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Pradhan Mantri Awas Yojana-Urban

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

सत्यमेव जयते

Ministry of Housing and Urban Affairs
Government of India

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Passive-design Response in Increasing Thermal Comfort with Viable Solutions (PRiTHVi)

PRiTHVi for better LiFE in Affordable Housing

Multi-Family Affordable Housing

Volume - 2

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WHY PRiTHVi FOR AFFORDABLE HOMES?

Prime Minister's "Housing for All" vision aims to meet the enormous affordable housing demand in urban areas to provide a better living space to many of our people by moving them from a kucha house or slum to a new age pucca house filled with all amenities and fulfil their dreams for a better life.

One of the necessities of better life is "Thermal Comfort" and it is an integral demand in human behavior since our birth. Our choice is to meet it either via passive measures (Climate and better LiFE) or active measures (higher energy use).

The occupants of these housing stock will demand for desired thermal comfort and will look for sources to meet the same. Thus, if our houses are incapable of providing the optimum thermal comfort via passive measures (through simple yet intelligent design), the occupant will be forced to meet the same via active measures and add to the current increasing demand of energy and resources.

The rapid urbanization is resulting in increasing pressure on our existing infrastructure. Thus, it is imperative that the homes we build today are future ready for the sake of our mother earth ("PRITHVI"), through a defined set of guiding principles, which are simple and low cost solutions that can be adopted to provide thermal comfort inside the affordable homes.

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खण्ड १

INTRODUCTION

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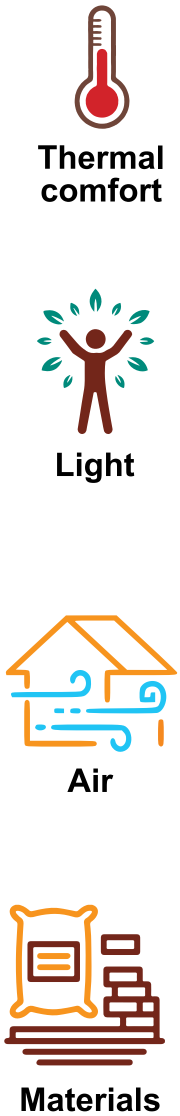
भाग १: PRiTHVi
for Affordable Housing

Passive-design Response in Increasing Thermal Comfort with Viable Solutions (PRiTHVi) is a guiding standard on how to build for achieving thermal comfort inside built environment. A lot of researches have been done in the past decade in this field but implementation is a challenge. Hence, in order to fast-track adoption, it is imperative that these researches are translated into easy to understand and simple to follow guidelines that can be adopted by the masses at various scales of construction.

PRiTHVi is a guiding standard with a comprehensive set of recommendations which emphasize on the passive approaches that could easily be adopted in affordable housing to enhance the thermal comfort in the built environment. If properly adopted from design concept stage of a building, it can ensure optimum thermal comfort to the occupants without use of active measures, thus averting the use of Air Conditioners.



PRiTHVi
for **Supporting NDC Targets of India**

Nationally Determined Contribution (NDC), is a climate action plan to cut emissions and adapt to climate impacts. NDCs play a crucial role in advancing global climate action by bringing together individual country efforts to collectively address the challenges of climate change and move towards fulfilling the below mentioned SDGs. PRiTHVi, with its unique features of passive-design adoption in affordable housing will contribute directly to the SDG goals of India.

PRiTHVi
for **Combating Climate Change**

The impact of heatwaves is more pronounced in cities due to the Urban Heat Island (UHI) effect and global warming. It is a phenomenon where densely populated and built urban areas witness higher temperatures than their surrounding rural areas.

More heat = occupant discomfort = more energy use.

To design for resilience and rising temperatures, improved thermal comfort-based designs are a novel solution for affordable housing. Its benefits are multi-fold:

Thermal Comfort | Energy Efficiency | Improved Family Health

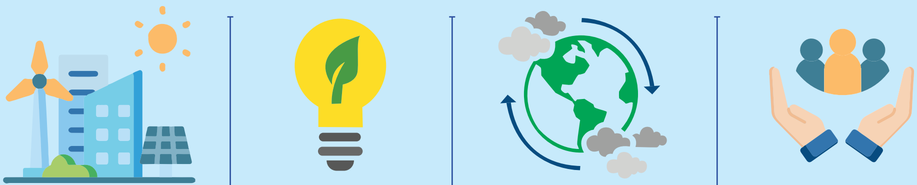
PRiTHVi
for India Cooling Action Plan

India Cooling Action Plan (ICAP) is a vision and comprehensive road map developed by the Government of India to address the challenges and opportunities related to space cooling and providing thermal comfort for all.

It promotes sustainable approaches for thermal comfort for all, reducing green house gas emissions, enhancing energy efficiency, and providing access to cooling for all, while ensuring the well-being of the people and the environment.

PRiTHVi can ensure optimum thermal comfort to the occupants without use of active measures, thus averting the use of Air Conditioners, GHG emissions, and use of ODP based refrigerants.

Provide thermal comfort solutions for affordable housing through passive design approaches



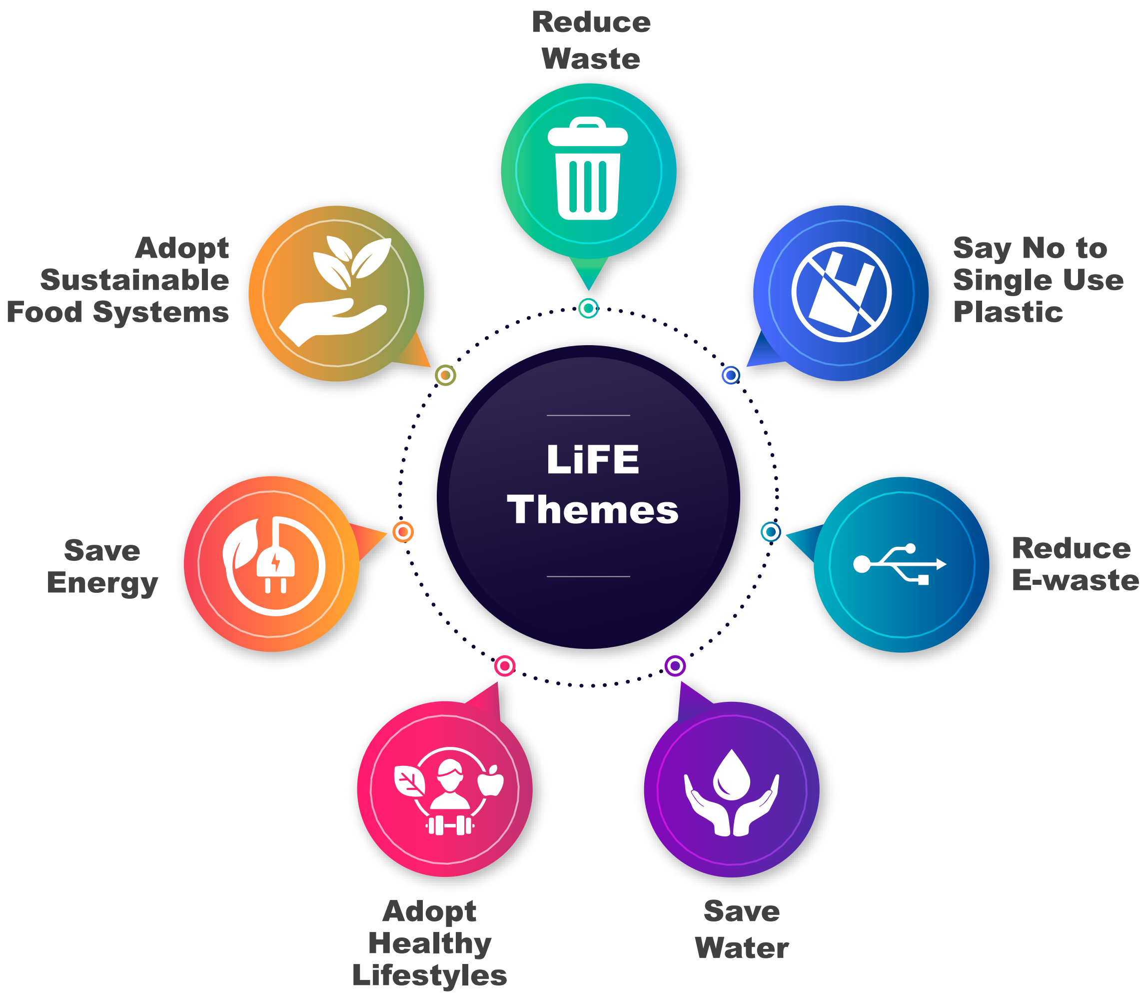
Cool city | Energy efficiency | Climate resilience | Social Upliftment

Thermally Comfortable Affordable Housing has the potential to contribute to India's commitment in COP28

PRiTHVi
for Supporting LiFE (Lifestyle for Environment)

The concept of Lifestyle for the Environment (LiFE) was introduced by Prime Minister Narendra Modi at COP26, calling upon the global community to drive LiFE as an international mass movement towards “mindful and deliberate utilization, instead of mindless and destructive consumption” to protect and preserve the environment and propagate a healthy and sustainable way of living based on the traditions and values of conservation and moderation, **LiFE – Lifestyle for Environment as a key to combating climate change.**

LiFE
Lifestyle for Environment



LiFE – Lifestyle for Environment as a key to combating climate change.

भाग २: Approach and Methodology for Development of PRiTHVi

01 Under the GHTC challenge, MoHUA has launched 6 Light House Projects as Live Laboratories to demonstrate innovative construction technologies and test the climate resilience of new age construction technologies with a single objective in mind - to provide a “liveable” pucca house to all citizens of this country. MoHUA has set up Climate Smart Building Cells at each of these LHPs to study the performance of these buildings in different climate zones in attaining the desired level of thermal comfort. Experiments were conducted in all LHPs to test the impact of various passive measures like orientation, window shading, window to wall ratio, natural and cross ventilation, mutual shading, cool and green roof, thermal performance of the envelope etc. to understand how each of these help in achieving thermal comfort, along with the level of impact of each passive measure. The live Laboratory Experiments were done to understand the impact in comfortable hours achieved in a year inside a built environment, with passive measures viz-a-viz a conventional building.

02 Additionally, the study has been further extrapolated to around 40 Demonstration Housing Projects (DHP), Affordable Housing Projects (AHP), Affordable Rental Housing Complexes (ARHC), and other public and private affordable housing projects across country to ascertain the findings and propose best solutions for thermally comfortable affordable housing design in India focusing on economically viable solutions. It was important to extrapolate the findings in LHP’s live laboratory experiments to diverse construction practices in affordable housing categories (both for public and private projects across country) to ascertain that the finding is relevant for the overall affordable housing segment and not limited to new age construction technology.

03 It’s an interesting experimental study to understand how Passive Design Measures - simple, naturally available, no and low cost solutions, can transform the thermal performance of a building significantly and can easily be applied in any building across the country. The results show a significant increase in the comfortable hours round the year.

04 The uniqueness of Passive Design Measures is that it does not require any technical simulation, any major funding decision, skilled expertise and complex technology deployment. All it needs is ONE RULE – Apply it from the design concept stage and prioritize these passive design elements.

भाग ३: Scope for PRiTHVi

01

Passive building design is a set of holistic design principles and strategies that maximizes the use of natural resources, solar path, wind direction for attaining an optimum building design that caters to the occupant satisfaction and thermal comfort.

02

This document translates passive design principles into design requirements to ensure minimum and advance thermal comfort performance in affordable housing.

03

This document identifies opportunities to provide thermal comfort based on no cost solutions widely available via nature or intelligent planning or minimal cost which shall retain the affordability of an affordable housing.

04

This document is also a step forward towards achieving Hon'ble Prime Minister's vision of sustainable lifestyles and climate justice to protect the poor and vulnerable from adverse impacts of climate change.

05

This document sets the guiding principles which apply to all multi-family affordable housing.

भाग ४: Thermal Comfort Performance Levels for Multi-Family Homes

Two (2) levels of thermal comfort performance are defined in PRiTHVi for Multi-Family Homes

Level 1 PRiTHVi Compliant Building
(Minimum Thermal Comfort Performance Level)

- This level gives emphasis on the thermal performance which can be easily achieved with passive measures.
- If adopted, the building will achieve the **acceptable level of thermally comfortable hours** inside the building and reduce the need of active cooling or heating **considerably.**

Level 2 Swarna PRiTHVi Compliant Building
(Advanced Thermal Comfort Performance Level)

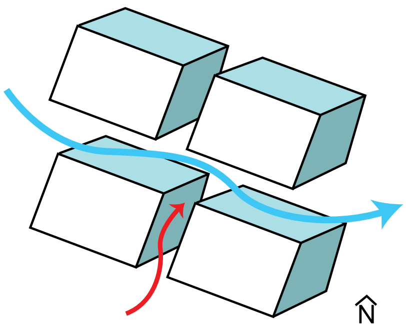
- This level gives emphasis on the advanced thermal performance by adopting all recommendations of Level 1 bundled with additional advanced measures.
- If adopted, it will ensure a building will **maximize the thermally comfortable hours** inside the building and reduce the use of active cooling or heating **significantly.**

खण्ड २

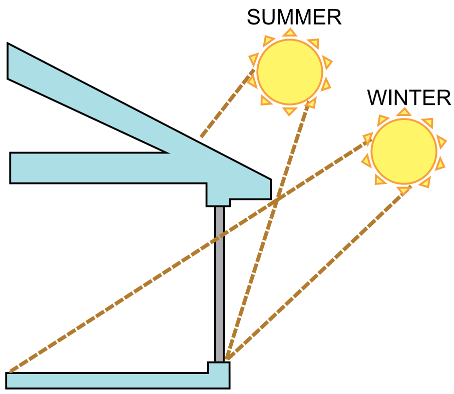
PRiTHVi PANCHAMRIT FOR MULTI-FAMILY AFFORDABLE HOUSING

Panchamrit Recommendations of PRiTHVi for Multi-Family Homes

This section lays out 5 'Panchamrit' to provide optimum thermal comfort based on passive and resilient principles having no or low-cost implications on a project. These solutions are based on natural elements like wind, sun, shade, etc., intelligent planning and minimal cost interventions. These solutions are suitable for affordable housing projects where not only the initial cost of construction is critical but also affordability in long-term operation and maintenance is important.



