To analyze the application of passive design techniques for Residential high-rise building

Bachelor of Architecture Research Thesis dissertation

JUNE 2023

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Thesis Title : To analyze the application of passive design techniques for Residential high rise building

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Declaration

I, **Satnam Kaur, 18bar034**, give an undertaking that this research thesis entitled **"To analyze the application of passive design techniques for Residential high rise building"** submitted by me, towards partial fulfilment for the Degree of Bachelor of Architecture at Institute of Architecture and Planning, Nirma University, Ahmedabad, contains no material that has been submitted or awarded for any degree or diploma in any university/school/institution to the best of my knowledge.

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This research thesis includes findings based on literature review, study of existing scientific papers, other research works, expert interviews, documentation, surveys, discussions and my own interpretations.

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Acknowledgment

I extend my foremost gratitude to my guide- Professor Shweta Suhane for her patient guidance throughout the semester, for encouraging me to allow the research to take its own course without my anxious assumptions and for bringing immense clarity in every phone call and discussion. I am extremely grateful to her for replying to my incessant queries even at 11 p.m. Ar. Shilpi Anand Ma'am have been a rock throughout my research journey, providing immense guidance with her knowledge and spending her precious time to help me get the desired results.

My most sincere thanks to our professors Ar. Biswanath Mudi and Ar. Purvi Jadav, both whose research studies and very kind guidance helped me a lot to take the thesis ahead. I am most grateful to my mother, for her unending emotional support and always encouraging me to work harder. I am grateful to our senior Prachi Mashruwala for answering all my minor and never ending queries. The entertaining presence of Neha Agarwal, Mahek Ruparelia, Sujan Jhaveri, Yashavee Nimbark and Radhika Totla,

made the monotonous task of writing bearable.

I am forever indebted to my college, IAPNU without which I would not have the knowledge or capability to undertake this research, and to Utpal Sir for the curriculum and immensely knowledgeable faculties the institute brings us under.

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Chapter 01 Introduction

1.1 Abstract

Development in the field of technology such as invention of safety elevators, fireproofing and skeletal structure has led to the advancement of high rise construction. High rises contribute to conserving land resources which are already scarce thereby preserving them to be used for other outdoor functions such as public interaction and agriculture. As there is a continuous increase in high rise construction more attention needs to be paid towards environment sensitive and climate responsive design which will help in increasing the efficiency of the building thereby reducing its dependence on external resources. Hence the implementation of passive design is a must. Passive design is a design which helps in reducing the mechanical dependence of a building for heating, cooling and ventilation by making use of local climate and natural elements to provide comfortable temperature and lighting inside the building. This study evaluates the different passive strategies applicable in hot and dry climate conditions through various examples. The purpose of the study is to study the performance of a few passive elements for improving thermal comfort inside an apartment building using simulation software Design builder. The inferences extracted from the study will help people in understanding the change in the comfort level after the application of passive elements and help prioritizing the same while designing a high rise building. The application of passive design elements should be an important criteria in building design as it helps in limiting the mechanical dependence and improves the thermal satisfaction.

Key words : *Passive design, High rises, Passive cooling, Thermal comfort*

1.2 Purpose Statement

Because of the climate change and ever-increasing global warming, the buildings use more energy to maintain the desired comfort level inside the space. Many constructed or constructing high rises of India are of low efficiency and unacknowledging towards local climate and site conditions leading to a very unsustainable development. As there is a continuous increase in high rise construction more attention needs to be paid towards environment sensitive and climate responsive design which will help in increasing the efficiency of the building thereby reducing its dependence on external resources.

1.3 Aim

The research aims to ascertain the design considerations which can increase the thermal comfort of high rises through passive techniques.

1.4 Objectives

- Analysing the various passive design techniques and elements and how do they vary with different climate conditions.
- To Study the buildings which are fulfilling the criteria of functional green building design and explore their potential use in high rise buildings in the city.
- To study the implementation of the passive design elements for hot and arid climate in high rises that increases the comfort level of occupants, reduces heat gain, is climate and site responsive.

1.5 Research questions

- How passive design elements can be implemented in high rise buildings so as to increase the comfort level of the occupants?

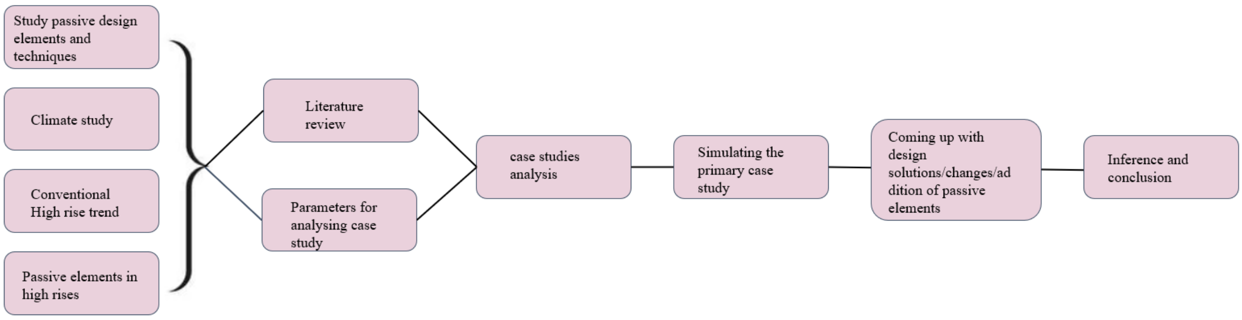
- What are the implications of passive elements on building thermal comfort and energy performance?

1.6 Scope and limitation

The scope of the study covers the application and impact of passive elements in high rise buildings and analyse their performance in enhancing the thermal comfort of the apartment in hot and dry climate of Ahmedabad. Different passive elements and techniques are studied through literature review. The primary research focuses on passive design considerations in high rise buildings for hot and arid climate - Ahmedabad. The thermal comfort will be studied through factors provided by ASHRAE55 - air temperature, radiant temperature, operative temperature, relative humidity and solar heat gain. The actual building conditions may vary because of software limitation. Building construction cost, surrounding context is not taken into account.

1.7 Methodology

- Deducing the parameters for analysing the primary study.
- Analysing the case studies and studying the different passive elements used in them.
- Simulating the primary case study of a high rise of Ahmedabad
- Coming up with design changes/solutions



Chapter 02 Issue and background study

2.1 Introduction

In response to many socioeconomic and environmental challenges, many high rise buildings are being built in our modern cities. Rapid population growth, lack of land resources, high land prices, and conserving land resources for green spaces are some of the factors for increased demand in high rise buildings. Despite concerns about energy constraint and global warming, it seems that many low-performance high-rise structures are giving cities additional floor area. The typical air-conditioned glass boxes are not energy-efficient in several respects.

By using passive environmental solutions rather than mechanical ones, energy consumption can be greatly lowered a well-designed naturally ventilated building, for instance, can use just a third of the energy needed to cool a building while arguably offering a same degree of comfort. This is due to the fact that passive design enables buildings to more adequately adapt to their local climates and take use of utilizing renewable energy sources, such wind and thermal buoyancy, to assist regulate their internal conditions.

In order to determine the impact of bioclimatic design principles on users' perception of the inside environment, Ismail (2007) undertook a comparative study of six Malaysian high-rise buildings (three bioclimatic and three conventional) on the environment and energy usage in buildings. They discovered that bioclimatic buildings use less energy, provide greater interior comfort, and enhance user's happiness. To ascertain the effect of various design solutions on energy-saving, Jahnkassim & Ip (2006) modelled and simulated three bioclimatic high-rises created by Malaysian architect Ken Yeang. They discovered that the service core should be located on the hot side and that employing external shading devices would result in the greatest energy savings when comparing the results between the simplified high-rise model (generic option) and the bioclimatic model (as built).

Thus, in-depth research into the design techniques that might increase the energy efficiency of high-rise buildings is still lacking. So, in order to determine design tactics that make a high-rise structure more energy-efficient in a hot and dry climate, the findings of a case study based on various high-rise buildings are described in this research.

2.1 Background study

Energy shortages in emerging nations during the past few decades is a sign of high energy use, and it is anticipated that this trend will continue as the global population grows and living standards rise. The use of air conditioning equipment has played a significant part in the recent rise in energy usage. Buildings consume approximately 20% of the total energy of the world (U. EIA, 2019). Forecasts suggest that the 20% share of building energy usage will increase to 25% by 2050 (U. EIA, 2019). The energy needs of mechanical systems for heating, cooling, and ventilation in the building sector have increased substantially as a result of rising thermal comfort demands, the availability of electricity produced by fossil fuels, and an increase in the worldwide average temperature because of global warming. As a result, the building sector accounts for 36% of global energy demand and 37% of energy-related CO2 emissions in 2020 as shown in Fig. 2. Fig. 1 shows that the CO2 production of commercial and residential buildings has been within the range of 35%–40% since 2000.

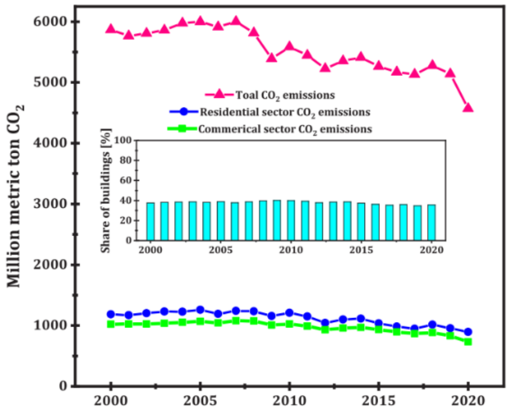


Figure 1: Total CO2 emission as well as commercial and residential buildings
Source: (https://www.eia.gov/totalenergy/data/monthly/2021).

The usage of fossil fuels and CO2 emissions lead to thermal accumulation, which contributes significantly to climate change. Utilizing natural cooling techniques was substantially affected by the use of contemporary technology. The continuation of this trend is inappropriate given the increasing amount of non-renewable resource deterioration and the negative effects of extreme fossil fuel usage.

Therefore, it's crucial to employ passive techniques that are recognized for their low energy use, minimal carbon emissions, and superior indoor air quality and minimise the use of mechanical systems. This can be achieved through suitable building orientation, form and massing responsive to the prevalent wind direction and sun path, making use of shading devices, using vegetation to block harsh solar radiations, adding colour and insulation which deflects heat.

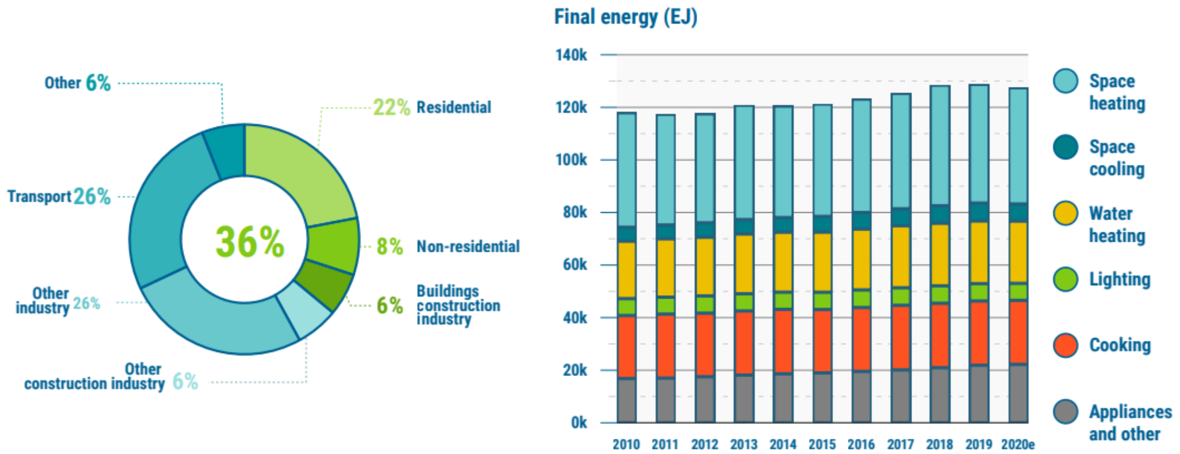


Figure 2: Global share of buildings and construction final energy (left) and by end use (right), 2020
Source: (IEA 2021a)

Chapter 03 Literature Review

Overview

The literature review covers all the different passive techniques and their working helping in expanding the knowledge about climate responsive architecture . It consists of findings observed from various books, articles and research papers. The literature review consist of –

Passive design

Passive design measures taken in early design stage-

- Building orientation, form and massing
- Building form and massing
- Choice of material
- Landscaping

Passive design for different climate conditions.

Passive techniques for hot and dry climate.

Thermal comfort standards and parameters influencing it.

Secondary case studies-

- Solar Passive Hostel, Jodhpur
- Pearl Academy
- Urban Oasis, Ahmedabad
- Pallacia, Jaipur
- Connecting riads, Casablanca
- Kowsar Residential Green Towers, Iran
- Analysis table

3.1 Passive design

Passive design is a design which helps in reducing the mechanical dependence of a building for heating, cooling and ventilation by making use of local climate and natural elements to provide comfortable temperature and lighting inside the building. The orientation, configuration and envelope of the building are important aspects to consider in the design, as well as local climatic and environmental conditions. Sustainable design methods such as passive design techniques offer many advantages which are, better thermal comfort, more daylight, better room quality and less maintenance due to less mechanical use. Since passive elements are mostly permanent, they must be introduced early in the design process. In order to enhance human comfort, the building envelope acts as a barrier between the inside microclimate and the exterior climate. Some of the main elements that affect human comfort are visual, thermal, and auditory comfort. The building envelope, together with the construction techniques used, is essential for providing the right level of comfort. These technologies, which make our comforts possible, can be either active, passive, or hybrid in nature—a combination of the two.

Passive design elements that affect the thermal comfort of a building are Building plan and orientation, Building envelope, courtyards, landscaping, fenestrations and shading tools.

Utilizing natural energy flows to ensure thermal comfort is the goal of passive design. Using the right building orientation, building materials, and landscape are important. To avoid or reduce heat gain, structures should be appropriately orientated, and the building envelope's material should be specified. To reduce sun radiation, shading should also be offered (Agboola 2011). Systems known as passive technologies rely on renewable energy sources to keep us comfortable without the need of artificial energy. The local climate has a significant impact on the passive design strategies that are used. The methods make advantage of natural resources and are sustainable. By using such methods, buildings may become live biological entities that can support human existence (Noguchi, 2016, ch. 8, 210).

There has been thorough research done on passive design and its elements. (H. Altan et al, ch.8, 2016) studies the strategies and benefits of passive design and found that the way to construct a passive building is by taking into account the local climate and hence early classification of climate type and its characteristics is necessary. Two fundamental measures of passive design are climate and comfort.

Passive design is an approach towards environmental design that uses techniques such as shading devices, fenestrations, cooling and heating techniques, ventilation, insulation etc. which are unique to the climate type. The orientation, configuration and envelope of the building are important aspects to consider in the design, as well as local climatic and environmental conditions. Sustainable design methods such as passive design techniques offer many advantages such as, better thermal comfort, more daylight, better room quality, less maintenance due to less mechanical use. Since passive elements are mostly permanent, they must be introduced early in the design process. All the surfaces of the building are exposed to various environmental influences depending on the geographical location of the building, climate, radiation, location, direction and shape.

Shading of openings like windows is very important. The Window-Wall-Ratio (WWR) should not be more than 60%. Effective daylighting is possible with a much lower WWR (S. Afreen et al, 2018).

Based on the concepts of traditional courtyard architecture in hot and dry regions, Alnusairat and Elsharkawy, (2015) propose a new method to passive design techniques in high-rise structures. The suggested method improves the subject of sustainable innovation and may offer suggestions for innovative passive design approaches that might offer greater efficiency for lighting, heating, and cooling. According to the research, sky courts are a type of architectural feature used in high-rise buildings that can improve social interaction while also using less energy. Energy expenses can be directly decreased by lowering the surrounding temperature and absorbing solar radiation. When compared to a similar air-conditioned structure, the energy consumption of the skycourts at the Commerzbank in Frankfurt, for instance, has been reduced by up to 50% by natural ventilation (Fosters + Partners n.d. 1997).

It was discovered that insulating qualities of green roofs can lower room temperatures by 10%, and that vertical planting can lower temperatures by 40% when compared to typical walls (Wong et al. 2010). Alexandri & Jones (2008) in their research deduced that by lowering the internal temperatures to more bearable levels, green walls can cut cooling loads by 32% to 100%. Castleton et al. (2010) inferred that in the summer, a green roof decreases the indoor air temperature by 2 degrees Celsius and 6% of the yearly energy requirement.

3.2 Passive design measures undertaken in initial design phase

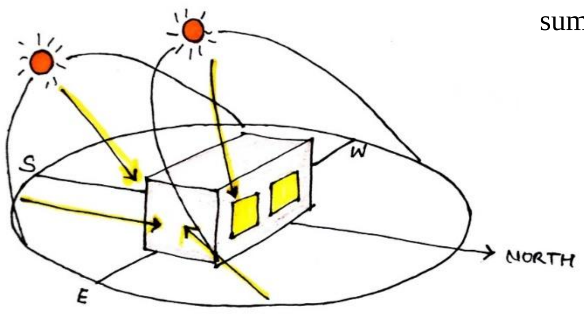
3.2.1 Building orientation

The installation of passive technologies within the design is governed by the orientation of the building blocks. Orientation should respond to the sites’s local climate, prevailing wind direction, surrounding context and sunpath. In addition, it manages window location and size, which affects a building's lighting and climatic management. Proper orientation may significantly reduce the lighting and space conditioning burden when used in conjunction with passive design strategies.

The design of the spaces in buildings should be such that the rooms face the equator. Thus, the early and afternoon low-angle summer sun shines on the eastern and western sides. Summer sun angles in the sky make it simple to shade windows with just a wide roof overhang or a horizontal shade. The building's longer north and south sides benefit from low angle winter sun. When the structure needs warmth in the winter, the roof overhang or shade on the equator side should let the sunshine in. In the summer, it should offer sufficient protection from high-angle Sun (Aksoy and Inalli, 2006).

Winter sun

- Low angle
- Direct light from sun because of low angle of sun
- Glare free light from north



summer Summer sun

- High angle
- Easy south shading
- Diffused light in north

Figure 3: Sun path and orientation

3.2.2 Building form and massing

Passive designing includes site planning as a key component. Every component's placement has an impact on how the site's microclimate is governed. In various climates, zoning and massing assist in creating the appropriate microclimate. If massing of the building blocks is constructed in accordance with climatological needs, it helps reach levels of thermal and visual comfort. Building components channel or hinder wind flow and provide adjacent areas with shade. The design and geometry of the building blocks can affect the direction and speed of the wind. Blockading wind flow in the winter and regulating summer wind in the summer may be accomplished by massing blocks (Noguchi, 2016, ch.8).

In order to reduce heat gain, buildings in hot, dry areas need to be compact and have fewer east and west openings.

