compared to that of the walls.
5) Considering the region’s climate, it is suggested to accumulate heat during half period of the year using heavy roofs with a time delay of more than 8 hours.
Comparison of the degree of adaptation of architectural climate with Mahoney’s suitable conditions for the architectural texture of Yasuj city:

For the assessment of the degree of adaptation of architectural climate of the houses in Yasuj city with Mahoney’s suitable conditions, results obtained using computer software were compared with standards of Mahoney’s methods and represented in Mahoney’s table 7. Assessment of the table numbers reveals the following results:

1) Based on building orientation, almost a high percent of buildings is in north-south direction which agrees with Mahoney’s criterion. As it was mentioned before, Yasuj City is surrounded by mountains which necessitate a precise focus on ground gradient and street networking. In this case, there is a low degree of adaptation of the region's climate with Mahoney's conditions.

2) Houses in Yasuj City are fully consistent with Mahoney’s conditions according to spacing and 100% of the assessed models possess a consolidated spatial texture.

3) Least agreement with Mahoney’s conditions was recognized according to dimensions of doors and windows.

4) Since the direction of dominant wind in Yasuj City is southward, the region’s climate is cold during more than half of the year. Hence, doors and windows are suggested to be installed in west-east walls for the use of Sun’s energy.

5) Mahoney’s criterion about external walls is heavy walls with a considerable thermal capacity. This feature is satisfied to a high extent in Yasuj City and a rather suitable adaptation with climatic conditions has been provided.

6) Based on Mahoney’s criterion, roofs of buildings in Yasuj City must be heavy with a time delay of more than 8 hours. This feature has also been observed in 85 buildings of the city and a full consistency between roofs of buildings and climate has been achieved.

Conclusion:

Influential factors on climatic features of a site are defined as: topography, direction, overlooking, and heights of hills or depths of valleys between them. They should be considered when choosing places of establishment of buildings and their impacts should be taken serious in building designing. Furthermore, ground surface, whether natural or man-made, permeability, and soil type and temperature are of special importance. Buildings must be designed in such a form that they provide further energy absorption and less heat loss. Optimal shape is considered the shape that confronts minimum heat drop in winter and minimum heat absorption in summer in any climatic conditions. Extended shape is in east-west direction. In all geographic latitudes and longitudes, buildings extended in east-west direction have proven to be the most efficient. In dry and warm climates, extended shapes have gained more efficiency since they provide less contact with sand surface. In mild climates, shape of a building is designed with more freedom. In warm and wet climates, there is no limitation for building designing in suitable direction. Generally, adjacent buildings with common east-west walls have produced much better results.

Evaluations indicate it is more important to overcome cold conditions climatically because relative humidity deficit and high variations of 10°C during the whole months of the year create disturbance. Since people are obliged to use heat-producing equipments in Yasuj City during more than half of the year, assessments showed that temperature variations play a more significant role in the case of bio-climatic index compared to other climatic elements.

Other than having various impacts on human’s health and relief, climatic conditions in architectural designing of houses in Yasuj City could be economically considerable based on the use of energy. It can be concluded that the degree of human’s relief and comfort in urban buildings and spaces can be enhanced with the
help of suitable climatological guidelines, proper management of resources, and development of appropriate and reasonable exploitation of climatic facilities.

REFERENCES