Optimized orientation and Wind direction



Window shading

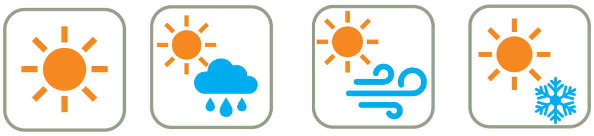
This document is structured in 2 parts

खण्ड २ describes 5 'Panchamrit'

खण्ड ४ covers detailed explanations of concepts of passive design and thermal comfort to explain the 5 'Panchamrit'

क Orientation and Mutual Shading

**Note: For all climate zones except cold climate zone*



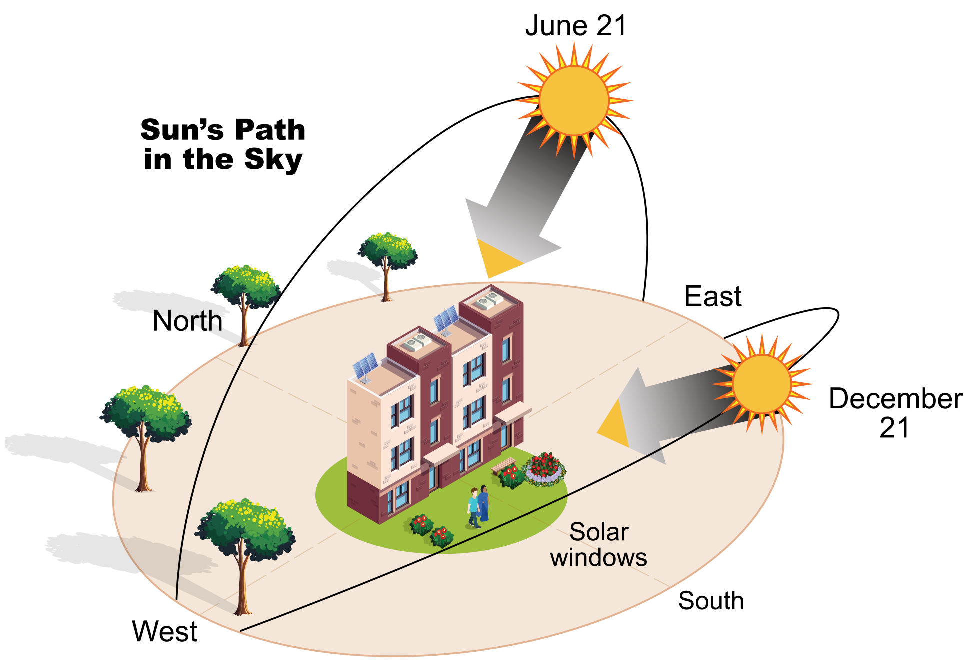
Building blocks on the site shall be oriented or mutually shaded to optimise the collective solar incident rays on the building envelope. **The orientation shall be corrected during the initial site planning itself.** To achieve this, the Orientation Axis Line (OAL)[1] of the building block shall:

Panchamrit 1

- Correct the orientation of a building block by aligning the block with the True North i.e., OAL[1] of the building is perpendicular to north-south axis with a maximum deviation of ±22.5 degrees (longer façade facing north and south direction).

OR

- Mutually shade the building block which has its OAL perpendicular to the east-west axis with a maximum deviation of ±45 degrees by locating an adjacent block as per the criterias mentioned in section 3 in this chapter covering Mutual Shading Requirement.



[1]OAL - The Orientation Axis Line (OAL) in building design is an imaginary line passing through the centre of the building and aligns with the longer side or length or façade of the building. For details, please refer to the examples of how to draw the OALs in this section.

1) Compliance Requirements for Orientation and Mutual Shading

Step 1
The compliance for orientation and Mutual Shading Criteria is at a site level under consideration

Step 2
To show compliance, OAL alignment of each block shall be tabulated and total weighted ground coverage area shall be calculated for the blocks which are compliant with the criteria mentioned in Panchamrit 1

Step 3
The compliance of a project is computed as per the criteria mentioned in Table 1

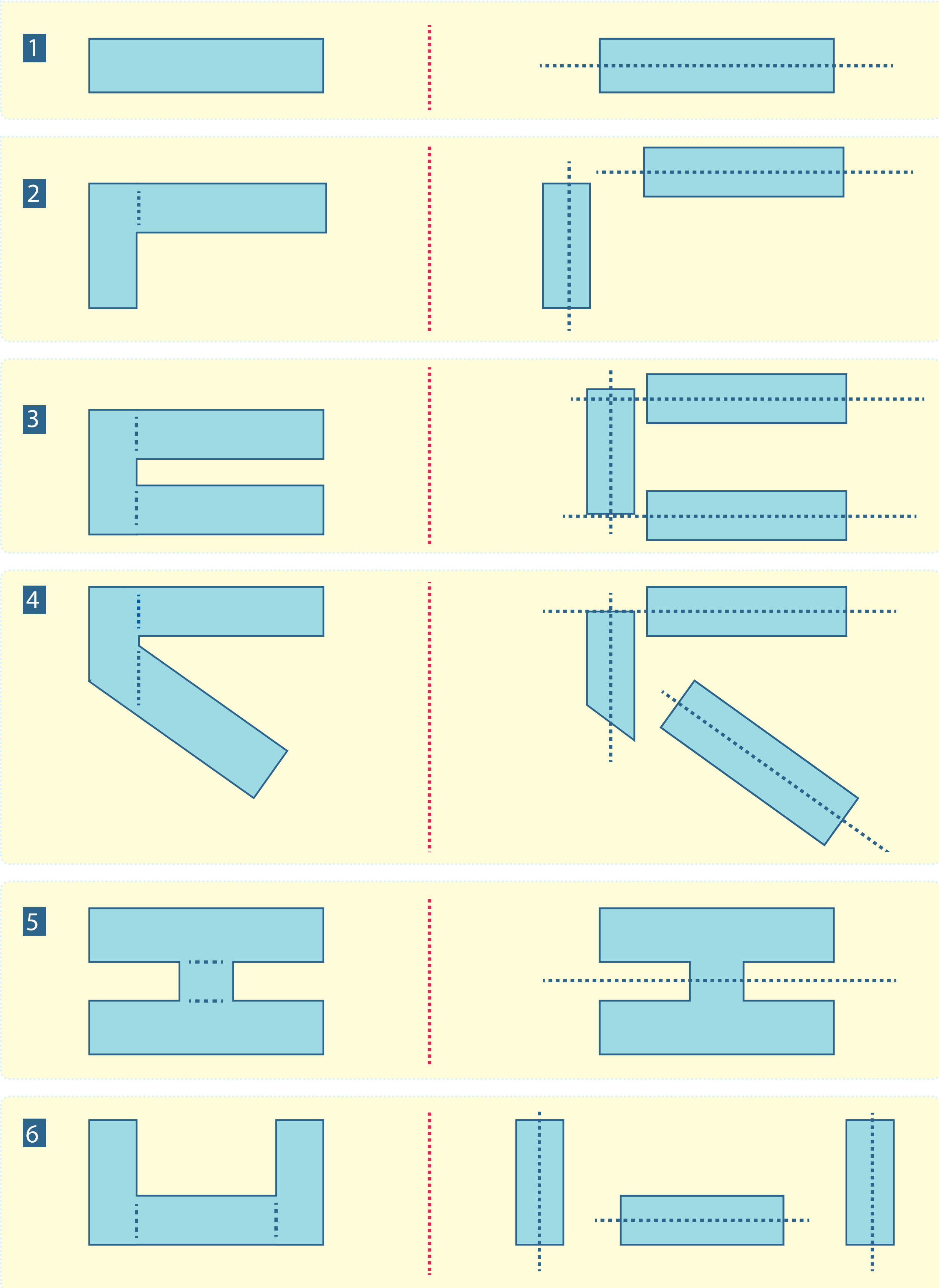
Table 1: Minimum threshold limit for Orientation and Mutual Shading as per planning category

Planning Category for Orientation and Mutual Shading	**Threshold limit of minimum % of building blocks* to have correct orientation and mutual shading**	**Additional Measures** (to be incorporated in addition to orientation and mutual shading to show compliance with Section 'क')
Ideal Planning	≥80%	No additional Compliance measure
Moderate Planning	≥70 and <80%	All Vertical fenestration (glass only) shall comply with the maximum SHGC of 0.7.
Lenient Planning	<70% and ≥40%	A permanent box frame external projections or recessed windows, having a minimum depth of 600 mm, for all windows except for the below 2 exceptions: • The windows which are overseeing a balcony • The windows on the wall parallel with north direction with a maximum deviation of ±22.5
Undesigned Planning	<40%	Mandatory compliance to Swarna PRiTHVi level is needed for compliance with PRiTHVi. The details of Swarna PRiTHVi requirements can be found in 'Swarna PRiTHVi' section (pg. 21)

**As per ground coverage area weighted average*

Example of how to draw OAL with different block shapes

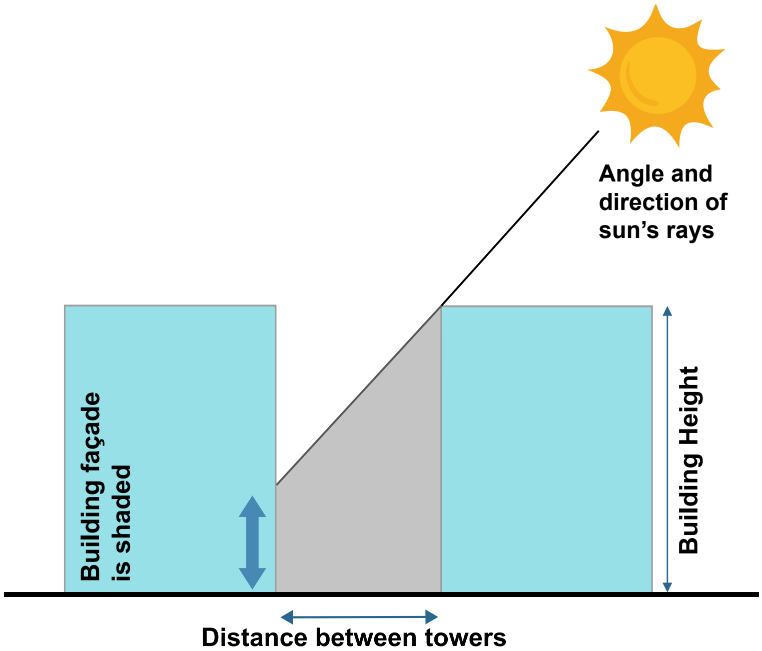
The Orientation Axis Line (OAL) in building design is an imaginary line passing through the centre of the building and aligns with the longer side or length or façade of the building. To draw the OAL for building blocks with complex shapes, the concerned block can be divided into simple forms on paper and each imaginary sub block can have its own individual OAL. Some examples are illustrated below:

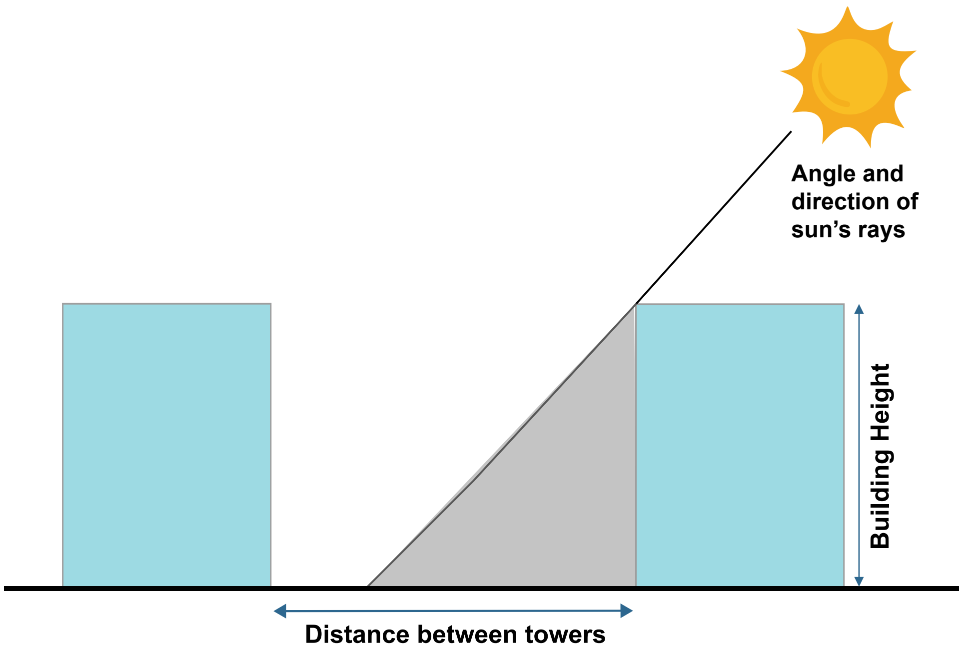


2) MUTUAL SHADING

Mutual shading is a term used to describe the shading effect that one building has on another building. It occurs when one building blocks the sun's rays from reaching to another building for a certain duration in the day, thereby reducing direct exposure from the sun on to the face of the building.

Designers can incorporate mutual shading during the initial design phase by considering several key factors. Firstly, the orientation and spacing between buildings should be carefully analysed to ensure optimal shading effects. The design of the building layouts must be carefully planned considering the seasonal changes as the angle of sun changes throughout the year, being low in winters and high in summers.

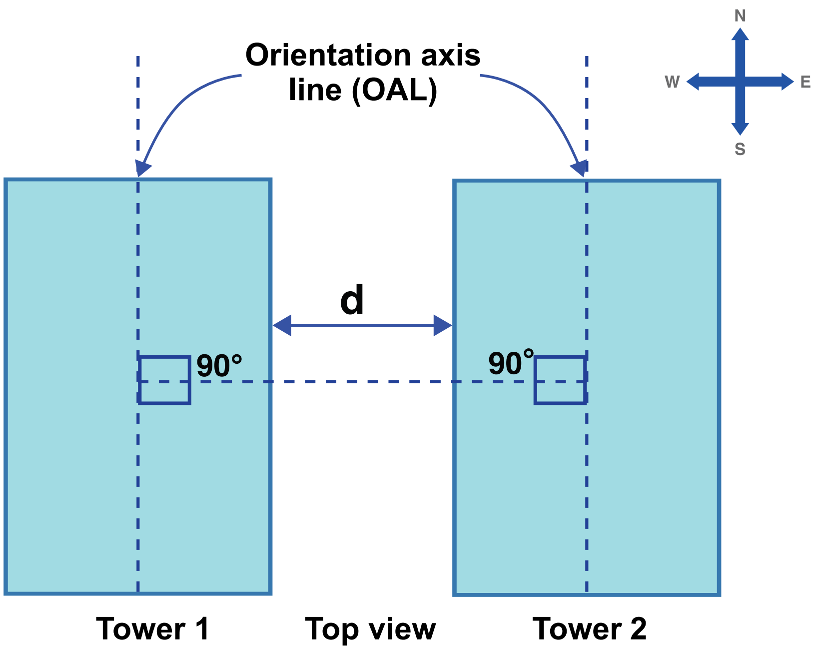




3) MUTUAL SHADING REQUIREMENT

Two blocks placed in an appropriate manner next to each other such that they cast a shadow on each other during different intervals of time is known as mutual shading. This helps one façade of the building to be under shadow for a duration of time and cut direct solar radiation on that façade. To comply with Mutual Shading requirement, all of following criteria shall be met:

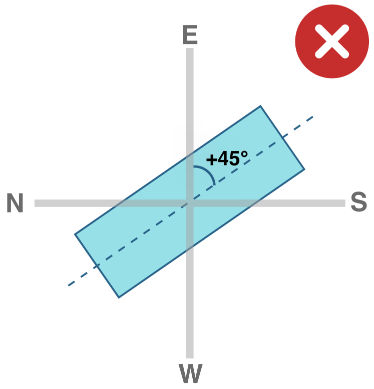
- i) Building blocks under consideration for mutual shading shall be of same height and length.
- ii) The 2 Building blocks under consideration for mutual shading shall have the respective orientation axis line (OAL) parallel to each other. That means an imaginary line joining the centre of the two similar size blocks shall be 90 degrees with OAL.