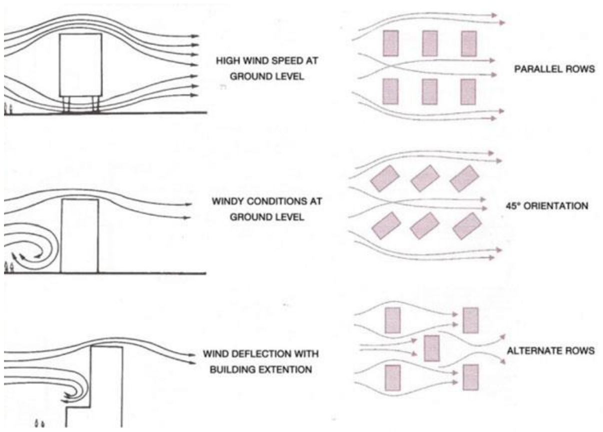


Figure 4: Massing of building blocks influence wind pattern
Sourcs: Pedata 2011

3.2.3 Choice of material

The thermal comfort of any place is greatly influenced by its materials. The material selection is influenced by the building's surroundings and climate. However, the colour, insulation, and assembly type of the material used—three distinct features—can be recognized and utilized to guide usage. The amount of heat and light that is absorbed and reflected changes according to the finish's colour. Darker hues get more absorption whereas lighter colours attain higher reflectance. The insulating property is also important while selecting materials. Adequate insulation is required to reduce heat transmission between the interior and outside areas. Building components are the fundamental pieces that encompass passive design features.

Materials for construction may be divided into two categories: visible and invisible. The visible category includes interior and exterior finishes, whereas the invisible category includes structural and non-structural elements. Utilizing materials with high thermal mass and low thermal conductivity will reduce heat transfer through the building in hot, dry conditions, reducing the need for interior air conditioning. Thermal mass materials often work best in daily-used areas because they slow down the transfer of heat. On the other hand, lightweight materials are more suitable for areas utilized at night since they enable the interiors to cool down quickly while people are sleeping.

3.2.4 Landscaping

The microclimate of the location is significantly influenced by the landscaping components. elements such as the quantity of hard paving, the placement of water bodies, the positioning of trees for shade, the orientation and location of building blocks, etc. The heat island effect, which is caused by heat being trapped around a structure, is influenced by the amount of hard pavement. Additionally, it will improve the run off from the site, decreasing the dampness around the site as a result of reduced percolation. Water bodies may act as a natural air conditioner in hot, dry climates. The hot breeze blowing above can be cooled by the moisture from the water body, which in turn cools the construction block.

Covering the west façade with planters help in drastically decreasing the heat absorption. Tress blocks the entry of the dusty summer breezes. There are less trees in the north to allow more light in and more trees in the north west and north east to block the summer sun.

Deciduous trees can be planted on the south side for shading in summer and solar access in winter as they shred leaves in winters and Evergreen trees on the north side helps with getting cool breeze and shade throughout the year.

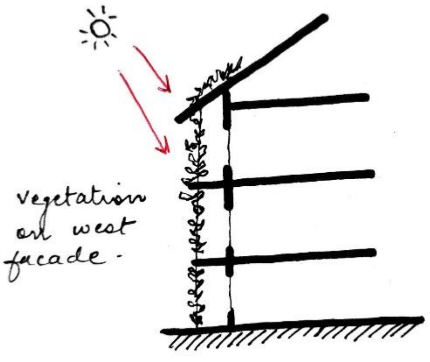


Figure 6: vertical plantation

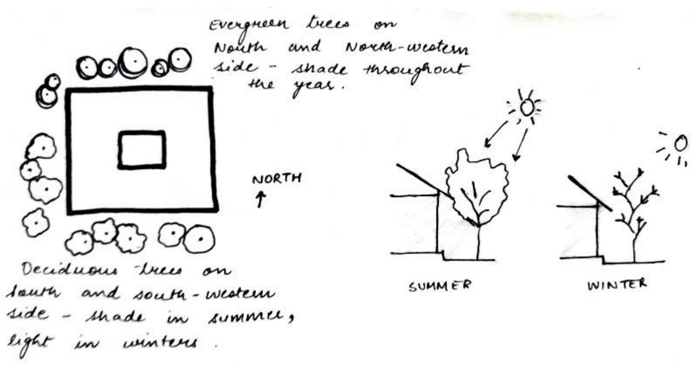


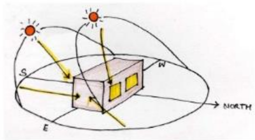
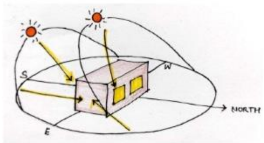
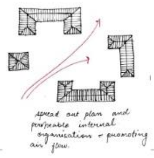
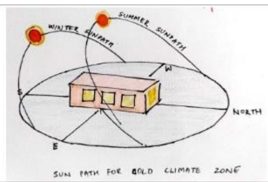
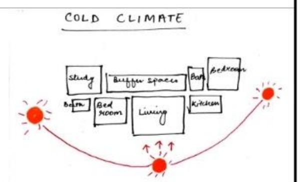
Figure 5: Trees and their positioning

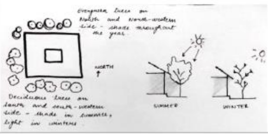
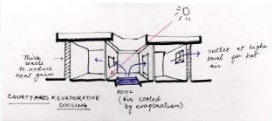
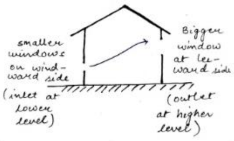
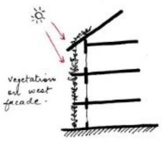
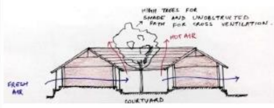
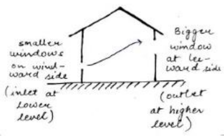
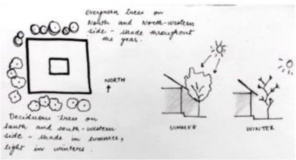
3.3 Passive design for different climate conditions

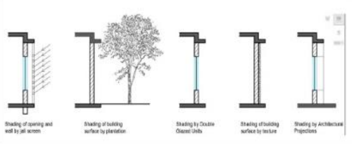
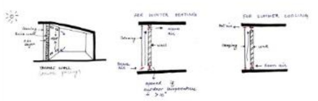
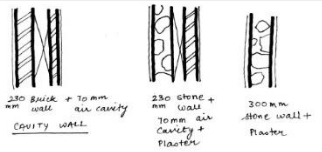
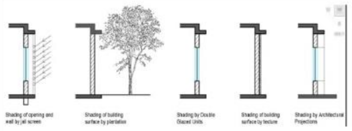
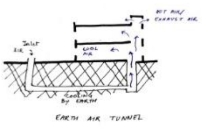
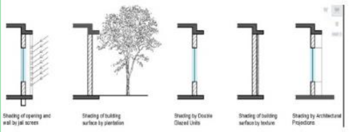
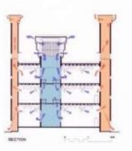
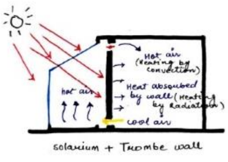
Passive strategies for climate management and energy efficiency in buildings vary with climate because various climatic zones have unique environmental factors, such as temperature, humidity, solar radiation, and prevailing winds. In order to control internal temperature, enhance ventilation, and reduce the need for mechanical heating or cooling systems, passive solutions make use of natural components and architectural principles.

Table 1 Passive cooling strategies

Passive Cooling Strategy	Passive Category	Description	Climatic Condition
PCS 1	DA	Orientation	All
PCS 2	DA	Geometry/form/height	All
PCS 3	DA	Courtyard	All
PCS 4	DA	Roof shape (dome, vault)	All
PCS 5	DA	Sloped roof	Hot and dry
PCS 6	DA	Window-to-ground ratio	All
PCS 7	DA	Patio	Hot and dry
PCS 8	DA	Space utilization	All
PCS 9	BE	Roof property	All
PCS 10	BE	Exterior wall property	All
PCS 11	BE	Interior wall property	All
PCS 12	BE	Glazing/window	All
PCS 13	BE	Replace single glazing with double glazing	All
PCS 14	BE	Overhang projection factor	All
PCS 15	BE	Horizontal shading	All
PCS 16	BE	Vertical shading	All
PCS 17	BE	Window-to-wall ratio	All
PCS 18	BE	Green roof	Hot and dry
PCS 19	BE	Floor/ground thermal property	All
PCS 20	BE	Cool roof	All
PCS 21	BE	Color (or paint) of exterior wall	All
PCS 22	CS	Passive evaporative cooling	All
PCS 23	CS	Natural ventilation	All
PCS 24	CS	Night ventilation	All
PCS 25	CS	Solar chimney	All
PCS 26	CS	Wind catcher	All
PCS 27	CS	Ground-coupling cooling (earth pipe cooling system)	Hot and dry
PCS 28	CS	Water-to-air heat exchanger	Hot and humid
PCS 29	CS	Hydraulic-driven ventilation device	Hot and humid
PCS 30	CS	Earth sheltering (semi-basement)	Hot and humid

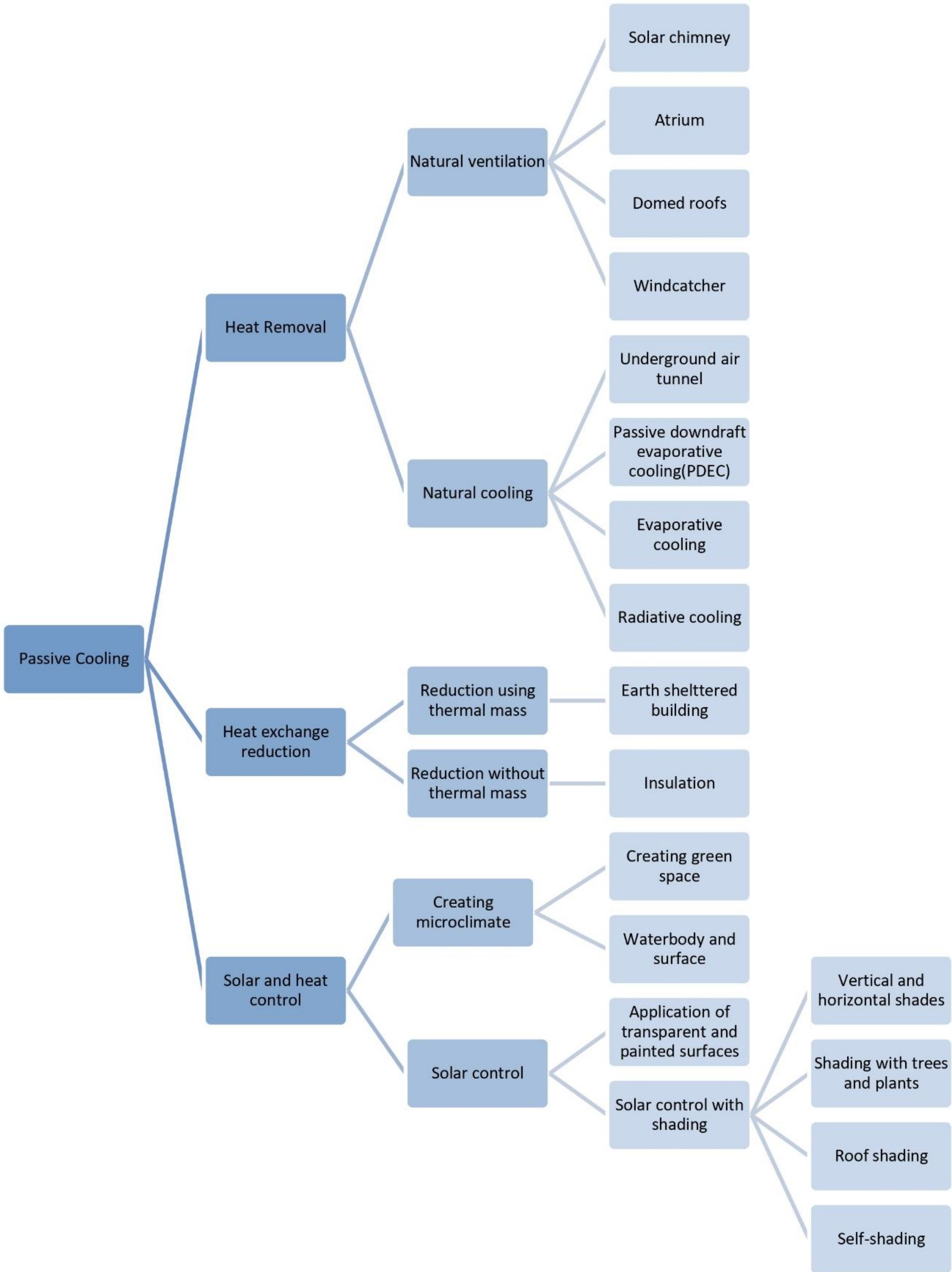
	Characteristics	Orientation	Form and Massing
Hot and Dry	Temperatures: Very hot weather in summer and cold in winter Summer- temperatures vary from 40 to 45 deg C Winters–Min temperatures- 5-25 deg C High-temperature difference between Day and Night High Solar Radiation causes glare Hot Winds Rainfall: Minimal rainfall Humidity: Low Relative Humidity	The building should be oriented North-South as in the longer walls of the building should face north and south.	Compact buildings to minimise heat gain from east and west side.Greater the perimeter - to - area ratio, greater is the heat gain by the building and the greater loss at night.
			
Warm and Humid	Temperatures: Not very high Vary between 25-35 degree C in summer and 20-30 degree C in winter. Humidity: Very high humidity Rainfall: High rainfall (about 12mm per year) Sky Condition: Clouds cover 40-80	The building should be oriented North-South as in the longer walls of the building should face north and south.	-Spread out plan and permeable internal organisation. (Chenvidyakarn, T., 2007)
			
Composite	-Covers central part of India. -has weather conditions outside of normal conditions for at least half a year -Composite climate displays the characteristics of hot and dry, warm and humid as well as cold climates. The characteristics change from season to season. -In summers day time temperature is 32-45 degree Celsius and during night time temperature is 27-32 degree Celsius. In winters day time temperature is 10-25 degree Celsius and in night time temperature is degree Celsius.	Preferred orientation of building is North east and south west- More natural light and ventilation and less radiation	The building must be low-rise and compact. It is better to have buildings with a courtyard. For most of the year, a somewhat compact internal layout of the house will be beneficial. Buildings should be clustered in order to take advantage of the prevailing winds during the brief time when air movement is crucial. It is appropriate to build a relatively dense, low-rise development that can guarantee the protection of outdoor areas, mutual shade of the outside walls, and shelter from the wind during the
Cold	Temperatures: Typically, low temperatures; are 17-20 deg C during summer and -7 to 8 deg C during winter. Humidity: low in sunny regions and high in cloudy regions. Rainfall: low (200mm per year) to Moderate (1000mm per year. Sky Condition: clean with less than 50% cloud cover.	For cold climates, orientation slightly east of south is favoured (especially 15° east of south), exposing the unit to morning and afternoon sun and enabling the building to heat during the day. (nzeb.in) East-West orientation is preferred.	For improved access to solar radiation, the building should be situated on the southern slope of a hill or mountain. Buildings should be placed on the leeward side to prevent cold breezes. High-mass construction for better insulation. Air tight construction is required.
			

	Landscaping	Courtyard	Windows
Hot and Dry	Tress prevents infiltration of dusty winds of hot summer. Fewer trees in the north to let in the daylight. More trees on the NW and NE to cut off summer radiation. Deciduous trees on the south side for shading in summer and solar access in winter.	Courtyards are important for daylight & ventilation. They need to proportioned such that they are mostly shaded and have cooling elements such as water body, vegetation, soft paving.	The main windows should face north and south, however the south-facing windows should be covered by roof overhangs, shading devices, or deciduous trees. **Windows area should be 15 to 20 percent of floor area.**
			
Warm and Humid	Decidious trees on west and south west side so that they provide shade in summers and sunlight in winter as they shred their leaves in winter.	Optimum shading when courtyard in northeast-southwest direction (approximate of 65% shaded area)(Muhaisen, 2006). Large courtyard ratio (width to height) resulted in better flow for indoor.(Tablada et al., 2005)	Large and fully openable with similar inlet size on both sides of the room for proper ventilation. Windows and doors with louvers are encouraged. Fixed glass on them should be avoided. WWR of 10%–30% in bedrooms and 20%–30% in living rooms allow a good balance between adequate daylight and reduced heat gains. (BEE, Design Guidelines For Energy-Efficient Multi-Storey Residential Buildings, Warm and Humid Climates, 2016).
			
Composite	Deciduous trees like mulberry or Champa on the southern side of a building as they stop direct sun during summer, and as these trees shed leaves in winter, they permit the sun to heat the building in winter, which is suitable in a composite climate. Summer setting sun can be avoided by planting dense trees and shrub plantings on the west and northwest sides of a building. Natural cooling can be encouraged by locating trees to direct southeast summer breezes.	If the roof surfaces are sloped towards the interior courtyard, the cooled air sinks into the court and enters the room through low-level openings, gets warmed up, and then leaves the room through high-level openings. However, care should be taken that the courtyard doesn't receive intense radiation, which might cause conduction and radiation heat gains into the building.	Large openings (preferable with solid shutters on opposite walls are suitable which helps in cross ventilation. Recessed windows help in reducing solar heat gain in the external facade.The windows should not occupy more than 25% of the total area. Shade is required for external openings during the hot and warm seasons. Orientation of the openings is determined by two factors–first, towards the breeze prevailing during the warm-humid season, to utilize its cooling effects and second, towards the sun during the cold season, to utilize the heating effect of radiation entering through the windows
			
Cold	Use trees as natural wind barriers or buffers by planting them near windows to block cold air from entering the building.		Cross ventilation - Placing windows at multiple facades at the right places to assist the exchange of the existing air with new air. Stack ventilation - since the prevailing wind tends to be at a higher pace in cold climatic areas, wind can be used in stack ventilation and also for energy production. Double glazing on windows is highly effective for cold climates to efficiently reduce heat loss. Provide south-facing glass windows to maximize the heat gain during the winter months when it will be the coldest. Window glazing with a low U-factor will help reduce winter heat loss and retain heat from the day for use during the night.

	shading	Passive cooling	walls and roof
Hot and Dry	- Jaali screens - Plantation - Double glazed units - Texture - architectural projections -louvers -light shelves	-Radiative cooling -Direct Evaporative cooling -Earth coupling -Earth sheltering -Earth air tunnels -Trombe wall -wind catcher -Passive down draught cooling	Thicker walls constructed with hollow blocks/bricks (cavity wall) provide more insulation towards heat. Roofs should be constructed with high-quality insulation that is sloped windward, reflects radiation, and does not absorb heat. False ceilings can be utilised to enhance a building's thermal performance.The flat roof should have terracing in the form of burnt clay block paving, lime concrete, foamed concrete, or mud phuska over the slab. Whitewashing or other reflective paint should be used to make the top of the roof reflective.
			
