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Adapting Indoor Thermal Comfort Through Passive Strategies of Different Architecture Styles in Modern Architecture

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***Abstract*: Human being's evolution from the outdoor environment to the enclosed spaces base itself in early ages and is continuing. People unlike outdoors and found indoors to be safer for them. Even today, 80-90 percent of humans spent most of their time in enclosed spaces. And now here comfort plays its role. Comfort, an essential factor for a better living in natural or artificial environment both inside or outside the building. In ancient time people creatively design the structures with locally available materials and also control the temperature for occupants and make the space bearable for surviving. Country like India, where there is variety of cultural and religion is result of different architectural styles. Different architectural style has its different persona of building and have different ways to control indoor thermal comfort through their various passive strategies. After the industrialization, the modern architecture is deteriorating the rich old ancient architecture and making building lifeless. Modern buildings use mechanical ways to control indoor thermal comfort whereas historic buildings provide passive architectural techniques used in tomb such as curved roof, high roof, natural ventilation, massive thick wall and openings. Ancient architecture is unique in their culture, landscape, and architecture, representing a huge potential for the socio-economic recovery of remote in lands.**

***Keywords*: Indoor thermal comfort, passive strategies, ancient architecture, modern architecture, predicted mean vote.**

1. Introduction

"The nature of a place must be explored. You don't plunk a building somewhere without the influence of what is around it. A building is the character of the place, the nature of it" - Louis Kahn.

Actualizing an ideal thermally comfortable living environment is one of the biggest demand for an architect especially in the world of energy crisis. Vernacular architecture is the best practice to perform as it has a sensitive adaption to local climate and is rich in different passive techniques to establish most favorable livable environment.

As shelter is a temporary or permanent covering under which a person can perform activities, as there are different forms of shelter like house, office, public places, etc. There is a simple relationship between occupants and temperature inside the building, if it satisfies the occupants required temperature inside the building, the occupant's work efficiency will be more and likewise. Now building envelope plays a vital role here as walls, roofs, openings, doors, windows, flooring all these contribute in maintaining indoor thermal comfort of any structure. The inside temperature is controlled by passive strategies of an ancient building or historic building. Indoor thermal comfort is important for occupant to survive and perform activity inside the structure. In ancient time people used to interact with each other very much as compare to modern and to their convenience they design interactive places which is also result in controlling thermal comfort.

Now a day's air conditioning has conquered in providing comfortable environment within the narrow defined thermal ranges energy consumption is high while utilizing it. Naturally ventilated buildings not always achieve a narrow stringent set of values are more acceptable in terms of energy consumption and resource utilization. As role of architects we shouldn't neglect the social responsibility of infusing a moderate lifestyle among people without upsetting the comforts denied if any. Architecture hence attains the role of a cultural influence also in harmonizing comfort and consumption factors efficiently.

In general, the proliferation of western lifestyles, clothing, technology in building construction and microclimate control have tended towards homogenizing indoor environments to which humans are exposed. These developments may be compelled by market forces, but the result is that humans are becoming adapted to a very narrow band of conditions. In a global ecosystem increasingly threatened by environmental degradation and anthropogenic climate change.

Humans have a fairly broad adaptability, a capacity for acclimatization to different conditions, but we can become "spoilt". Living in artificially maintained and homogenized environments would reduce this adaptability, the limits of survival would be narrowed.

2. Interaction between three personal and environment factors of thermal comfort

Physiological: the manner in our bodies work and interact with our environment.

Physical: the main elements of the environment which surrounds us (air temperature, air humidity, air movement, room surface temperature);

Socio Psychological: the way we feel as a whole (for example, if we are tired, stressed, happy…) and the kind of social environment we live in.

The physiological aspect: Control systems in body balance our heat exchanges processes with the environment repeatedly, by speeding up and slowing down the heartbeat to vary our blood flow and regulate heat distribution by shivering when too cold in conduct to increase heat production, by sweating more when too hot to curtail skin temperature in contribution with evaporation.

A comfortable indoor environment restraint the efforts our bodies need to make to regulate body temperature and helping in establishing a good energy balance.

The physical aspect:

In the physical environment, thermal energy (heat or cold) is transferred through three processes i.e. conduction, radiation and convection.

Conduction is energy transfer via a solid, such as the floor, slab or wall. Convection is energy transfer from a solid to an adjacent gas or fluid (air or water). And radiation is the energy emitted from a surface, such as a radiator.

The socio psychological aspect:

Thermal comfort is also depended on the individual's current emotional state, mood, level of fatigue in result will affect their experience of an environment. Expectations play an important role in how an individual experiences the physical world, but more generally, perceptions are likely to based on one's own thermal history. Increased overheating sensation may be lead from other environmental factors, noise or glare for example which may influence thermal perception.