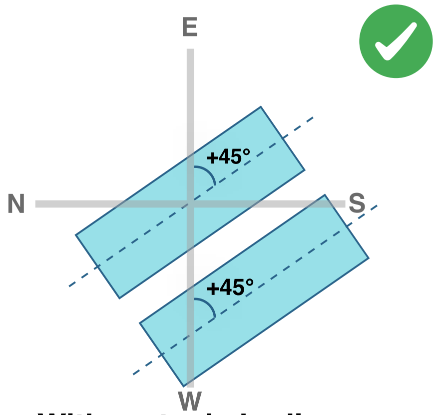


d = distance between towers | h = height of tower | h:d = 2:1

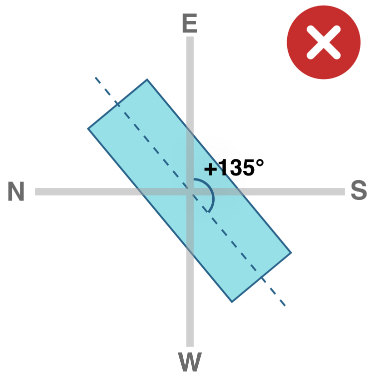
- iii) The two blocks shall be aligned perfectly with each other. *(Such that the 2 blocks under consideration are parallel to each other and their edges are flush with each other.)*
- iv) The height of tower: distance between the tower ratio to be minimum 2:1. (*Where the Height is the height of the block under consideration and distance is the distance between the two blocks under consideration for mutual shading, measured as perpendicular distance between the outer surface facing each other. The distance shall be maximum ½ of the height of the building.)*
- v) However, in an event where any state building bye law limits the minimum distance between the two blocks which is lower than the 2:1 ratio mentioned above, the state building by-law shall have precedence and the mutual shading benefit cannot be considered in that scenario for orientation compliance.

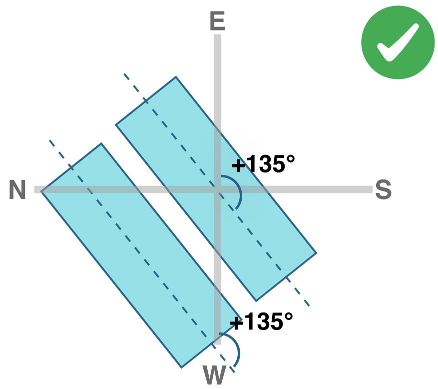
- vi The mutual shading is only applicable when the OAL of the building block is perpendicular to the east-west axis with a maximum deviation of ±45 degrees.
- vii Only 50% of the ground coverage area of each mutually shaded building block is considered for final percentage calculation.





With mutual shading

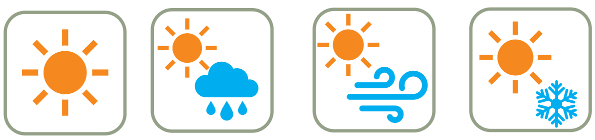




With mutual shading

ख Shading of Glazed Façade

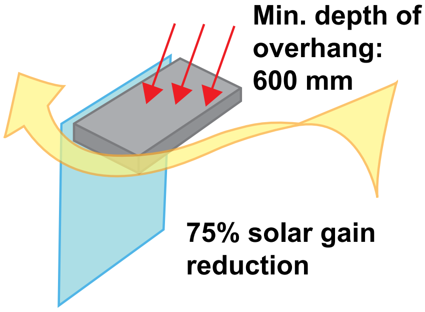
**Note: For all climate zones except cold climate zone*



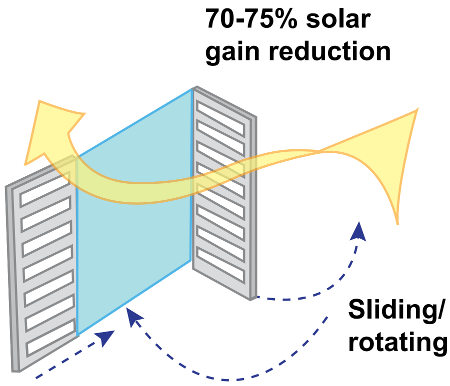
Panchamrit 2

- A minimum shading of 600 mm is required at the top of all windows, located appropriately, with permanent external projection, such as overhangs, side fins, box frames, verandas, balconies, and fixed canopies that offer continuous shade, except for the lenient planning category mentioned in Table 1. For lenient planning category, comply with requirement of lenient planning category mentioned in Table 1.

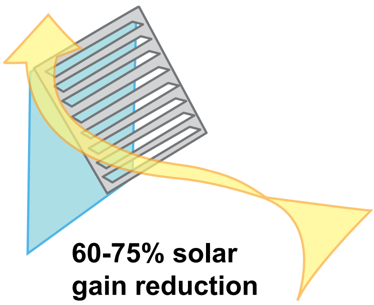
Types of window shades



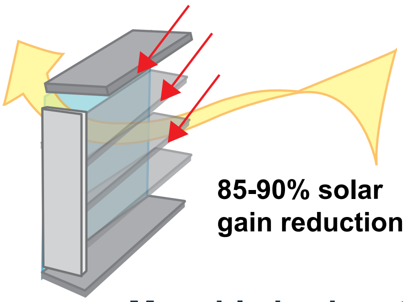
Horizontal solar shading
(south)



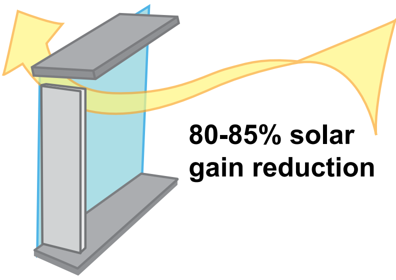
Movable vertical shading
(west/east)



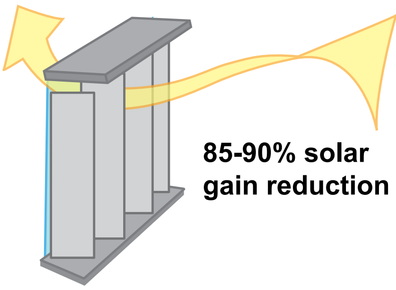
Flexible awning



Movable horizontal shading



Horizontal + vertical 'fins' of minimum depth of 600 mm
(SW/SE)



Movable vertical fins/louvres

ग Window Size and Planning

Panchamrit 3

- Maximum allowable Window Wall Ratio (WWR) is 15% and minimum is 12%

Compliance approach for WWR as mentioned in 'Window to Wall Ratio' section (pg. 48)

घ Natural and Cross-ventilation

Panchamrit 4

- Main entrance door of all units in an affordable housing project located in warm and humid and composite climate zone should have an additional full length Jaali door fitted at the entrance of the unit (entrance door) to allow cross ventilation.
- All windows in bedroom to be casement windows with 90% openable area.
- All windows in living room and kitchen having width less than 1.25 metres should be casement windows with 90% openable area.

Cool Roof

Panchamrit 5

To show compliance with Roof section, the building shall adopt atleast one of the following criteria:

- The roof should have 7 mm reflective white coloured China terrazzo tiles on the entire Terrace floor with appropriate spacing over 50 mm bedding cement mortar.

  OR

  Choose light-coloured or reflective roofing materials that reflect sunlight. Apply special coatings (high SRI paints with minimum SRI value of 0.7) that make your roof reflect sunlight and stay cooler.

  OR

  Shade minimum 50% of the roof area with canopies/shading structure/green vegetation/solar PV.

Additionally:

- Consider having plants on your roof, as they provide natural shade and help cool down the building.
- Remember to take care of your roof by keeping it clean and fixing any damage to maintain its cooling properties.

Compliance Requirement for Cold Climate Zone

1 Orientation

Optimize the building's orientation to maximize solar gain during the winter months. The living spaces and large windows should face south to capture the most sunlight.

2 WWR

Maximum allowable WWR is 12%. Plan maximum no. of windows on South, West and East direction.

3 Roof

Insulate your roof to keep the cold outside and retain the heat inside.

Table 2: Summary of Recommendations

	Hot and Dry / Warm and Humid / Composite / Temperate	Cold
Orientation and Mutual Shading	Adopt the orientation and mutual shading concept as per Table 1.	Optimize the building's orientation to maximize solar gain during the winter months. The living spaces and large windows should face south to capture the most sunlight.
Shading of Glazed Façade	A minimum shading of 600 mm is required for all windows with permanent external projection.	
Window Size and Planning	Maximum allowable WWR is 15% and minimum is 12%.	Maximum allowable WWR is 12%. Plan maximum no. of windows on South, West and East direction.
Natural and Cross-ventilation	• Main entrance door of units located in warm and humid and composite climate zone should have an additional full length Jaali door fitted at the entrance of the unit. • All windows in bedroom to be a casement windows. • All windows in living room and kitchen having width less than 1.25 metres should be casement windows.	
Cool Roof	The roof should have 7 mm reflective white coloured China Mosaic tiles on the entire Terrace floor with appropriate spacing over 50 mm bedding cement mortar. **OR** Light-coloured or reflective roofing materials that reflect sunlight. Apply special coatings such as high SRI paints with minimum SRI of 0.7. **OR** Shade minimum 50% of the roof area with canopies/ temporary shading structure/green vegetation/solar PV.	Insulate your roof to keep the cold outside and retain the heat inside.

Additional Recommendations of Swarna PRiTHVi for Multi-Family Homes

PRiTHVi focuses on the passive approaches and natural remedies to attain optimum level of thermal comfort, it is important to mention the importance of building envelope design in attaining thermal comfort inside a built environment.

Thus, to further strengthen the impact on comfortable hours attained due to 5 passive measures stated in this document, an advance level of **Swarna PRiTHVi** is recommended which can be attained by fulfilling following criterias:

Step 1
Adopt all the criteria of PRiTHVi compliance level

Step 2
Opaque above grade of external walls shall comply with the maximum assembly **U-factor of 0.8 W/m^2K**

Step 3
Thermal transmittance of roof shall comply with the **maximum assembly U-factor of 1.2 W/m^2K**

Swarna PRiTHVi

खण्ड ३

COMPLIANCE CHECKLIST FOR PRiTHVi AND SWARNA PRiTHVi LEVELS

Project Information

Project type: Multi-family

Date			
Project Address			
City		Plot/site area	
Climate zone		Total built up area	
Applicant Name		No. of Dwelling Units	
Applicant Address		Carpet area/DU	
Applicant Phone		Number of floors	

Project Description

Briefly describe project and construction material used

<u>Compliance Requirements for all Climate Zones except Cold Climate</u>

To show compliance with PRiTHVi recommendations, the project shall have ***atleast 1 YES in each of the Mandatory Panchamrit listed below.***

For validation and proof of compliance, all Panchamrit's requirements shall be incorporated in the tender document floated for the design and construction of the project for mandatory adoption.

Mandatory Panchamrit 1: Orientation and Mutual shading

01

Ideal planning category

Orientation cum Mutual Shading correct for more than 80% blocks (as per area weightage) and no additional measures are needed under this recommendation.

YES ☐ NO ☐

OR

02

Moderate planning category

Orientation cum Mutual Shading correct for more than or equal to 70% blocks and less than 80% of the blocks (as per area weightage) and additional measures of ensuring SHGC of all glasses to be maximum 0.7.

YES ☐ NO ☐

OR

03 Lenient planning category

Orientation cum Mutual Shading correct for more than or equal to 40% blocks and less than 70% of the blocks (as per area weightage) and Permanent box frame - external projections with projection of minimum 600 mm.

YES ☐ NO ☐

OR

04 Undesigned Planning

Orientation cum Mutual Shading correct for less than 40% blocks (as per area weightage) and Mandatory compliance to Swarna PriTHVi level as mentioned in Swarna PRiTHVi section.

YES ☐ NO ☐

Mandatory Panchamrit 2: Shading of Glazed Façade

01 A minimum depth of permanent external projection such as overhangs, side fins, box frames, verandas, balconies, and fixed canopies that offer continuous shade to be at least 600 mm

YES ☐ NO ☐

Mandatory Panchamrit 3: Window Size and Planning

01 Maximum allowable WWR is 15% and minimum is 12%

YES ☐ NO ☐

Mandatory Panchamrit 4: Natural and Cross-ventilation

01

Criteria: Jaali door at entrance requirement for Warm and Humid and Compoisite Climate Zone only

Description: Main entrance door of all units in an affordable housing located in warm and humid and composite climate zone should have an additional full length Jaali door fitted at the entrance of the unit (entrance door) to allow cross-ventilation.

YES ☐ NO ☐

AND

02

Criteria: Bedroom windows

Description: All windows in bedroom to be a casement window with 90% openable area.

YES ☐ NO ☐

AND

03

Criteria: Living room and Kitchen windows

Description: All windows in living room and kitchen having size less than 1.25 metres should be a casement window with 90% openable area.

YES ☐ NO ☐

Mandatory Panchamrit 5: Cool Roof

01 The roof should have 7 mm reflective white coloured China Mosaic tiles on the entire Terrace floor with appropriate spacing over 50 mm bedding cement mortar. YES ☐ NO ☐

OR

02 Choose light-coloured or reflective roofing materials that reflect sunlight. Apply special coatings (high SRI paints with minimum SRI value of 0.7) that make your roof reflect sunlight and stay cooler. YES ☐ NO ☐

OR

03 Shade minimum 50% of the roof area with canopies/ shading structure/green vegetation/solar PV. YES ☐ NO ☐

Additional Requirement for Swarna PRiTHVi: Building Envelope

Opaque above grade external walls shall comply with the maximum assembly U-factors of 0.8 W/m²K.

Thermal transmittance of roof shall comply with the maximum U-roof value of 1.2 W/m²K.

YES ☐ NO ☐

Performance Level Achieved

Level 1

PRiTHVi

Full compliance to the 5 Mandatory Panchamrit (Panchamrit 1 to 5). YES ☐ NO ☐

Level 2

Swarna PRiTHVi

Full compliance to the 5 Mandatory Panchamrit (Panchamrit 1 to 5) along with Additional Requirement for Swarna PRiTHVi: Building Envelope. YES ☐ NO ☐

For Cold Climate Zone, an undertaking by the project developer on the confirmation of adoption of all measures mentioned for Cold Climate zone shall be submitted to the designated authority.