Warm and Humid	- Jaali screens - Plantation - Double glazed units - Texture - architectural projections -louvers -Brise-soleils -light shelves	-ventilative cooling -Radiant cooling -Indirect evaporatve cooling(roof pond, a spray of water over a roof surface and a roof garden) -Dehumidification techniques	Traditionally, walls were made of wood with ventilation gaps and had woven bamboo strip flooring. A layer of insulation, such as foam or glass fibre, is added on the surfaces which receive strong solar radiations. Aditionally a ventilation gap can also be provided to decipate the heat collected. Thermal mass material for spaces used in day time and lightweight materials for spaces used in night. Clay tiles for roof.
			
Composite	- Jaali screens - Plantation - Double glazed units - Texture - architectural projections -louvers -Brise-soleils -light shelves	-Ventilative cooling -Earth tunnels -Wind tower -Evaporative Cooling -Passive Down Draught Cooling	For a 9–12 hour time lag in heat transfer, solid masonry or concrete should be used to build roofs and exterior walls. For the chilly and sweltering dry seasons, the thermal capacity will be useful. It is possible to use the roof pond system as insulation. The external walls or roof should have resistance insulation applied to the exterior surfaces. Because low-rise construction has more of the walls in contact with the ground, the earth will also serve as thermal storage.The external surfaces should be painted in medium-tone colors. The prevention of warmth entering through the outer surfaces of the walls and roof may be a fundamental rule. A light-colored or shiny polished metal finish is preferred for surfaces exposed to the sun during the hot and warm seasons.
		Wind Tower- Torrent research center, Passive down draught cooling 	
Cold	Overhangs, Louvres, Awnings, vegetation	**Passive Heating -** Earth berming Active Solar Systems Hot Water Heating Systems	Use of glass facades and roofs for appropriate daylighting for spaces that require the most light. Thicker walls help insulate the space and help retain the heat inside the building. Darker coloured exterior walls are preferred to help absorb the maximum amount of heat. In spaces where there is a lot of rain or snow, the provision of steep and sloped roofs help prevent water stagnation on the roofs. Insulating materials such as timber and mud plaster can be used on the walls to create facades that prevent heat loss as much as possible. Timber panelled walls and windows help reduce the rate of transfer of heat and are also mostly available in cold climatic spaces.
			

3.4 Passive design for Hot and Dry climate conditions

For hot and dry areas, passive design solutions seek to reduce heat gain, encourage natural cooling, and create comfortable interior environments. Here are some essential strategies frequently applied in hot and dry climates:



3.4.1 Natural ventilation

Ventilation, the movement of air, has three useful functions:

1) Provide fresh air to the building occupants.

2) Maintain the thermal comfort.

3) Cools down the interior building space when outdoor air is cooler.

Natural ventilation, which depends on pressure variations at the vent openings caused by wind-induced force or temperature changes (buoyancy ventilation), can be used to accomplish passive ventilation. (Calautit, J.K., et. Al, 2013).

The two methods of providing natural ventilation inside the building are –

1. Cross ventilation: In hot and dry climate, the inlet window should be smaller and on lower level and outlet should be of bigger size and on the higher level.

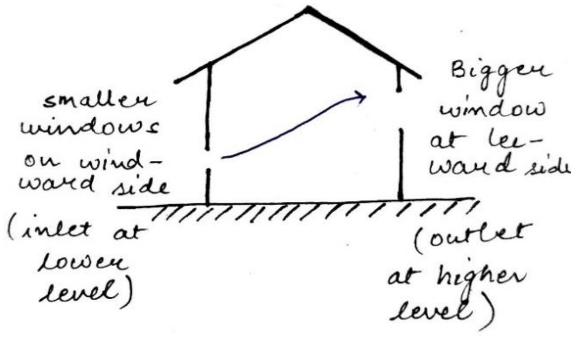


Figure 7: Cross ventilation

2. Stack Ventilation: High rise structures frequently use void areas or atriums to accommodate this buoyancy-driven ventilation. When interior air is warmer than outside air, buoyancy-induced ventilation occurs, which causes indoor air to rise and leave the structure through higher apertures. Through bottom inlets, the exterior's cooler, denser air enters the structure, pushing the interior's warmer, lighter air upward.

3.4.1.1 Domed roof

A structure with a spherical form is more energy efficient than a standard cubic construction in terms of heating and cooling needs for a given volume since the geometry of the building dictates that the lower the surface area to volume ratio, the lower the heat gain would be. As a result, a dome home has 30% less surface area than a box house of a comparable size, which results in a one-third reduction in the amount of heat transmission to and from the environment (Wang, S., & Shen, Z., 2012).

Dome roofs have been used in traditional dwellings for many years in hot and arid regions like the Middle East and the Mediterranean basin due to its thermal advantages, structural advantages (self-supporting arch and vault), and accessibility of the building materials (adobe, stone).

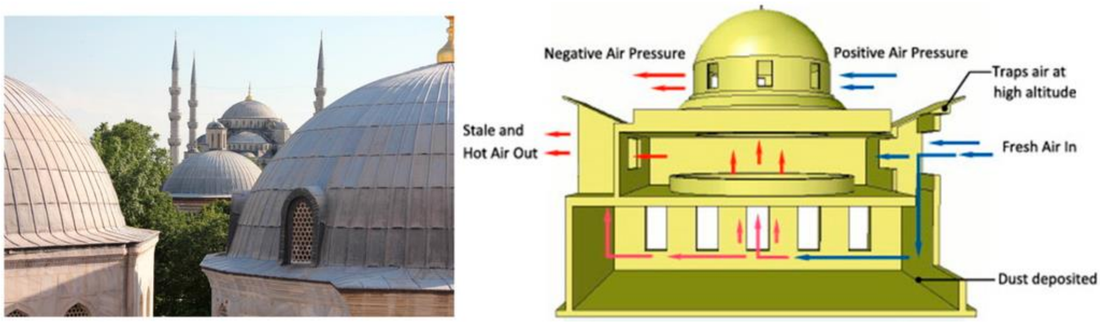


Figure 8: Domed Roof
Source: (Hughes, B. R., et. Al, 2012)

Several research looked at the passive properties of dome roofs to keep inside rooms cool in the summer with very low energy use for a variety of reasons, including:

1.	Thermal lag supply reduces the extreme temperature difference between day and night by using masonry thermal mass, such as stone and adobe.	(Passe, U.; Battaglia, F., 2015)
2.	Due to the greater height of the interior, heated, expelled air is trapped at a higher level than with a flat roof, keeping the inhabitants in a cooler lower area.	(Hassan, F., 1986)

3.	Using stack ventilation through ceiling vents, which enable the rising heated air to escape through and provide the fresh, cold air to route into the area through small peripheral holes at lower level.	(Calautit, J.K.S., et. al, 2013)

3.4.1.2 Solar Chimney

The application of solar chimney is a vernacular concept and can be seen in the middle east, by Persians and also in Europe by Romans. As the inside temperature of the chimney increases during the day, causing the air density to reduce hence the hot air moves upward. According to studies, using a solar chimney in warm weather can cut power use in a building by 10% to 20%, depending on the type of ventilation system used (Zhai et al., 2011).

The factors impacting the performance of solar chimney are -

• The aspect ratio of the chimney

• Ventilation height (the difference between the height of the inlet and outlet)

• The area of awning windows

• Thermal properties of heat-absorbing materials

• Slope (40–60◦ as an optimal slope)

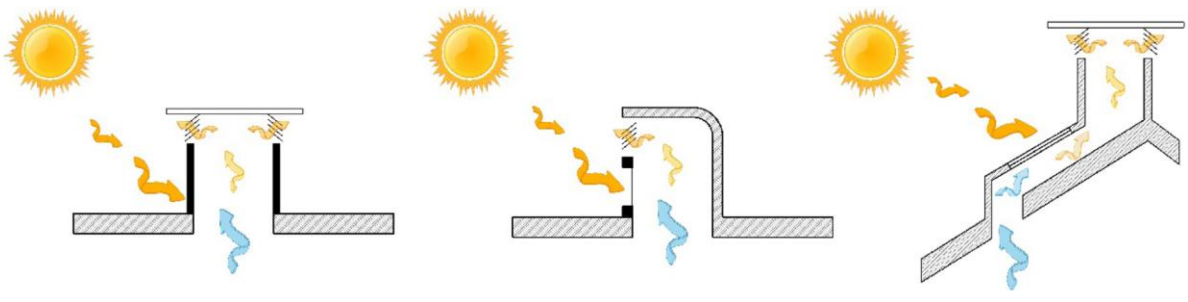


Figure 9: Solar Chimney
Source: (Song, Y., et al., 2021)

3.4.1.3 Atrium

Atrium space, a huge, almost glassed central area, is a common space that has seen expanding usage throughout the ages, especially in non-residential structures. Atrium provides impressive aesthetic space, exposing adjacent indoor spaces to daylight, maximizing benefits from direct solar gain, and increasing inhabitants' socialization and interactions (Saxon, R., 1983). The performance of atriums improves as a building's height rises, according to studies. However, in order to achieve balance in the atrium's use, elements such as its translucent surface and the weather are deciding (Getino-De la Mano and Getino Grande, 2015).

3.4.1.4 Wind catcher

For thousands of years, regions with extremely hot temperatures have been using windcatchers, also known as wind towers or wind scoops, as a cooling architectural element. Air movement is brought on by warm air ascending and chilly air descending. A zone of low pressure results from warmer air rising from the land's surface. In the process of rising, air cools, moves toward the surface of the ocean where it falls, creates a pressure area, and forces cold air in the direction of the land. These motion is what creates the wind. In order to improve performance, new wind catchers are combined with other cooling techniques such as evaporative cooling. Buildings such as the Tassilo Hager tower in Germany and the Al Taha skyscraper in Dubai have made use of contemporary windcatcher forms.

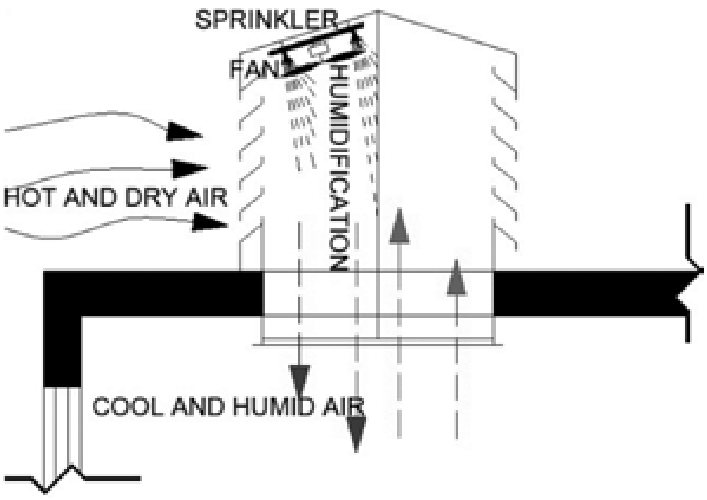


Figure 10: Adding moisturizing element into traditional wind catcher
Source:(Pour, L.Y., 2012)

3.4.2 Natural ventilation

3.4.2.1 Evaporative cooling

In this method the air is cooled by evaporating water before entering the inside space.

Evaporative cooling is of two types –

1. Direct evaporative cooling – In this method the cooling happens due to an increase in relative humidity. A fountain is an example of direct evaporative cooling.

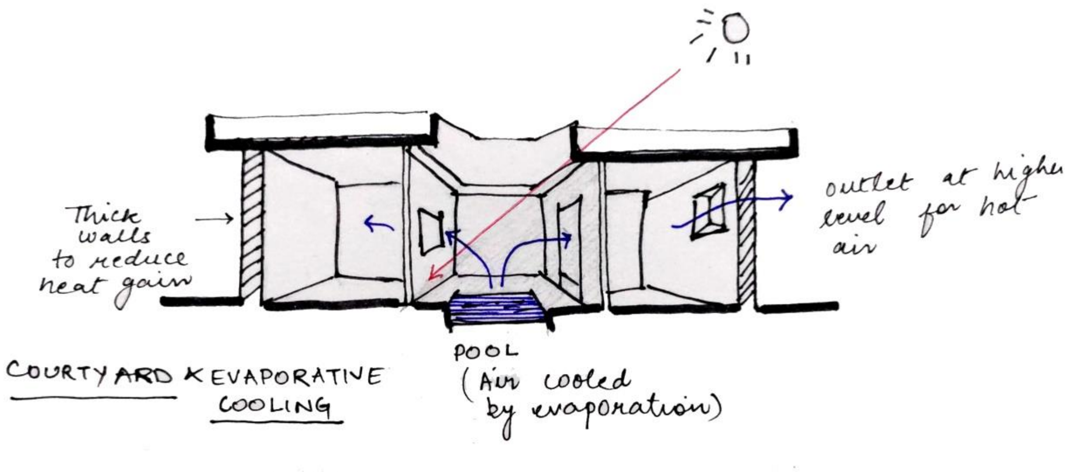


Figure 11: Direct Evaporative cooling

2. Indirect Evaporative cooling – In this method the cooling happens when the transfer of heat takes place through conduction from a solid to a water source, which is cooled by evaporation to ambient air. Roof pond, water spray on the roof surface or roof garden are a few examples of indirect evaporative cooling.

3.4.2.2 Passive down draught cooling

The PDEC system collects hot outside air from the top of the building and cools it using passive cooling methods like water-filled containers or mechanical cooling methods like nozzle sprays, which causes an increase in air density. The cool, dense air then sinks to the bottom of the rooms. PDEC towers have been applied in Torrent Research Centre, Ahmedabad, India. The indoor temperature is in the range of 29–30 ◦C while the outdoor temperature is recorded between 41– 43 ◦C.

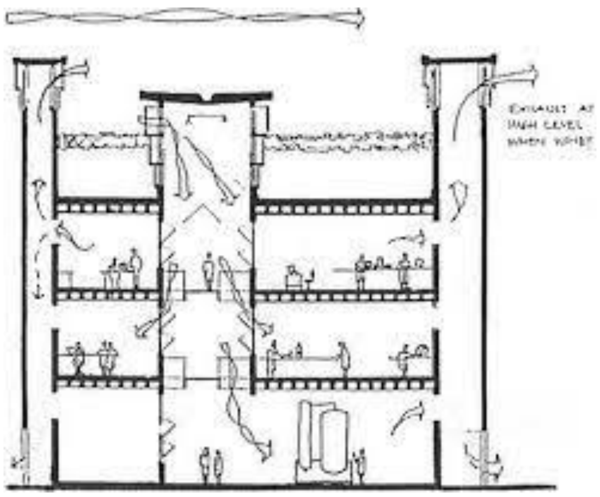


Figure 12: Torrent Research Centre, cross section showing airflow (architects: Abhikram, with Brian Ford Associates)
Source: (Bowman N.T.et al, 2000)

3.4.2.3 Radiant cooling

Radiative heat exchange will take place when two surfaces with varying surface temperatures are in close proximity to one another. This technique is necessary for radiant cooling to remove heat from a building or a person's body. One of the most popular radiant cooling systems uses the building's roof as a radiator to release heat into the nighttime atmosphere. Through this process, the roof is cooled, acting as a heat sink for the inhabited area below.

- On the roof, a little pond is created using this technology. The roof is covered throughout the day to reduce sun radiation near the pond. The pond's water is cooled at night when the cover is removed. As the building is covered during the day, the cold water on the roof takes heat from the structure. To prevent solar heat from being absorbed, the surface of the roof is additionally insulated. Without any insulation, the roof temperature reaches 65.6 °C. By placing a pond on the roof with depths of 0.05 m and 0.15 m, the temperature may be reduced to 39.4 °C and 42.2 °C, respectively (Gupta, N., Tiwari Gopal, N., 2016).
- It is possible to construct a moveable roof cover to block heat radiation during the day and expose the full roof surface to the night when the cover is removed. As a result, the roof fully utilizes radiant cooling while decreasing radiant heating. Little space exists between the roof and the cover needed to permit daytime convection. The moveable devices can have solar panels attached to them so that during the day, solar energy can be used to provide the electricity required to move

the coverings. The best option for the roofing in this case is high thermal mass materials. This is because high thermal mass building materials enable the storage of heating and cooling air.

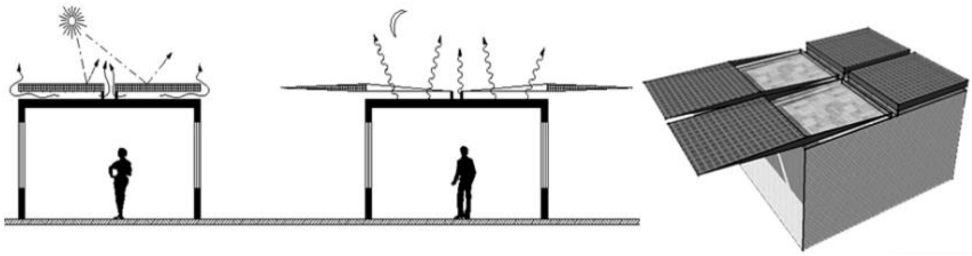


Figure 13: Movable cover on the roof can reduce radiant heating and increase radiant cooling Source:(Lavafpour Y., 2011)

3.4.2.4 Underground air tunnel

The primary source of air heating is the ground; despite substantial yearly changes, the temperature of the surface soil is roughly equal to that of the air. The temperature of the soil does, however, change less and less as the depth of the soil rises to roughly 6 meters due to the significant time lag of the earth. Traditional Iranian homes include a space development called Sabestan/Shavadan, which consists of a room or rooms that are 5–10 meters below ground level and the ground floor. These spaces frequently maintain a steady temperature throughout the year that is between 22 and 25 °C. For the purpose of providing light and air circulation in Shavadan, one meter diameter cylindrical vertical passageways were excavated. These canals connected homes' top floors to Shavadan and let cold air to travel from the deep soil to homes' interiors (Lavafpour Y., 2011).

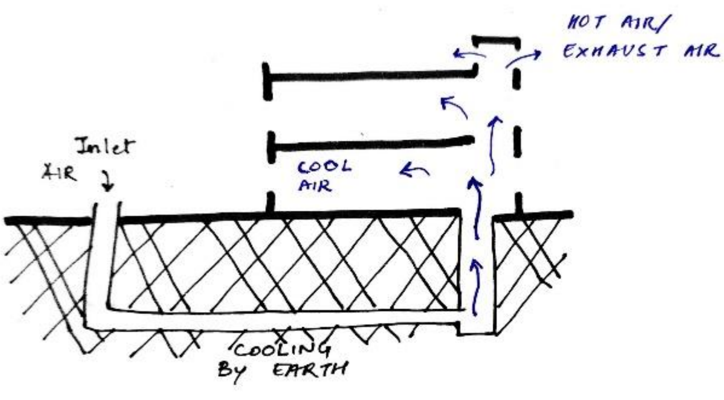


Figure 14: Earth air tunnel

3.4.3 Thermal mass

A material that absorbs or releases heat from or to an interior area is referred to as having thermal mass. It helps keep the inside cool when the outside temperature is high by reducing heat transmission through the building envelope. In addition, when thermal mass is exposed to the inside, it absorbs heat from inside sources and lessens the degree of temperature change there. Ogoli (Ogoli, 2003) in his research looked at how thermal mass affected the lowering of indoor temperature in four test rooms built in Nairobi, Kenya, using wood and stone. According to this study, the highest inside temperature ever recorded in a structure with a high thermal mass was 25.4 °C when the outside temperature was 33 °C. The highest inside temperature was 2-3 C higher than the external peak temperature in rooms that had low thermal mass, though.

