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Effect of Building Form for Low energy Architecture: Evaluation of Bio-Climatic Design, Bhubaneswar

Mayarani Praharaj
Department of Architecture, C.E.T., Bhubaneswar.

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ABSTRACT

Climatic responsive buildings are examples of a sensitive approach to energy consciousness for indoor comfort conditions. It has now become essential to develop energy efficient building design. The basis requirement of a building is to provide thermal comfort to its occupants. In modern buildings this is usually accomplished with the help of mechanical cooling or heating. With the advent of energy crisis there has been a need to develop climatic design tools which will provide thermal comfort in a building without or with minimum expenditure of energy. Climate determines the amount of solar radiation and mean outside temperature that a building is exposed to. Buildings are experiencing overheating during summer. For a built form, vertical surfaces are the most critical to the impact of solar radiation. This study examines the effect of different plan forms on the total solar radiation received by vertical surfaces of the buildings. The aim of this paper is to analyse the climatic conditions with respect to thermal comfort in buildings for the location of Bhubaneswar. The impact of building location and orientation on thermal comfort has been investigated. Different building shapes (square and rectangular) have been studied with variations in width-to-length ratio (aspect ratio) and building orientation. This study guides designers on choosing optimum form and appropriate orientation for buildings. The present paper describes how different plan forms are affected by solar radiation. Based on that the optimum aspect ratio (Length: Width) of the building over the location of Bhubaneswar has been found out which will receive minimum radiation in summer and maximum radiation in winter. This result in significant saving in the energy consumed while creating comfortable indoor environment.

Introduction

Eastern India has wide variations in minimum and maximum temperature during different seasons. The level of climate comfort/discomforts over the area also undergoes drastic changes with the change of the seasons.

The Global climate change has its impact on the coastal climate, and making the coastal climate of Orissa, significantly warmer.

Further various anthropogenic Causes including rapid urbanisation and industrialisation, large scale deforestation and increase in hard surface causing surface runoff and reduction of ground water recharge are the cause of predominate change in microclimate.

The study area Bhubaneswar having 20^{0}-13'N latitude 85^{0}-50'E longitude is located in coastal Orissa about 40Km west of North Bay of Bengal. For more than a decade it has experiencing contrasting extreme weather conditions like heat waves. The coastal area is a region otherwise known for its moderate temperature. But now the coastal area is also experiencing heat waves. If we take the example of Bhubaneswar, now the temperature remains above 40°C during summer.

To consider how climate affects the building design, one needs to first consider solar radiation. The solar position plays the main factor in the amount of radiation a region receives and is a big impact on climate. The solar radiation plays an important role in deciding the optimum orientation of a building. With proper orientation the building receives minimum solar radiation is summer for comfort condition. Normally roofs are horizontal, and hence these will receive the same heat irrespective of the building orientation. The total amount of solar radiation incident on different vertical surfaces may be considered for optimum orientation of the building.

Location and Climatic condition of Bhubaneswar

The climate of Bhubaneswar is warm-humid. It receives moderate to high direct solar radiation, depending on the season. People feel hot and sweaty owing to intense solar radiation accompanied by high humidity. Here, the building design should be such that it will receive minimum solar radiation during summer months.

Bio-Climatic evaluation: The method by Olgyay

Olgyay was the first to propose a systematic procedure for adapting the design of a building to the human requirements and climatic conditions. His method is based on a "Bioclimatic Chart" showing the zone of human comfort in relation to ambient air temperature and humidity, mean radiant temperature, wind speed, solar radiation and evaporative cooling. The comfort zone is in the centre, with winter and summer ranges indicated separately taking seasonal adoptions into account.