खण्ड ४

PASSIVE-DESIGN MEASURES IN PRiTHVi: DETAILED EXPLANATION

Passive building design focuses on strategies and principles based on natural elements that make the living environment within the building more comfortable without relying on equipment or mechanical means which cost higher and consume more energy.

भाग १: Building Form and Typology | भाग २: Orientation and Mutual Shading | भाग ३: Window Design and Natural Ventilation | भाग ४: Walling | भाग ५: Cool Roofs

Introduction

This chapter translates the principles of passive design into implementable strategies for affordable housing. Passive design needs to be adopted from the very inception of the project since it draws heavily from the site, context and existing conditions. The guidelines list out how best to respond to the context to take maximum advantage of natural wind, solar movement, seasonal and diurnal changes in temperature etc.

Aspects like massing, shape and size of the building, size and placement of buildings with respect to orientation as well as with respect to other blocks on site are all decided based on the impact it has on the thermal comfort inside the building.

Going beyond site level planning the guidelines also give insights towards the design of the building itself, in terms of internal planning, placement of rooms and corridors, size and placement of openings and other building features such as balconies, courtyards etc.

Lastly the guidelines help make informed choices on the material to be used – in terms of its properties, dimensions/thicknesses, colour and other such specifications to maximize thermal comfort within the living spaces.

Benefits: national and global level

- Reduced load on electricity grid
- Reduced demand for electricity
- Carbon mitigation

Benefits: beneficiary level

- Occupant satisfaction (thermal comfort)
- Adequate air circulation
- Adequate day lighting
- Lower electricity bills
- Low dwelling unit cost

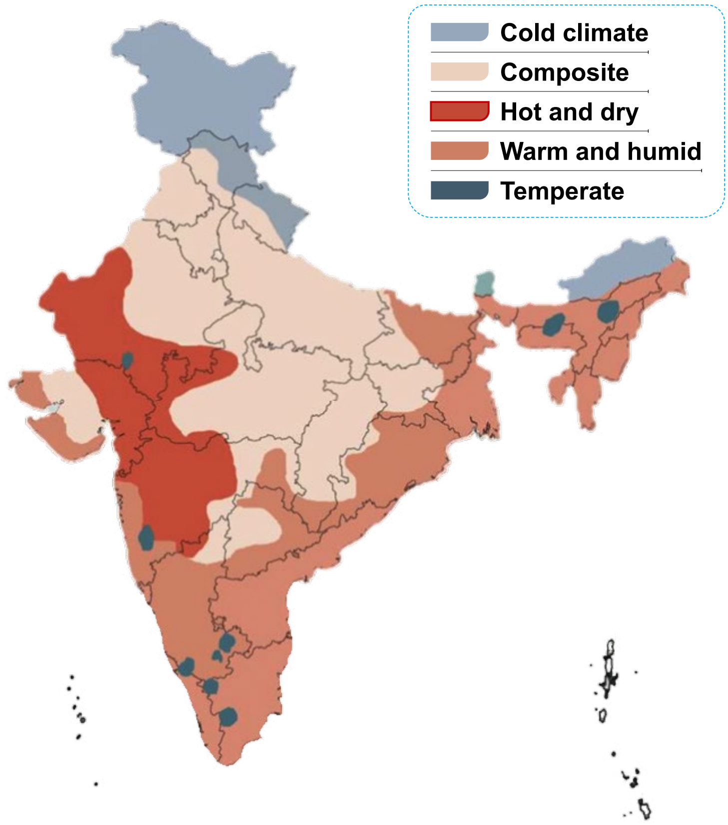
Passive Design Measures

Passive building design is a set of design principles/strategies that allow for attaining an energy efficient building that caters to the occupant satisfaction (thermal comfort). These design principles can be applied to all buildings, including single-family homes, multifamily apartment buildings, schools etc.

Passive design strategies are decided based on the climate and location of the building. The variation in climates in India is shown in the Climatic Zones of India map as seen in Figure.

Passive design exploration can be broadly categorized into **spatial design decisions-based** strategies and **construction material-based** strategies.

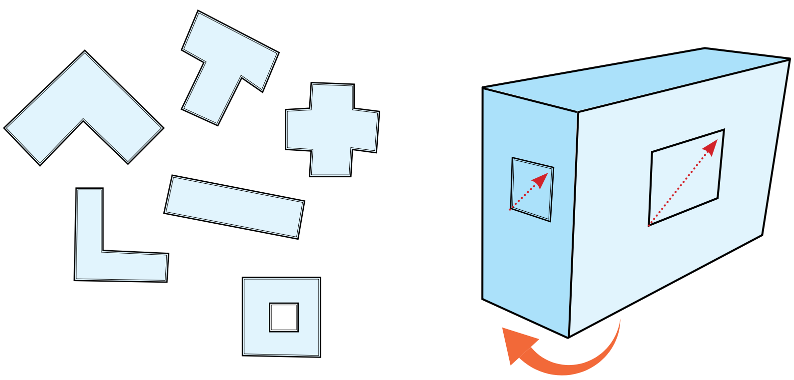
Figure 3.a Climatic zones in India



Spatial design:

This is the first layer of decision chain that holds potential to reduce heat gains in a building. Choices such as typology, building form and compactness, orientation, shading techniques, window placement etc. to determine the amount of solar radiation reaching the building envelope and inside. By optimising solar radiation from interacting with the building, spatial design strategies allow better thermal comfort in the buildings.

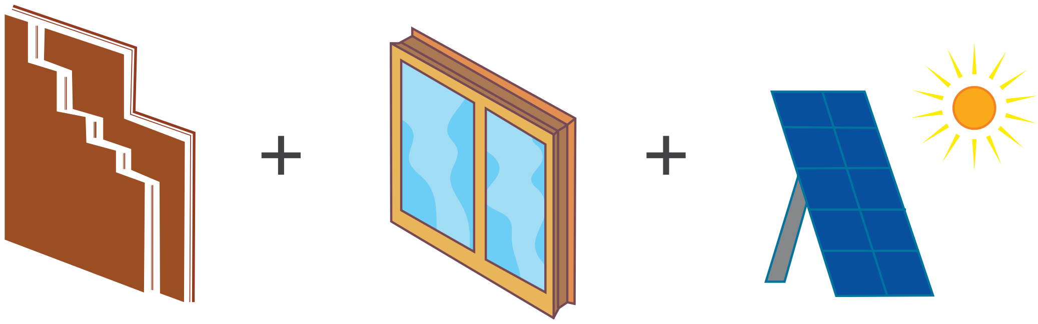
Figure 3.b Geometry Optimization



Construction Material:

After optimizing spatial design, the second approach for minimizing heat gains is selection of building envelope material. Preferences pertaining to construction materials of the envelope categorize as construction material-based design decisions.

Figure 3.c Passive and Active strategies optimization



This section presents how measures such as material choice; natural ventilation design and solar design can have low to high impact based on the climatic zones. For instance, for warm and humid climate, natural ventilation design is a high impact strategy and designers must explore how to maximize achieving cooling through this mode.

Impact of Passive Strategies based on Climatic Zones

Hot and Dry	Very High	Natural ventilation control, sunlight control, orientation
	High	Wall surface area, windows
	Neutral	Material, typology
Warm and Humid	Very High	Natural ventilation control, sunlight control, orientation
	High	Windows
	Neutral	Material, typology, wall surface area
Temperate	Very High	Sunlight control, orientation
	High	Windows, natural ventilation
	Neutral	Material, Typology, Wall surface area
Cold	Very High	Sunlight control, orientation, material
	High	Wall surface area, windows, natural ventilation
	Neutral	Typology
Composite	Very High	Sunlight control, orientation, natural ventilation
	High	Wall surface area, Material, Windows
	Neutral	Typology

भाग १: Building Form and Typology

The building typology defines the shape and size of a particular building which is the first step in establishing how much of the building envelope interacts with the outside environment. The typology defines the compactness of the built form and in turn its thermal exposure.

The various verticals of affordable housing under PMAY-U can be divided into 2 broad typologies:

1. Single family homes

These are homes built on individual plots such as those under Beneficiary Led Construction *(discussed in Volume 1 of PRiTHVi)*

2. Multi-family homes

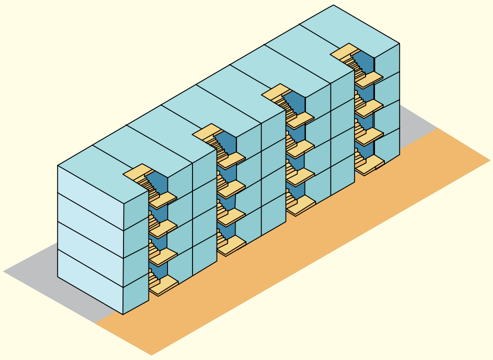
These are homes built in group housing format by a developer, builder, or state housing department to house multiple families such as those developed under AHP and ISSR verticals.

Muti-family home typologies

Multi-family homes are usually developed in low rise (walk up apartments up to ground +4 storeys), mid-rise (up to 8 storeys) and high rise (beyond 8 storeys) formats. The building height is usually determined by the land value and FAR available in a region. Certain typologies are more suitable for certain heights and kinds of development. The various multi-family typologies are discussed below.

Building typology in affordable housing

Row house Two side open

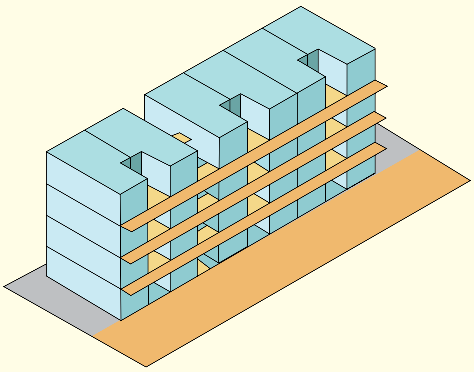


This is a walk-up typology where each staircase serves 2 units and adjacent units share the longer walls. The front and back walls of each unit have openings for light and ventilation and are exposed to the outside weather conditions.

CHARACTERISTICS

- Ideal for low rise construction
- Offers a fair degree of compactness.
- Results in a linear form with opening on 2 sides thus allowing the block to benefit from good orientation.
- Block size is comparatively smaller thus it allows for ease in site planning

Singly loaded corridor

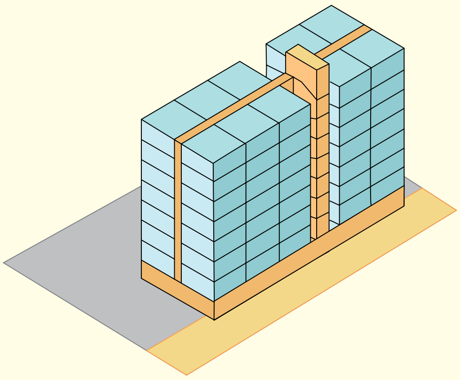


When building is mid-rise this typology helps reduce the number of staircases required, by connecting a series of units through a corridor on 1 side.

CHARACTERISTICS

- Enables installation of a lift and ideal for low to mid rise structures
- Can accommodate a large number of units in a compact built form, continuous linear blocks can be developed connected through corridors.
- The corridor on 1 side provides a buffer to the units from the outside temperature.
- This linear form can benefit from good orientation.

Doubly loaded corridor

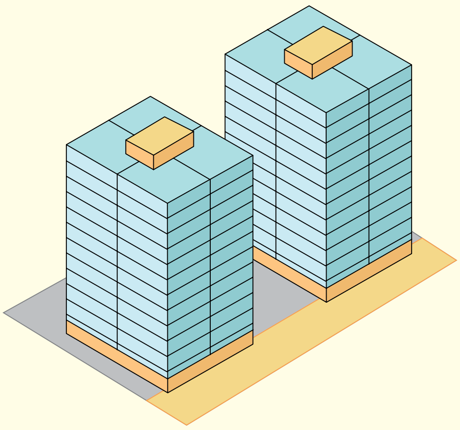


This linear typology has a central corridor with units on both sides connected to a central staircase/lift core. It is ideal for mid to high rise developments.

CHARACTERISTICS

- Most units are exposed to the outside only on 1 side
- This linear form can benefit from good orientation and mutual shading.

Tower (stand-alone)

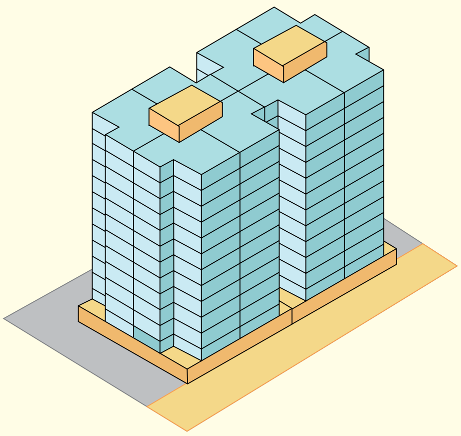


The tower typology has a central core for vertical circulation around which 4-8 units are arranged.

CHARACTERISTICS

- Units are located around a central core, all 4 sides have openings and are exposed to the weather. Benefits from ideal orientation are minimized.
- Orientation specific shading design can be helpful in these cases.

Tower (Connected)



These are designed as connected towers which can add up to a linear form, thus having units with mostly openings on 2 sides.

CHARACTERISTICS

- The tower typology converts to a linear form in this format with prominent openings and exposure limited to 2 sides which can take advantage of ideal orientation.
- This also saves space in site layout and limits exposure of walls while allowing the possibility of mutual shading.

भाग २: Orientation and Mutual Shading

Orientation refers to the placement of the building block on site. Building orientation has a significant impact on energy efficiency of a building designed for achieving comfort through passive measures. Orientation and massing of the building act as passive design strategies by influencing the quantity and quality of radiation reaching the envelope surface.

The ideal orientation must allow for minimizing solar radiation in summers (or in hot climate zones) and maximizing solar radiation in winters (or cold regions).

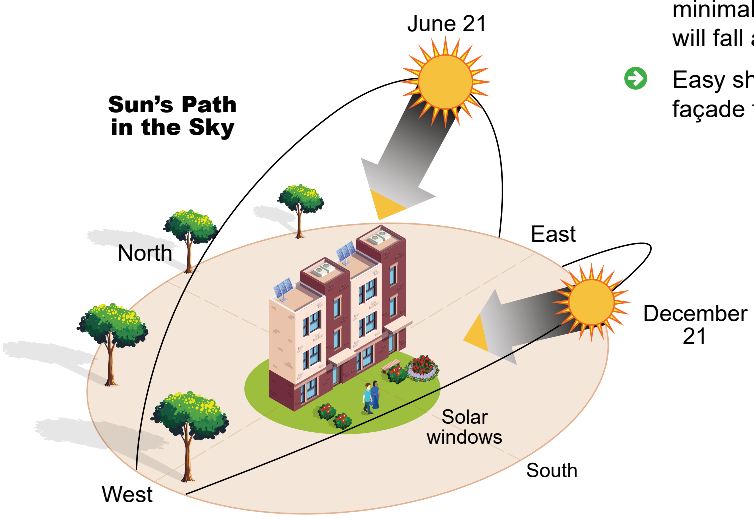
Figure 3.d Understanding the sun path for ideal orientation.

