Passive Design Strategies for High-Rise Building in Composite climate

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Abstract - Passive cooling architecture refers to a building design approach that aims to maintain comfortable indoor temperatures without relying on mechanical or electrical systems. Instead, it utilizes natural phenomena such as convection, radiation, and ventilation to regulate indoor temperatures and improve energy efficiency. Passive design strategies are becoming increasingly important in high-rise buildings, particularly in composite climates where both hot and cold weather conditions are experienced. The most advantageous aspect of all passive cooling methods is the emphasis on daily changes in relative humidity and temperature. The relationship between a built form and its surroundings tends to be the primary focus for scientific study. Thus, it is necessary that architectural design to consider the environmental context. The paper discusses an overview of passive design strategies tailored for high-rise buildings in composite climates. Composite climates are characterized by a wide range of temperature and humidity variations throughout the year. Implementing effective passive design strategies can significantly reduce the energy demand for cooling and heating, leading to reduced environmental impacts and operational costs. The effectiveness and applicability of the strategies in composite climates are explored, taking into account climate-specific considerations. Additionally, emphasizes the importance of integrating passive design strategies with active systems and technologies for optimal performance.

IndexTerms - Architecture, indoor temperature, Passive design strategies, composite climate, weather condition

1.0 INTRODUCTION

Passive design systems in India are gaining popularity as a sustainable and energy-efficient approach to building design. In recent years, there has been an increasing focus on the importance of passive design systems in India, particularly in response to the country's growing energy needs and climate change concerns.
The Indian government has also taken several initiatives to promote passive design systems in buildings. The Bureau of Energy Efficiency (BEE) has developed a star rating system for buildings, which assesses their energy performance based on various parameters, including passive design strategies. Moreover, the Ministry of Power has launched the Energy Conservation Building Code (ECBC), which provides guidelines for energy-efficient building design and construction. The ECBC also emphasizes the use of passive design strategies such as natural ventilation, day lighting, and shading. These initiatives promote the use of passive cooling techniques such as natural ventilation, building orientation, and insulation to improve the energy efficiency of buildings.
The article published by The World Bank (7 Jan 20230) ' Fostering innovation in the green cooling sector' has to say that 'India's cooling plan may simultaneously reduce heat-related dangers to lives and livelihoods, reduce carbon emissions, and establish India as a major centre for the production of environmentally friendly cooling systems'. The news published in The Economics Times (Oct 02, 2017) wrote on 'Passive cooling to cut electricity bills'. Therefore environment, ecosystem health, and balance are the main considerations that guide the designs.
The design process is approached by studying natural systems, emphasising humility and sensitivity both in relation to nature and at the building level. Numerous geographic elements, including topography, climate, soil, water, and vegetation, have an impact on how people and nature interact. These variables affect a variety of characteristics, including the building's orientation, and they at times operate as designing factors for development settlement. It is develop by recognizing sun paths, breezes and shade trees, etc.

Satisfying the spiritual economic and material needs of the people is determining condition for sustainable architecture and every decision concerning areas, the design of a building must be sensitive to the culture, the resources, and the character of the place. The risk is global standards global modes of building and global processes will overwhelm the local context.

- Williamson et al. (2003)

2.0 LITERATURE REVIEW

A composite climate is a type of climate that is a combination of two or more climate types. These climates occur in regions where no single climate type dominates. These climates usually occur in large land masses near the tropics of cancer Capricorn, which are sufficiently far from the equator to experience marked seasonal changes in solar radiation and wind direction. The composite climate is characterized by distinct seasonal variations in temperature and precipitation. For example, in some regions of India, a composite climate is prevalent due to the coexistence of the tropical wet and dry climate of the north and the tropical monsoon climate of the south. These regions experience dry and hot weather during the summer season and heavy rainfall during the monsoon season.
The characteristics of a composite climate can vary depending on the specific combination of climate types present in a region. However, generally, a composite climate is characterized by a wide range of temperatures and precipitation levels throughout the year. This can create unique challenges for agriculture, wildlife, and human settlements in the affected regions. Is it feasible to design a setting that fits modern requirements while still integrating tradition? To understand that good architecture meets the anthropological, social, and psychological needs of man and is constantly in tune with the context in which it is situated. It is essential to understand the lessons from the past and showcase how technology may be applied successfully to develop decent, sensitive, and sustainable design. The contemporary approach is regarded as extremely utilitarian in its use of materials and technology, practical in

