Bio Climatic Analysis of Bhubaneswar-An Investigation to Arrive Human Comfort through Natural Ventilation

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Abstract- The objective of this paper is to study and analyse the local climate of Bhubaneswar and to assess the potential of using natural ventilation for arriving thermal comfort conditions in residential buildings. Various theories in response to Thermal comfort have been analysed to assess the thermal comfort of the city which has a very distinct hot and humid climate. Since natural ventilation is a key factor for achieving thermal comfort in hot and humid climate a typical mean monthly weather data has been selected from a 10 years weather data. The weather data are analysed on the basis of temperature, Humidity, wind speeds which are the key parameter for any typical Bio climatic chart. Thermal comfort models applicable for Bhubaneswar are used for assessment of thermal conditions. The study concludes that thermal comfort during night time can be achieved all most throughout the year by controlling the wind speed to 1-1.5m/s at least. Except the month April and May, in most of the months even it is possible to achieve Thermal comfort during the day time in Bhubaneswar. This study can also be used as a basis for developing strategies on naturally ventilated building forms.

Index Terms- Hot and Humid, Residential Buildings, Thermal comfort, Building form,Bhubaneswar

I. Introduction

The simplest definition of Thermal comfort is given by Givoni, who explained that thermal comfort could be defined as the range of climatic conditions considered comfortable and acceptable to humans. Studies of human response to a thermal environment have been conducted by ASHRAE since the 1920s. Some significant studies in this area include the ASHRAE Comfort Charts, Olgyay's Bio-climatic Chart, Givoni's Building Bio-climatic Chart and Fanger's Predicted Mean Vote [1].

Research stated that air movement is one of the major factors for arriving Thermal Comfort in Hot & Humid Climate. There are a number of ways air movement can induce comfort conditions. It can help the mental and psychological state of mind of people as well as increase the thermal performance of a building. In warm and humid condition, the former is more apparent. Many a time's air movement is the only natural method of reducing heat stress especially in developing countries [2].

Natural ventilation reduces operation costs, improves indoor air quality and provides satisfactory thermal comfort in certain climates. Passive cooling of houses using natural ventilation has become an effective alternative to alleviate energy related costs and associated problems of air-conditioned buildings [3]. Power consumption of the domestic sector of Odisha is around 79.43% way ahead of the commercial and industrial requirement. Therefore, the investigation of natural ventilation applicability in hot-humid climates for residential sector is significant for providing guidance to optimize building forms.

Achieving thermal comfort through passive cooling strategy is relatively difficult to accomplish for hot and humid climate. This is due to the relatively high humidity level present in the air. For this reason, passive cooling designs in hot and humid climates need to pay careful attention to building design, orientation, planning, material selection, window treatments, ventilation, including proper facility planning and management [1]. Particularly in developing countries, air-conditioners are becoming more common in both residential and commercial buildings resulting increase in energy consumption. Without a proper understanding of micro climate of the site, designers continue to design, providing adverse effect to human thermal comfort.

This particular paper aims to study and analyse the thermal comfort level of Bhubaneswar by applying various standards suggested by ASHRAE and Olgay. Considering the average temperature and humidity of Bhubaneswar for a period of 10 years and the prevailing wind direction and wind speed of 12 years, comfort level of Bhubaneswar is assessed. Appropriate suggestion is derived at the end to understand whether natural ventilation can provide thermal comfort in Bhubaneswar. Research may extend in a later stage in developing strategies for naturally ventilated building form.

II. Thermal Comfort

Thermal comfort is that condition of mind which expresses satisfaction with the thermal environment. Because there are large variations, both physiologically and psychologically, from person to person, it is difficult to satisfy everyone in a space. The environmental conditions required for comfort are not the same for everyone. However, extensive laboratory and field data have been collected that provides the necessary statistical data to define conditions that a specified percentage of occupants will find thermally comfortable [4].

Air temperature, radiant temperature, humidity, and wind speed are the four environmental parameters those influence this heat exchange. There are two personal parameters – clothing level and activity level, those also have influence on this heat exchange [4].

III. Study Area

Investigating the comfort conditions of Bhubaneswar, characterized by a very hot and humid climate is the main purpose of this study. Comfort conditions of Bhubaneswar analysed through various theories will support the potential for using natural ventilation as a design strategy for residential buildings especially multi-storeyed group housing. High rise group housing developments have both outdoor and indoor spaces to sit rest and socialize. Hence measuring the thermal comfort conditions both indoor and outdoor are important in these types of developments.