Bioclimatic analysis

Humans are comfortable within a relatively small range of temperature and humidity conditions, roughly between 20-30 ^{0}C and 30-60% relative humidity (RH), referred as the "comfort zone." These provide a partial description of conditions required for comfort. Other variables include radiant temperature, rate of

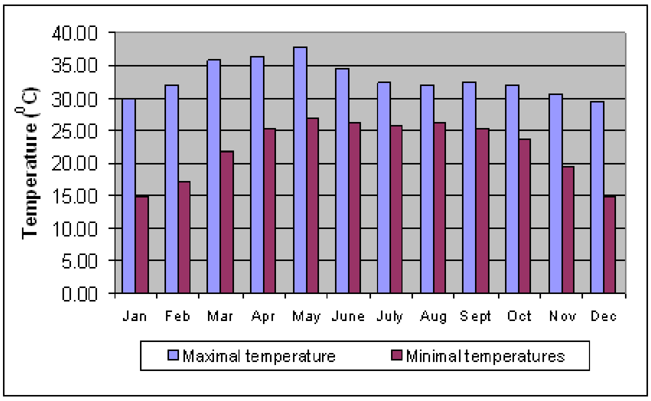
Tele:
E-mail addresses: mayapraharaj@gmail.com

air flow, as well as clothing and activity (metabolic rate). Givoni (1976) and Milne and Givoni (1979) have proposed a design method using the Bioclimatic Chart. It is based upon the psychometric format, overlaying it with zones defining parameters for the appropriate bioclimatic design techniques to create human comfort in a building interior.

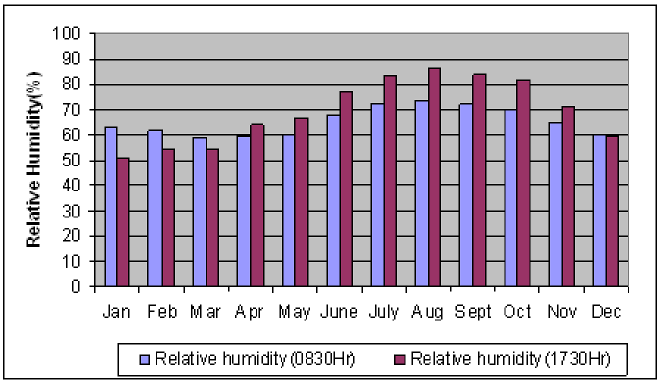
Bio-climatic evaluation: Bhubaneswar

Bio-climatic evaluation is the starting point for any architectural design aiming at environmental climatic balance. Prevailing climatic conditions can easily be plotted on the chart and will show the climatic condition of the region with regard to comfort condition. From the bio-climatic chart of Bhubaneswar (fig.3) it has been observed that May is the hottest month with the monthly average daily maximum temperature reaching as high as 38 □C, coupled with a humidity of about 66% during daytime. The chart shows that mechanical air-conditioning is required from April to July during the day. At nights, wind or fan induced ventilation can provide comfort. In March, only ventilation cooling is needed. The months of January, February, August, September, October and December are mostly comfortable.

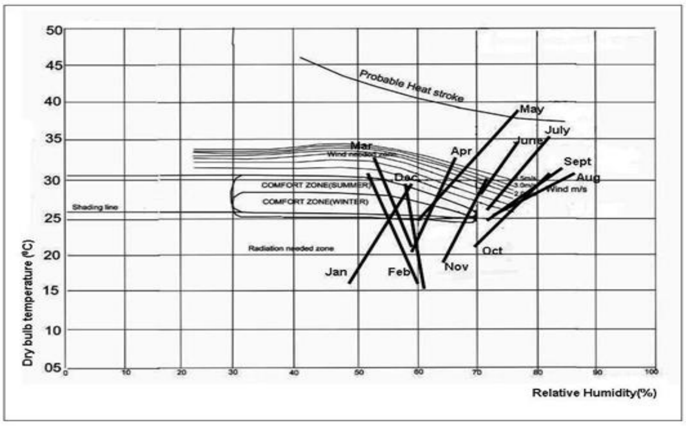
Fig, 1 Temperature Analysis: Bhubaneswar