3.4.4 Earth sheltering

A building that is earth-sheltered has a less heating and cooling load because of the substantial thermal mass that the soil provides. With this technique, the soil serves as a heat sink to absorb a lot of energy. Although it has been shown that underground buildings consume less energy and experience less temperature change than above-ground ones, the loss of natural light and prolonged usage of artificial light are seen to be drawbacks of this strategy. In an earth-sheltered construction, vertical ducts are advised for ventilation and sunlight.

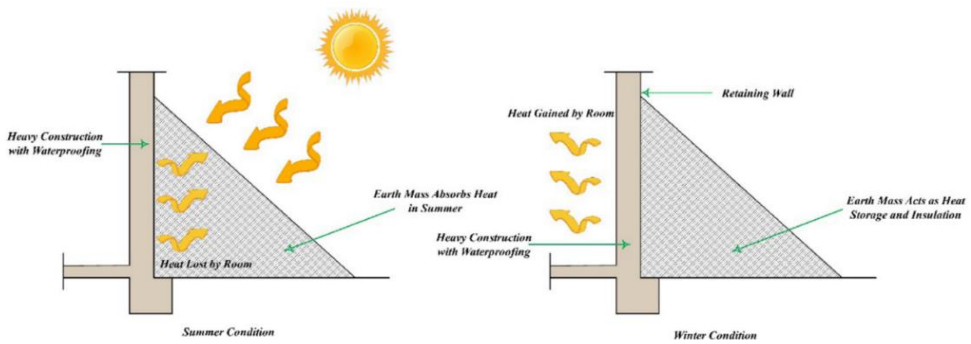


Figure 15: Thermal performance of the earth-sheltered system
Source: (Kamal, 2012)

3.4.5 Insulation

Insulation functions as a barrier to heat flow, lowering heat gain in the summer to maintain a cool home and lowering heat loss in the winter to keep the home warm. The ceiling, floors, and walls all employ insulation. To lessen the thermal impact of solar radiation, a building envelope may need to be constructed from many layers of different materials. To successfully limit heat conduction through opaque surfaces exposed to intense solar radiation, it may be essential to add an additional layer of insulation, such as foam or glass fibre. All forms of insulation enhance the thermal efficiency of a building's circumferential surfaces in such a way as to lower those surfaces' U values by 36% to 61% (Walker and Pavía, 2015).

3.4.6 Green roof

Green roofs are the vegetative covers applied to building roofs in order to absorb solar flux. A green roof does not allow heat transfer from the roof surface to living space. Green roofs are a way to improve the sustainability and energy efficiency of buildings, but they also have a number of other positive social, economic, and environmental effects. These advantages include lowering greenhouse gas emissions and the urban heat island effect, mitigating acid rain by raising pH levels, improving air quality by increasing oxygen production and carbon dioxide sequestration, and minimizing noise pollution from vehicles in metropolitan areas (Cascone, 2019).

By acting as insulation and minimizing heat transmission, green roofs can improve the thermal comfort of buildings. Here are several ways that green roofs might improve thermal comfort:

Insulation- For structures, green roofs give an extra layer of insulation. Heat transfer through the roof assembly is decreased by the plant and soil layers, which offer thermal resistance. This insulating effect lessens the demand for mechanical heating and cooling by keeping the inside warmer in the winter and cooler in the summer.

Reduced heat island effect - Cities with plenty of paved surfaces and construction often produce heat islands, which are hotter than the nearby rural regions. By absorbing and diffusing solar radiation, green roofs can lessen this impact, lowering ambient temperatures and enhancing comfort levels.

evaporative cooling - Plants lose moisture through transpiration, and the soil absorbs it to provide cooling effect. The evaporation from the plants on the green roof cools the air around it, which in turn lowers the temperature of the roof's surface and the building below.

Careful design, including optimal plant selection, soil depth, and irrigation systems, can maximize the special advantages and performance of a green roof for thermal comfort.

3.4.7 Wall systems

3.4.7.1 Cavity wall

A cavity wall is created by joining two distinct walls into one wall while leaving a space or void between them. These two distinct walls are referred to as cavity wall leaves. Metal ties or links are used to join the two leaves together. The outer leaf of the wall, which is mostly non-load bearing is half brick thick and the inner leaf is always load-bearing and its thickness should not be less than one brick. Compared to solid walls, cavity walls provide higher thermal insulation. It happens because the air-filled area between two leaves of cavity walls limits heat transfer into the structure from the outside. This promotes energy efficiency and keeps the interior atmosphere more pleasant. Typically, insulating material is used inside the cavity to improve thermal efficiency even further.

3.4.7.2 Trombe wall

The Trombe wall essentially consists of a substantial, highly resistive wall made of stone, brick, or concrete that is put next to a glass partition, as shown in Fig. 1. Although Trombe walls are frequently used in colder areas for passive solar heating, they may also be modified for usage in warmer climates to offer cooling advantages and is named after french scientist, Felix Trombe. Trombe walls should have their design changed to allow for operation in a variety of modes that minimize conduction heat gains through the storage wall and maximize heat removal from the interior through ventilation in order to increase the likelihood that they can be used in hot climates (Ali M. et al, 2016). Here are some factors to take into account when creating a Trombe wall for a hot climate:

Ventilation - To avoid heat accumulation in the Trombe wall system, adequate ventilation is necessary. Airflow between the wall and the interior area can be facilitated by carefully placing vents or windows that can be opened. This encourages natural ventilation and enables heated air to leave, aiding in the building's cooling process.

Insulation - For a building with Trombe walls to have the best ventilation rate possible, appropriate thermal insulation is required. In order to increase the effectiveness of the system, the inside of Trombe walls should be thermally insulated in both the winter and the summer (Ali M. et al, 2016).

Nighttime cooling: The Trombe wall can be used to promote nighttime cooling in hot locations with considerable temperature reductions at night. Cool air may be sent into the space through windows or vents, where it will flow through the Trombe wall, which serves as a heat sink to absorb extra heat from the inside.

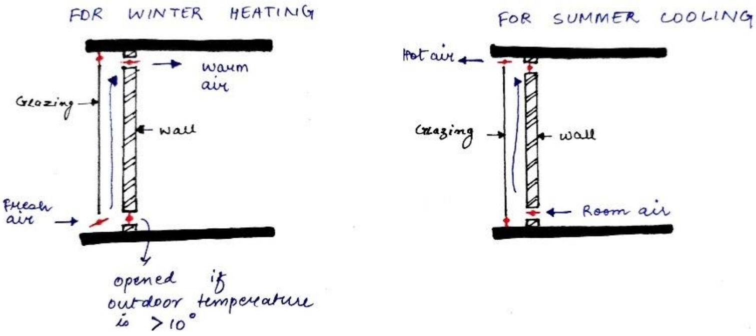


Figure 16: Trombe wall

3.4.8 Shading devices

A building's heat gains frequently include a significant amount of solar gain through its windows. Additionally, solar radiation on the opaque portions of the building exterior raises the envelope's surface temperature and aids in heating the inside space. When sun control and shading systems are properly designed, they may dramatically reduce peak heat gain and cooling needs while also improving the quality of interior lighting in buildings. Depending on the location and amount of fenestration, it has been reported that there can be savings of 5% to 15% in annual cooling energy usage. Sun control and shade solutions can also improve user experience visually by reducing glare and contrast ratios. The effectiveness of shading devices will depend on the solar orientation of a given building façade. For instance, overhangs are a particularly effective technique to shade south-facing windows during the summer, when sun angles are strong. The same horizontal device is ineffective in blocking late afternoon light from entering west-facing windows during the summer's peak heat gain hours. It is essential to comprehend the sun's position in the sky before designing colouring structures. The positions of the sun are described by their height and azimuth angles.

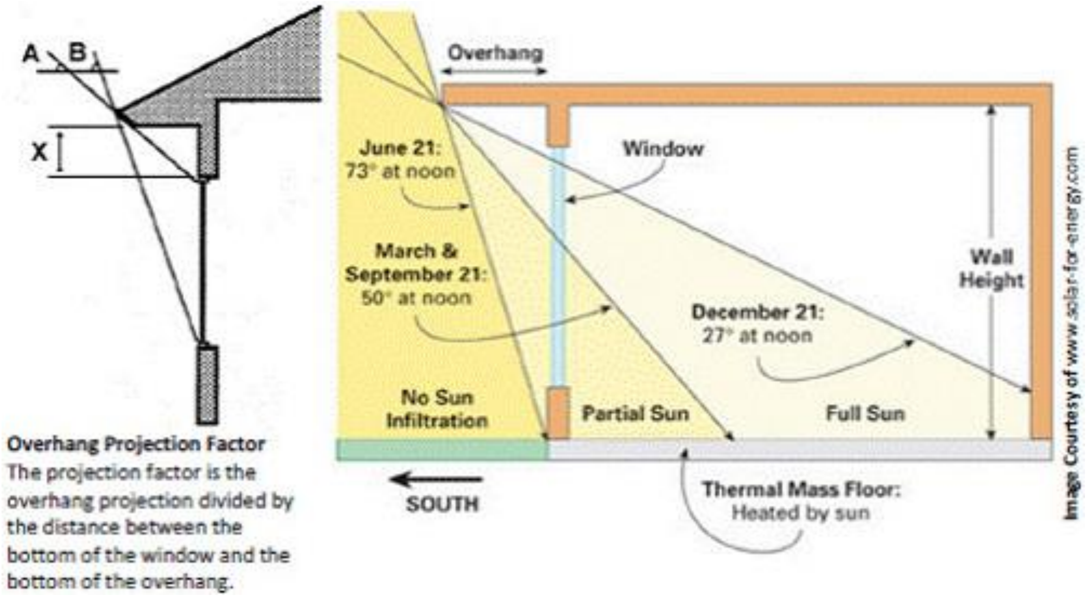


Figure 17: Sun angles
Source: https://www.wbdg.org/resources/sun-control-and-shading-devices

3.4.8.1 Double glazing

A double-paned window contains two layers of glass with an air or gas pocket in between to better insulate a space. Two glass panes are fitted into a frame to make a double layer of glass. Glass can seal and maintain a barrier from the outside, despite the fact that it isn't a particularly good thermal insulator. When it comes to energy efficiency, double-paned windows have a clear benefit since they act as a stronger barrier against outside temperatures than single-paned windows. Glass panes can be vacuumed or gas can be used to fill the space between them.

3.4.8.2 Louvers

Louvres are frequently utilized in hot climate regions as solar shading devices. Louvres are horizontal or vertical slats that are commonly constructed of metal, wood, or glass. The quantity of heat and daylight that enters a building may be controlled by adjusting the louvres. The following are some essentials about louvres as sun protection shading devices:

i. Louvres are efficient in reducing solar heat gain by preventing direct sunlight from penetrating a structure. It is possible to let in natural light while avoiding heat accumulation by altering the angle of the louvres, which can assist in decreasing the need for artificial cooling and cut energy use.

ii. Daylighting: Louvres may be made to exclude direct glare while allowing diffused natural light into a space. With the aid of daylighting, it is possible to create a comfortable and adequately illuminated indoor space without compromising sun protection.

3.4.8.3 Jaali screen

Jaalis are designed to screen direct sunlight and so lessen solar heat intake. The jaali's delicate designs minimize heat and glare while permitting diffused natural light to enter. This lessens the need for excessive cooling while maintaining a suitable interior climate. A building's natural ventilation is encouraged by the jaalis' perforations, which enable air movement. In addition to increasing energy efficiency, this lessens the dependency on mechanical cooling systems.

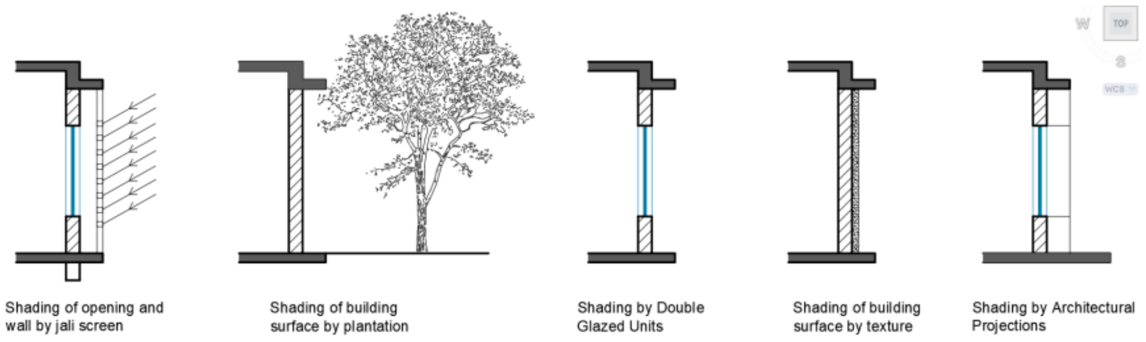
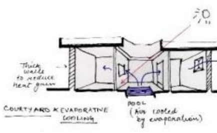
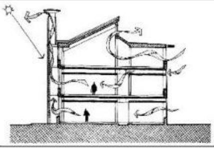
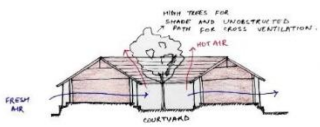
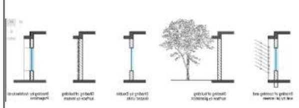
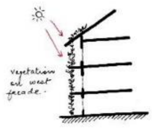
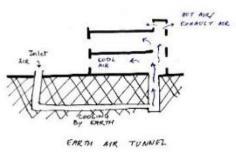
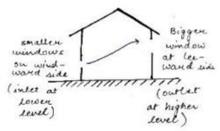
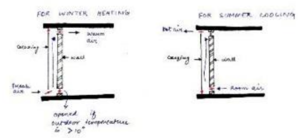


Figure 18: Shading devices
Source: https://thearchspace.com/design-strategies-for-hot-and-dry/

Table 1. Passive cooling techniques and temperature change table

Passive Techniques		Temperature change	References
Evaporative cooling		8.5°C to 9.6°C It can reduce cooling demand by 20%.	(Abbas M. Hassan, 2016)
Wind tower		2.5°C to 5.5 °C	(Yasmina Bouchahm, 2011)
Courtyard		The courtyard has a significant positional influence, which can vary on the climatic conditions under which it is constructed.	(Bansal, 2018)
Shading device		0.5°C to 1 °C Solar heat gain by glazing can be reduced up to 80% using external shading devices.	(Emad S. Mushtaha, 2012) (2030 palette – A database of sustainable design principles, strategies, tools and resources at your fingertips, n.d.)
Vegetations		3°C to 5°C	(Sharma, 2016)
Solar control/panels		3.2°C to 5.45°C	(Emad S. Mushtaha, 2012)
Earth air tunnel system/Earth coupling		2°C	(Alaa Alaidroos, 2015)
Natural ventilation		2.7°C	(Emad S. Mushtaha, 2012)
Trombe wall		2.2°C The use of PCMs in heavy constructions may be substantial, with up to 17% energy saving potential.	(Marwa DAbaieh A.E., 2015) (Ali M)
Earth sheltering/ Earth berming		2°C to 4°C Structures that are earth-sheltered use 65-85% less energy than conventional structures and also reduces the humidity rate by 5-10%.	(Abbas M. Hassan, 2016)
Thermal mass		3.4°C Recommend using small external openings with a 20-40% window to wall ratio	(Emad S. Mushtaha, 2012)

Chapter 04 Secondary Case Studies

4.1 Passive Solar Hostel, Jodhpur

Client - University of Jodhpur

Location - Jodhpur, Rajasthan, India

Principal Architect : Vinod Gupta

Site area : 420 sq.m

Floors - G+1

About the project and context – The principal architectural restrictions for this dorm for married students were the severe water shortage and the harsh desert winds. The solar hostel was constructed as a part of a research project by the Centre of Energy Studies at the Indian Institute of Technology, Delhi. The design intended to test and illustrate viable techniques of delivering thermal comfort in Rajasthan's hot and dry environment, despite the fact that energy conservation was the declared goal.

Seven rooms on the ground level are partially submerged to benefit from the earth's insulating and heating properties. Wind tower are a major part of the design as the prevailing wind direction of the region is southwest, but it is unfavorable to provide window openings in this orientation because of harsh solar radiations. The tower faces the south west direction of the wind and provides cool air to the rooms.

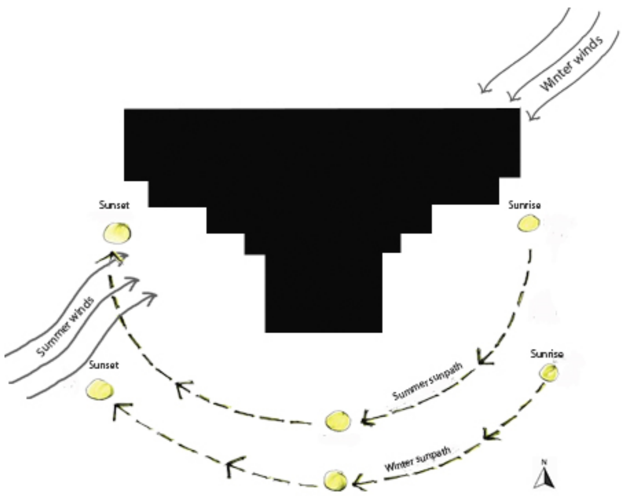


Figure 19: Passive solar hostel : Orientation

Hot room air exits through the exhaust tube/chimney over each room. Local light colored stone is used in the walls and large slabs of the same stone have been used for roofing, staircases, partitions, and for lintels over windows.

Figure 20: Passive solar hostel views

A water tank is present at the top of staircase which also has the wind tower helping in cooling the building mass and lowering the temperature through **Indirect evaporative cooling.** Since stone is a local resource and can offer adequate thermal mass to counteract diurnal temperature changes, stone masonry has been employed in walls**.** The wall thickness varies from 0.30 meter to 0.45 meters. **Small inverted terracotta pots** have been used as **insulation** material between the stone slab and finished flooring and the gaps are filled with lime concrete.

Since the university often takes a break during the hottest summer months, winter comfort is just as crucial as summer comfort given that winter temperatures can dip as low as 16.6 °C. There are windows in south for allowing sun during winters and to prevent heat loss during night, solid timber shutters are there along with glass. This is a low-embodied energy building as a very few manufactured materials have been used.