Winter Sun

- Sun path at a low angle, south to E-W axis
- Solar radiation will penetrate south facing façades at a low angle during winter

Summer Sun

- Sun path at a high angle sun, north to E-W axis
- Glare free daylight is most easily available on north façade as minimal solar radiation will fall at high angle
- Easy shading of south façade from high angle sun

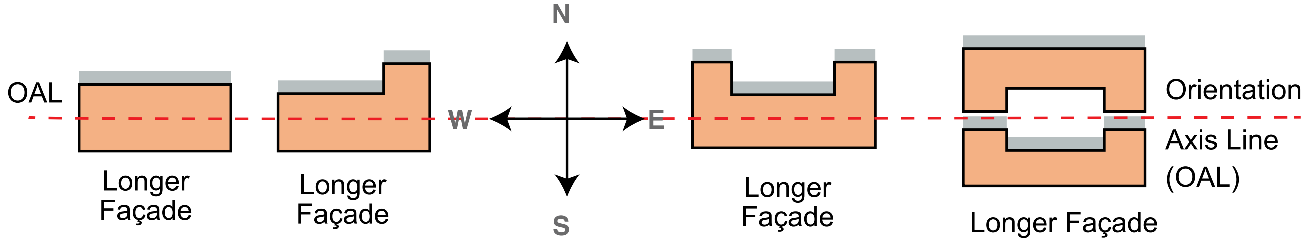


East and west façade receive uniform and strong sun radiations at low angle throughout the year.

Since East and West directions receive strong solar radiation at a low angle throughout the year the preferred orientation to reduce solar gains in northern hemisphere is to have longer walls of buildings facing north and south as can be seen in Figure 3.d.

For ideal orientation (refer to Figure 3.e for understanding longer and shorter façade) the longer façade should face true north and south directions but on site sometimes achieving ideal orientation is not possible due to shape or other constraints. For achieving the benefits of optimum orientation, a deviation of up to 22.5° on either side is acceptable as seen in Figure 3.f.

Figure 3.e Understanding the longer and shorter façade of buildings.



With respect to the orientation, building blocks on the site shall be oriented to minimize the collective solar incident rays on the building envelope (for warm climates). The orientation shall be corrected during the initial site planning itself. To do the same, the Orientation Axis Line (OAL) of the building block shall be aligned as per the recommendations in **खण्ड** २.

Figure 3.f Acceptable limits of orientation of the longer façade

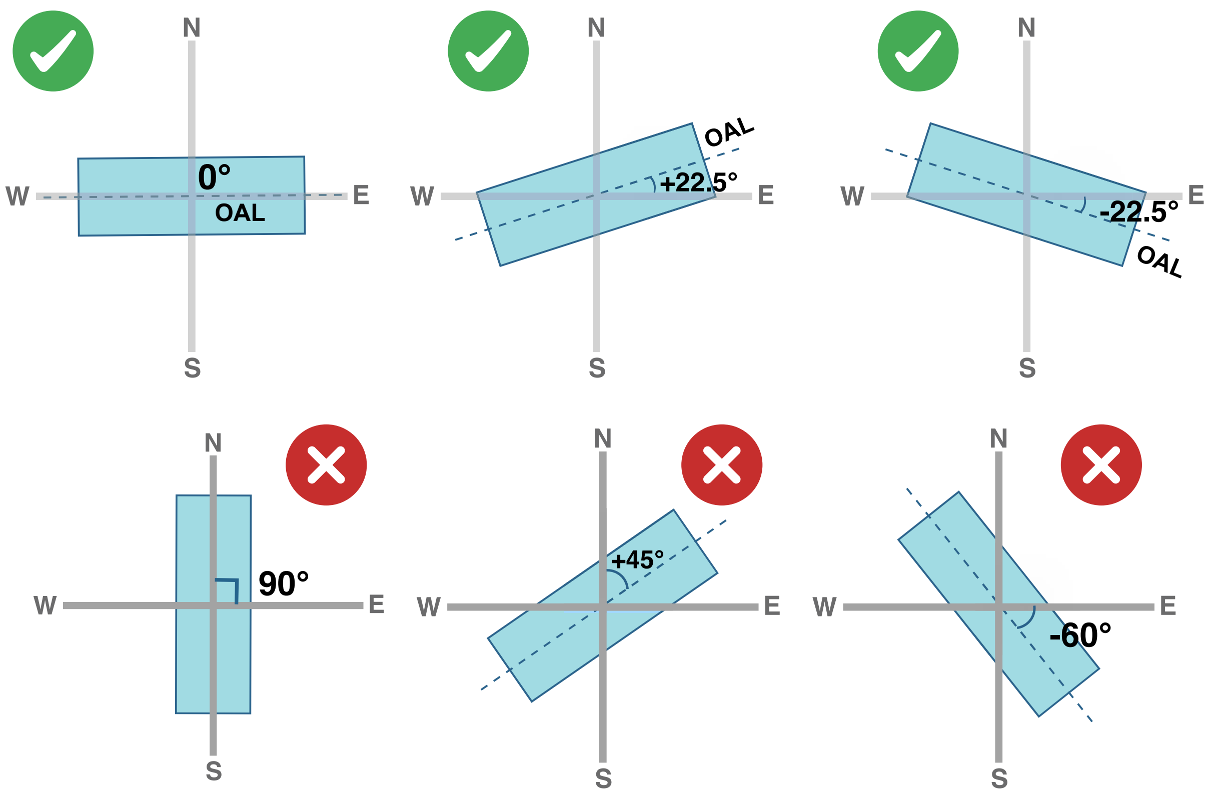


Table 3: Orientation of longer façade as per the climatic zones of India

Hot and Dry	Longer walls of building should face north and south. Non-habitat rooms can be located on outer faces to act as thermal barrier. The surface to volume ratio should be kept as minimum as possible to reduce heat gains.
Warm and Humid	Longer walls of building should face north and south.
Cold	Longer walls of building should face south to receive more solar heat during winter months. Windows should face south (or East and West) to facilitate direct gain. Living areas can be located on the southern side while utility areas such as stores can be on the northern side (which does not receive direct sun).
Composite	Longer walls of building should face north and south as these are easier to shade. The surface to volume ratio should be kept as minimum as possible to reduce heat gains.
Temperate	Longer walls of building should face north and south as these are easier to shade. The surface to volume ratio should be kept as minimum as possible to reduce heat gains.

At site level, the cumulative area of all the building blocks planned on a site, which meet the requirements of orientation mentioned in the recommendations, shall meet the threshold limit mentioned in the Table 1.

Table 1: Minimum threshold limit for Orientation and Mutual Shading as per planning category

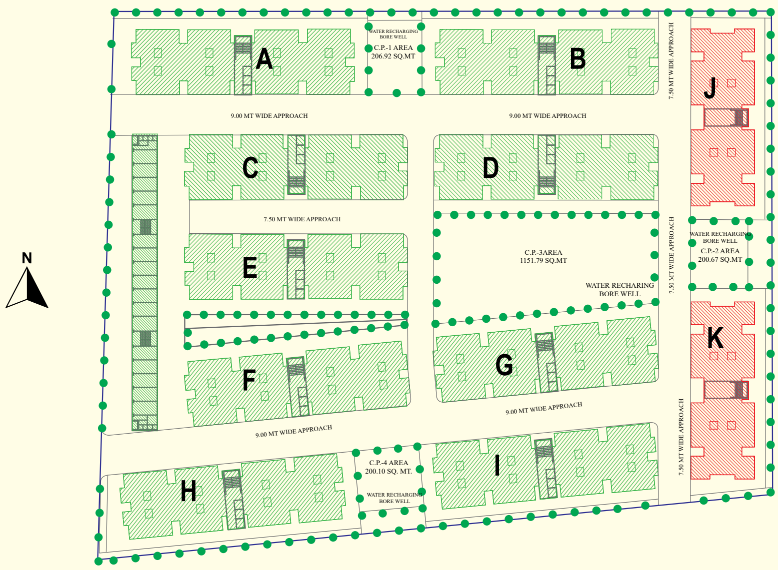
Planning Category for Orientation and Mutual Shading	Threshold limit of minimum % of building blocks* to have correct orientation and mutual shading	**Additional Measures** (to be incorporated in addition to orientation and mutual shading to show compliance with Section 'क')
Ideal Planning 	≥80%	No additional Compliance measure
Moderate Planning 	≥70 and <80%	All Vertical fenestration (glass only) shall comply with the maximum SHGC of 0.7.
Lenient Planning 	<70% and ≥40%	A permanent box frame external projections or recessed windows, having a minimum depth of 600 mm, for all windows except for the below 2 exceptions: - the windows which are overseeing or attached with a balcony - The windows on the wall having face within the range of ±22.5 degrees of the Cardinal North direction
Undesigned Planning 	<40%	Mandatory compliance to Swarna PRiTHVi level is needed for compliance with PRiTHVi. The details of Swarna PRiTHVi requirements can be found in 'Swarna PRiTHVi' section

As per ground coverage area weighted average

WORKING EXAMPLE 1 (Ideal Planning Category)

Calculation of orientation of blocks. Let us consider the site layout as shown in the figure 3.g.

Figure 3.g Site layout of the project

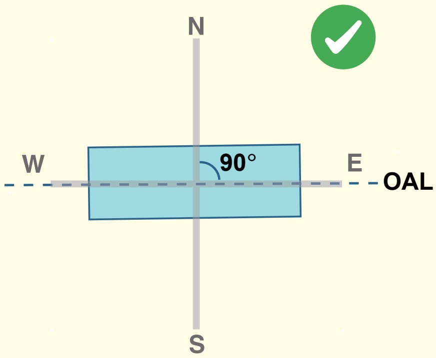


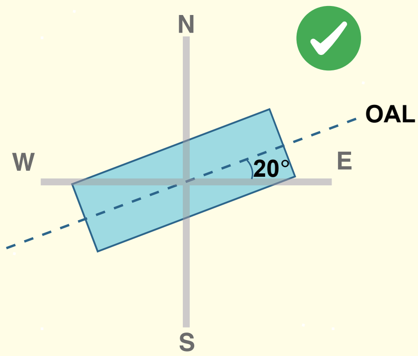
STEP ONE **01** **Calculate the total number of blocks.**

The figure shows a total of 11 building blocks, labeled from A to K.

STEP TWO **02** **Calculate the total number of building blocks oriented in the North-South direction and the number of blocks with a deviation of ≤ 22.5° with respect to East on either side for compliance.**

Calculate the total number of blocks oriented in the North-South direction, where the OAL passing through the longer façade should be perpendicular to true North. To make it easier to understand, let's consider one block, specifically block C. The OAL passing through the longer façade of block C is perpendicular to true North.





From the figure 3.g, it can be observed that there are 5 blocks (A, B, C, D, E) oriented in the North-South direction.

Calculate the total number of building blocks oriented in the N-S direction with a deviation of up to 22.5° with respect to East on either side. From the figure, it can be observed that building blocks F, G, H, and I have a deviation of 20°, which is acceptable.

Mark the total number of building blocks oriented towards the N-S direction and the number of blocks with a deviation of ≤ 22.5°.

From the previous steps, it can be observed that there are a total of 9 building blocks (A, B, C, D, E, F, G, H, and I) which are in acceptable range.

STEP THREE **03** **Calculate the area weighted summation of all the building blocks in the site which are oriented in the North-South direction.**

To do so, consider the roof area of each block to estimate the area weighted value.

Let's say that the roof area of one block is 34 X14 m^2, then for 9 blocks (A to I), the total roof area would be 4284 square metres (assuming the roof area is same for all blocks).

STEP FOUR **04** **Calculate the area weighted summation in order to check compliance.**

First, calculate the area weighted summation of all the building blocks (remaining) on the site that are NOT oriented in the North-South direction.

Let's say that the roof area of other block is 28 X 14 m^2, then for two blocks J and K, the combined roof area would be 784 square metres. The total roof area for all 11 blocks (A to K) would be 5068 square metres.

This is considering height is equal for all blocks and no. of floors are same (say 9).

STEP FIVE 05 Calculate the weighted area percentage of the building blocks which are oriented in the North-South direction.

$$\text{Weighted Area} = \sum\left(\frac{\text{Total Weighted Roof Area of N–S blocks x no of floors}}{\text{Total Roof Area x no of floors}}\right) * 100$$

$$= \frac{4284 \times 9}{5068 \times 9} * 100$$

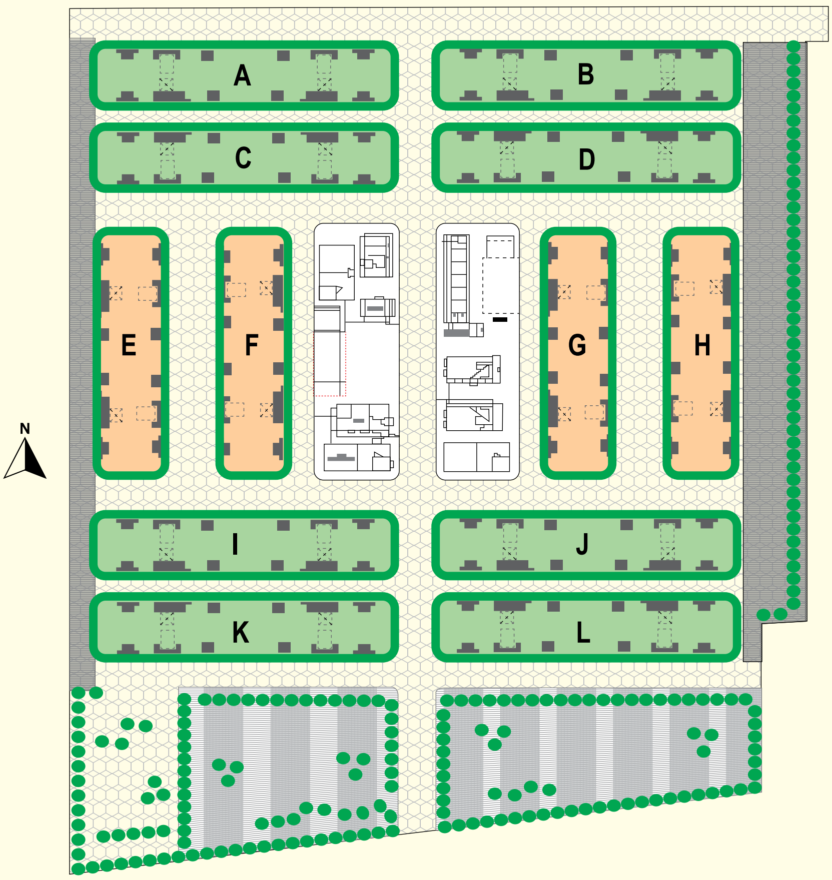
$$= 84\%$$

The building blocks combined weighted area percentage that are oriented in the North-South direction is 84%, which is within the Ideal planning category as per Table 1. Hence, no further compliance measures are necessary.