Fig, 2 Humidity Analyses: Bhubaneswar



Fig, 3 Bio-climatic Chart: Bhubaneswar



Orientation of the building

Orientation affects the ability of a building to receive solar radiation. To minimise solar heat gain traditional buildings in warm-humid climates usually employ spread-out plans. By orientating the longer sides of the buildings to intercept prevailing winds and the shorter sides to face the direction of the strongest solar radiation, effective ventilation can be achieved, while solar radiation is minimised. Such strategy can also be applied effectively to modern buildings, both in smaller scales, such as single houses and larger scales, such as residential blocks. However the optimum width to length ratio (Aspect ratio) has to be worked out which will be suitable to the particular region as per the solar radiation data.

Criterion for optimum shape

It can be taken as a rule that the optimum shape is that which receive the minimum amount of radiation in summer and maximum amount of radiation in winter. It is widely believed that a square building has the best characteristics of preserving the heat in winter and remaining cool in summer. This conviction is based on the fact that a square building combines the largest practical volume with the smallest outside surface.

Methodology

The study is carried out by using the bio climatic analysis for the study area Bhubaneswar. The climatic condition of the region can be studies from the chart. The available solar radiation data over the vertical surfaces used for the calculation with different aspect ratio of the building. This study focuses only on the cumulative incident solar radiation fall on the external surfaces of building before it enters the internal space of the building. All forms were considered as stand-alone building without overshadow from any adjacent buildings. Selection of the design-day has been considered as May 15.

Solar radiation

Solar radiation is the radiant energy received from the sun. The radiation incident on a surface varies depending on its geographic location (latitude and longitude of the place); it is the most important weather variable that determines whether a place experiences high temperature or is predominantly cold. The effect of solar radiation is to increase the temperature of a building and the living space. The temperature of the structure is increased by absorption and radiation of heat by walling and roofing materials. This in turn, heats up the living space, abetted by further heating due to direct penetration of sun's rays through windows and other openings. This leads to uncomfortable living conditions.

The design of a building will first take into account the solar geometry of a region. Solar azimuths and altitude angles from sunrise to sunset are used to calculate a region's solar position.

In many countries, meteorological observatory makes routine measurements of solar radiation on a horizontal surface. Meteorological observatory can rarely produce solar radiation data for all the localities where buildings are erected. Even for places for which the data are available, the data are restricted to total (direct + diffuse) solar radiation on a horizontal surface. For building purposes solar radiation on vertical surfaces are also required. In general, no measured data for these surfaces are available. In the absence of measured data, computational methods have been developed for the estimation of solar radiation intensities on vertical surfaces, and are used widely for solar heat-gain calculation of buildings.

Total solar radiation for summer (May 15) has been computed for horizontal and vertical surfaces for Bhubaneswar (latitude 21^0N). May 15 has been selected because the solar radiation is very close to its maximum value during summer months. For the sake of generalization, no shading device or verandah is taken.

It has been observed that heavy radiation load is acting on the horizontal surface (roof) and on the east and west exposures during the summer. South exposures permit moderately significant heat gain during the summer, but they allow very significant heat gain during the winter. North exposures receive minimal radiation throughout the year.

Building form

Building form has significant effect on the exposed walls and roof. Exposed surface area is one of the parameters used in determining heat gain. It is however important to determine how minimum fabric heat gain may be achieved in terms of building form so that some basic standard may be arrived which can subsequently be used to compare the consequences of alternative building form. For the purposes of explanation and to illustrate the basic principles involved, a few relatively simple and idealized examples are used. As a starting point, it would seem reasonable to assume that minimum exposed surface area will achieve minimum heat gain.

A sphere has minimum exposed surface area, but spheres have limited building application and can therefore be disregarded. Of rectangular forms, the cube has least exposed surface area. However the cube has limited general building application as all building can not be resolved into cubic form. For example it may be possible to accommodate the floor area required in a given building in a square plan or a number of square plans layered one above the other, but the height of the building will be governed by floor to floor height, thus limiting its application.