Bhubaneswar is situated at a longitude of 20° 16' 12” N and latitude of 85° 50' 24” E. The city has an average altitude of 45 m (148 ft) above sea level. The climate follows a hot and humid pattern because of its proximity to the sea. Summer lasts from March to May with the maximum temperature going as high as 38^0 C during the day and 28^0 C during night. The temperature remains above 35^0 C during the day in these 3 months. Humidity is another factor which is distinct here. It has very high humidity level, above 80% from July to October during monsoon season. In summer the relative humidity goes near 70%.

Due to its high temperature and high humidity level appropriate analysis is required to understand if the thermal comfort can be achieved with natural ventilation in Bhubaneswar’s climate. Typical meteorological data of 10 years, month wise has been collected from Meterological centre for analysis. Since there is not much variation observed in the weather data, the maximum and minimum temperature of the most recent year 2014 has been used in the thermal comfort chart (Fig-1).

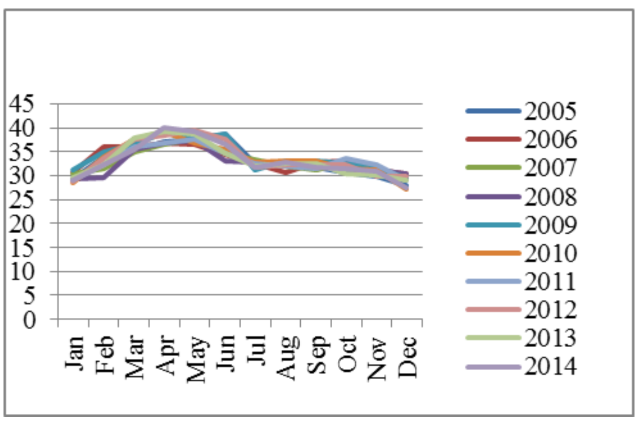

Fig -1: Maximum temperature measurement- month wise from 2005-2014

IV. Thermal Comfort Chart

In order to evaluate applicability of natural ventilation and achieving thermal comfort in Bhubaneswar, the primary task is to select appropriate theory to analyse typical weather data. The purpose of thermal comfort is to provide comfortable thermal environment for residents where the major parameters include air temperature, relative humidity and air velocity. Thermal comfort of three conditions, day time, night time and indoor comfort has to be tested using carefully selected Thermal comfort chart of Olgay and ASHRAE 55. Both Olgay and ASHRAE 55 have wind velocity as major criteria for achieving thermal comfort and are appropriate for the hot and humid climate.

It is important to mention that the comfort conditions of tropical climate in respect to cold and temperate climate are different. Comfort preferences of people in different locations vary in terms of acclimatization to a particular climate. The long-term experience of a warmer climate may result that people of that environment have a tolerance to higher temperatures as compared with people in colder regions. There is the ability of people to adapt to a particular environment in the way of behavioural patterns [5].

Mallick conducted a thermal comfort study of occupants living in urban housing in Bangladesh. The results showed that people could endure high temperature and very high humidity for comfort. Under still-air conditions comfort temperature ranges for people engaged in a range of household activities wearing ordinary clothing was between 24 and 33 °C. Forrair flow of 0.3 m/s there is a rise in the lower and upper limits of temperatures by 2.4 and 2.2 ° C respectively. There are instances where people have reported to be comfortable in humidity above 95%. An air temperature range of 24 to 32 °C along with relative humidity values between 50 and 90% indicates that it is in the range in which people feel comfortable without or in little air movement [6].

Similar study has been conducted in hot-humid vernacular environments of Thailand during hot and rainy seasons in 2003. A proposal was given to shift the comfort zone to a new dimension for thermal comfort study, especially in the contexts of contemporary tropical architecture and vernacular environments [7].

It is common experience that air movement, be it a natural wind, or generated by a fan, has a cooling effect. This largely depends on the velocity of that air movement. Under everyday conditions the average subjective reactions to various velocities are:

< 0.25 m/s unnoticed
0.25-0.50 pleasant
0.50-1.00 awareness of air movement
1.00-1.50 draughty
> 1.50 annoyingly draughty

These reactions however, depend on the temperature of the air. Under hot conditions 1 m/s is pleasant and indoor air velocities up to 1.5 m/s are acceptable. [8].

As a rough guide, for persons at sedentary activity (1.2 met) and wearing light clothing (0.5 clo) the ASHRAE Handbook of Fundamentals permits extension of the upper comfort limits by 1 K for every 0.275 m/s air velocity. Givoni suggested that for warm climates air velocity should be extended to 2 m/s. Most sources take the limit as 1.5 m/s for non-thermal reasons [3].