WORKING EXAMPLE 2 (Ideal Planning Category with mutual shading)

Calculation of orientation of blocks. Let us consider the site layout as shown in the figure 3.h.

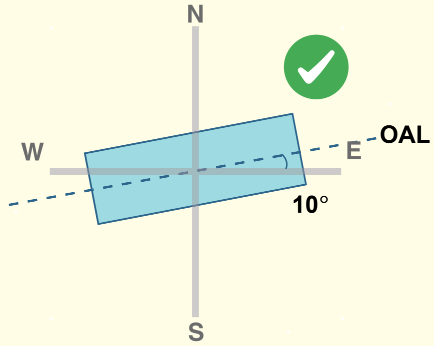
Figure 3.h Site layout of the project



STEP ONE 01 Calculate the total number of blocks.

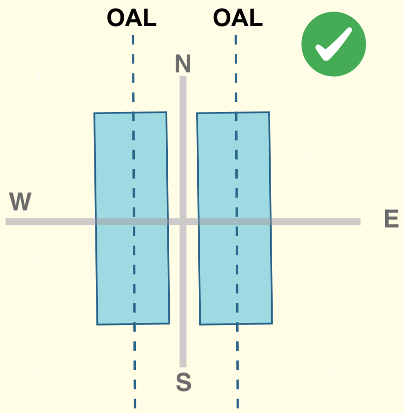
The figure shows a total of 12 building blocks, labeled from A to L, all are of same height and no. of floors.

STEP TWO 02 Calculate the total number of building blocks oriented in the North-South direction, the number of blocks with a deviation of ≤ 22.5° with respect to East on either side, and (or) mutually shaded blocks for compliance.



Calculate the total number of blocks oriented in the North-South direction, where the orientation axis line (OAL) passing through the longer façade should be perpendicular to true North. To make it easier to understand, let's consider one block, say block C.

From the figure 3.h, it can be observed that there are 8 blocks (A, B, C, D, I, J, K, L) oriented in the North-South direction with a deviation of 10°, which falls within the acceptable range.



Identify the buildings which are not oriented north-south but has potential for mutual shading.

In order to benefit from mutual shading, building towers must fulfil all the criterion mentioned in 'Mutual Shading Requirement' section.

STEP THREE 03 Calculate the area weighted summation of all the building blocks in the site which are oriented in the North-South direction.

To do so, consider the roof area of each block to estimate the area weighted value, along with no. of floors (say 5).

Let's say that the roof area of one block is 38 X 15 m^2, then for 8 blocks, the total roof area would be 4560 square metres (assuming the roof area and no. of floors are same for all blocks).

STEP FOUR 04 Calculate the area weighted summation in order to check compliance.

First, calculate the area-weighted summation of all the building blocks on the site that are not oriented in the North-South direction but are mutually shaded.

Let's say that the roof area of other block is 38mX15m, then for 4 blocks (E,F, G, H), the combined roof area would be 2280 square metres with same no. of floors (say 5).

Total roof area for all 12 blocks (A to L) would be 6840 square metres.

Under mutual shading category only 50% of the total blocks E, F and blocks G,H would be considered for mutual shading category as it satisfies the requirement of h:d ratio of 2:1. Hence the total area weighted of 4 blocks is

$$= \left(\frac{1}{2}\right) * \sum \text{combined roof area of blocks considered for mutual shading}$$

$$= \left(\frac{1}{2}\right) * 2280$$

= 1140 square metres

STEP FIVE 05 **Calculate the weighted area percentage of the building blocks which are oriented in the North-South direction.**

$$\text{Weighted Area} = \sum \left(\frac{\text{Total Weighted Roof Area of N–S blocks x no. of floors + 1/2 x Total Weighted Roof Area of mutually shaded blocks x no. of floors}}{\text{Total Roof Area x no. of floors}} \right) * 100$$

$$= \left(\frac{4650 \times 5 + 1/2 \times 2280 \times 5}{6840 \times 5} \right) * 100$$

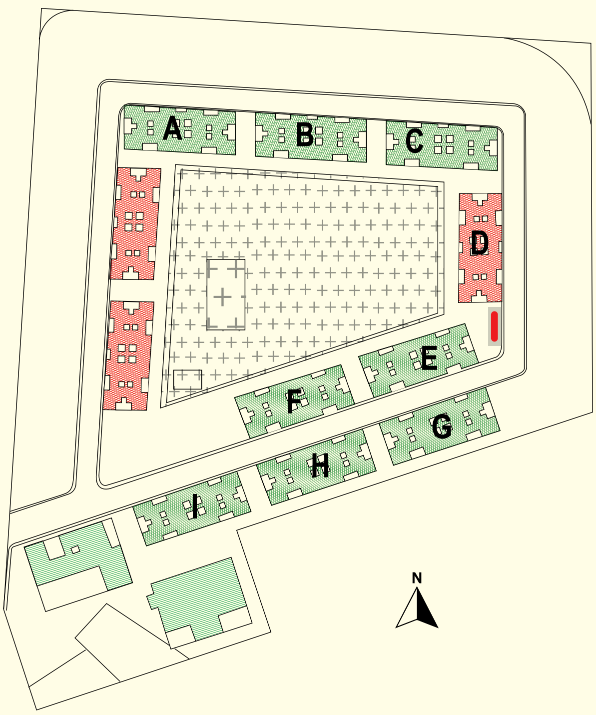
= 83%

The building blocks combined weighted area percentage that are oriented in the North-South direction and mutually shaded blocks is 83%, which is within the Ideal planning category as per Table 2. Hence, no additional compliance measure is necessary for this Panchamrit.

WORKING EXAMPLE 3 (Moderate Planning Category)

Calculation of orientation of blocks. Let us consider the site layout as shown in the figure 3.i.

Figure 3.i Site layout of the project



STEP ONE 01 **Calculate the total number of blocks.**

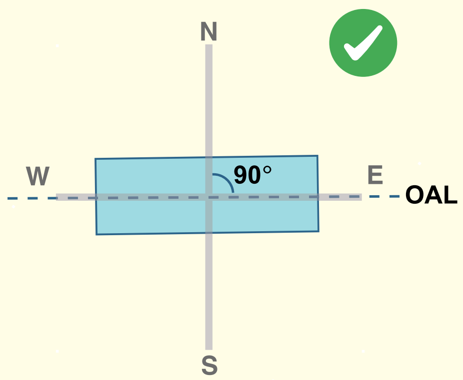
The figure shows a total of 11 building blocks, labeled from A to K.

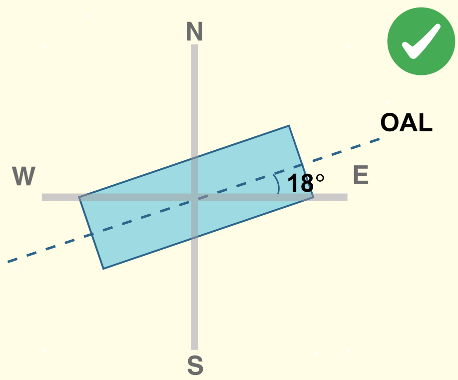
STEP TWO 02 Calculate the total number of building blocks oriented in the North-South direction and the number of blocks with a deviation of ≤ 22.5° with respect to East on either side for compliance.

From the figure 3.i, it can be observed that there are 3 blocks (A, B, C) oriented in the North-South direction.

Calculate the total number of building blocks oriented in the N-S direction with a deviation of up to 18° with respect to East on either side, which is acceptable.

From the figure 3.i, it can be observed that building blocks E, F, G,H and I have a deviation of 18°, which is acceptable.





Mark the total number of building blocks oriented towards the N-S direction and the number of blocks with a deviation of ≤ 22.5°.

From the previous steps, it can be observed that there are a total of 8 building blocks (A, B, C, E, F, G,H and I) oriented in the North-South direction.

STEP THREE 03 Calculate the area weighted summation of all the building blocks in the site which are oriented in the North-South direction.

To do so, consider the roof area of each block to estimate the area weighted value along with no. of floors (say 8)

Let's say that the roof area of one block is 30 X14 m^2, then for 8 blocks (A, B, C, E, F, G,H and I), the total roof area would be 3360 square metres (assuming the roof area and no. of floors are same for all blocks).

STEP FOUR 04 Calculate the area weighted summation in order to check compliance.

Calculate the area weighted summation of all the building blocks in the site which are NOT oriented in the North-South direction.

Let's say that the roof area of other block is 30 X 14 m^2, then for 3 blocks (J,K and I), the combined roof area would be 1260 square metres with same no. of floors (say 9).

The total roof area for all 11 blocks (A to K) would be 4620 square metres.

STEP FIVE 05

Calculate the weighted area percentage of the building blocks which are oriented in the North-South direction.

$$\text{Weighted Area} = \sum\left(\frac{\text{Total Weighted Roof Area of N-S blocks x no. of floors}}{\text{Total Roof Area x no. of floors}}\right) * 100$$

$$= \frac{3360 \times 9}{4620 \times 9} * 100$$

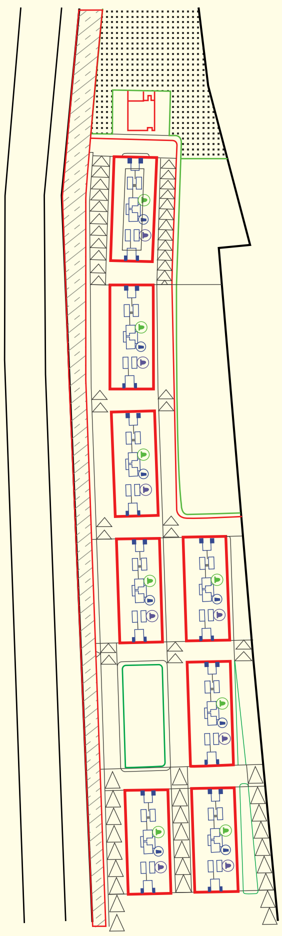
$$= 73\%$$

The building blocks combined weighted area percentage that are oriented in the North-South direction is 73%, which is within the Moderate planning category as per Table. Therefore, additional measure to be adopted as mentioned in Table 1.

WORKING EXAMPLE 4 (Lenient Planning Category)

Calculation of orientation of blocks. Let us consider the site layout as shown in the figure 3.j.

Figure 3.j Site layout of the project



STEP ONE 01

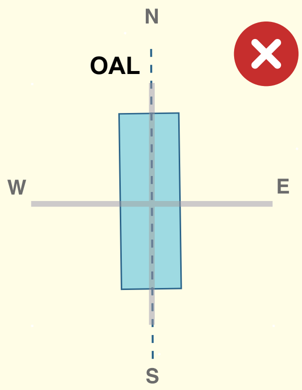
Calculate the total number of blocks.

The figure shows a total of 8 building blocks, labeled from A to K.

STEP TWO 02 Calculate the total number of building blocks oriented in the North-South direction, the number of blocks with a deviation of ≤ 22.5° with respect to East on either side, and (or) mutually shaded blocks for compliance.

Calculate the total number of blocks oriented in the North-South direction, where the orientation axis line (OAL) passing through the longer façade should be perpendicular to true North.

To make it easier to understand, let's consider one block, specifically block C. The orientation axis line (OAL) passing through the longer façade of block C is not perpendicular to true North.

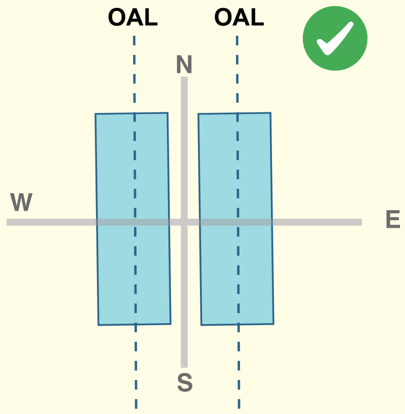


From the figure 3.j, it can be observed that all the 8 blocks (A to H) are oriented in the East-West direction, which is not appropriate.

Identify the buildings which are not oriented north-south but has potential for mutual shading.

In order to benefit from mutual shading, building towers must fulfil all the criterion mentioned in 'Mutual Shading Requirement' section.

Let us consider blocks D,E, G, H for mutually shaded category. Block D, Block E and Block G, Block H flush with each other (OAL). The height of blocks are 16 metres and distance between blocks is 7 metres which satisfy the requirement of 2:1.



STEP THREE 03 Calculate the area weighted summation of all the building blocks in the site which are oriented in the North-South direction.

To do so, consider the roof area of each block to estimate the area weighted value and no. of floors (say 9). However, for this example, there are no blocks oriented in North-South direction. Hence, the value will be 0.

STEP FOUR 04 Calculate the area weighted summation in order to check compliance.

First, calculate the area-weighted summation of all the building blocks on the site that are not oriented in the North-South direction but are mutually shaded.

Let's say that the roof area of other block is 32 X 16 m^2, then for 4 blocks (D, E, G, H), the combined roof area would be 2048 square metres with same no. of floors (say 9).

Total roof area for all 8 blocks (A to H) would be 4096 square metres (assuming roof area and no. of floors are same for all blocks).

Under mutual shading category only 50% of the total blocks D, E and blocks G,H would be considered for mutual shading category as it satisfies the requirement of h:d ratio of 2:1. Hence the total area weighted of 4 blocks is

$$= \left(\frac{1}{2}\right) * \sum \text{combined roof area of blocks considered for mutual shading}$$

$$= \left(\frac{1}{2}\right) * 2048 = 1028 \text{ square metres}$$

STEP FIVE 05 Calculate the weighted area percentage of the building blocks which are oriented in the North-South direction.

$$\text{Weighted Area} = \sum \left(\frac{\text{Total Weighted Roof Area of N−S blocks x no. of floors + 1/2 x Total Weighted Roof Area of mutually shaded blocks x no. of floors}}{\text{Total Roof Area x no. of floors}} \right)$$

$$= \left(\frac{0 \times 9 + 1/2 \times 2048 \times 9}{4096 \times 9} \right) * 100$$

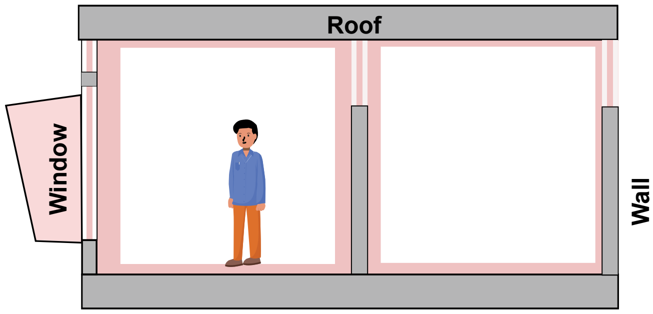
$$= 25\%$$

The building blocks combined weighted area percentage that are oriented in the North-South direction and mutually shaded blocks is 25%, which comes under lenient planning category of Table 1. Therefore, additional measure to be adopted as mentioned in Table 1.