The plan form with aspect ratio and the design day has been given in Table 2 for the purpose of the study

Plan form	Aspect ratio	Perimeter	Total solar radiation on vertical surfaces
N	1:1	140	51870
N	1:1.5	143	48552
N	1:2	149	47662
N	1:3	162	47539
N	1:4	175	48825
N	1:5	188	50471
N	1:6	200	52293
N	1:7	212	54217
N	1:8	222	56018
N	1:9	233	57925
N	1:10	243	59790

Fig.4 Total solar radiation on vertical surfaces (W / Sq.m) with different aspect ratio

Observation

Different plan forms have different capacity to receive solar energy under the same conditions due to its geometric characteristics. Table 2 illustrates the effects on perimeter length and the changes in aspect ratio form 1:1 to 1:10. From this it has been observed that, when compared to the perimeter length for the square shape (1:1), changes in perimeter length are relatively small up to an aspect ratio of 1:3. . At aspect ratio 1:4 the perimeter length has increased by about 25% and at 1:10 by about 74%.

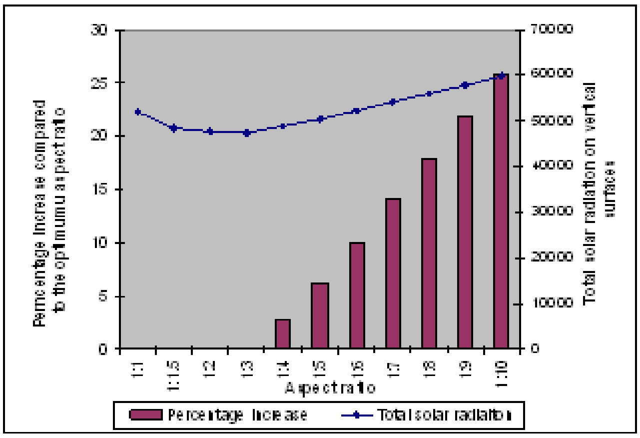


Fig.5 Percentage increase of solar radiation on vertical surfaces with different aspect ratio

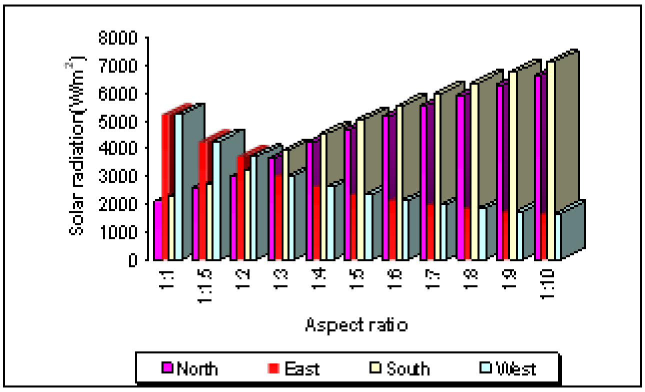


Fig.6 Total solar radiation on different orientation with different aspect ratio

For basic geometric shape, square shape with W/L ratio 1:1 height 3.5 meter received solar radiation of 51870 W/m^2. The solar radiation reduces with W/L ratio 1:1.5 with 48552 W/m^2, W/L ratio 1:2 with 47662 W/m^2, W/L ratio 1:3 with 47539 W/m^2. After that the solar radiation increases with W/L ratio 1:4 with 48825 and further increased with W/L ratio 1:5 to 1:10. The percentage increase compared to the optimum aspect ratio(1:3) varies from 3% for aspect ratio 1:4 to 26% with aspect ratio 1:10.

Though for economic consideration a square plan is an ideal one, the aspect ratio (W/L) 1:3 is considered as the optimum shape in minimizing the total solar radiation on vertical surfaces for development of energy efficient design in the present study. The result indicated that main factors that determine the relationship between solar radiation and building shape are aspect ratio (W/L ratio) and building orientation.

