EFFECT OF CLIMATE ON THE MORPHOLOGY OF A PUBLIC BUILDING

Ar. Harshad Raisoni[1] Ar. Rakhi Begampure[2] Dr. Jitendra Singh[3]

Abstract

The current trend in architectural community is highly focused on sustainable design measures or designing a building which maximizes the utilization of the energy available from natural resources. This paper presents an analytical study on the effect of the climate on the morphology or the form, shape and other parameters of any public building.

Discussion focuses on the climate related analysis of the building in the context of the building envelope. The issue of sustainability without consideration of the basic principles of architecture related to climate is put forth initially. Later section deals with the study of variations in various climatic factors present in three prominent climatic zones of India. The main outcome of this analysis is on various types of the form and their behavior under different climatic zones. The two major constraints used to study the morphology were perimeter to area and surface to volume ratios of the building in prominent three climatic zones of India. The present condition on the energy consumption by the buildings in India is considered to analyze the public buildings.

A comparative analysis on of buildings present in three prominent climatic zones is done to conclude that climate of particular area has its effect on buildings form, shape, orientation i.e. building morphology.

Key Words: Effect of Climate, Building Morphology, Public buildings, building envelope, Indian Climate

1. Building morphology & its relation to climate

It's a glaring fact that almost **1/3rd** of the energy produced worldwide is utilized in construction and it's allied activities (UNEP, 2010). Given the dramatically increased demand in the sector, there is a critical need to develop sustainable design concepts.

The word sustainability in present context has become an architectural statement to be blindly used in each and every aspect of the building design. The terms to which sustainability accounts for is that, any building which fulfils the need of the present without affecting the need of future generation. Such a building may be green, energy efficient, climate responsive or any other sort but to satisfy the above statement. Sustainability has long been associated to be an uneconomical or costly affair in building design. Especially for the countries in third world where the need of a basic building comes first then the allied terminologies it's quite difficult to achieve sustainability in current form. Moreover, in such countries lack of basic infrastructure hampers the thought for green concerns in any building.

New construction in India is currently growing at more than 10%, and is projected to increase. (BEE Project, 2009). Even though sustainable habitat and green building design are inherent to each region of India, and reflected in the vernacular design strategies; the process of building design, construction and operation is increasingly influenced by images of buildings designed for the developed world. While there is a huge potential to achieve energy efficiency by incorporating passive design, efficient envelope and systems, the current trend in mainstream architecture is not toward such aims. Energy audits conducted by TERI in 2005-06 for buildings in Gurgaon indicate that many existing glass intensive buildings do not respond to the climate. Sustainability is often overlooked over the basic or traditional design concepts. (TERI, 2006).

Morphology is derived from the Greek word 'Morphe', which in its present sense means "study of shapes". The word morphology carries different meanings in different study areas but in architecture it refers to the morphology of a building. The basic concepts related to Form, Shape, Size, Orientation etc. with respect to the site and environmental condition go long way in helping the building to achieve basics of sustainability. Once the building construction ends, it becomes a part of its environment and is exposed to the Sun, wind and rain. If a building is designed with these environmental conditions in mind, it may take advantage of available Solar or wind energy or avoid its negative impact. To cater such a scenario, it is important to focus on the basic design principle rather than blindly adopting the western truce of sustainability, discomfort and the corresponding energy demand for mechanical systems can be significantly reduced by judicious control of the climatic effects.

Moreover, the architects from the past 'Louis I Kahn' till present 'Ken Yeang' have acknowledged the fact about the influence of climate on building design. The effect of climate on the building's form, shape, size etc. have been the main aim of the study on bio climatic architecture by Ar. Ken Yeang. His buildings stand as a testimony to the principles of architecture in accordance with the climate & surroundings.