its adaptability to the climate, accommodation of activities, and use of the site, as well as beautiful in its sculptural representations of mass and volume. It is important to understand that while many traditional technologies, materials, or forms are appropriate and sustainable, there are a few that are no longer effective due to shifting cultural and ecological conditions. As traditional structures were created for a different culture and climate, it is not practical to return to them. Learning the essential lessons and principles of traditional construction techniques and figuring out ways to incorporate them into development initiatives for bringing back existing settlements and planning new ones are the major challenges in the 21st century. The strategies create a new design typology by integrating traditional and contemporary elements.

2.1 AN OVERVIEW ON PASSIVE COOLING

Passive cooling is a design approach that aims to keep indoor spaces cool without using active mechanical systems, such as air conditioning. This approach takes advantage of natural phenomena such as convection, radiation, and evaporation to regulate indoor temperatures. In composite climates, passive cooling strategies must address both hot and cold conditions. Passive cooling is a sustainable and energy-efficient alternative to traditional cooling systems, which can be costly and environmentally harmful. Passive cooling can be used in a variety of settings, including homes, offices, and public buildings, and can be adapted to different climates and geographical locations. According to the convection principle, a comfortable temperature is created by hot air rising from the courtyard and cool air arriving from shaded streets. Architecture in this genre is shaped by ecology and nature. The aim is to work with nature and not against it. The effects of globalization are being seen on a worldwide scale. Consequently, new industrial materials like steel and concrete are quickly replacing the vernacular style of architecture. In professions such as architects, designers, and builders, the future is extremely exciting. Every day, new high-performance items hit the market, current ones are improved, and fresh problems are found. Utilizing the environment's natural resources to heat, cool, ventilate, and light a structure is the main objective of passive design solutions. Climate, site conditions, building materials, and construction methods are examples of these natural resources.

2.2 COMPOSITE CLIMATE AND HIGH-RISE STRUCTURES IN INDIA

In India, many high-rise buildings are constructed in regions with composite climates. These regions typically experience both hot and cold temperatures, as well as significant fluctuations in precipitation levels throughout the year. Designing high-rise buildings in composite climate regions presents a unique set of challenges. Architects and engineers need to take into account the climatic conditions of the region and design buildings that can withstand the temperature and precipitation variations.

High-rise buildings in composite climate regions in India require special insulation to keep the building cool during the hot summer months and warm during the cold winter months. Additionally, buildings may require specialized ventilation systems to maintain adequate airflow and prevent moisture, which can cause structural damage. Overall, designing high-rise buildings in composite climate regions requires a careful consideration of the regional climate conditions, and incorporating the right materials and technology to ensure that the buildings can withstand these variations and provide a comfortable indoor environment for occupants. There are several problems associated with composite climates for high-rise buildings in India. The following are some of the problems faced by high-rise buildings in composite climates in India:

a) Heat gain: High-rise buildings in composite climates tend to experience significant heat gain during the day, particularly during the summer months. This can result in discomfort for occupants and higher energy bills due to increased air conditioning usage.

a) Thermal bridging: High-rise buildings in composite climates are prone to thermal bridging, which occurs when heat is conducted through materials that connect the interior and exterior of the building. This can lead to heat loss during the winter months and heat gain during the summer months, further exacerbating the problem of temperature control.

