Passive architectural cooling principles for arid climates

S.M. Mofidi
University of Science and Technology, Iran

ABSTRACT

This paper will synopsize the results of a research on energy-conscious architectural elements and principles used throughout the history. The selected case studies were classified into historical eras regardless of their climatic or cultural diversity and were investigated by the date of construction, ranging from prehistoric to the current vernacular buildings, and they were cross-referenced and compared to each other. The analysis of the cases demonstrates similarity and some contrast in elements and principles, differing in history and culture but being similar in climate.

1. INTRODUCTION

Life thrives only in favourable environmental and climatic conditions. The ancient settlers discovered these conditions and they became factors, which affected the way they planned their buildings. Once these factors were clear and understood, then the principles were deduced and their designs were based upon them. For contemporary designers these principles, which were established on the basis of natural conditions and factors, and were supported by trial and error over thousands of years, could become significant decision-making constituents. Morphology, Density, Arrangement, Circulation, Roof Form, Surface, Openings, Shading Device and Material are preferred as the main topics for architectural principles and elements in different climates. The purpose is to identify strategies that would create more bioclimatically comfortable indoor spaces for the inhabitants, as they have been for many millennia.

Travelling around hot-arid or semi-arid regions, we can easily see the extent to which climate has influenced the shaping of the urban fabric of towns and cities. Some of the existing settlements date back to pre-history, some have roots in ancient times, and others have been planned in the present time.

“Nearly 43% of the earth’s land surface lies in hot-arid and semi-arid climates.” The B regions are mainly concentrated in central Asia, most of Australia, in the northwest Indian Sub-continent, the Middle-east, northern and southern Africa, west of North America, and in southern and western Central America. Hot-arid and semi-arid climates have provided the setting for the birth of many cultures and have sustained an environment for the creation of urban civilisations. As Golany and almost all urban historians believe: “Most of the early urban civilizations of the world emerged in the arid or semi-arid zones, primarily in the Fertile Crescent of the Middle East and in the Nile region.” Where three great river systems cross the hot-arid or semi-arid region, three separate groups of people settled down, irrigated the land, and built cities. It is precisely in this area that the first urban centres were born. The Indus, the Nile and the Tigris-Euphrates were the birthplaces of these cultures.

The examination of these settlements and others could be extremely valuable as living workshops in the study of the relationships between urban form and climate in this region. These relationships were investigated in the previous chapter, in urban centres such as Çatal Huyuk, Ur, Mohenjo-Daro, Arg-e-Bam, Timгад and Mesa Verde. In this section the attempt is to identify the most common elements of the majority of urban centres in the B regions. The settlements in the different hot-arid and semi-arid regions show a much greater similarity in their physical and morphological aspects in comparison to other climate types. The most important climatic urban elements that have shaped the spatial form in these regions are similar, whether located in Mesopotamia or Mesoamerica.

Fig. 1: Hot-Arid and Semi-arid Regions of the World (the shaded areas)

2. SELECTION CRITERIA

Architectural meanings are ultimately always set in history, advancement of knowledge and environmental context. Therefore, the three criteria that will define the entity of an urban centre are history, culture and
climate. Each elements and principles according to its criteria is unique, however, many of their physical patterns are similar to each other, specifically patterns of elements and strategies influenced by the physical environment and climate. These criteria have been considered in order to include fairly representative examples of architecture from various historic periods, climatic zones and cultures, in other words, to have a homogeneous and balanced distribution of the selected buildings. Such a method will help in achieving comprehensive results and in making recommendations.

2.1 Climate
Climate has played and should play a significant role in determining the overall architectural form and fabric of the future sustainable architecture and living style. The purpose is to observe the continuity or discontinuity by considering the climatic influence on the architectural form in the course of history. It is important to emphasise, as the findings of the study that indigenous architectural styles are defined less by national frontiers and more by environmental considerations. The evidence for this can be found in all continents.

The following are the types of climate, which were considered in the selection of the cases. These climates can be regarded as ‘habitable climatic zones’, since most civilisations and land occupied by human beings have been located within these areas. For the purpose of generalisation, these buildings were divided into the four major climatic regions with some variation. These regions are abbreviated according to Köppen’s generally accepted classification of the climate, and they are: A: Hot-Humid / Tropical rainy, B: Dry or Hot-Arid [BW] / Semi-Arid [BS], C: Temperate / Warm-Humid, and D: Cold/ Semi-polar. The climate of every settlement should fall into one of four general types that exist in the world. The guideline-chart at the end is organised and divided according to the divisions of the climates and will recapitulation the study. This will enable the reader to comprehend the universality of climate as a phenomenon, expressed in the elements and principles of architecture.