Conclusion

From the above study it has been observed that the aspect ratio 1:3 will provide the minimum exposure to the solar radiation. Although solar heat gain is the main consideration in the selection of optimum form of buildings, other factors like the direction of wind and site conditions cannot be overlooked in the final choice of the building form.

Table-1

SOLAR RADIATION CHART : Bhubaneswar (Latitude 21^0 N) ON MAY 15													
Hrs	6	7	8	9	10	11	12	13	14	15	16	17	18
Horizontal	148	386	591	761	904	992	1024	992	904	761	591	386	148
North	151	257	239	215	187	*	*	*	*	*	*	*	*
South	*	*	*	*	*	204	269	204	*	*	*	*	*
East	311	693	750	680	559	398	269	*	*	*	*	*	*
West	*	*	*	*	*	*	269	398	559	680	750	693	311
Note * Less effect						All readings are in W / Sq.m							

Table 2. Basic Base model (10 numbers)

Plan form	Square & Rectangle	Design day
Aspect ratio	Square 1:1 Rectangle 1:1.5, 1:2, 1:3, 1:4, 1:5, 1:6, 1:7, 1:8, 1:9, 1:10	May 15

In most of the cases, building byelaws and other regulations do not permit selection of optimum building form. Where best form in proper orientation is not possible for a building, the next choice for good orientation is to be selected. The selection of optimum orientation should be based on the summer conditions or, in other words, the orientation chosen should lead to minimum summer heat gain into the building. This result in significant saving in the energy consumed while creating comfortable indoor environment.

References

1. Prof. Schild Erich, H.F. Casselmann, Gunter Dahmen, Pohlenz Rainer, 1981, "Environmental Physics in Construction: It's Application in Architectural Design", Granada Publishing limited, London. ISBN 0-246-11224-7, PP-81-84

2. IS (Indian Standard): 7662 (PART-I) -1974, Recommendations for orientation of buildings, Part-I Non-Industrial Buildings.

3. Seshadri T.N., Rao K.R., Sharma M.R., Sarma G.N. and Ali S., Climatological and solar data for India, CBRI, Sarita Prakashan, Meerut, 1968.

4. Martin Evans, 1980 "Housing, Climate and comfort", The Architectural press, London, ISBN 0-85139-102-8, p.109-124, p-39, 40

5. B. Givoni, 1976, "Man, Climate and Architecture", Van Nostrand Reinhold company, New York. P.181-185, ISBN 0-442-26296-5, p-311

6. Arbind Krishan, Nick Baker, Simons Yannas, S.V. Szoklay,2001, "Climatic Responsive Architecture: A Design Handbook for Energy Efficient in Buildings"**,** Tata Mc Graw Hill publishing company Limited, New Delhi, ISBN 0-67-463218-3,2001, p-388-399

7. Koenigsberger, Ingersoll, Mayhew, Szokolay, 1980, "Manual of Tropical Housing and Building, Part-1, Climatic Design, ISBN 0582-44546-9, P -110,111,297

8. Donald Watson, 1977, Time-saver standards for architectural design data The McGraw-Hill Professional Book Group, I.S.B.N. 0-07-068506-1. P-23,26

9. Chia Sok Ling, Mohd. Hamdan Ahmad and Dilshan Remaz Ossen, 2007, The Effect of Geometric Shape and Building Orientation on Minimising Solar Radiation on High-Rise Buildings in Hot Humid Climate, Journal of Construction in Developing Countries, Vol. 12, No. 1.

10, Ishwar Chand, R.D. Singh, S.S. Aggarwal, Design development of Energy Efficient Residential Building, 2004, Journal of Indian Building congress, Vol-11, No-1.

11. Mayarani Praharaj, Climatic responsive residential design for coastal areas: A case study Orissa, PhD Thesis, Department of Architecture, T & RP, Bengal Engineering and Science University, Howrah, 2010