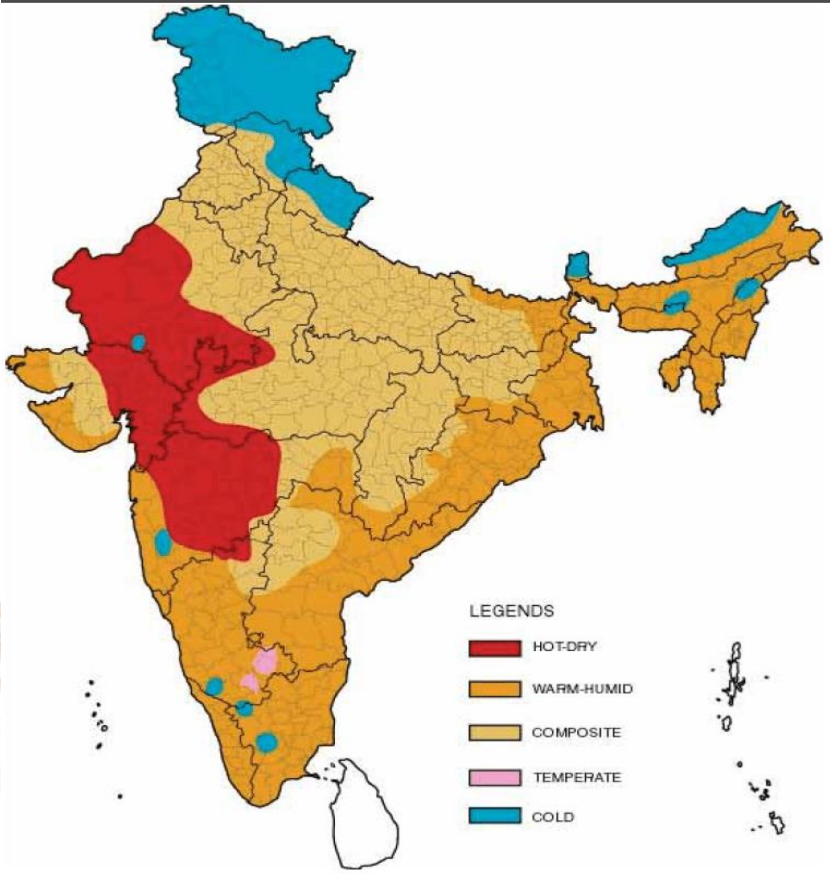
b) Humidity: Composite climates in India tend to be humid, which can lead to issues with mold and mildew growth, as well as discomfort for occupants. High-rise buildings with inadequate ventilation or insulation can be particularly prone to these problems.

c) Wind pressure: High-rise buildings in composite climates may experience significant wind pressure, particularly during the monsoon season. This can result in structural damage, as well as discomfort for occupants due to increased air infiltration.

d) Solar radiation: High-rise buildings in composite climates may experience high levels of solar radiation, particularly during the summer months. This can lead to increased cooling loads and higher energy bills, as well as discomfort for occupants due to glare and heat.

3.0 METHODOLOGY

Finding the right climate zone for the building site is the first stage in according to the Energy Conservation Building Code (ECBC). This will determine the particular specifications for the design and construction of the building systems and components. The distribution of land and sea masses, along with the interaction of solar radiation with the atmosphere and gravitational forces, results in an infinite variety of climates. India has a wide range of climates, which may be roughly divided into five regions, each having a different climate. The map shows the five climatic zones, which are often categorised as hot and dry, warm and humid, composite, temperate, and cold (fig.01). The functional design of buildings is aided by the classification of climate for various building types. Because of the way our country is divided into several zones, the varying climates in each location might influence how buildings are designed, necessitating certain unique considerations for each.



(Fig. 01)

(Table 01)

Climate Zone	Description	Mean Temperature(°C)					Mean Relative Humidity	Annual Precipitation	Sky Condition	Places
		Summer Midday (High)	Summer Night (Low)	Winter Midday (High)	Winter Night (Low)	Diurnal Variation				
Composite	High temperature in summer cold in winter | Low humidity in summer and high in monsoons | High direct solar radiation in all seasons except monsoons high diffused radiation | Occasional hazy sky Hot winds in summer, cold winds in winter and strong wind in monsoons | Variable landscape and seasonal vegetation	32- 43	27- 32	10- 25	4-10	35-22	Variable dry period 20-50%wet Period=50-95%	Variable 500- 1300mm/yr During monsoon reaching 250mm in the wettest month	Variable overcast and dull in the monsoon	U.P. Haryana Punjab Bihar Chattisgarh Madhya Pradesh etc.