भाग ३: Window Design and Natural Ventilation

The building envelope is the outer skin of the building which forms a barrier between the inside and the outside environment. This is composed of 3 major elements as shown in figure 3.k.

Figure 3.k Building envelope



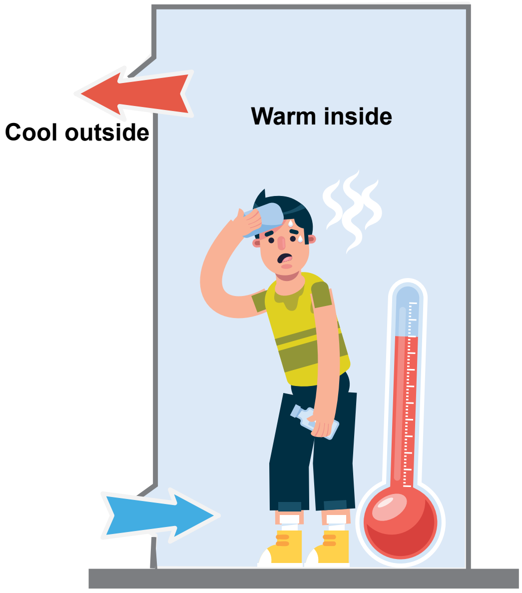
1) Windows

Windows play a crucial role in buildings. It provides views of the outdoors, allow daylight, and helps in ventilation in the buildings.

2) Natural Ventilation

Natural ventilation is defined as provision of fresh air and removal of stale air using the naturally occurring forces of wind. The size and orientation of windows controls the natural ventilation potential inside the house. It is mainly of two types i) Buoyancy ii) Wind driven.

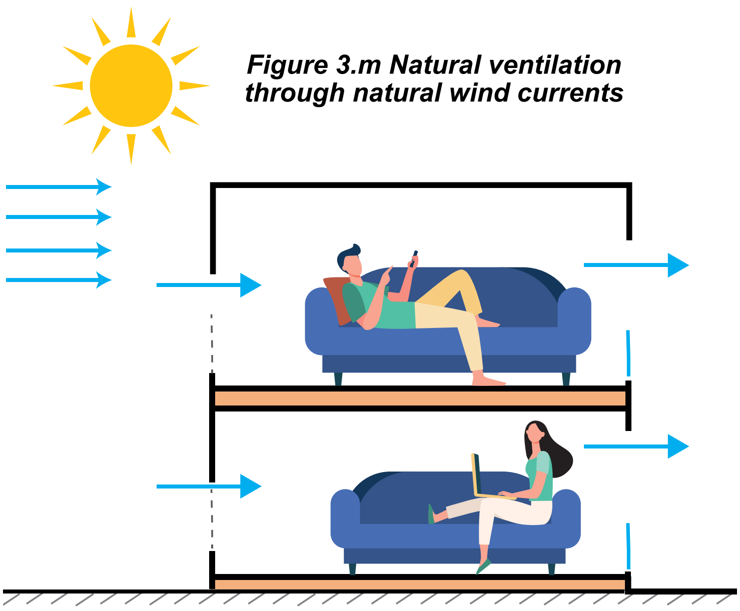
Figure 3.l Natural ventilation through buoyant forces



1 Buoyancy:

It relies on the temperature difference between the air inside the building and the outdoors to drive the flow. Warmer air rises due to less pressure and cold air settles down.

Figure 3.m Natural ventilation through natural wind currents

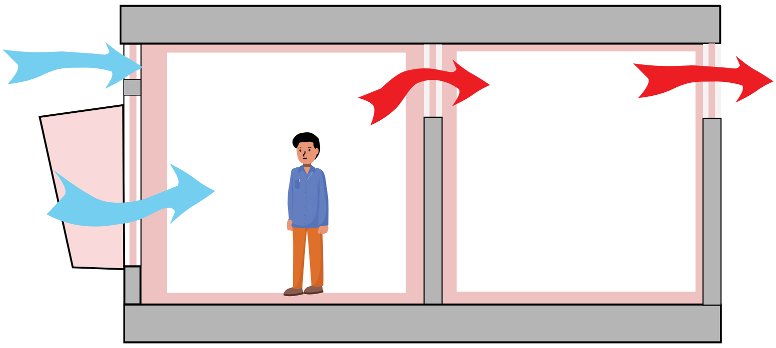


2 Wind driven:

To make use of this effect, windows on the windward side (direction from where the wind comes) can be made larger and the windows or openings on the leeward side can be made smaller.

Figure 3.n Cross ventilation in a dwelling unit using ventilators and windows

Optimizing openings and windows to encourage cross-ventilation through the room/ building will add effectively to comfort of beneficiaries. Having ventilators on top and jaali doors/ windows helps assist air flow as seen in Figure 3.n.

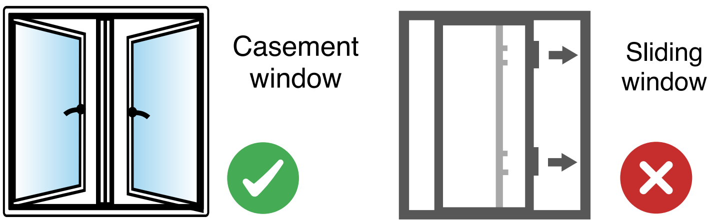


3) Window Size and Type

Window size also plays an important role in enhancing ventilation potential. Selection of appropriate window type and size will aid in optimizing the ventilation potential. Casement windows allow 90% of the window area to be openable and effective towards ventilation/airflow. Sliding windows restrict the openable area to 50-60% therefore leaving less scope for ventilation.

Affordable housing projects have smaller floor area, with smaller rooms, thereby limiting the air movements. If proper windows and openings design is not done, natural ventilation potential will be compromised.

A good strategy is to make use of jali doors in the main entrance of the house which can be kept open based on ventilation requirement or having an independent balcony for the unit which is not accessed via kitchen.



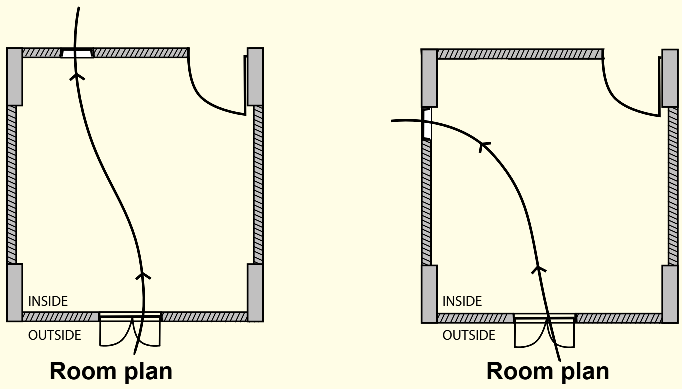
WORKING EXAMPLE

CASE ONE 01

Openings on adjacent or opposite external walls for cross ventilation

Figure 3.o Openings on adjacent or opposite external walls for cross ventilation

The air will enter from outside from the bigger window and escape through the ventilator window/openings either on an adjacent or opposite external wall.

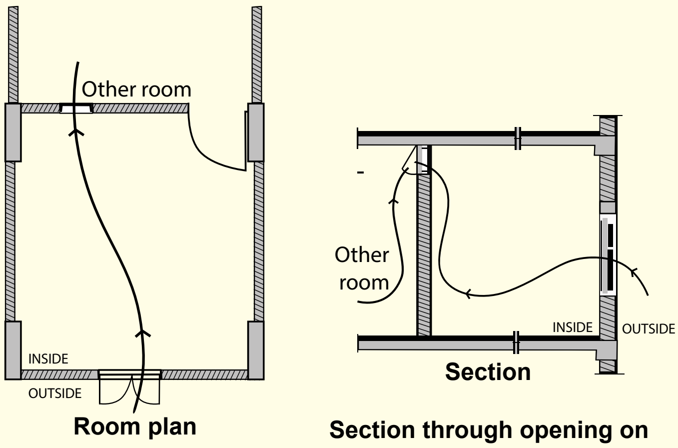


CASE TWO 02

Openings on external wall and internal wall for cross ventilation

Figure 3.p Openings on external wall and internal wall for cross ventilation

The air can enter from the window on the external wall and enter through an opening in the internal wall (placed higher than the other window). This will introduce air in the whole dwelling unit.



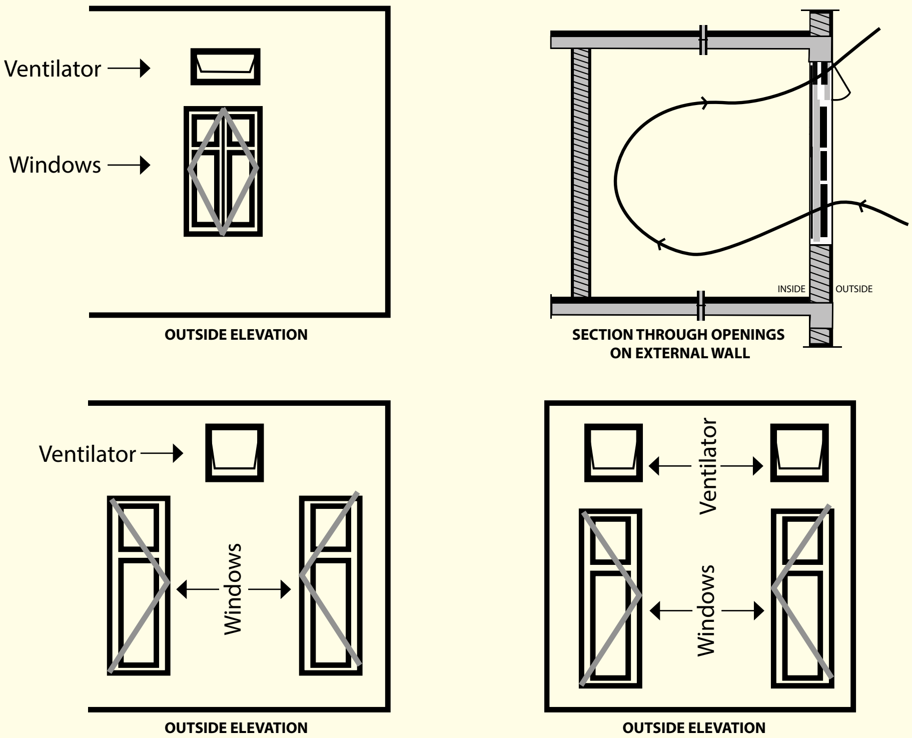
Section through opening on external wall and opening on any other wall

CASE THREE 03

In rooms with only one external wall, and where cross ventilation is not possible.

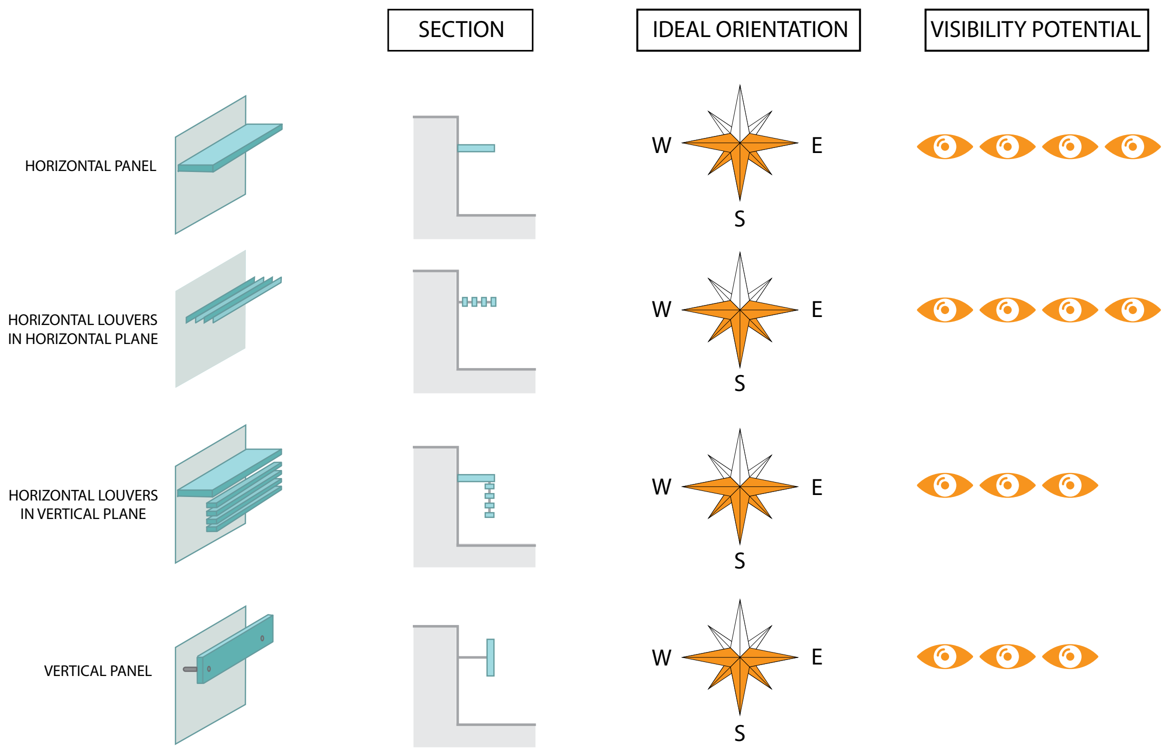
Figure shows ventilators are provided in 3 window design options for natural ventilation. Here, the hot air rises and escapes from the ventilator. This creates a suction effect which pulls the air from outside through the windows

Figure 3.q Adding ventilators above windows improves ventilation especially when the room has only 1 external wall