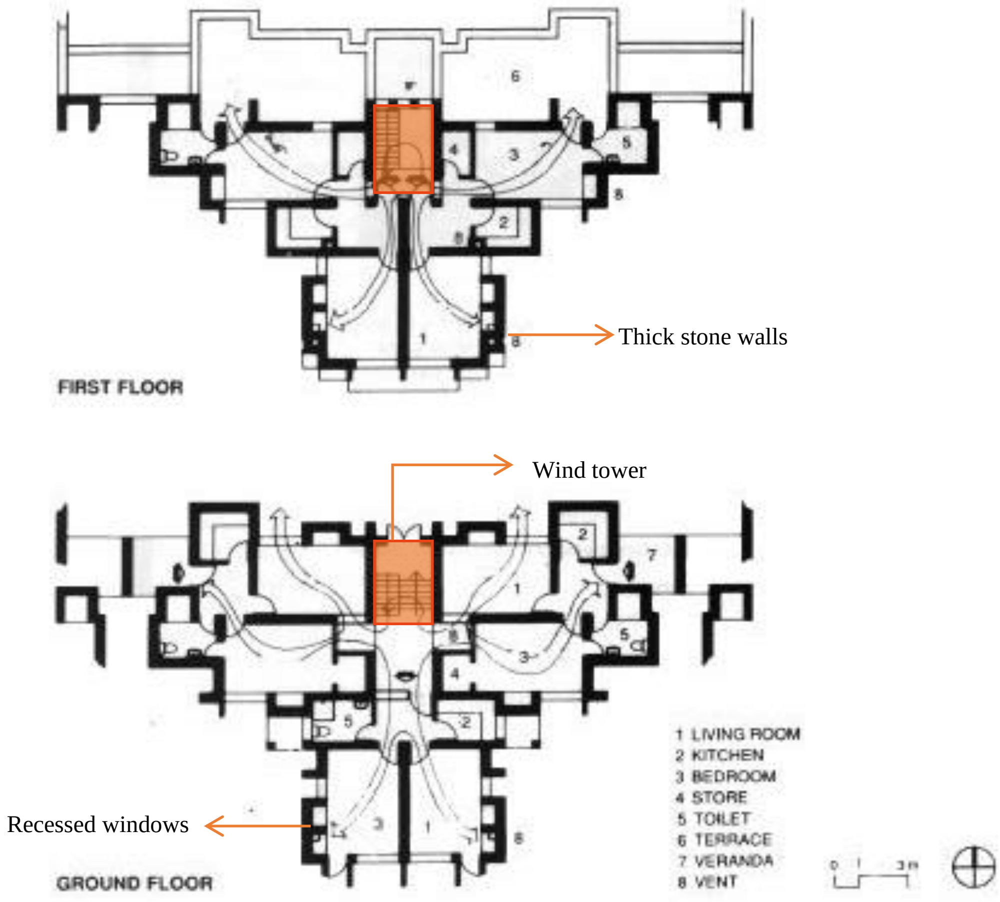


Figure 22: Passive solar hostel : Floor plans
Source: Gupta, V. (1992). Solar passive hostel, University of Jodhpur. Architecture+ Design, 34-35

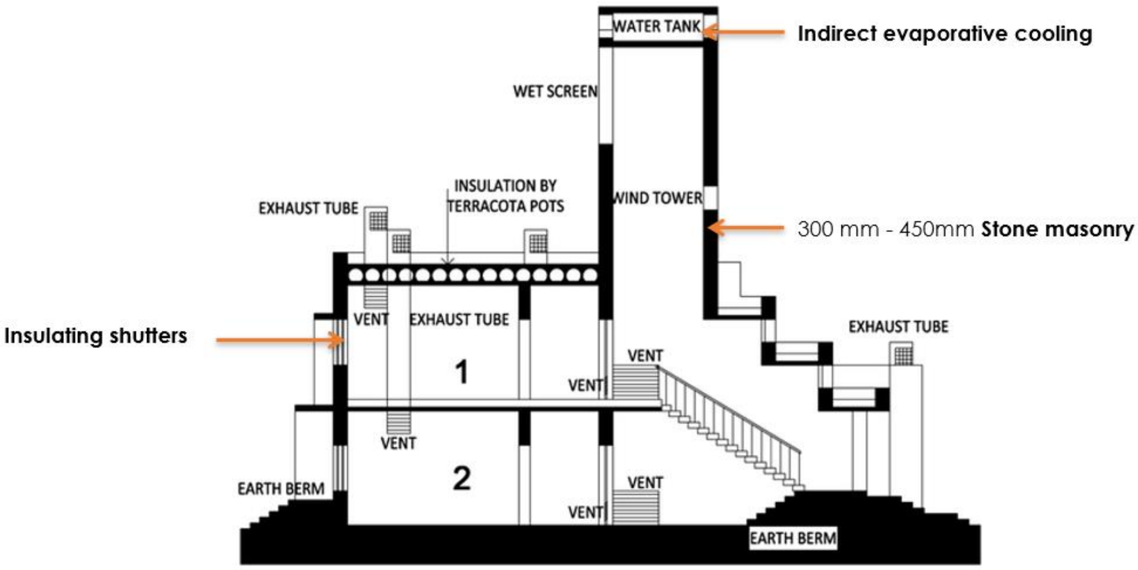


Figure 21: Passive solar hostel : Section
Source: Gupta, V. (1992). Solar passive hostel, University of Jodhpur. Architecture+ Design, 34-35.

4.2 Pearl Academy, Jaipur

Client - Pearl Academy

Location - Jaipur, Rajasthan, India

Principal Architect : Morphogenesis

Area : 11745 m²

Floors - G+2

About the project and context – The institute is situated outside of Jaipur in the lifeless Kukas industrial district, around 20 kilometres from the well-known walled city, in a typical hot, dry, desert-like atmosphere. Due to the adverse climate, it is challenging to control the microclimate within the project. Adding more passive climate control techniques is thus necessary and will also help reduce the requirement for resource-intensive mechanical environmental control systems. The academy is oriented towards southwest-northeast.

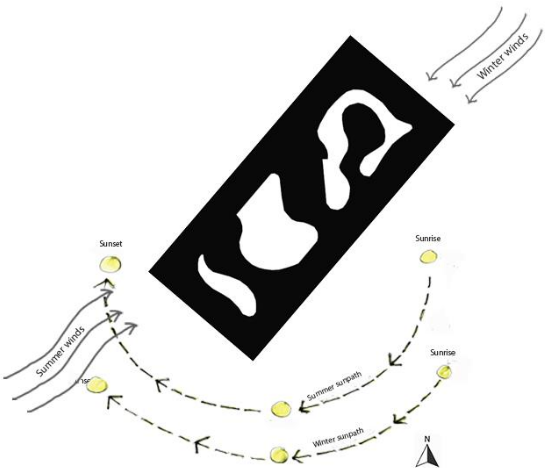


Figure 23: Pearl Academy : Orientation

Due to the building's elevation above the ground, a natural thermal sink is created, which is cooled by an evaporating water body. A microclimate is created by the air coming from the inside and the underneath. Green areas and water bodies are directed to be in shaded regions to minimize water evaporation and to enhance evaporative cooling. There are courtyards that regulate the temperature of the interior areas and open tiered wells while providing enough natural light for studios and schools.

Thermal insulation using a traditional Indian technology was used: flat roof is covered with earthen pots (mutkas) that are about 35 cm in diameter and spaced 2.5 cm apart. The spaces between the mutkas are filled with sand and crushed bricks and then coated with a thin coating of concrete. Insulation is provided by the fill and air inside the pot. A thermal barrier is created between the building and its surroundings by the double skin. Computational shadow analysis has been utilized to calculate the density of the perforated outer skin based on the orientation of the façades. The outer skin is 4 feet away from the structure and blocks direct sunlight from entering through openings while yet allowing diffused light to enter. Thus, the jaali fulfills the roles of three filters: air, light, and privacy.

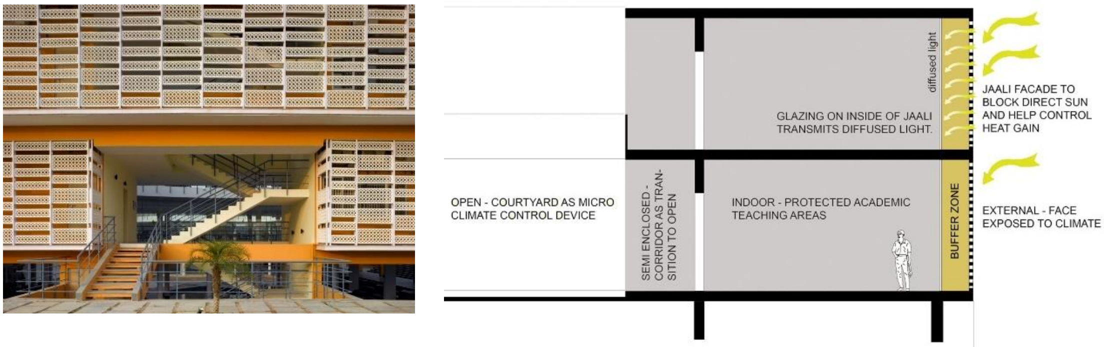


Figure 24: Pearl Academy : Double skin façade
Source: https://www.archdaily.com/40716/pearl-academy-of-fashion-morphogenesis

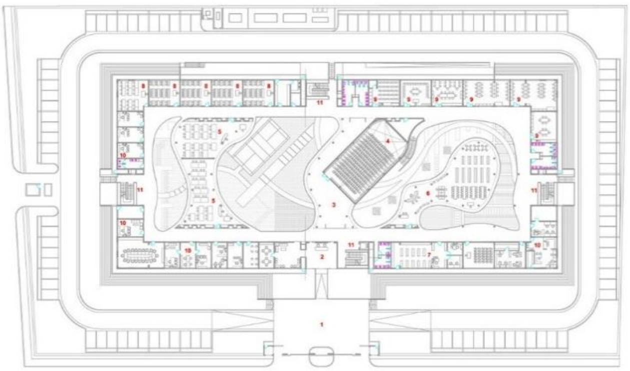


Figure 26: Pearl Academy : Plan
Source: https://www.archdaily.com/40716/pearl-academy-of-fashion-morphogenesis

Figure 25: Pearl Academy : Section
Source: https://www.archdaily.com/40716/pearl-academy-of-fashion-morphogenesis

4.3 Urban Oasis, Ahmedabad

Client - Mr. Sanjay Jain

Location - Ahmedabad, Gujarat, India

Principal Architect : tHE gRID Architects(Snehal Suthar/ Bhadri Suthar)

Site area : 7102 sq.m

Built up area : 19455.9 sq.m

North and South blocks - G+7

East and West blocks - G+3+basement

The building's plans were finalized so that the central area would be shielded from the sun's rays by two high-rise towers on the north and south, and two low-rise blocks on the east and west.

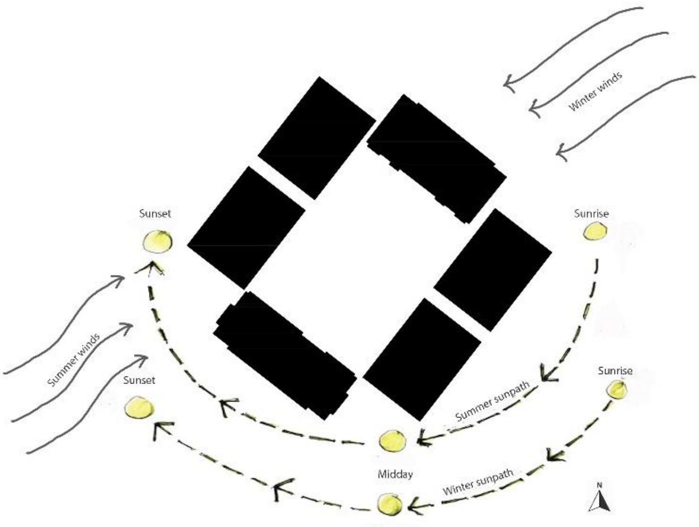


Figure 27: Urban Oasis: Orientation

The material palette included glass, granite, vitrified tiles, aluminium powder coated louvres, exposed RCC high pressure laminate, fsc certified wood, sandstone, and stonecrete. It also included eco-friendly colours. The environmental effect of extraction, shipping, installation, etc. is decreased by the systematic use of green construction materials. Because they are non-toxic, emit few chemicals, and have low moisture resistance, green materials help improve the quality of the air within buildings. decreased expenses for maintenance and replacement during the building's lifetime. The central landscaping, the enormous trees, and the terraces, which have been transformed into gardens, activity hubs, and gathering spaces, make up the three levels of greenery. 2,228 sq.m, or 31% of the plot is covered with landscaping on the ground. The entire landscaping has drip irrigation. The presence of a water body aids in reducing the temperature in the immediate area.

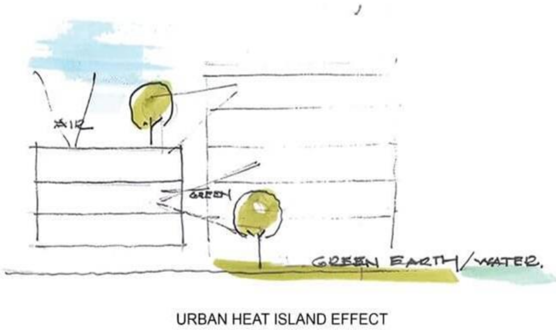


Figure 28: Urban Oasis : Landscaping
Source: https://amazingarchitecture.com/residential-building/urban-oasis-gated-community-living-housing-in-ahmedabad-india-by-the-grid-architects

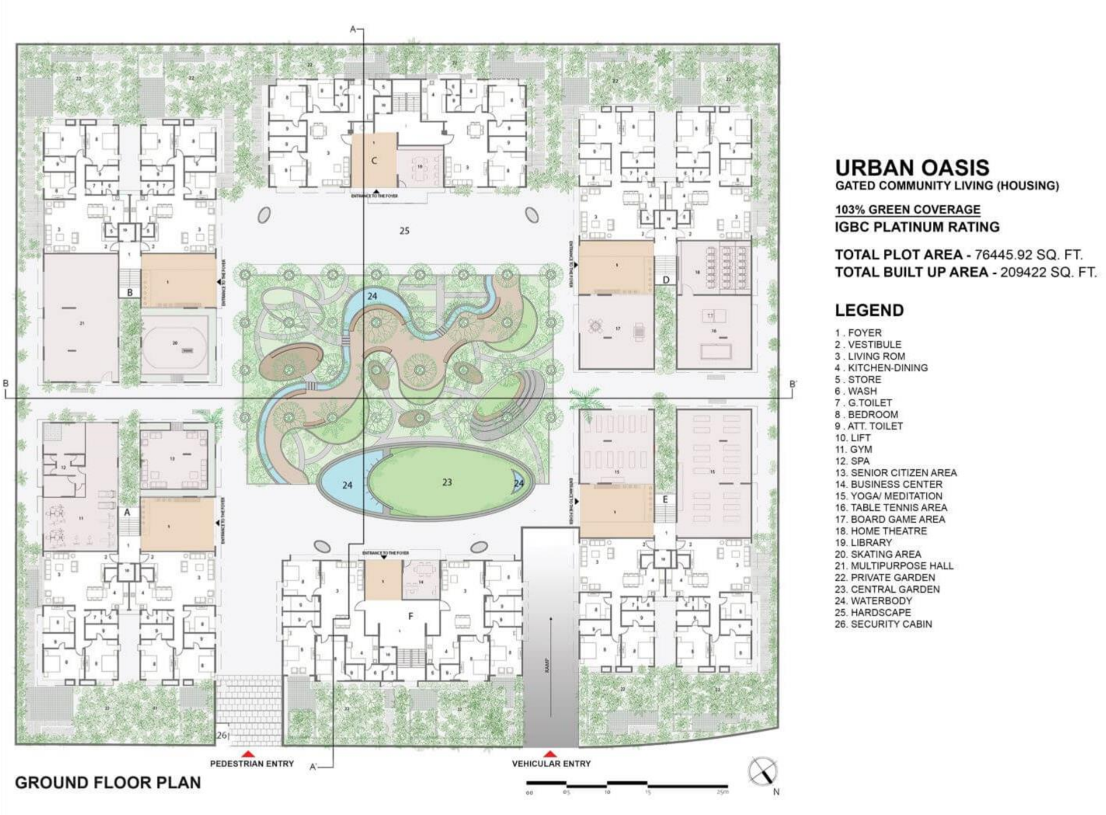


Figure 29: Urban Oasis : Plan
Source: https://amazingarchitecture.com/residential-building/urban-oasis-gated-community-living-housing-in-ahmedabad-india-by-the-grid-architects

The design was created as a monolithic RCC shear wall construction with raft foundation. The walls are efficient with a U value of 0.75 W/sq.m deg K. The roof's China mosaic serves as a heat reflector. Doubly glazed Reflective glass is installed in the windows reducing the amount of heat and allowing up to 67% light inside.Plantations and balconies serve as a buffer for shade. On the roof are solar panels that power the whole common area, lobby, and outdoor area. There are other sustainable techniques like recycling graywater and collecting rainwater employed in the project.

Figure 31: Urban Oasis : Section
Source: https://amazingarchitecture.com/residential-building/urban-oasis-gated-community-living-housing-in-ahmedabad-india-by-the-grid-architects

Figure 30: Urban Oasis : Façade views

4.4 Pallacia, Jaipur

Client - OM Metals Pvt. Ltd.

Location - Statue Circle, C-scheme, Jaipur

Principal Architect - STUDIOS architecture NY + m a architects

Site Area - 20234.3 sq.m

Built Up Area - 92,900 sq.m

Project Size - 152 units

Floors - G+8 (max.)

About the project and context - Pallacia is situated at the heart of Jaipur, i.e C-Scheme encompassed by the remarkable landmarks like the Statue Circle, Central Park, Vidhan Sabha and Birla Auditorium. A grid derived from the site location at the Statue Circle was interlayered with urban design, sun-paths round the year, Vaastu considerations beautiful views of Central Park, Statue circle and Nahargarh hills to arrive at the cascading form of the East apartments and the vertical massing of the West.