3.1 CLIMATE FACTORS

Building design must take into account the climate factors that can affect their performance and comfort of occupants. Understanding these factors and incorporating appropriate measure help to ensure, high-rise buildings in composite climates in India may need to incorporate features such as high-performance insulation, adequate ventilation, and shading devices to reduce heat gain and control solar radiation. Additionally, careful consideration should be given to building orientation, material selection, and construction techniques to minimize thermal bridging and ensure the overall durability of the building. Learning the various factors that constitute a climate, such as temperature, precipitation, wind, and sunlight, is essential to understand how the climate affects building design.

a) SOLAR RADIATION

Solar radiation refers to the energy that is emitted by the sun and travels through space. This energy includes both visible light and other forms of electromagnetic radiation, such as ultraviolet (UV) and infrared (IR) radiation. Solar radiation is a key driver of many Earth processes, including climate, weather patterns, and the growth of plants through photosynthesis. The amount of solar radiation that reaches the Earth's surface varies depending on factors such as time of day, season, latitude, and cloud cover.
Solar radiation plays an important role in composite climate, which is a type of climate that combines the features of both tropical and temperate climates. Elevation from sea level affects the intensity of solar radiation on land. Higher the elevation from the sea level lesser is atmosphere the sun's rays have to pass through to reach the surface. This means that at higher elevations, there is less atmospheric absorption and scattering of solar radiation, resulting in a higher intensity of solar radiation reaching the land surface. In addition, at higher elevations, the air is usually less dense, which means that there is less air to absorb and scatter the sun's rays. This also leads to a higher intensity of solar radiation reaching the surface.

Overall, the relationship between elevation and solar radiation intensity is complex and depends on a variety of factors such as latitude, time of day, season, and weather conditions.

In composite climates, the annual temperature range is relatively small, and there are two distinct seasons: a wet season and a dry season in such climates, solar radiation is a significant factor in determining the amount of heat that is absorbed by buildings and other structures. During the dry season, solar radiation can cause temperatures to rise significantly, which can lead to increased cooling loads and energy consumption for air conditioning.

b) TEMPERATURE

In composite climates, temperatures are generally warm to hot throughout the year, with a small annual temperature range. The temperature in the wet season is typically lower than in the dry season due to the cooling effects of rainfall. During the dry season, temperatures can become quite high, particularly in areas with high solar radiation levels. This can lead to increased cooling loads and energy consumption for air conditioning. To mitigate this, buildings in composite climates are often designed with passive cooling features such as shading devices, natural ventilation, and thermal insulation to reduce the amount of heat that enters the building. In terms of indoor temperature, buildings in composite climates often aim for a comfortable range of 24-27°C (75-81°F) for most of the year. However, during the dry season, indoor temperatures can rise above this range, particularly in buildings without effective passive cooling features or air conditioning.

c) WIND

Wind is another important factor in composite climates. During the dry season, winds can be relatively light, which can exacerbate the effects of high temperatures and solar radiation. In contrast, during the wet season, winds can be stronger due to the influence of monsoon systems, which can bring in cooler air and help to dissipate heat.

In building design, the orientation and layout of the building can be optimized to take advantage of prevailing winds for natural ventilation and cooling. This can help to reduce the reliance on mechanical cooling systems, which can be energy-intensive and costly. Buildings in composite climates may also incorporate features such as wind towers or chimneys, which can help to enhance natural ventilation and air circulation. Overall, wind is an important consideration in the design and operation of buildings in composite climates, as well as in the development of renewable energy sources. By leveraging natural wind patterns and utilizing wind energy technologies, it is possible to reduce energy consumption, greenhouse gas emissions, and costs in these climates.

d) HUMIDITY

Humidity can play a significant role in determining the level of comfort and indoor air quality high and mildew. To combat this, it's important to ensure that the indoor air is properly ventilated and that humidity levels are controlled. During dry seasons, humidity, or RH, is low at 20 to 55% and has a vapour pressure of 1 300 to 1 600 N/m2. It increases to 55 to 95% during the wet season, with a vapour pressure of 2000 to 2500 N/m2. Overall, controlling humidity in a composite climate is a crucial aspect of maintaining indoor air quality and ensuring a comfortable and healthy living environment. (S.C. Kaushik, 2003)