3. Components of thermal comfort

Metabolic heat production: Human body is endothermic, and produce their own heat through metabolism. Depending on degree of activities and person-to-person physiological differences, metabolic heat production can vary a lot. Metabolic heat turn into an important part of how people perceive their thermal comfort.

Clothing: Material and designing of clothes that people wear plays an immense role in thermal comfort for a place. Energy transfer rate between skin and environment is affected by clothing.

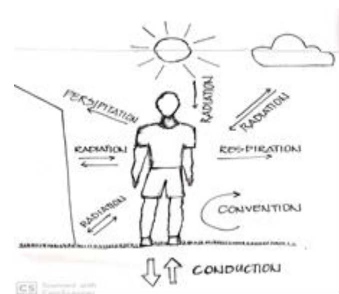
Relative humidity: The efficiency of evaporative heat dissipation is strongly influenced by relative humidity. Evaporative pathways are alternative process where people begin to struggle to lose heat at high relative humidity. Therefore, discomfort could be happening when relative humidity is high with respect to low air temperature.

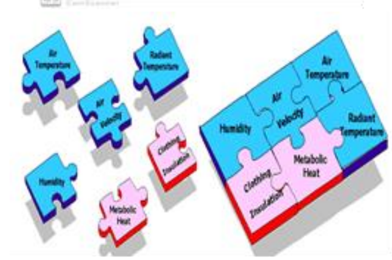
These first three influence people's sensitivity to the thermal environment, and now the next three points will dictate thermal comfort.

Convection: Process in which energy is transfer via the flow of air. For people in the workplace, the convective component of thermal comfort is governed primarily by the air temperature and ventilation rate.

Conduction: Process of energy transferring through direct contact with surfaces of surrounding.

Radiation: Process of energy transferring via radiation from surrounding surfaces. Radiation is an important and largest component of thermal comfort, as humans experience the thermal environment as over 50 % the MRT.





4. Thermal Comfort and Building

Considering the thermal comfort factors every building will have designed differently as the activities perform under the building will be varied. Circumstances of both thermal environment and occupant's activities are more dynamic with respect to a building or any other structure. According to ASHRAE Standard 55, which defines thermal comfort in commercial buildings, success depends on satisfying the thermal comfort needs of 80% of occupants. The conventional way to achieve that threshold is to design a highly predictable, functioned and controlled environment using mechanical equipment's which are energy intensive.

Two models to calculate thermal comfort:

1. Predicted mean vote (PMV)
2. Predicted percentage of dissatisfied (PPD)

In the 60s, Fanger wanted to develop a method (an index), by which HVAC engineers would be able to predict whether a certain thermal environment would be acceptable to a large group of people. Through experimental work involving linear relationships between (i) mean skin temperature and the activity level and (ii) sweat secretion and the activity level were established.

These were then substituted into the heat balance equations to develop the comfort equation which could predict the conditions that people would feel thermally neutral. To have

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practical applications, an index called the predicted mean vote (PMV) was derived by expanding the comfort equation to incorporate the seven-point ASHRAE thermal sensation scale.

Table 1
ASHRAE thermal sensation scale

Value	Sensation
+3	Hot
+2	Warm
+1	Slightly warm
0	Neutral
-1	Slightly cool
-2	Cool
-3	Cold

PMV is a function of the four environmental variables and two human variables:

- Air temperature
- Mean radiant temperature
- Relative air velocity
- Air humidity
- Activity level
- The clothing insulation

PMV represents the mean thermal sensation vote on a standard scale for a group of building occupants for any given combination of the four environmental variables, prevailing activity level and clothing.

People are not alike, and there will always be a certain variation in the thermal sensations of a large group of people. It is important to know the percentage of people who would be dis-satisfied with the environment, because these are the ones who would most likely make complaints and can disturbs the environment of a space.

Based on experimental studies in which participants voted on their thermal sensations, an empirical relationship between PMV and the predicted percentage of dissatisfied (PPD) was developed as follow: PPD indicates that even at thermal neutrality (i.e. PMV = 0), about 5% of the people may still be dissatisfied. Instead of trying to achieve actual thermal condition of a space, design objective should therefore be exploring the range of thermal comfort according to the occupancy.