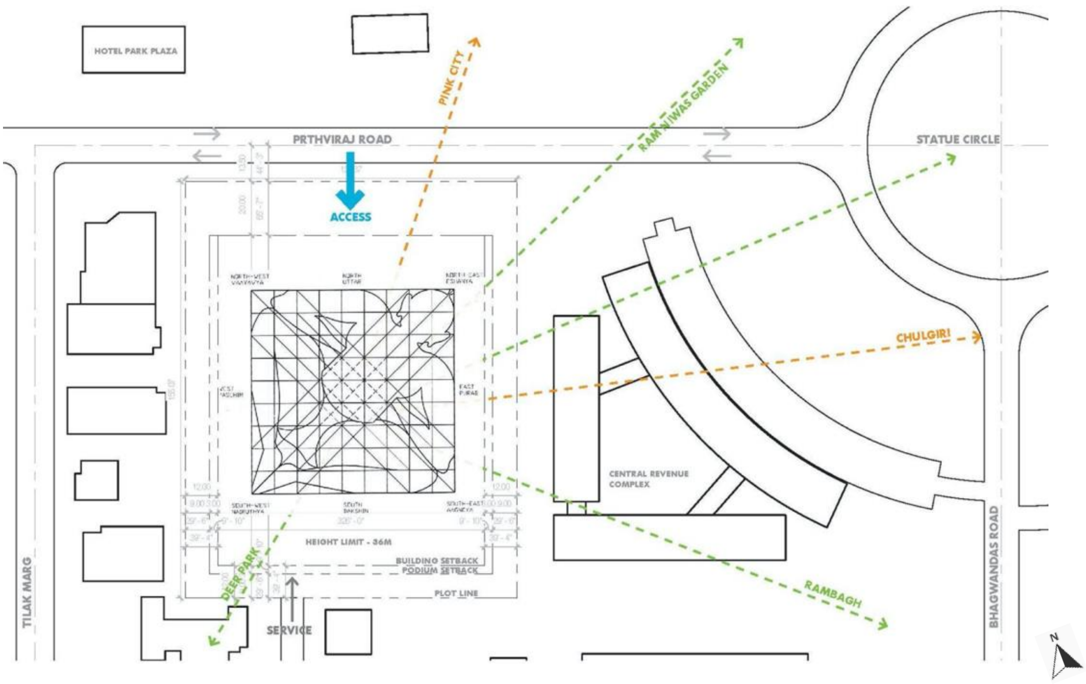


Figure 32: Pallacia : Site context

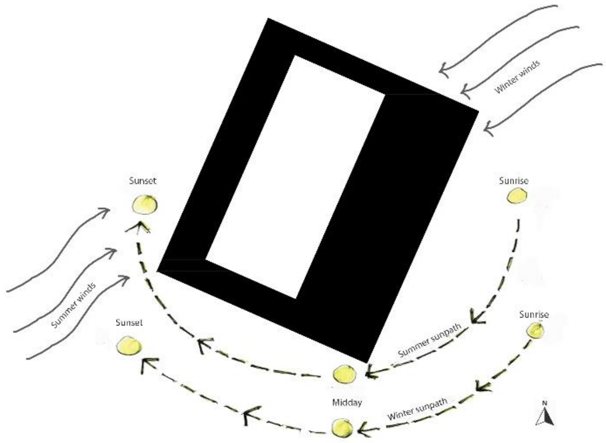


Figure 33: Pallacia : Orientation

The development's distinctive residential unit options depend on the site's massing. The sloping cascade of terraces, which follows the Vaastu massing hierarchy and access to vistas, faces out toward Statue Circle. The inside of each unit in the stepped East tower is illuminated by continuous vertical voids and smaller patios.

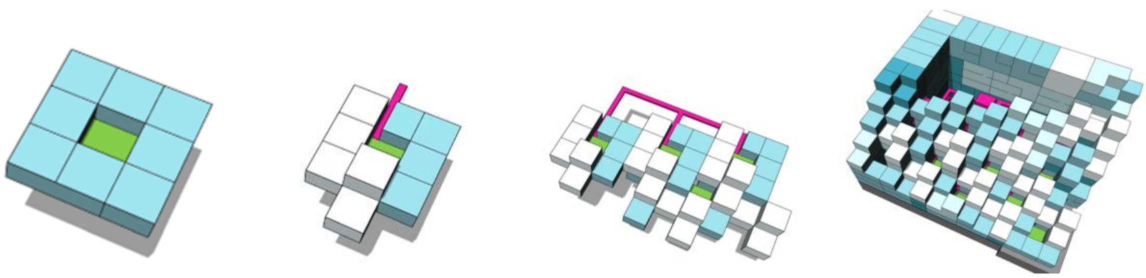


Figure 34: Pallacia : Form and massing
Source: https://studios.com/jaipur-residential-development.html

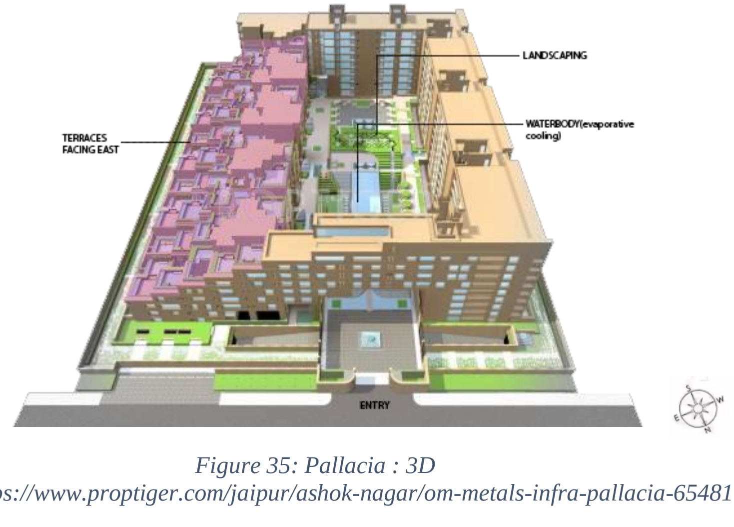
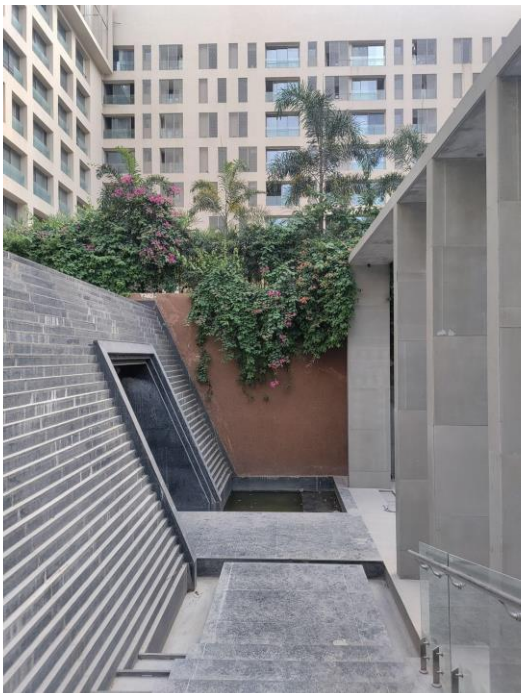


Figure 35: Pallacia : 3D
Source: https://www.proptiger.com/jaipur/ashok-nagar/om-metals-infra-pallacia-654816

The Central courtyard consists of plantation and water body leading to evaporative cooling hence improving the thermal comfort of the gardens. Every massing concept that was explored in the design process revolved around a courtyard, which offers a distinctive entrance to the opulent property. Drama is added to the spacious courtyard by the North tower's overhang above the main entrance. A water element in this interior landscaping contributes to the complex's passive cooling. Every house has a view of the city and a private garden on opposite sides. Materials used are Clay bricks, double glazed glass, Fibre jaali screens, Karauli stone, sagar black stone, Italian marble, granite. Balconies and fibre jaali act as heat buffer.

Protuding balconies

Central Lawn view



Steps to underground utilities

Fibre jaali on balconies

Figure 36: Pallacia views

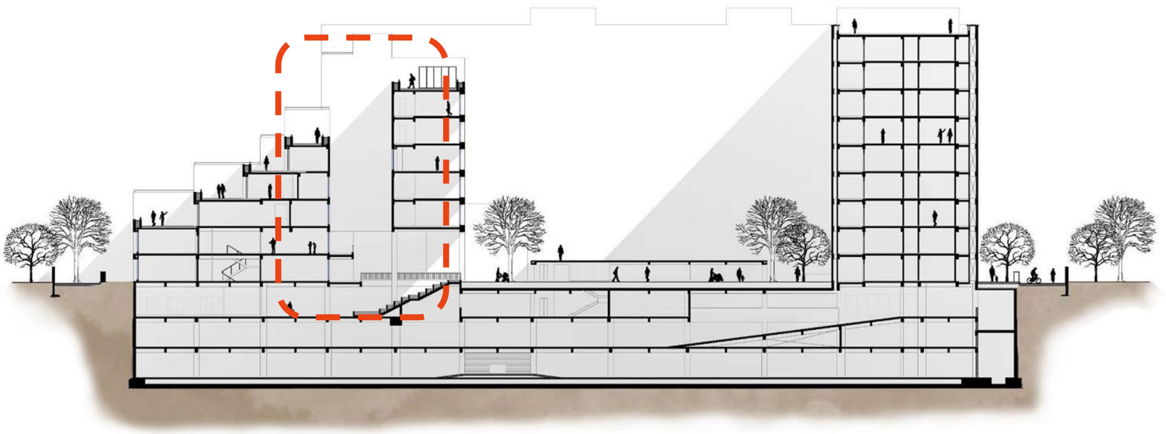


Figure 39: Pallacia: Section AA'
Source:https://maarchitects.in/ourprojects/pallacia/

Figure 37: Pallacia Section BB'
Source: https://maarchitects.in/ourprojects/pallacia/

Figure 38: Pallacia : Sectional elevation AA' detail
Source: https://maarchitects.in/ourprojects/pallacia/

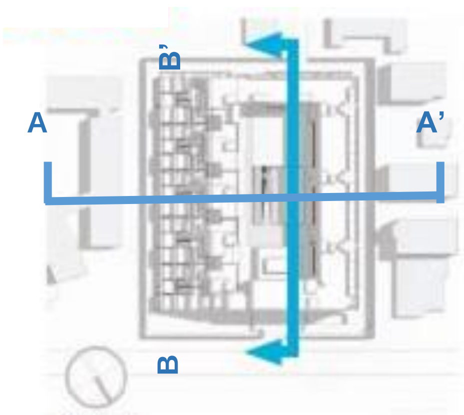


Figure 40: Pallacia: Key Plan
Source: https://maarchitects.in/ourprojects/pallacia/

Typical Unit Plan (B41, C41, D41, E41) - Facing east

Carpet Area - 622.4 sq.m (6700 sq.ft)

Bedroom - 4

Terrace – 1

Readings timing - 3.30 - 4 p.m, Date - 14.04.2023

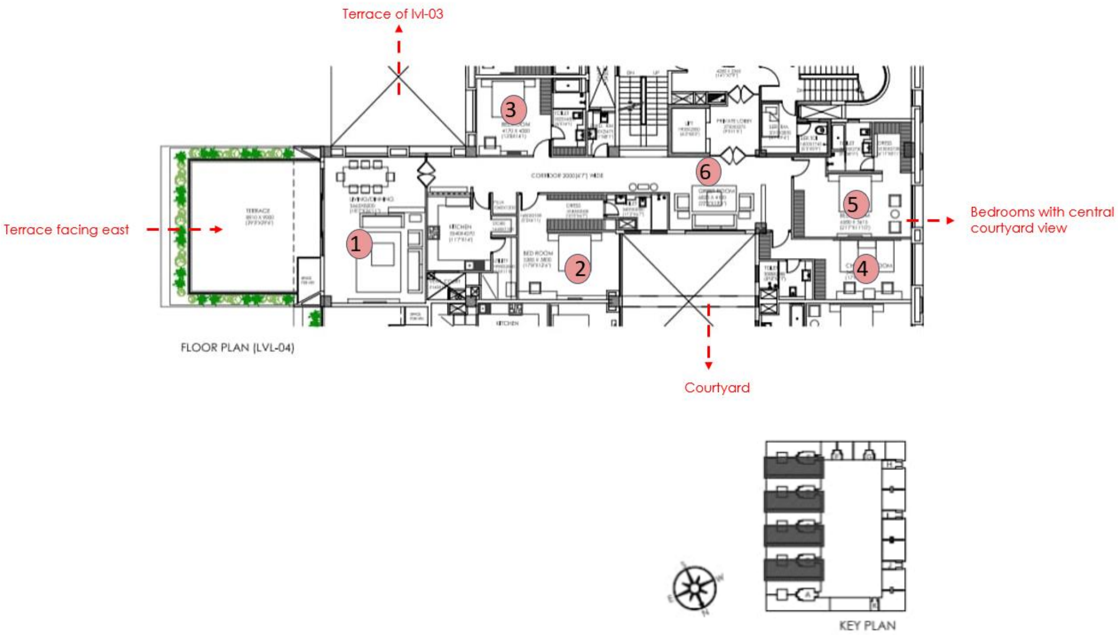


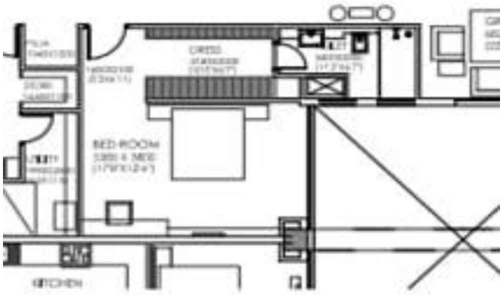
Figure 41: Pallacia east facing apartment plan

i. Room 1

Date/013Time	013[°C]	013[%RH]	013 Dew Point[°C]	013 Wet Bulb Temperature[°C]
4/12/23 3:32:28 PM	30.4	33.5	12.6	18.9
Overall Average	30.4	33.5	12.6	18.9
Minimum Total	30.4	33.5	12.6	18.9
Maximum Total	30.4	33.5	12.6	18.9

Living room(1) facing the east terrace with the opening in south has temperature difference of 2.8 degrees less than the outside temperature. whereas the Relative humidity inside is more than the outside by 11.7 percent.

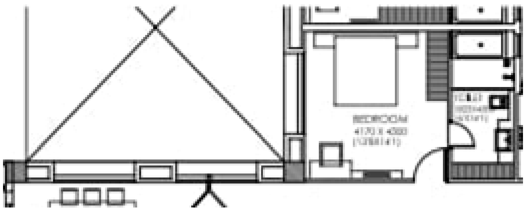
ii. Room 2



Date/013Time	013[°C]	013[%RH]	013 Dew Point[°C]	013 Wet Bulb Temperature[°C]
4/14/23 3:34:56 PM	31.7	27.0	10.5	18.3
Overall Average	31.7	27.0	10.5	18.3
Minimum Total	31.7	27.0	10.5	18.3
Maximum Total	31.7	27.0	10.5	18.3

Room 2 has only one opening facing the courtyard in west. The temperature difference is 1.5 degrees less than the outside temperature. whereas the Relative humidity inside is more than the outside by 5.2 percent.

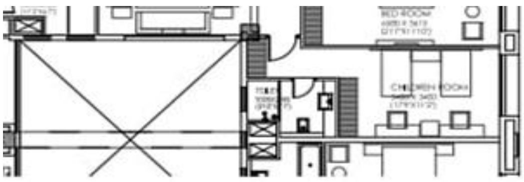
iii. Room 3



Date/013Time	013[°C]	013[%RH]	013 Dew Point[°C]	013 Wet Bulb Temperature[°C]
4/14/23 3:36:17 PM	31.9	27.1	10.6	18.4
Overall Average	31.9	27.1	10.6	18.4
Minimum Total	31.9	27.1	10.6	18.4
Maximum Total	31.9	27.1	10.6	18.4

Room 3 has only one opening facing the east. The temperature difference is 1.3 degrees less than the outside temperature. whereas the Relative humidity inside is more than the outside by 5.3 percent.

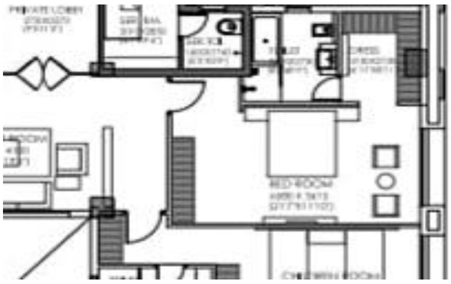
iv. Room 4



Date/013Time	013[°C]	013[%RH]	013 Dew Point[°C]	013 Wet Bulb Temperature[°C]
4/14/23 3:38:38 PM	32.0	26.1	10.2	18.4
Overall Average	32.0	26.1	10.2	18.4
Minimum Total	32.0	26.1	10.2	18.4
Maximum Total	32.0	26.1	10.2	18.4

Room 4 has only one opening facing the central courtyard in west. The temperature difference is 1.2 degrees less than the outside temperature. whereas the Relative humidity inside is more than the outside by 4.3 percent.

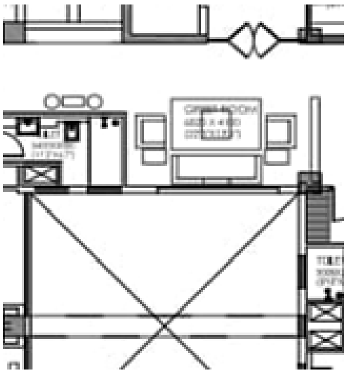
v. Room 5



Date/013Time	013[°C]	013[%RH]	013 Dew Point[°C]	013 Wet Bulb Temperature[°C]
4/14/23 3:40:11 PM	32.1	24.7	9.4	18.0
Overall Average	32.1	24.7	9.4	18.0
Minimum Total	32.1	24.7	9.4	18.0
Maximum Total	32.1	24.7	9.4	18.0

Room 5 has only one opening facing the central courtyard in west. The temperature difference is 1.1 degrees less than the outside temperature. whereas the Relative humidity inside is more than the outside by 2.9 percent.

vi. Room 6



Date/013Time	013[°C]	013[%RH]	013 Dew Point[°C]	013 Wet Bulb Temperature[°C]
4/14/23 3:41:21 PM	32.3	23.2	8.6	17.8
Overall Average	32.3	23.2	8.6	17.8
Minimum Total	32.3	23.2	8.6	17.8
Maximum Total	32.3	23.2	8.6	17.8

Living space has a view of courtyard. The temperature difference is 0.9 degrees less than the outside temperature. whereas the Relative humidity inside is more than the outside by 1.4 percent.

vii. Underground canteen

Date/013Time	013[°C]	013[%RH]	013 Dew Point[°C]	013 Wet Bulb Temperature[°C]
4/14/23 3:56:09 PM	30.0	37.1	13.7	19.3
Overall Average	30.0	37.1	13.7	19.3
Minimum Total	30.0	37.1	13.7	19.3
Maximum Total	30.0	37.1	13.7	19.3

viii. Outside temperature

Date/013Time	013[°C]	013[%RH]	013 Dew Point[°C]	013 Wet Bulb Temperature[°C]
Overall Average	33.2	21.8	8.4	18.0
Minimum Total	33.2	21.8	8.4	18.0
Maximum Total	33.2	21.8	8.4	18.0

Observations –

The room facing east shows maximum difference in temperature and relative humidity. The room has openings in east and south direction, wherein the south side was shaded as the readings were taken in afternoon between 3.30 – 4.0 p.m causing less heat gain inside. The other rooms have openings in either the west side or towards the courtyard.

4.5 Connecting Riads, Casablanca

Client - Nokta Group

Location - Casablanca, Morocco

Principal Architect - AQSO Architects

Site Area - 9814 sqm

Gross Floor Area - 49154 sq.m

Floors - G+11(max.)

Casablanca is located in the western part of Morocco, on the Atlantic coast. The city experiences mild, wet winters and warm, dry summers. The average temperature in Casablanca ranges from about 12°C (54°F) in January to 22°C (72°F) in August. The city receives most of its rainfall between November and March, with January being the wettest month. During the summer months, there is very little rainfall and the city experiences long periods of sunshine. During the summer months, the prevailing wind direction in Casablanca is from the northwest and northeast during the winter months.