3.1 DESIGN PARAMETERS FOR PASSIVE TECHNIQUES

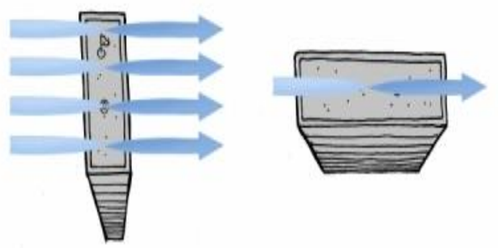
a) ORIENTATION FOR MAXIMUM PASSIVE VENTILATION

The orientation of a building refers to the direction that the building faces in relation to the sun and prevailing winds. To provide a building with passive thermal comfort, orientation is regarded as the most important stage. The following three factors must be taken into account to determine a building's suitable orientation: solar radiation, prevailing wind and topography.
It is important to examine the direction of the sun and diurnal change to recognise solar gain intensity by the structure in order to determine the best orientation for high rise buildings.

During winter, the sun radiates on the building's south wall, while during the summer, it falls slightly on the north wall. As a result, the sun is greatly exposed to the east and west, which causes more heat gain at sunrise and sunset. To receive less heat throughout the day, it suggests to keep the south and north facades wider and longer than the east and west. The building's design and shape should also be taken into consideration. The overall intensity of solar heat that hits the building's exterior depends on the building's shape.

b) RESPONSE TO CLIMATE

The basic principle of an attempt at climate-responsive design is to consider climate into account while designing every element of the structure. The goal of climatically responsive design is to adjust environmental factors such that people are constantly in, or as near to, their comfort zone. The landscape, building form, envelop, material, and other control methods modulate the condition to keep it within the comfort range during the course of a 24-hour cycle. The objective of climate-responsive design is this. These many elements offer a thorough grasp of how the architecture and the microclimate interact. An east-facing structure in India's composite climate may encounter wind pressure, but whether or not it is suited depends on a number of criteria, including the site, the building's layout, and the direction of the predominant wind.. Tall structures also increase the impact of natural ventilation as higher elevations have larger wind speeds. The stack effect and cross ventilation are benefited by this. Tall buildings provide natural ventilation while reducing sun exposure at lower latitudes (Fig. 02).

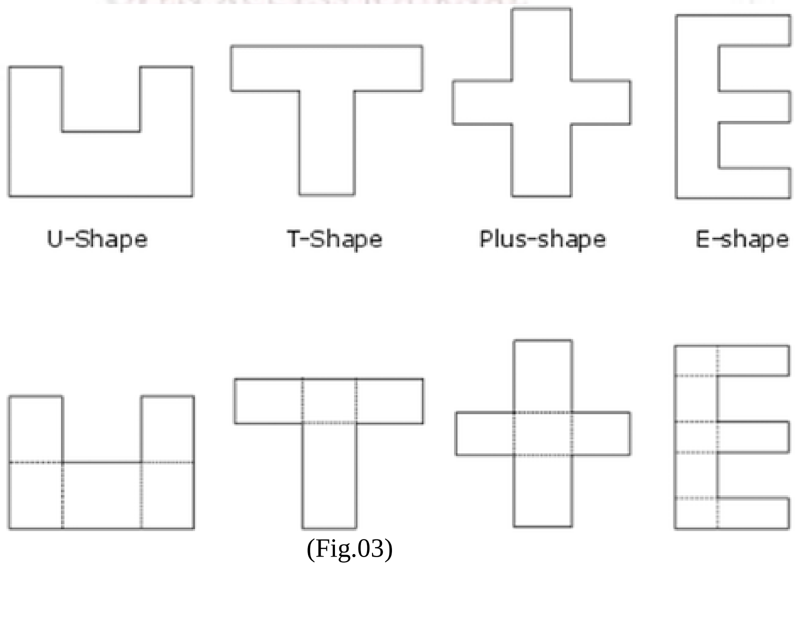


(Fig.02)