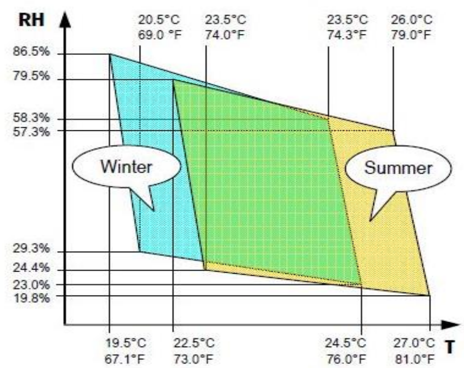
That is how cold or warm the thermal conditions could deviate from the optimum and what percentage of dissatisfied would be acceptable. This has important energy use implications because a wider range of conditions of thermal dynamins aim to consume less heating and cooling of air to energy than a narrow one. The PMV–PPD model has been adopted by various national and international standards/guide-lines (e.g. ASHRAE Standard 55[49]and ISO 7730[50]).

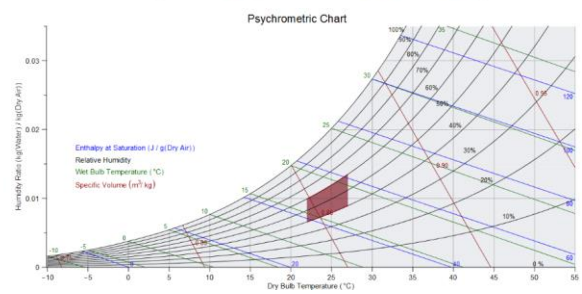
This corresponds to thermal conditions that may be acceptable to 80% of the building occupant sand is based on a PPD of 10% (i.e.0.5 < PMV < +0.5) and an additional 10% dissatisfaction due to local environment thermal discomfort. For an indoor relative humidity of 50%, the temperature range is approximately from 20°C (lower limit of the winter zone) to just over 27°C (upper limit of the summer zone).

5. Psychometric Chart

Literature of thermal comfort only concentrates on two aspects of environment temperature and humidity.

Humans normally feel comfortable between of 22 °C to 27 °C temperatures and a relative humidity of 40% to 60%. In this particular function, air at 35 °C and 60% relative humidity will be conditioned into the human comfort zone, plotted on a psychometric chart with the thermodynamic process. To perform the activity, we have to first cool the air to 14 °C, and then proceed to heat the air to 24 °C.





Red highlighted part is meant an ideal comfort zone

A. *Psychometric chart consists of*

1) Dry-bulb temperature (DBT
2) Wet-bulb temperature (WBT)
3) Dew point temperature
4) Humidity
    - Specific Humidity
    - Absolute humidity
    - Relative humidity
5) Specific enthalpy
6) Specific volume

6. Literature Case Study

A. *The building of the Museum of History of Valencia*

It was built in 1850 to serve as the public reservoir for drinking water for the city, and it continued to play this role satisfyingly for more than one century. The building, with its brickwork and vaults, is a model of an era that made the instrument of change to make the leap to progress engineering.

The reservoir is designed by a maze of two hundred and fifty pillars, which hold up a roof formed by eleven arched vaults made with bricks that are locally available.

The main objective of the museum has been to showcase the history of the city from its origins to the present day. The Museum has a perfectly rectangular geometry and a single plant. The main entrance of museum is located on the north façade.

1) Statistical Study of the Thermal Comfort of Museum

The number of visitors registered during the period of monitoring (August, 2015 - February, 2016) is 8.434 persons. 413 surveys have been registered and, by means of statistics calculations, a level of confidence of 95%, a simple error of 5%, and a recommended size of the sample of 368 has been observed have been observed, according to simple random sampling formula (knowing the population).

The studied sample is distributed exactly to 50 % between man and women, and the range of predominant age is the one that understands the ages of 18 years and 30 years with 141 polled ones (38%).

This range is followed by the ranges of ages of between 31 up to 40 years (22 %), and 41 to 50 years (23 %), with about 85 visitors for each range. Finally, the visitors between 51 years and 60 years do not reach the 40 (10 %), and for what concerns the ones older than 60 years, only 24 answers have registered (7%).

Regarding the origin of the individuals, 54 % of them has answered to be local and 46 % turns out to be from other cities in Spain, and even some of them from other countries.

With regard to the subjective opinion of the visitors of the indoor temperature of the Museum, the values "neutral" (30 %) and "cool" (35 %) have turned out to be the most selected ones together with "warm" (14 %) and "cold" (13 %). The values "very cold" (5%) and "hot" (3%) have received 18 and 13 responses, respectively. AS the last selected option, "very hot" shows only 1 response. These results show that the level of satisfaction with the indoor comfort is more than acceptable, with a small tendency to point out a little bit too low temperatures.