1.1. Reasons for study

The basic principles of climatic or bio climatic designs are often neglected over the modern technologically advanced solutions which aren't cost effective. The sustainability has become mind block over the traditional issues addressing the same principles in an efficient way. Majority of the buildings in India do not adhere to the climatic variations even though there is a wide climatic diversity in India with about five climatic

zones in different parts having different climatic conditions during different period of months in a year. The design of the public buildings often stands neglected on the basic climate responsive strategies in India. The construction and allied activities consume 20% of the total energy produced in India (CII, 2009). The potential for energy savings in new buildings of 40-50% has been observed if basic design principles along with energy efficiency measures are inculcated in the design stage (BEE Project, 2009).

1.2. Discussion

The several principles of designing a sustainable building has been referred prominently from ECBC guidelines, CPWD report, Green building principles by Ken Yeang, Arvind Krishnan's climatic study etc.

1.2.1. Building Morphology by Ken Yeang

Architect Ken Yeang suggests that building morphology, i.e. aspect ratio, the shape of the building footprint, orientation, and placement of structural vertical core/walls can be designed to maximize passive-mode systems. For Yeang, there is an ideal aspect ratio for each different climate zone. He states that for the four major climate zones, the long axis of the footprint should be oriented east-west except in a cool climate. The rationale is to control the amount of exposed area to the sunlight for each individual side of the building. (Yeang, 1999).

Orientation helps to increase or decrease the heat gained from the sun by either maximizing or minimizing amount of time that the building is exposed to direct sunlight. Choosing the ideal position of the structural vertical cores with regard to the climate zones may help to modulate building interior temperatures. In principle, heavy and opaque structural cores provide shade and thermal mass to the building, potentially helping to keep it cool or to restrict heat penetration in the building. Thus, one would place the vertical cores to avoid or accommodate direct solar gain according to a climate zone. Yeang suggests that in a cool climate where solar gain can help to offset heating energy costs, it is optimal that the structural core is placed in the centre of the building where it cannot block an of the sun's direct rays.

In a temperate zone the structural core is placed on the north face, in a tropical zone cores are placed on both east and west sides and in an arid zone cores cover 50% of east and west sides. Thus, a set of directives are provided for high rise buildings which are taken into consideration for study (Yeang, 1999).

1.2.2. Passive design strategies by Cheung

Cheung published a study in 2004 that describes an investigation of the effects of six passive design strategies *(insulation, thermal mass, glazing type, window size, colour of external wall and external shading devices)* on the annual cooling energy for a high-rise apartment building in Hong Kong. This study shows that a reduction in energy consumption for cooling load of 31.4% can be obtained, as a result of modifying building envelope to match the local climate. However, this achievement is specific to this building type and this particular climate. (Cheung, et al., 2005).

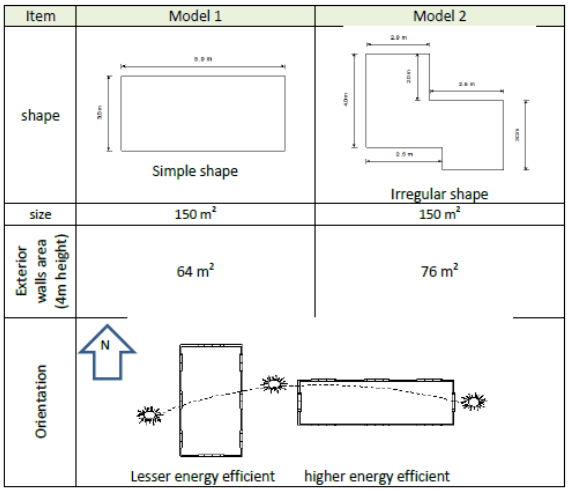

Fig:1 Energy efficient building shape *(BEE Project, 2009).*

1.2.3. Surface area to volume ratio (S/V) and Perimeter to area ratio (P/V)

The author Arvind Krishnan states a more theoretically logical approach to calculate the heat gain in the structures. Surface area to volume ratio (S/V) and Perimeter to area ratio (P/V) according to him are an important aspect in determining the heat gain and loss. It implies that the building with minimum S/V ratio have low heat gain and vice versa. Perimeter to area ratio is considered to be apt to calculate the heat gain by a building form during day time and also the amount of heat loss during night time. Higher the ratio higher is the heat gain and vice versa. Considering the five basic forms adopted for the planning of a general public building the P/A ratios vary accordingly. Surface to volume ratio is effective for the 3 dimensional calculations while the perimeter to area ratio focuses more on the 2 dimensional aspect of the building or any structure. (Krishnan, 2001).