c) PLANNING

Building Plan

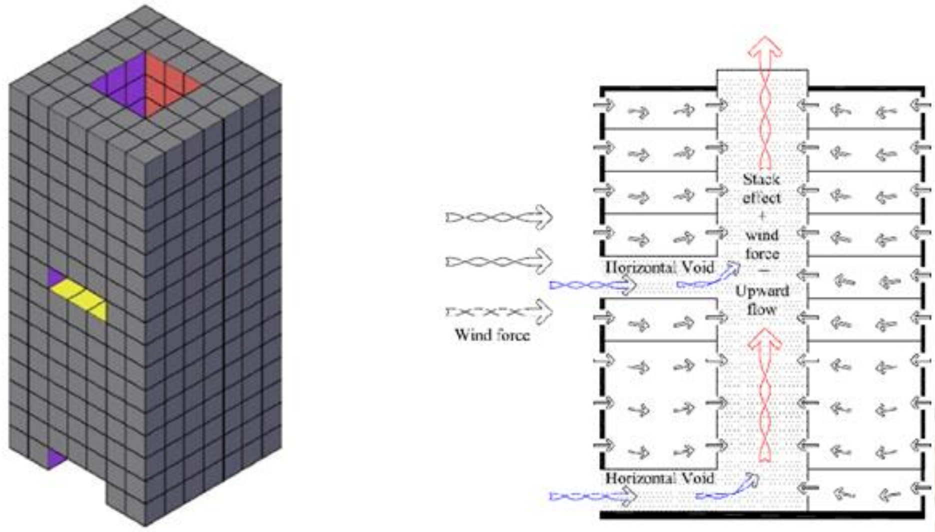
Considering the perception of the climate zone, planning is the fundamental or first stage. This must be emphasized that design decisions should consider environment, orientation may affect planning in several ways. Building facades and planning concepts should make sense and be practical. Planning typically involves selecting suitable openings to allow optimum heat gain and breeze. The parameters for this category are based on the numerous kinds of spatial organization. Buildings with linear wings of corridors spreading radially from a central were evaluated for their potential to achieve energy benefits through natural ventilation. Internal courtyards were also designed for day lighting, natural ventilation, and sun control for maximum energy efficiency when combined with rectilinear building layouts and projecting corners. The analysis of natural ventilation for high-rise residential structures should use a central clustered plan arrangement with concave corners that create a cruciform shape.



(Fig.03)

d) Building Void

Building Void is the open areas inside the footprint of a structure that are usually created by the absence of enclosing surfaces that are next to the outside. When it deals with creating voids, atria, courtyards and light-wells are the parameters. The atrium is one of the architectural forms that are near to courtyards that studies about how it affects natural lighting and ventilation in high-rise structures. Horizontal voids in the direction of wind should be planned that is connected to light-wells for buoyancy-driven natural ventilation. To design high rise structure, it becomes important to examine the wind-path to provide airflow for natural ventilation. Light-wells or Air-wells are vertically continuous voids that exhaust the warm air from individual apartments in a high rise building. The process is called stack effect, which causes warmer air to rise and cool air to enter the apartment making space comfortable (fig.04).



(Fig.04)

DESIGN STRATEGIES

a) PLAN-FORM

The term "plan form" refers to a building's orientation, which depicts all four directions. A rectangle with a longer axis running north-south is preferable for composite climates. This aids the building's structure in reducing summertime heat gain and wintertime heat loss. The building's performance is dependent on which one of its four directions it faces. In the same way that orientation affects heat gain and loss and ventilation, the building's plan form also has an impact on these factors.