B. Gohar Mahal Bhopal

- The Gohar Mahal is an elegant example of Hindu and Islamic architecture which is situated in the upper bank of lake. The first women ruler of Bhopal named Gohar Begum in 1820 built it the palace for her.
- It totally works on solar passive design i.e. is a technique of collecting, storing and radiating heat energy in winter and rejects solar heat in summer.
- The various passive solar features of magnificent Gohar Mahal are discussed as following:
- Courtyard: The Gohar Mahal is divided into three part with two centrally beautiful courtyards. Courtyard is an affective technique of shading, and also allowing light to enter inside the building. It helps in maintaining pressure difference between hot air and cool air, which results in air flow. To humidify the air, water sprinkler was used, hence thermal comfort is achieved.
- The courtyards act as prime area for air exchange and day light which contributes in maintaining the temperature cooler with proper lighting of interior space.
- Building envelop: Building envelop contributes primarily for the heat exchange of built up mass.
- Wall: The colossal wall of Gohar Mahal is made up of adobe bricks with some space made of stone.
- Sun is kept off from adobe wall by means of over hangs, shading device, verandas, and proper orientation, so that they stay cool during the day and night of summer.
- Gap between the two ceiling comprises of air, which is a non conductor of heat, hence reduces the transmission of heat from roof to interior of building.
- Ventilation refers to exchange of air from outside, as well as flow of air within the building. Natural ventilation is done by pressure difference between indoor and out-door air and with effective opening for the escape for warm air.
- Shading device: Shading devices helps by facilitating in control of sunlight required in interior, by cutting off the harsh summer sun and to gain direct solar radiation in winter. The over hangs are provided on all the four side of the Gohar Mahal. The shading devices are 900mm wide with slight slope towards outside of the building for easy run-off of rainwater and curtail the undesired sunlight. Decorative stone brackets support the shading devices in form of overhangs. Hence the only desired sun light is allowed within the built up mass to achieve the thermal comfort.
- The material majorly contributes in heat exchange processes and maintain the total thermal mass of building, which helps in cutting down energy requirement as well as maintains indoor human comfort. The building material used in various building component of the Gohar Mahal are: Adobe sun dried bricks, stone, timber, lime, surkhi.

7. As with every old building its passive strategies come along and some architectural style which contribute in maintaining indoor thermal comfort in India

A. Passive Concept Used in

1) Tomb of Bahu Begam (Awadh Architecture)

Light color exterior: The tomb has light color.

Openings: The builders have made special arrangement for ventilation in the center room.

They have made sloppy window on the top of the wall and they have made adjacent verandah with two room and the door of the both rooms open in verandah and for good cross ventilation they have made a special curved window in such a way that curve is directed toward the verandah by which they bend the air toward verandah and they also made small windows for air input and big door for output of air by which they create pressure difference and by which a cross ventilation is always facilitated.

High Roof: The height of building is about 10 m. This type of Architecture allows warm air to collect at the top and stratification of warm air maintains cool air at the floor level, thus maintaining air temperature in a comfortable zone and provide good Stack Effect.

2) La Martiniere College (European Architecture)

Vegetation and Water bodies:

Building is situated near the river bank of Gomti and surrounded by the vegetation by which is become cool in summer by evaporation process from both river and vegetation.

High Roofs: Roofs of the building are very high so it facilitates good Stack effect in the building.

Light Color: Building is light colored which has low absorption and high reflectivity so building does not become hot in the summer.

Openings: Size of the windows and doors are very large by which it facilitates very good day light factor and ventilation.

Wind Tower: They have created wind tower in the building for cooling the basement of the building in which the tomb of the Martinera is placed that is very good for fresh air supply in the basement and also cooling the basement of building.

3) University of Lucknow (British Architecture)

High and Domed Roofs: Heights of the buildings are about 20 feet, which facilitate very well Stack effect in buildings.

Openings on the Top: There are openings on the rooftop of the building by which Chimney effect in the building creates and removes the hot air collected in the top of the roof and create a space for the new fresh air in the bottom and make a continuous flow of the fresh air. It also facilitates the day lighting in buildings.

Thick walls: Walls of the University of Lucknow are very thick by which they prevent thermal heat transfer from atmosphere to buildings, and time lag is very high and decrement factor is low.

Chajjas all around the Buildings: Buildings are surrounded by chajjas on the windows and roofs by which windows and walls of the buildings do not become so hot.

Cluster Pattern of the Roofs: The roofs of the buildings are clustered so as to provide shadings of the buildings.

8. Modernisation

Modern buildings are only blocks of concrete which are performing their function without thinking the health of human and environment. To counter the discomfort conditions ceiling fans, air coolers and AC's are constantly used for a large part in year in modern building all over the India. However, relying only on active cooling leads to maximum demands and overall energy consumption in a building.