2.2 History
The historical periods that are most appropriate for the objectives of this study are those in which urban civilisations were already established and whose progress could be manifested in the culture, innovations and works of art of their people. This study is not a review of the architectural history, but history is used as a conveyer of climatic influence upon the morphology of urban centers and their vernacular architecture.

Some chronological divisions are perhaps too simple for a particular brand of history to be applicable beyond their system. For example the term Medieval or Renaissance conventionally are appropriate for the west but cannot be applicable to most parts of the world. A more definitive distinction, especially one that has the merit of being universally valid, would serve well in this study which undertakes a broad overview. Therefore, the following are the historical periods from which climate-oriented buildings were selected. They are not necessarily categorised according to the divisions or the denominations used by historians. Rather these periods are divided and named by their characteristics as a turning point in the history of climate-sensitive design. They are: Prehistoric (~5500 - ~3500 BC), Ancient Time (~3500 BC - 422 AD), Pre-industrial Era (422 AD - 1735), Modern Era (Industrial) (1735 - 1970s), and Sustainability Era (1970s →).

2.3 Culture
Cultural impacts on the formation and configuration of architectural elements have been extensively researched, with various intentions. The importance of cultural influence on architectural form need not be re-examined or re-emphasised in this study, since it is beyond the scope, and there is already a large body of evidence and research in this area for further studies. However, it is important to mention that cultures have been considered to be influenced by climate itself. There are many different and advanced cultures that could be considered in the selection of architectural samples, and for the diversity of the study, most major cultures were included. Many cultures or civilisations were not considered, but their impression can be found in the selected buildings. Many cultures are non-existent, so-called dead cultures, but they have left their mark on the urban civilisation of the existing cities, or have left a legacy which should be studied and from which lessons can be learned. Examples of extinct cultures could be the Harappan in the Indus Valley (Pakistan) or the Aztec in Central America (Mexico), who, from many viewpoints, including climatic study, left cities and structures with unprecedented richness. Some cultures existed in close physical or climatic proximity to each other, and had many common influences on the spatial characteristics of each other’s architectural form. There are buildings in different climatic regions but built by the same or similar culture. The study of this type of buildings will be an important aspect of the research in order to investigate how their morphology in the same culture was transformed and modified as different locations and/or climates were selected for the placement of settlements. Some Near Eastern or Roman cultures can be considered as such. East, Near-east, West, and Mesoamerica are the four
3. DESIGN STRATEGIES

In order to extract a set of guidelines, the primary purpose in this study is to focus on the physical aspects of climatic and vernacular architecture of the past. The following is the main architectural strategies, building configuration and design elements, and the reasons and the basis for more comfortable indoor and outdoor spaces for the inhabitants of the regions for thousands of years. In the following, there are the architectural aspects in the B climate, which include the most important design strategies that were driven from the analysis.

a) Introverted building morphology in the form of a courtyard or atrium in many shapes and spatial layout was popular: To create a better inhabitable microclimate.

b) Medium-compact configuration with internal open space was essential: To reduce the structure’s exterior surfaces in proportion to the interior volume, and to reduce the insolation impact.

c) Close arrangement around the courtyard for the effect of cold air drainage during nighttime was planned: To increase daytime cooled spaces.

d) Spatially efficient circulation between functional spaces was an important strategy: To reduce the internal circulation, to increase space-efficiency, and to reduce volume and therefore minimise the need for cooling.

e) Roofs in the shape of domes and vaults for closed and semi-open spaces were a common feature: To reduce the effect of insolation, to create more shadow and self-shadowing, and to increase contact with the outdoor winds.

f) Rough building surfaces were applied: To decrease heat gain, to increase the contact with air movement, to reduce the exposure of the sun to the surfaces, and to create a more effective cooling.

g) Minimum window areas located, particularly on the west facing facades: To reduce the afternoon direct insolation and indoor glare.

h) Few small windows were used facing the direction of the cooler winds: To allow some ventilation and avoid glare.

i) Wind-catchers in many different sizes, directions and height in relation to specific breeze were used in most regions: To produce effective convective cooling.

j) Wooden screens (composite shading devices) were used in the regions where wood was available: To control and filter daylight, and to reduce indoor glare.

k) Block and heavy construction materials were used: To increase the time-lag, and to retain some heat for nighttime warming.

l) Some degree of porosity in building material was essential: To facilitate the dissipation of heat.