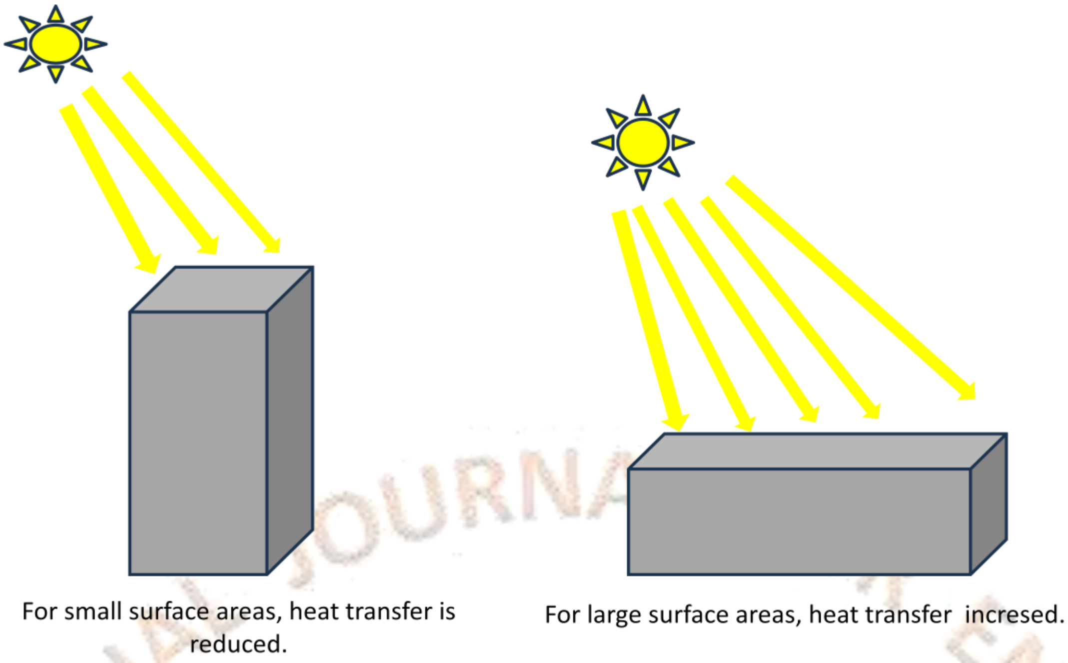
P/A, or perimeter to area ratio, is an important indicator of heat gain and loss it also plays an essential role in natural ventilation. It is well known that physical obstructions in the way of airflow induce pressure differences, which result in a new pattern of airflow. In general, air moves from high-pressure to low-pressure regions. Building openings between high- and low-pressure regions would result in efficient ventilation.

It is known that physical obstructions in the way of airflow induce pressure differences, which result in a new pattern of airflow. In general, air moves from high-pressure to low-pressure regions. Building openings between high- and low-pressure regions would result in efficient ventilation. Larger buildings are known to have bigger perimeters than smaller buildings. Therefore, the heat gain during the day and the heat loss at night are both greater the higher the P/A ratio. The heat gain during the day and the heat loss at night are lowered when the P/A ratio is less. P/A is hence an important aspect.

b) EMISSIVITY OF SURFACE

In the context of passive cooling, the emissivity of a surface is an important factor because it influences the amount of heat that is radiated away from the surface. Emissivity is typically represented as a value between 0 and 1, where 0 indicates a perfectly reflective surface (emits no radiation) and 1 indicates a perfectly black surface (emits all incident radiation).

An essential aspect of a building's performance is its surface area to volume ratio (S/V). The possibility of heat gain or loss through a surface increases with surface area. Therefore, a low S/V ratio denotes less heat input and heat loss.



(Fig.05)

CONCLUSION

It takes careful planning, simulation, and teamwork to implement passive design strategies in high-rise building projects in composite climates which requires a holistic approach that considers the unique challenges posed by both hot and cold seasons. Although these methods might need some initial investments, the long-term advantages in terms of energy savings, occupant comfort, and sustainability make them an intelligent choice for the future of high-rise building. In essence, building planning is a comprehensive process that involves careful consideration of various factors to create structures that are not only functional but also environmentally responsible, safe, and economically viable. As we look towards the future, building planning will continue to evolve to meet the challenges of urbanization, sustainability, and changing societal needs, playing a crucial role in shaping the built environment for generations to come. Successful high-rise building design in composite climates requires a multifaceted approach that integrates various design elements and technologies.

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