Energy specialist's estimated that India's electricity demand will be double by consumption of air- conditioning in 15 years, which result in necessity of 200 to 300 new electric plants. Consuming plenty of electrical energy through air- conditioning is part of reason that India is expected to be the world's largest contributor to new electricity supply demand between now and 2040.

Most cities are very hot and very crowded Four of the five most populous cities with the highest cooling, namely, Chennai, Mumbai, Kolkata and New Delhi – which means that getting luxurious lifestyle, as people get wealthy, the demand for room air-conditioning will increase. ACs are the first thought, people want to buy when they cross a certain income threshold.

9. Mesaures to counter in today's scenario

Countless determinates affect thermal comfort in buildings. Some of these can be addressed, at least in some conditions, without utilizing conventional, energy-intensive technologies. Here are a few examples:

- To control radiant temperature of hot or cold surfaces provide a high-performance thermal envelope.
- An efficient curtain wall or other wall system can eradicate the perimeter heating, even in relatively cold climates in large buildings.
- Well-insulated walls and windows can remove the need for delivering heating and cooling to the outside walls in residential buildings.
- Equip an airtight building envelope to minimize drafts and unwanted latent heat gain from outside.
- Expose high-mass building elements to equalize temperature difference. This strategy, often coupled with night-flushing of a space to precool the mass, works best in dry climates when nights are cool and days are hot, region like Rajasthan.
- Arrange facility for occupants to control over their immediate environment. When people have control, to attain lesser than "ideal" conditions. This flexibility of the occupants to adjust temperature can result into less energy spent maintaining a fixed temperature.
- Use air movement to increase comfort in a space. Airflow should be capable to manage to avoid discomfort from excessive wind, and shouldn't create unbearable space however, and fans should be turned off to save energy when not affecting occupants directly and minimize the energy consumption.
- Store the humidity in ventilation air. As humidity itself is difficult to control and only done with the help of a lot of energy. We can fluctuate the humidity in mechanically ventilated buildings, Machines like enthalpy wheels can be used to transfer moisture from coming air to passing/outgoing air (or vice versa). It reduces the need to dehumidification or add moisture and allow cooling equipment to diminish and hence reduce the consumption of electricity.
- Encourage seasonally clothing with respect to season accordingly. Occupants can make themselves comfortable in a range of temperatures by adjusting their

clothing according to the season. This flexibility can allow higher set-points during the cooling season, and lower ones during the heating season and contributes to individual thermal comfort.

- Make use of passive strategies which are inspired by ancient architecture.

10. Conclusion

This paper aimed to utilize passive strategies to control indoor thermal comfort in the modern buildings. Passive strategies encourage vernacular architecture which leads to sustainability and less carbon footprint. These are gives platform to traditional architecture which depleting day by day. As there is rapid growth in population over 10 years, therefore demand of resources and energy is also increasing. So to control and minimize the resources people should use environment friendly techniques for construction. An architect should always consider the factors of thermal comfort for better functioning of the building.

People's perceptions of their environment change basically based on seasonal expectations of temperature and humidity and also their capacity to control the varied conditions in a space by understanding human comfort zone through adaptive thermal comfort. On a hot summer day, for example, people may be more accepting of warmer temperatures indoors if they can open a window. This not only allows breezes, which reduce the perceived temperature but it also orients occupants to the conditions outdoors, improving productivity and overall occupant satisfaction. Installing cooling devices like fans and cooler near workstations also gives building occupants more control over the conditions in their immediate environment.

The another method in sustainable building is addressing the passive design strategies that can be implemented at the site. The comfort achieved by natural processes is far more appreciating for the building users then being stuck in a windowless room with only an HVAC system to condition the air and breathe artificial air.

With demand for fossil fuels and natural resources still rising and the science behind global climate change becoming clearer, the strategies of passive design are at paramount importance to reducing energy usage in the built environment and make the environment healthy.

Passive design strategies have the extreme potential to decrease energy usage in building and help pioneer our planet to a more sustainable future.

Lack of social awareness and way along with unawareness about the far flung consequences of the energy intensive construction practices which lead to thermal inefficiency indoors. Architects, Planners and Visionaries should focus on the methods and means to reduce the energy cost incurred in the construction and maintenance of domestic structures as well as spread a general awareness among the society and people involved in construction activities and process.

In naturally conditioned buildings/structures absorb less energy in comparison to modern well-conditioned buildings and also people behave flexibly towards varying outdoor environmental circumstances and utilize various adaptive controls to make the indoor environment thermally comfortable.

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