4. THE RESULTS

The results from the above aspects are the pieces which is put together to provide a guideline-chart indicating the effect of climate on architectural configuration. The buildings in all of the four climatic zones may be hundreds of kilometres apart, but in the same types of climate similar urban morphology, climatic design principles and physical appearance, with variable depth, are evident and transparent. The selected structures might differ in size, texture and scale, and might have different culture, but their spatial climatic organisation binds them together. The investigated buildings were a few samples from the vast and rich variety and represent a good spectrum of the culture, history and climate. The principles and elements of design were identified and explored for each climatic region. The results for the climates were obtained, the findings were analysed and the aims were identified to establish a comprehensive perspective for the climatic design.

Table 1 is a summary of ‘the results’ from analysis of the architectural aspects. This summary is the findings for each of the climatic zones, categorised by the nine principles and elements. They are presented in such a format as to provide and facilitate a comparative study of the results. High humidity in A, high temperature in B, and low temperature in D climates have been the main climatic elements causing anxiety in their inhabitants. However, the presence of these elements did not impose limitations for the development of their architecture. It has been demonstrated that many urban centres in the above climates were the first to establish urban civilisation and some were the most progressive and made extraordinary achievements.

In the present paper, the systematic organisation of the outcomes and their overall conclusion was the main goal, in order to extract the strategies and elements which would be beneficial for establishing the final recom-
3. CLIMATIC ZONE B: hot-arid/ semiarid

<table>
<thead>
<tr>
<th>MORPHOLOGY</th>
<th>Introverted building morphology in the form of a courtyard or atrium in many shapes and spatial layout was popular.</th>
</tr>
</thead>
<tbody>
<tr>
<td>DENSITY</td>
<td>Medium-compact configuration with internal open space was essential.</td>
</tr>
<tr>
<td>ARRANGEMENT</td>
<td>Close arrangement around the courtyard for the effect of cold air drainage during night time was planned.</td>
</tr>
<tr>
<td>CIRCULATION</td>
<td>Spatially efficient circulation between functional spaces was an important strategy.</td>
</tr>
<tr>
<td>ROOF FORM</td>
<td>Roofs in the shape of domes and vaults for closed and semi-open spaces were a common feature.</td>
</tr>
<tr>
<td>SURFACE</td>
<td>Rough building surfaces were applied.</td>
</tr>
</tbody>
</table>

| OPENINGS          | Minimum window areas located, particularly on the west facing facades. Few small windows were used facing the direction of the cooler winds. Wind catchers or scoop in many different sizes, directions and height in relation to specific breeze were used in most regions. |
| SHADING DEVICE   | Wooden screens (composite shading devices) were used in the regions where wood was available.                   |
| MATERIAL         | Block and heavy construction materials were used. Some degree of porosity in building material was essential. Lighter weight materials for outdoor structures were employed. |

5. CONCLUSION

Climate and energy have not made man, rather he has made himself, but without controlling and utilising them, he would not have evolved as much as he has. However, the influence of climate on man’s evolution, on one hand, has affected the evolution of architectural form indirectly, and on the other hand, climate has affected the architectural configuration directly. In other words, indigenous and vernacular architecture is mainly born out of the climatic conditions. The followings are the main concluding notes:

- The empirical accomplishment of the past and what we scientifically know now about climatic design are similar and complement each other. The regional recommendations in the study confirm the similarities and contrasts of architectural elements and principles for habitable climatic zones.

- The concentration of major urban civilisations was mainly in the habitable climates throughout the world. However B and C type human inhabited climates were the first to see established urban centres, as these two climates provided a better environment for the development of architectural styles.

- The investigation of buildings in the same type of climate or geographical proximity but of different cultures suggests that the same pattern of architectural elements and strategies was developed, and that they were planned with similar configuration and design, and very similar forms and elements. Conversely, in many of the expansive and known civilisations around the world, although the same culture or even religion was practised, different architectural forms evolved or were implemented in different climates.

REFERENCES


NOTES


(3) The base map is adapted from Köppen’s climatic classification.