Figure 42: Morocco in world map
Source: https://ontheworldmap.com/morocco/morocco-location-map.html

About the Project and context - The building is a residential complex that is situated on the east side of the Anfa district, a historically significant region of the city close to an upcoming dismantled airport. The land is located between a residential neighbourhood with low-rise structures and an urban park and the Grand Theatre Boulevard.The plan is conceptually solved as a continuous block lining up with the nearby streets and around two substantial "riads." This straightforward action is further characterized by the unique context of each side of the site in a way that makes the variation in elevation height into a modern and expressive form, with green terraces in the shape of a staircase forming the roof. In this way, the building develops to give the street an urban feel and reduces its scale to the opposite side.

Figure 43: Connecting Riads: Courtyard views
Source: https://www.archdaily.com/234968/connecting-riads-residential-complex-aqso-arquitectos

The building grows as a continuous block that is parallel to the streets in the area and coils around two sizable courtyards. A continuous volume that snakes around two semi-public courtyards defines the shape. Different elevation heights combine to create a modern and expressive design, and green terraces in the shape of a staircase constitute the roof.

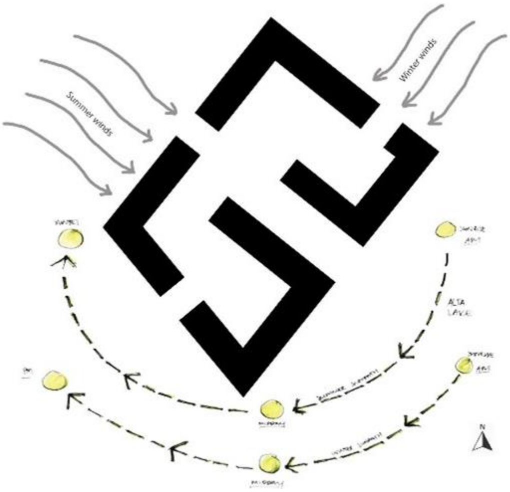


Figure 45: Connecting Riads: Orientation

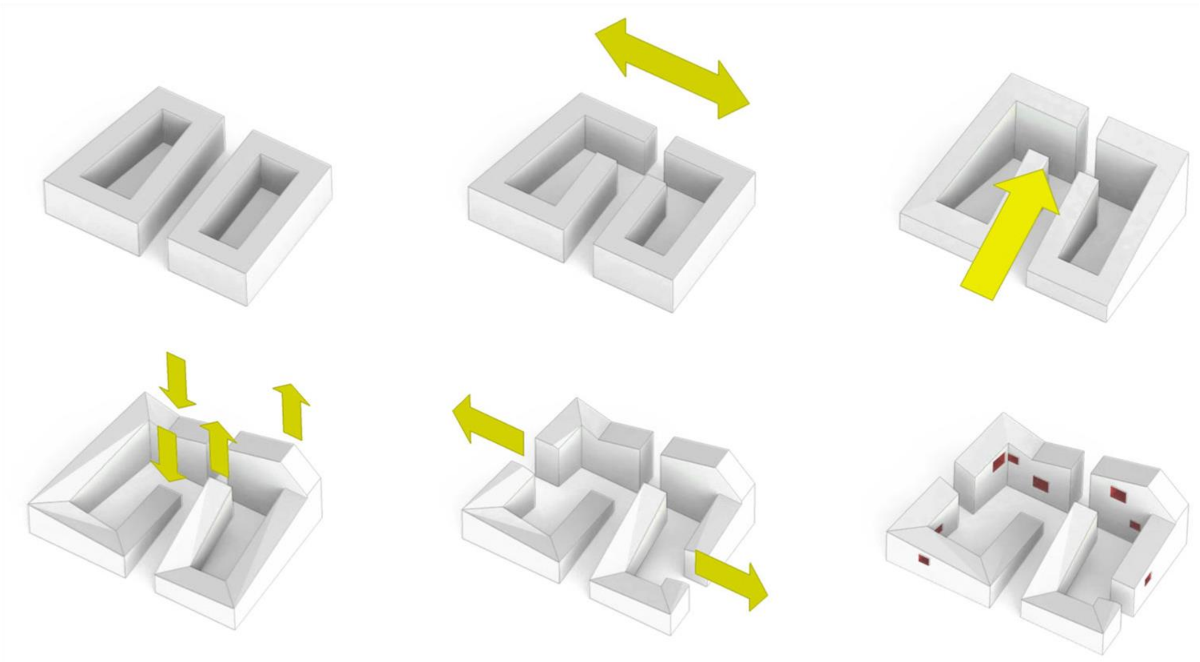


Figure 44: Connecting Riads: Form and massing
Source: https://www.archdaily.com/234968/connecting-riads-residential-complex-aqso-arquitectos

Figure 46: Connecting Riads: Ground floor plan
Source: https://www.archdaily.com/234968/connecting-riads-residential-complex-aqso-arquitectos

The semi-public spaces have a landscape design that combines cobbled concrete walkways, water features, and native trees and low-maintenance flora. There are two semi-public courtyards in the book. The inner skin facing the private courtyards becomes extrovert and domestic, whilst the external skin facing the most public surroundings becomes an introverted and formal feature.

Street view

View from the courtyard

Figure 47: Connecting Riads: View from the courtyard
Source: https://www.archdaily.com/234968/connecting-riads-residential-complex-aqso-arquitectos

The external façade presents a series of long balconies, peculiarly enclosed by sliding, latticework panels. Protruding balconies and Sliding latticework panels act as shading buffer. On the big perforation of the blocks there are communal gardens and seating areas enjoying both the view of the boulevard and the inner courtyards. Additionally, the structure is perforated with large apertures that serve as green terraces and provide ideal ventilation and views.

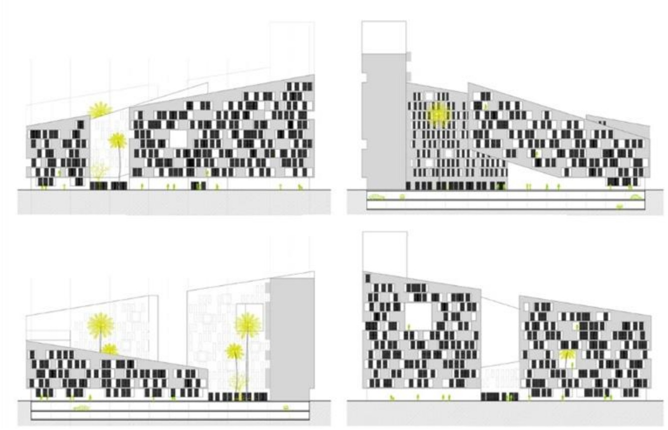


Figure 50: Connecting Riads: Elevations
Source: https://www.archdaily.com/234968/connecting-riads-residential-complex-aqso-arquitectos

Figure 49: Connecting Riads: Voids
Source: https://www.archdaily.com/234968/connecting-riads-residential-complex-aqso-arquitectos

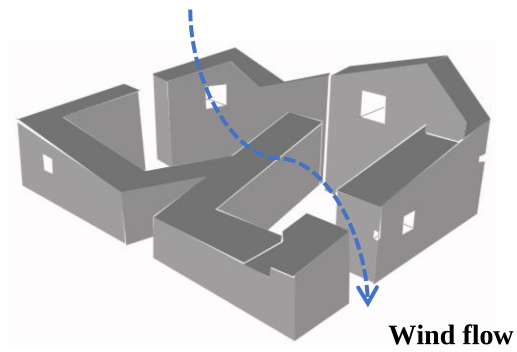


Figure 48: Connecting Riads: Massing and wind flow

4.6 Kowsar Residential Green Towers, Mashhad

Location - Mashhad, Iran

Principal Architect - KCW Group

Floors - G+ 22+2 basement

About the Project and context - Mashhad is a city located in the northeast of Iran, in the province of Razavi Khorasan. The climate of Mashhad is classified as a continental climate with hot summers and cold winters.In summer, which lasts from June to September, the temperature in Mashhad can reach up to 40°C (104°F) during the day, while nights are relatively cooler with temperatures around 15-20°C (59-68°F). Humidity is generally low during the summer, making the heat more bearable. Winter in Mashhad lasts from December to February, with temperatures ranging from 0 to 10°C (32-50°F). The city receives most of its rainfall during this season.

"Kowsar residential green towers", Iran's first green building project is situated on Kowsar Boulevard on an area of around one hectare. Clean energy has been utilised at every level of the building's construction in this project, which is Iran's first actual demonstration of green architecture. Solar panels, wind turbines, geothermal systems, reclaimed water, and double-skinned facades are a few examples of ways to reduce the use of fossil fuels.

Figure 51: Iran in world map
Source: https://www.freeworldmaps.net/asia/iran/location.html

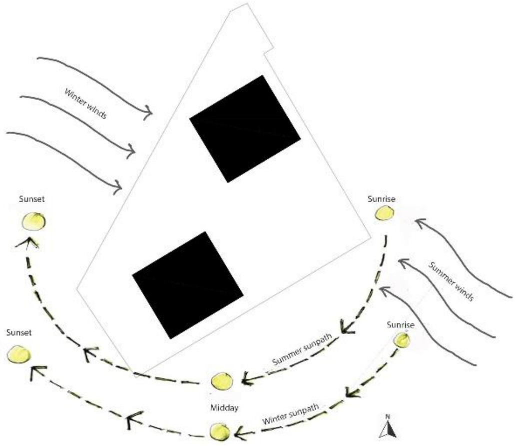


Figure 52: Kowsar green tower: Orientation

Each unit is required to have a cultivable, green yard that is automated irrigated. A green roof for the occupants and a linear park with a high bike path are also included in this proposal. A winter garden on the north side floors of both buildings, easy access to storage in the basement, and sophisticated "BMS" systems for each residential unit are additional features of all apartments on each level of the Kowsar residential green towers.

Figure 53: Kowsar green tower: views
Source: https://www.archdaily.com/234968/connecting-riads-residential-complex-aqso-arquitectos

Sustainability in the residential green towers in Kowsar:

-Using a layer of greeneries on the terraces, which prevents noise from entering the living area.

-Planting trees and green spaces on the terrace, which promotes natural ventilation and lowers the need for ventilation systems.

-In summer, green area on floors reduces the ambient temperature by around 3°c.

-Using trees that change their appearance with the seasons gives terraces a four-season feel and appearance.

-Utilizing natural materials (green goods, paints devoid of volatile organic compounds, recyclable plastics, natural gypsum, and mineral products) is crucial for reducing air pollution in interior spaces.

- Using grey water: Rainwater and water from sinks are collected in separate pipelines and used for irrigation of green spaces, cleaning the landscape, and flash tanks after being processed and purified.

-Using power plants to generate more than 20% of the project's electricity.

- Making use of solar lights in the landscape to generate power for free.

-Using a double skin façade (movable louvres) to manage radiation in the summer, trap heat in the winter, and keep strong winds from blowing through the tower's top levels.

Figure 54: Kowsar green tower: sectional 3D
Source: https://architizer.com/projects/kowsar-residential-green-towers/

Figure 55: Kowsar green tower: Plan
Source: https://architizer.com/projects/kowsar-residential-green-towers/

Figure 56: Kowsar green tower: Section
Source: https://architizer.com/projects/kowsar-residential-green-towers/

Case Study Analysis

To understand the application of different passive techniques, two low rise and four high rise buildings were studied based on the parameters such as orientation, form and massing, fenestration treatment, material, courtyard, roof treatment, shading devices and vegetation.

Table 2 : case study analysis – Low rise buildings

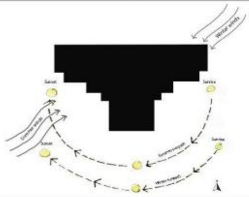
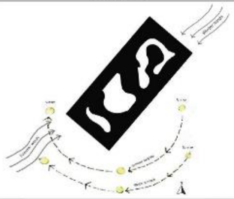
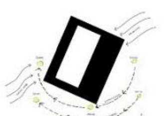
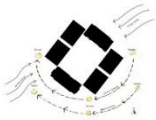
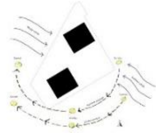
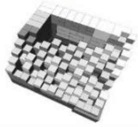
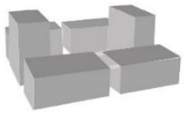
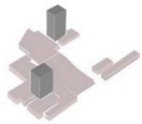
	LOW RISE BUILDINGS	
	Solar passive hostel, Jodhpur	**Pearl Academy, Jaipur**
Orientation		
Form amd Massing		
Vegetation	Not Present	- Trees along the periphery of the building. - Water body (shaded so as to minimise evaporation)
Courtyard	Not Present	Courtyards of organic form 
Materials	Stone masonry, Insulating shutters, Terracotta filler slab	Rcc, Earthen pots in roof slab, jaali
Shading device	Recessed windows, shadows because of uniques massing cause shading	Double skin facade
Roof treatment	Small inverted terracotta pots have been used as insulation material between the stone slab and finished flooring and the gaps are filled with lime concrete.	Flat roof is covered with earthen pots, The spaces between the mutkas are filled with sand and crushed bricks and then coated with a thin coating of concrete.
Fenestrations	Insulating shutters – Reflect cold and the window is kept at a stable temperature, therefore no large flow of heat due to winds can take place	Jaalis in the facade

Table 3 : case study analysis – High rise buildings

	HIGH RISE BUILDINGS			
	Pallacia, Jaipur	**Urban Oasis, Ahmedabad**	**Connecting Riads, Casablanca**	**Kowar Green Towers, Iran**
Orientation				
Form amd Massing				
Vegetation	-Landscaping in central courtyards -Terrace gardens	- Landscaping in central courtyards - Plantations on terrace and balconies	- Landscaping in central courtyards - Stepped green roofs	- All units have their own cultivable green yards
Courtyard	A central courtyard and small courtyards in east apartments 	A central courtyard 	Two central courtyards 	Not present
Materials	Clay bricks, double glazed glass, Fibre jaali screens, Karauli stone, sagar black stone, Italian marble, granite	Exposed rcc (concrete), high pressure laminate, fsc certified wood, sandstone, stonecrete, aluminum powder coated louvers, glass, granite and vitrified tiles and eco-friendly colors		
Shading device	Fibre jaali and balconies and plantation on terraces act as shading buffer	Balconies and plantation acting as shading buffer	Protruding balconies and sliding lattice panels act as shading buffer	Plantation for each unit and double skin facade(mobile louvers) act as shading buffer.
Roof treatment	Terrace gardens	China mosaic on roof surface	Stepped green roof	
Fenestrations	Double glazed reflective glass with aluminium frame shaded by balconies	Double glazed reflective glass with aluminium frame shaded by balconies	Fenestrations shaded by balconies and lattice panels	Louvers are present

Definitions -

Solar gain in buildings – Solar gain is short wave radiation from the sun that heats a building, either directly through an opening such as a window, or indirectly through the fabric of the building.

Air temperature – Air Temperature is a measure of the hotness or coldness of the air. Air temperature is the temperature indicated by a thermometer exposed to the air but sheltered from direct sun exposure.

Mean Radiant temperature- Mean radiant temperature (MRT) is a measure of the average temperature of the surfaces that surround a particular point, with which it will exchange thermal radiation. If the point is exposed to the outside, this may include the sky temperature and solar radiation.

Operative temperature- Operative temperature can be defined as the average of the mean radiant and ambient air temperatures, weighted by their respective heat transfer coefficients.

Relative humidity - Is a ratio, expressed in percent, of the amount of atmospheric moisture present relative to the amount that would be present if the air were saturated. Since the latter amount is dependent on temperature, relative humidity is a function of both moisture content and temperature. Relative Humidity is derived from the associated Temperature and Dew Point for the indicated hour.

Chapter 05 Primary study and Analysis

Primary Study – Ganesh Genesis

Ganesh Genesis in Gota, Ahmedabad North is a ready-to-move housing society with 2BHK and 3BHK apartments. The project has 15 towers, with 11 floors each and 792 units on offer. It is Spread over an area of 7.41 acres. The structure is of RCC with AAC blocks in the walls. The external wall has double coat plaster with acrylic paint and stone finish cladding and internal walls has putty finished mala plaster. Windows have single glazed glass with anodized aluminum frame.

Location – S.G. Highway, Ahmedabad, India

Floors - G+ 10

Parking – Ground floor

Structure - RCC frame structure

Flooring - Vitrified tiles in all areas

Windows - single glazed with anodized aluminum frame windows

Wall / paint - external wall in double coat plaster with acrylic paint and stone finish cladding, internal walls with putty finished mala plaster

Elevators - 2 in each block

Figure 57: Ganesh Genesis: Site Plan
Source: https://housing.com/buy-shree-siddhi-ganesh-genesis-by-shree-siddhi-group-in-gota-ahmedabad-pid-17833

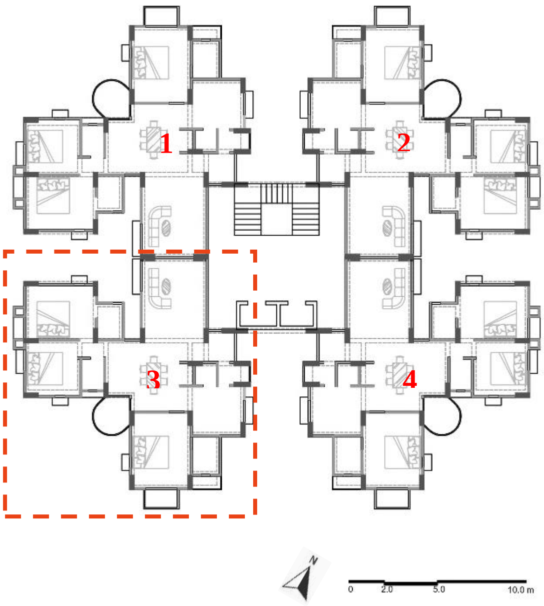


Figure 59: Ganesh Genesis: Block E, 3 Bhk Plan

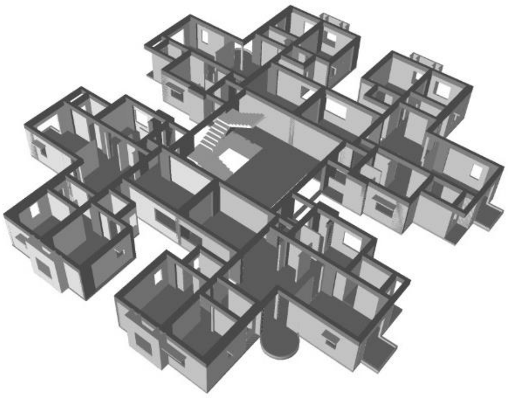


Figure 58: Ganesh Genesis: : Block E, 3 Bhk 3D

Figure 61: Ganesh Genesis: Apartment 3 Floor Plan

Figure 60: Ganesh Genesis: Block E Model

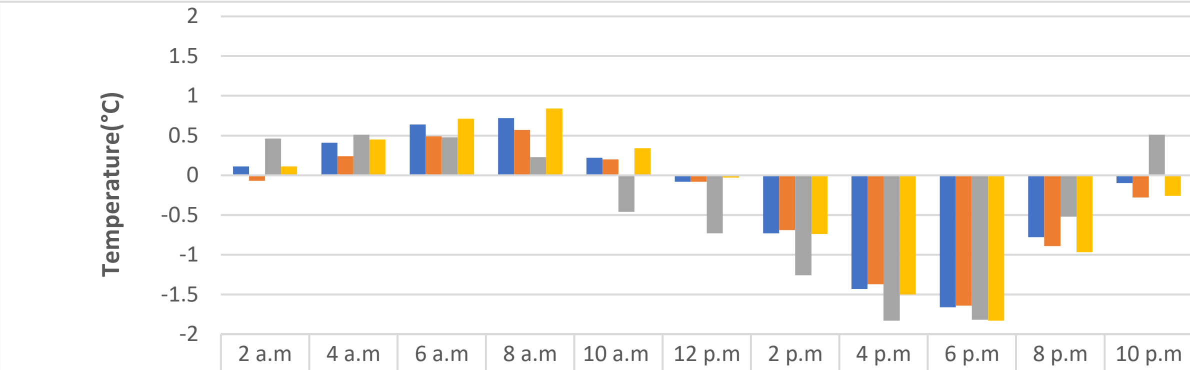
Figure 62: Ganesh Genesis: Site pictures

Criteria for selection of case study:

Apartment 3 is the most exposed to harsh solar radiations as it has bedrooms getting direct sun from south and west sides. The apartments 1 and 2 have their south side covered and shaded and exposed to west and east direction respectively. Hence, apartment 3 is the most appropriate for the research.