1.3. Climatic zone selection for study

It is observed from the chart that almost 85% of the geographical area of India is covered under the three climatic zones Warm & humid, Hot & dry and Composite.

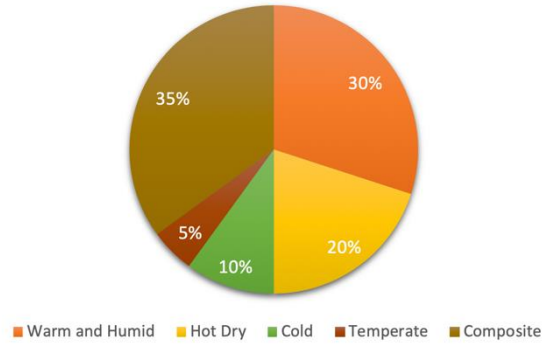

Fig1: Area under various climatic zones in India *(BEE Project, 2009).*

Through detail climatic study, we can say that there is much variations in the climatic conditions throughout the year in the three prominent climatic zones which has a significant effect on building namely; Hot & dry, warm & humid & composite climates.

The information helps a designer to build a house that filters out adverse climatic effects, while simultaneously allowing those that are beneficial. Discomfort and the corresponding energy demand for mechanical systems can be significantly reduced by judicious control of the climatic effects.

1.4. Case Study selection

It is significant that, 1/3rd of the energy produced worldwide is utilised in construction and it's allied activities, given the dramatically increased demand in the sector (UNEP, 2010).

Commercial buildings *(Public buildings are categorized under commercial buildings)* are the third largest consumers of energy in India after industry and agriculture. Such buildings annually contribute to more than 20% of the electricity used in India (CII, 2009). Energy saving potential in the range of 23% - 46% has been identified through energy audits conducted in public buildings with government buildings in focus (BEE Project, 2009).

Thus, public buildings in the selected three prominent climatic zones are taken into consideration for the study purpose.

Sr. No.	Case Study Name & Location	Climate
1	PCNTDA, Pune	Warm & Humid
2	PEDA, Chandigarh	Composite
3	CII Sohrabji Godrej Centre, Hyderabad	Hot & Dry

2. Case Studies

Following cases are studied in detail and a comparative analysis has been done based on multiple criterias to get the desired outcome.

Table: Comparative Analysis of Case Studies

Source: Authors

Factors	Case study 1	Case study 2	Case study 3
Name	PCNTDA	PEDA	CII centre
Location	Pune	Chandigarh	Hyderabad
Climate	Warm & humid	Composite	Hot & Dry
Type	Public admin.	Public admin.	Semi public
Form , Shape & orientation			
P/A ratio	1.25	1.15	0.8
S/A ratio			
Height	18m	12m	8m
North			
South			
East			
West			
Exposure Analysis	Maximum towards north while min. towards East & west	Maximum towards the north &south min. at west	Equal amount of exposure on all direction
Features	Massing, Funnel effect, Service Core, Self-Shaded design	Passive solar strategies, Staggered southern end, Roofing in levels	Courtyard effect, Use of Jali, Effective use of form, Wind tower
Roofing	Flat slab with evaporative cooling through air	Hyperboloid roof frames in levels.	Gentle slope with roof garden and solar panels to prevent heating
Fenestration	Glazing, Heavy massing, Aluminium fins	Simple brick masonry, Minimum massing	Less massing, Stone cladding, Brick jali
Laurels	GRIHA certified (5 Star)	BEE Certified (5 Star)	LEED certified (Platinum)
EPI	17 kw/ sq. m/year	14 kw/sq. m/year	84kw/sq. m/year

2.1. Outcome of the Case Study Analysis

Case Study 1: PCNTDA, Pune

- Orientation of the building plays an important role in controlling the heat gain
- Use of effective building envelope along with shape and size of the structure helps in achieving the level of comfort conditions.
- Functional use of massing to direct the air through it and keep the roof cool through evaporative cooling.