A general guide is given by the numerical approximation for such cooling
effect (thus extension of comfort limits) (1):

$$dT = 6\cdot(v-0.2) - 1.6\cdot(v-0.2)2 \qquad (1)$$
(up to v = 2 m/s)

V. Wind Data Analysis

Wind is a complex phenomenon than can change in a short period both in wind speed and in wind direction. Figure 2 & 3 shows the selected ranges of wind speed distribution over 12 years during the day and night. Figure 2 reveals that on average, wind speed is low during the night time. Wind speeds in the day time are mainly in the range of 1.5 -4.5m/s and come preferably from due South and Southwest. It is evident that the prevailing wind directions in Bhubaneswar is South and South west over the year.

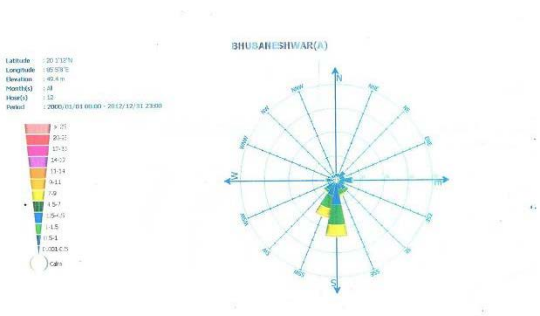

Fig -2: Wind speed and direction during the day

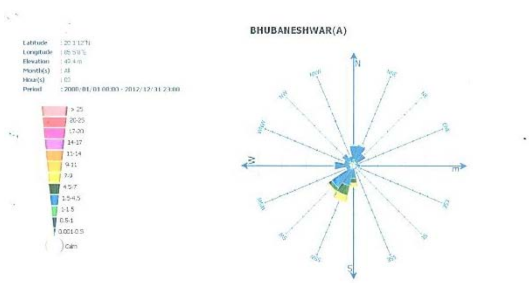

Fig -3: Wind speed and direction during the night

The number of stations supplying wind velocity data suitable for present considerations is very small. Most stations measuring such data are usually considered morning 8:30 am or evening 5:30 pm. The situation possess considerable problem of assessment of night time wind velocities which are most important for night time comfort.

VI. Bioclimatic approach and thermal comfort

a) Outdoor Spaces: There is adequate understanding of the influence of climate on urban settlements. For example, the way self-shading streets protect the outdoor urban spaces from the hot son in hot arid climates; or dispersed buildings allow for easy flow of wind through the spaces is greatly been acknowledged [9]. The quality of open urban spaces has received a lot of attention in recent years. There is a broad recognition that microclimatic conditions contribute to the quality of life in cities, both from the economic as well as from the social viewpoint.

The bioclimatic approach explores the opportunities to design according to the local climate conditions. Olgyay (1963) developed the first bioclimatic chart based on outdoor climate conditions aiming to identify mitigation measures like solar radiation, air movement or shading to achieve a comfortable climate [10]. Hence Olgyay's chart has been used for the Bio-climatic analysis of Bhubaneswar for analyzing the thermal comfort of outdoor spaces.

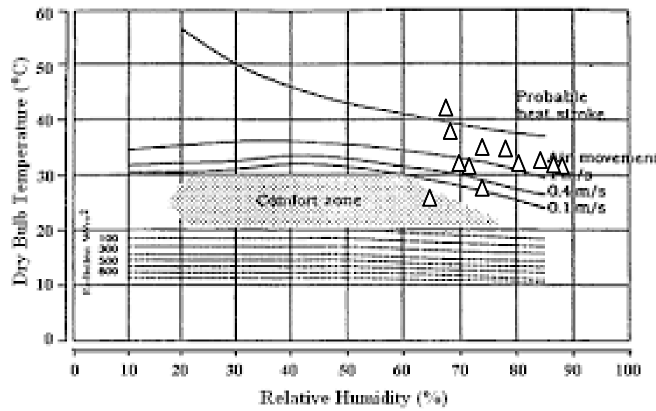

Fig -4: Outdoor Comfort conditions of Bhubaneswar month wise during the day

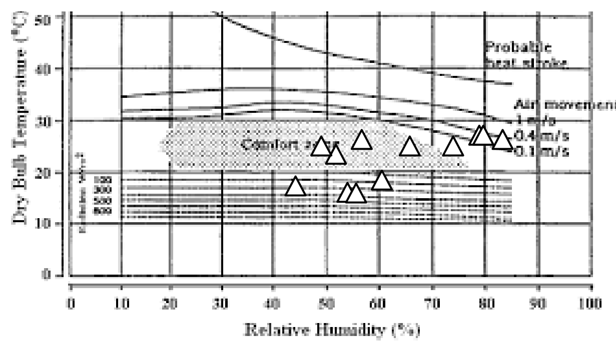

Fig -5:Outdoor Comfort conditions of Bhubaneswar month wise during the night

Indoor Thermal Comfort:

For naturally ventilated buildings ASHRAE Standard 55 proposes the adaptive thermal comfort approach and defines a range of acceptable indoor temperature of 2.5 K above and below optimum comfort temperature for 90% acceptability based on De dear and Brager's equation [8]. In the approach, thermal responses in naturally ventilated spaces are linked with the outdoor climate. Thereby, the comfort temperature is calculated by the outdoor temperature using the equation (2).

$T_n = 0.31\,T_m + 17.8$ (2) (de Dear & Brager, 2002) where T_n is the Thermal neutrality comfort temperature and T_m is the mean outdoor temperature.

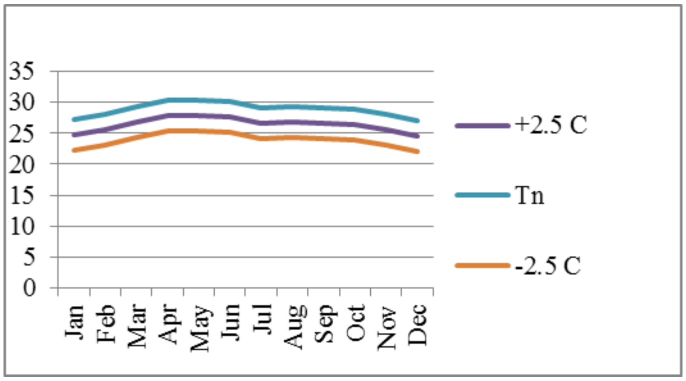

Fig -6: Indoor Thermal Comfort conditions of Bhubaneswar month wise

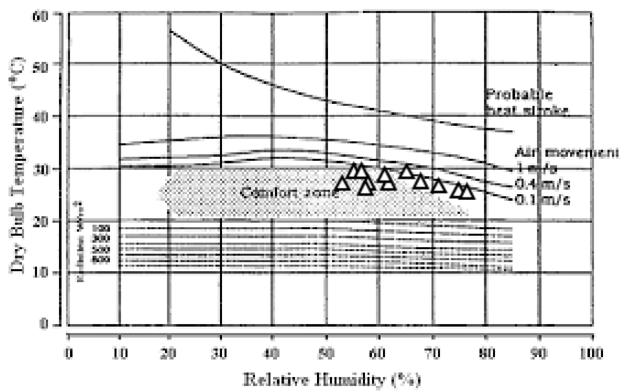

Fig -7: Indoor Comfort conditions of Bhubaneswar month wise

VII. Discussion

Based on the analysis of the above Bio-climatic charts, the following recommendations are derived which can be adopted for outdoor spaces of a Group housing development. The bio-climatic charts (Fig. 4, 5) show that outdoor maximum temperatures are within the extended comfort zone which require additional air movement between 1.0-3.0m/s during day time except for the month of April and May when people need to stay indoor to avoid heat stroke.

During night time a wind speed of 0.5-1m/s is enough to provide thermal comfort in the outdoors except winter seasons. Note that temperature (Min) has been considered for measuring the night time thermal comfort and not the evening temperature (when the residents actually use the outdoor spaces) due to non-availability of meteorological data.

Indoor thermal comfort is possible all most all months except for the monsoon season i.e July, August and September when it is difficult to achieve comfort due to the high humidity (Fig-7). Certain amount of dehumidification is required during these periods [11].

VIII. Concluding Remarks

It is observed from the analysis that outdoor comfort during the day can be achieved with the additional air movement between 1.0-3.0m/s during day time except for the month of April and May when people need to stay indoor to avoid heat stroke.

During night time a windspeed of 0.5-1m/s is enough to provide thermal comfort in the outdoors except winter seasons. Hence outdoor spaces has to be orientated in such a way to allow summer breeze but eliminate winter cold wind.

Indoor thermal comfort is possible in almost all months except the monsoon season when the humidity is too high. Dehumidification is required for these seasons.

The wind rose diagram of Bhubaneswer signifies the average wind velocity is between 1.5-4.5m/s during most part of the day and night. Hence creating adequate strategy to allow maximum wind flow inside and around building both during the day and night will help to achieve Thermal comfort conditions in Bhubaneswar at least for 09-10 months of the year.

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