Observations-

Analysis 1



	2 a.m	4 a.m	6 a.m	8 a.m	10 a.m	12 p.m	2 p.m	4 p.m	6 p.m	8 p.m	10 p.m
Base case	0.11	0.41	0.64	0.72	0.22	-0.08	-0.73	-1.43	-1.66	-0.78	-0.1
AAC cavity wall	-0.07	0.24	0.49	0.57	0.2	-0.08	-0.69	-1.37	-1.64	-0.89	-0.28
Brick	0.46	0.51	0.48	0.23	-0.46	-0.73	-1.26	-1.83	-1.82	-0.52	0.51
Brick cavity wall	0.11	0.45	0.71	0.84	0.34	-0.03	-0.74	-1.5	-1.83	-0.97	-0.26

Heat gain from walls – 1st May Hourly simulation

The 1st analysis shows that the solar heat gain from walls reduces when AAC or brick walls are replaced by AAC cavity wall and Brick cavity wall respectively.

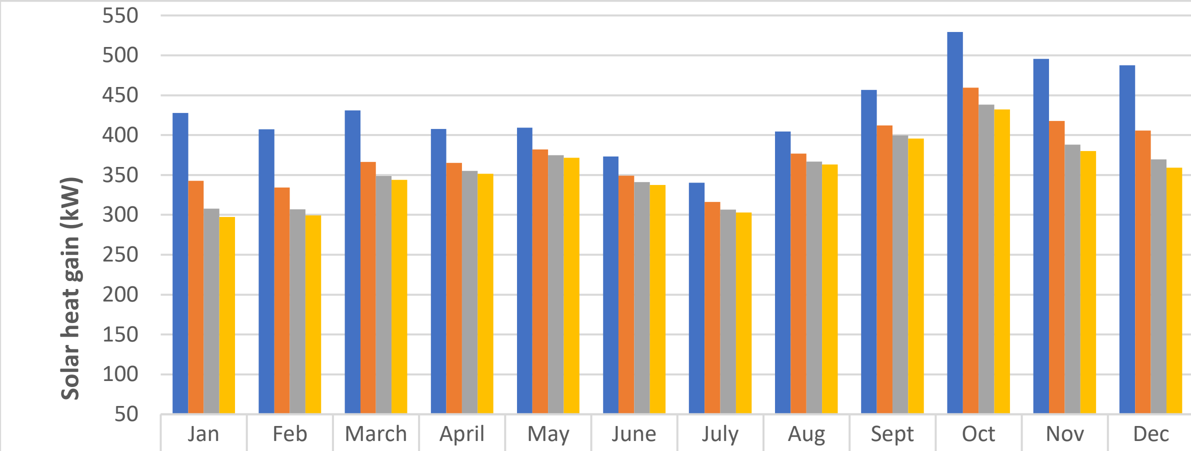
Heat gain from walls - AAC walls > AAC Cavity walls : Between 8 p.m. – 10 a.m.

AAC Cavity wall > AAC walls : Between 2 p.m. – 8 p.m.

Heat gain from walls – Brick walls > Brick Cavity walls : Between 8 p.m. – 8 a.m.

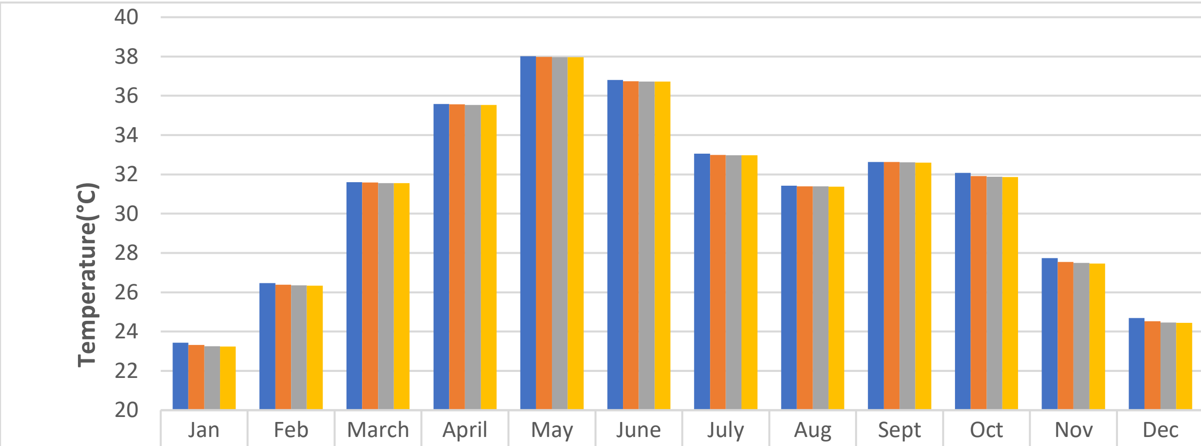
Brick cavity walls > Brick walls : between 10 a.m. – 8 p.m.

Analysis 2



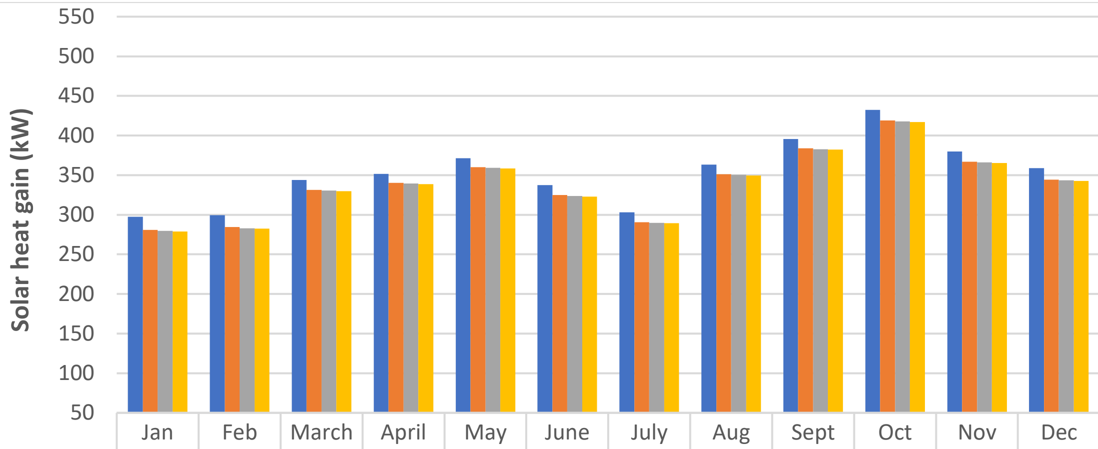
	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Base case	427.59	407.14	431.1	407.88	409.45	373.13	340.28	404.6	456.81	529.47	495.68	487.47
AR = 1	342.57	334.17	366.39	365.09	382.05	349.32	316.04	376.86	412.09	459.63	417.76	405.51
AR = 2	307.79	307.09	348.53	354.99	374.72	340.97	306.75	366.91	399.62	438.05	388.07	369.66
AR = 3	297.53	299.35	343.78	351.62	371.56	337.31	302.97	363.13	395.74	432.36	379.89	358.95

Solar heat gain– Annual simulation



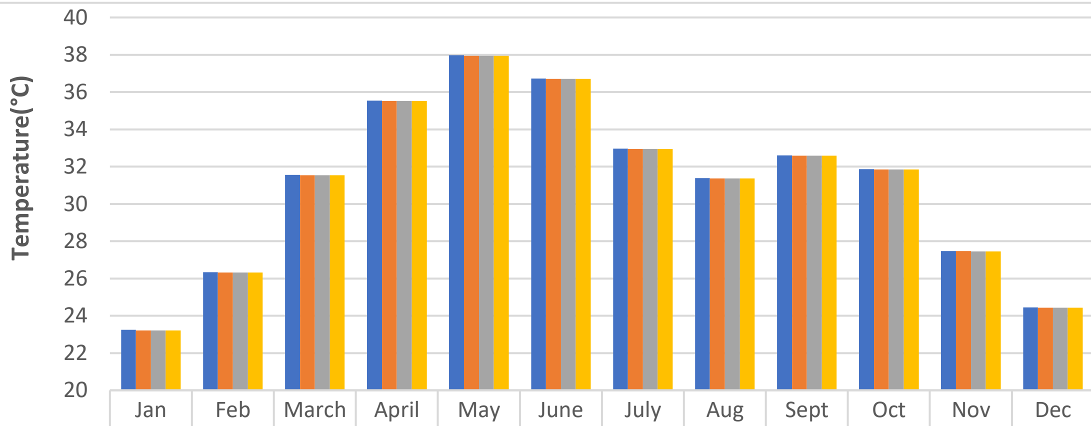
	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Base case	23.43	26.47	31.6	35.58	38.01	36.8	33.06	31.43	32.64	32.07	27.74	24.69
AR = 1	23.32	26.39	31.59	35.56	37.98	36.74	32.99	31.4	32.63	31.91	27.54	24.52
AR = 2	23.26	26.35	31.55	35.54	37.97	36.73	32.97	31.39	32.61	31.88	27.49	24.46
AR = 3	23.24	26.33	31.55	35.54	37.97	36.72	32.97	31.38	32.6	31.87	27.47	24.45

Temperature – Annual simulation



	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Slate angle 0°	297.53	299.35	343.78	351.62	371.56	337.31	302.97	363.13	395.74	432.36	379.89	358.95
Slate angle=20°	280.8	284.36	331.53	340.31	360.05	324.71	290.73	351.24	383.74	419.01	367.07	344.27
Slate angle=40°	279.69	282.97	330.41	339.26	359.05	323.7	289.77	350.29	382.74	417.84	366.07	343.35
Slate angle=60°	279.01	282.4	329.71	338.57	358.39	323.07	289.17	349.7	382.12	417.13	365.44	342.77

Solar heat gain– Annual simulation



	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Slate angle = 0	23.24	26.33	31.55	35.54	37.97	36.72	32.97	31.38	32.6	31.87	27.47	24.45
Slate angle = 20	23.21	26.31	31.53	35.52	37.95	36.7	32.95	31.37	32.59	31.85	27.46	24.43
Slate angle = 40	23.21	26.31	31.53	35.52	37.95	36.7	32.95	31.36	32.58	31.85	27.45	24.43
Slate angle = 60	23.21	26.31	31.53	35.52	37.95	36.7	32.95	31.36	32.58	31.85	27.45	24.43

Temperature – Annual simulation

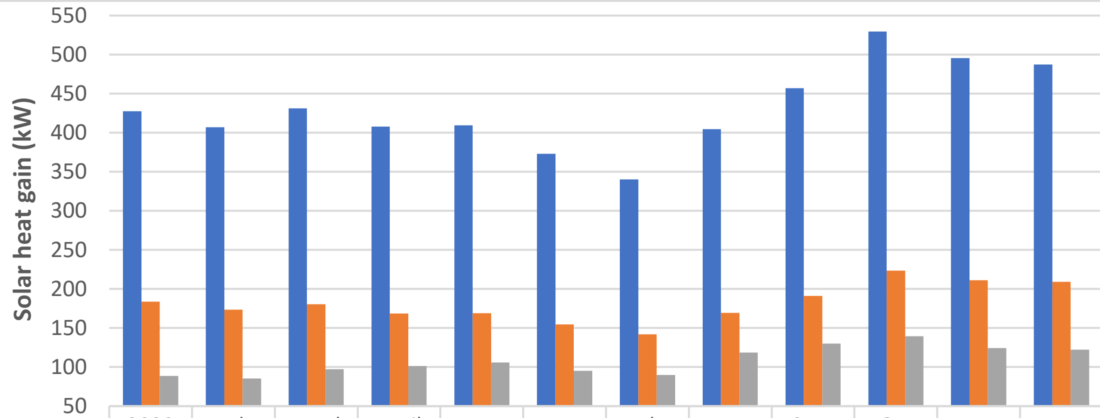
The analysis shows that there is a maximum of 18.11% decrease in solar heat gain from exterior windows when the Louver width is 3 times the louver spacing i.e AR=3 compared to 12.43 % and 16.77% decrease in case of AR=1 and AR=2 respectively.

There is 0.40 % decrease in temperature with AR=3 compared to 0.25 % and 0.35 % decrease in case of AR=1 and AR=2 respectively. Therefore, showing that AR=3 is the most suitable option for louvers.

Analysis 2 shows that there is 4.17 % decrease in temperature when the Louver slate angle is 60° compared to 3.69% and 3.99% decrease in case of slate angle=20° and 40° respectively.

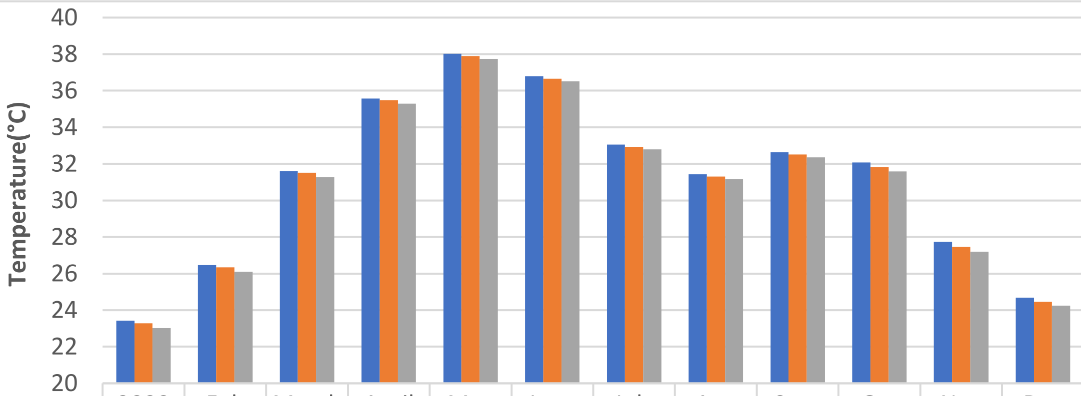
There is 0.067% decrease in temperature when the Louver slates are angled. And the temperature is same is all the cases with angled slate. The analysis shows that there is a significant decrease in solar heat gain and temperature when the louvers are angles but there is only negligible difference in the readings of different angles. Keeping the louvers at 60 ° is the most preferable case.

Analysis 3



	2022	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Base case	427.59	407.14	431.1	407.88	409.45	373.13	340.28	404.6	456.81	529.47	495.68	487.47
Double glazed	183.67	173.5	180.4	168.75	168.8	154.72	141.82	169.28	191.16	223.28	211.21	209.05
Louvers	88.59	85.27	97.3	101.36	105.91	95.41	89.71	118.54	130.12	139.51	124.2	122.14

Solar heat gain– Annual simulation



	2022	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Base case	23.43	26.47	31.6	35.58	38.01	36.8	33.06	31.43	32.64	32.07	27.74	24.69
Double glazed	23.29	26.35	31.52	35.49	37.9	36.66	32.93	31.3	32.52	31.83	27.46	24.46
Louvers	23.02	26.09	31.27	35.3	37.74	36.51	32.8	31.17	32.35	31.59	27.2	24.24

Temperature – Annual simulation

The analysis shows that Double glazed glass on a window can reduce the solar heat gain by 57.9% and louvers used on double glazed glass window reduces the solar heat gain by 74.89 %.

The air temperature drops by 0.4% when the single glazed glass is replaced by double glazed glass and the temperature drop is 1.134% when louvers are added on the outer side of the window with double glazed glass.

Relative humidity increases by 0.93% when the single glazed glass is replaced by double glazed glass and increases by 2.06% after addition of louvers on the outer side of double-glazed window.

Conclusion

The research is intending to look at passive elements which when applied to a high-rise building is observed to affect the solar heat gain, temperature and relative humidity of the inside space. The purpose is to look at how the comfort level of a space changes by adding various passive elements. The thesis has explored the role and significance of passive elements in high-rise buildings. From the literature review it can be inferred that the application of passive techniques affects the inside temperature making it more comfortable. For example, addition of shading devices can reduce the temperature upto 1°C and cut off the glazing by 80%. Also, the presence of vegetation near or inside a building can create a temperature difference of 3 to 5°C. Wind tower is an excellent passive cooling technique for hot and dry regions and can reduce the temperature by 5.5 °C. From the different cases studied through simulation it can be observed that adding cavity walls on the south and west side of the buildings can help in reducing the heat gain through walls. Use of double-glazed glass and louvers vastly affect the comfort level of inside space by reducing the solar heat gain and air temperature and increasing the relative humidity. It is clear that more is the aspect ratio of the louvers, less is the heat gain and inside temperature hence more comfortable the space. Also the heat gain is less when louver slate angle is 60° compared to 40 °, 20 ° and 0 °.

Way Forward

The research analysis can be implemented in actual buildings as it providing a simulated data for passive elements which can be used by architects in addressing the need of the buildings while still making it climate responsive. The research briefly looks into passive elements and techniques employable in different climate conditions then a detailed study is done on passive techniques required in hot and dry climate regions like fenestrations, materials, wall systems and others. Through this study, cooling loads and energy efficiency can also be looked at. The analysis is of annual simulation. Hence future researchers can look into different seasons or months for an in depth analysis so that enough parameters are generated for constructing a good climate responsive and thermally comfortable high rise building. Also the other researchers can look into additional passive elements (not covered in this study) which can be implemented in high rises.

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