Case Study 2: PEDA, Chandigarh

- Effective utilization of the Southern façade by staggering the walls to let in more light and less heat

during summers, while more heat during winter according to climatic conditions.
- Variations in roof levels help in gaining daylight and also to minimize the exposed surface.

Case Study 3: CII Center, Hyderabad
- Use of traditional design methods of courtyard and jali to achieve the desired comfort levels in the structure.
- Using the form of the structure in accordance with the climate.
- Balance of morphology and height to width ratio helps to minimize the exposed surface area.

(Source: Authors)

3. Inferences

-Orientation of the building in accordance with the climatic condition's help's in making a building energy efficient.

-Choosing the ideal position of the structural vertical cores with regard to the climate zones may help to modulate building interior temperatures.

-Surface area to volume ratio can help determine the amount of heat gain on broad level.

-Perimeter to Area ratio a subordinate to S/V ratio applicable on two dimensional bodies also helps in determining the ambient shape of the structure to minimise the heat gain.

-P/V and S/V ratio help in determining the effect of climate on the form and shape of the building i.e. building morphology.

-Better ventilation can be achieved through positioning of windows in accordance with climate.

-Effective use of building form with respect to climate helps in curtailing the exposure towards the heat.

-For hot and humid climate, the building must be oriented towards the direction of wind flow to maximize the ventilation, while in hot and dry climates the form of the building should be such so as to reduce the heat gain and for the composite zone building should respond equally to heat gain and loss principles to cater equal amount of heating and cooling during summer and winter respectively.

4. Conclusions

The Form and Shape of a building i.e. building morphology in calculated proportions and sizes does have effect on the performance of a building specific to a particular climate. With the variations in climate in different climatic zone the orientation, shape, form, size etc. of any given structure also varies.

Proper orientation of the form along with the applied principles help in achieving the basic comfort level which are of prime necessity in a public building. The basic design principles in accordance with the climate, inculcated at design stage help in making the building sustainable.

Thus, it can be concluded that, there is a significant effect of climate on deciding a morphology of a building.

5. About the Authors

Author 1: Ar. Harshad Raisoni.
Assistant Professor at MIT School of Architecture, MIT-ADT University, Loni Kalbhor, Pune.
& Research Scholar at ASAP, Amity University, Rajasthan.

Author 2: Ar. Rakhi Begampure
Associate Professor at Yashoda College of Architecture, Satara
& Research Scholar at ASAP Amity University, Rajasthan.

Author 3: Prof. (Dr.) Jitendra Singh
Director, ASAP Amity University, Rajasthan.

6. References

- BEE Project, U. E.-I., 2009. *Energy Conservation Building Code User Guide,* New Delhi: Bureau of Energy Efficiency.
- UNEP, 2010. *The 'State of Play' of Sustainable buildings in India*, France: UNEP Sustainable Buildings and Climate Initiative.
- TERI, 2006. *The Energy & Resources Institute.* [Online] Available at: http://www.teriin.org/publications
- Yeang, K., 1999. *The green skyscraper : the basis for designing sustainable intensive buildings.* New York: Prestel.
- Cheung, C. K., Fuller, R. J. & Luther, M. B., 2005. Energy-efficient envelope design for high-rise apartments. *Energy and Buildings*, Issue 37, pp. 37-48.
- CII, 2009. *Confederation of Indian Industry*. [Online] Available at: https://www.cii.in/CII_Research
- Krishnan, A., 2001. *Climate responsive architecture.* New Delhi: Tata McGraw-Hill Pub. Co.