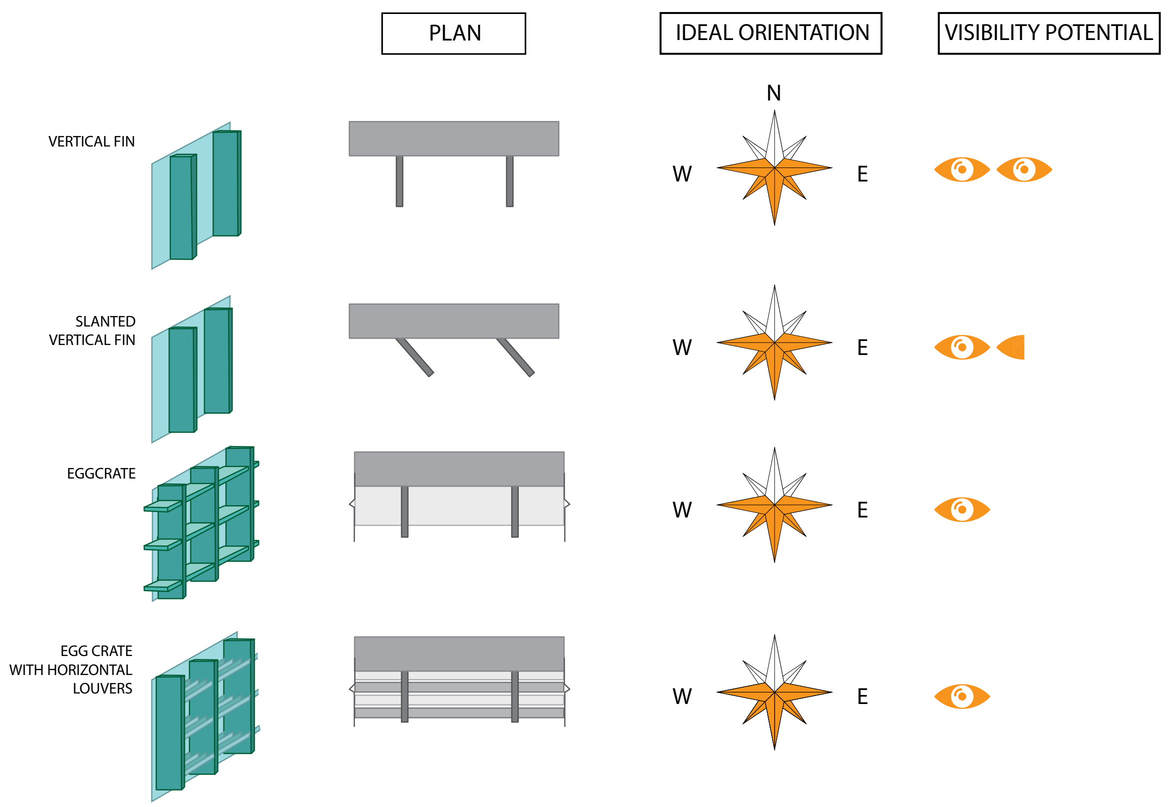


4) Shading

Shading devices obstruct the unwanted solar radiation (undesirable heat) entering the buildings through windows. Fixed or movable shading devices can be chosen depending on the trajectory of sun and direction of the façade. Shutters, jalis, and vertical screens can also act as effective shading strategies to reduce radiative heat transfer.

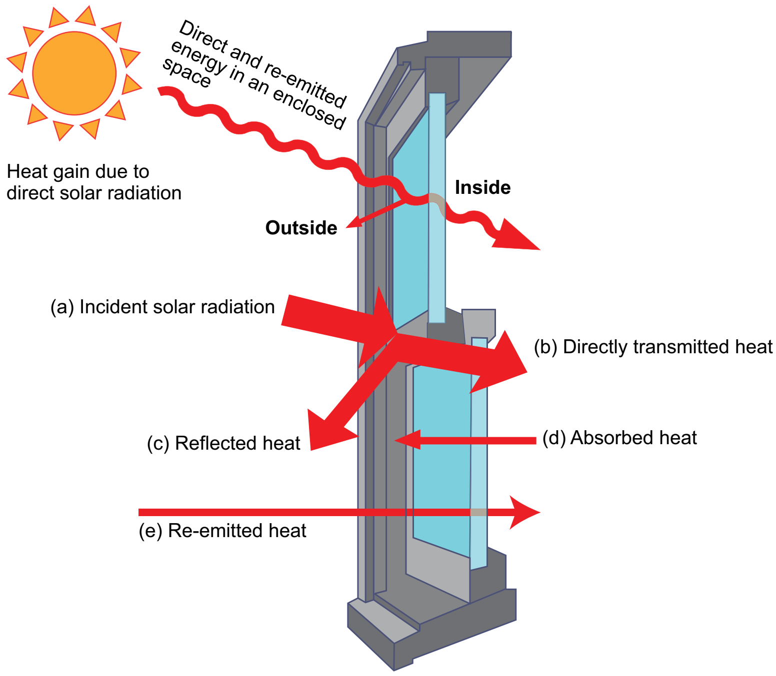


Horizontal shading devices and design implications



Vertical shading devices & design implications

Windows not only allow natural ventilation, but also allow natural light to come inside the house which is beneficial for conducting daily activities and reducing the need for artificial light. A naturally lit house will have substantially low electricity requirements for lighting fixtures. However, along with daylight, sun rays also enter which cause the inside of the house to heat up.

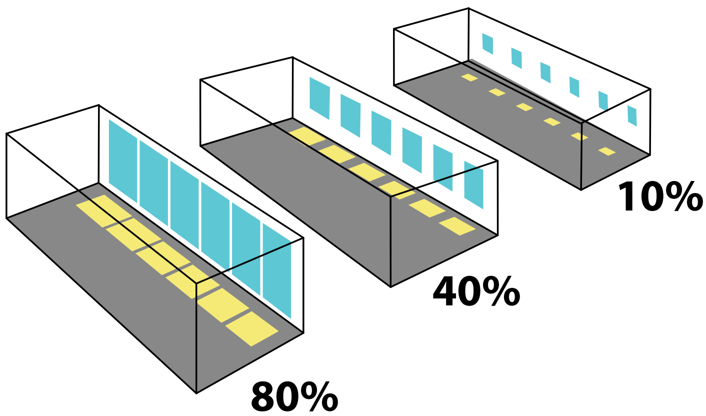


These rays from the sun enter through the glass. A part of it is daylight (which causes little heating) and the other is the part of sunlight which causes heating. Optimum window design is a crucial passive strategy, and the goal is to balance the amount of solar radiation that enters as daylight and as heat.

The most common shading element found in affordable housing projects is the horizontal chajja (overhang). Projection factor enables designers to establish the shading impact of the chajjas and is calculated as can be seen in working example.

5) Window-to-Wall Ratio (WWR)

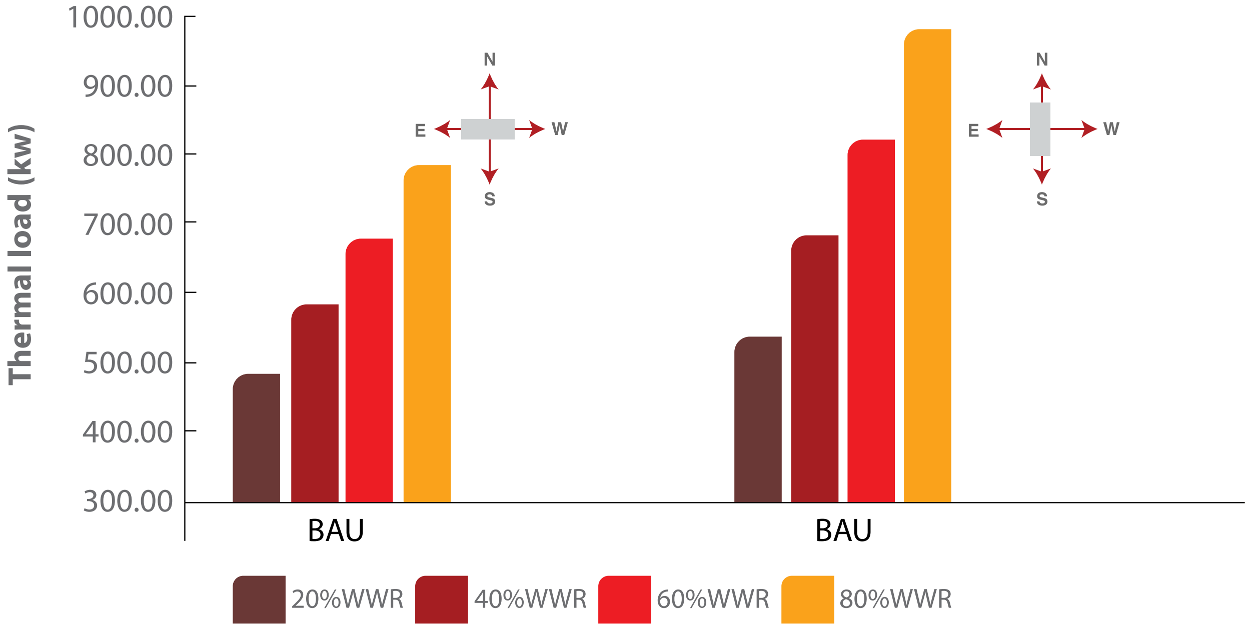
Another passive design strategy to control the heat gain in buildings is through optimizing the ratio of window (glass) area to total wall area, referred to as WWR. Greater WWR would mean more sun will enter through the windows (or transparent/ translucent ventilators, doors, etc.) besides the usable day light.



$$WWR = A_{non\text{-}opaque} / A_{opaque}$$

Figure 3.w shows that the need for cooling is higher in buildings with higher WWR. The lowest cooling needs were in a building which incorporated the following strategy: a) Longer façade facing N-S b) Lower WWR.

Figure 3.r Effect of WWR on thermal load



WORKING EXAMPLE

Calculation of WWR in multifamily apartment buildings

STEP ONE 01 **$A_{non-opaque}$ calculation**

Calculate the total non-opaque (transparent/translucent panels of windows, doors, ventilators, etc.) area of the building envelope for each dwelling unit, as seen in Table 3.

STEP TWO 02 **A_{opaque} calculation**

Calculate the total envelope area (excluding roof) of dwelling units of the building block. For each wall of the building surface (exposed to the outside), calculate the gross wall area (i.e., overall area of a wall including openings such as windows, ventilators, and doors, with measurement taken horizontally from outside surface of one corner to outside surface of another corner and measured vertically from the top of the floor to the top of the roof). Add the gross wall area of all the walls to get the total surface area (excluding roof) for the whole building to get A_{opaque}. Walls facing open corridors and enclosed shafts, as well as walls of common services such as lifts and staircase are to be excluded.

STEP THREE 03 **$WWR\,\% = A_{non-opaque} / A_{opaque} \times 100$**

Tables 4 and 5 represent a sample calculation of WWR of a multifamily apartment block.

Table 4: Calculation of non-opaque area of building envelope (Step 1)

Orientation	Opening name	Opening area (m^2)	Non-opaque (glass) area in opening (m^2)	No. of openings	Total opening area (m^2)	Total non-opaque (glass) area (m^2) $A_{non\text{-}opaque}$
North	W1	1.92	0.64	56	107.52	35.62
North	W2	1.04	0.35	56	58.24	19.26
North	W3	1.28	1.28	56	71.68	71.68
North	D	1.88	0	56	105	0
South	W1	1.92	0.64	56	107.52	35.62
South	W2	1.04	0.35	56	58.24	19.26
South	W3	1.28	1.28	56	71.68	71.68
South	D	1.88	0	56	105	0
Total					**684.88**	**253.16**

Table 5: Calculation of non-opaque area of building envelope (Step 1)

Orientation		Area (m^2)
North	Non-opaque (glass) area	126.56
	Opaque area 1 (AAC wall)	743.83
	Opaque area 2 (PVC panel in doors and windows)	215.88
South	Non-opaque (glass) area	126.56
	Opaque area 1 (AAC wall)	743.83
	Opaque area 2 (PVC panel in doors and windows)	215.88
East	Non-opaque (glass) area	0
	Opaque area 1 (AAC wall)	652.86
	Opaque area 2 (PVC panel in doors and windows)	0
West	Non-opaque (glass) area	0
	Opaque area 1 (AAC wall)	652.86
	Opaque area 2 (PVC panel in doors and windows)	0
Total Envelope Area or A_{opaque}		**3478.26**

WWR % = $A_{non\text{-}opaque}$ / A_{opaque} x 100

= 253.16 / 3478.26 x 100
= 7.2%

6) Solar Heat Gain Coefficient (SHGC) and Visual Light transmittance (VLT)

The Solar Heat Gain Coefficient (SHGC) factor of window glass is the ratio of heat transferred to the indoors to the total amount of sun ray's incident on the glass.

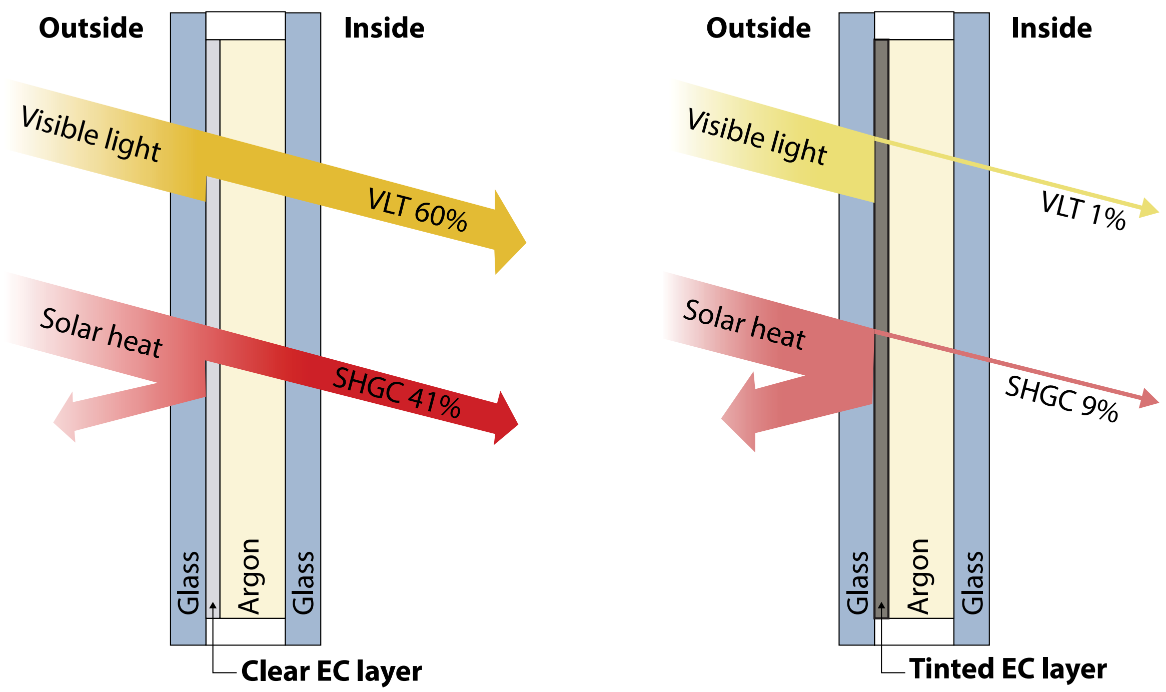
As a rule of thumb, designers must focus on:

1. Providing optimzed shading – This will reduce the overall sun rays falling on the glass in summer and allow useful solar radiation inside during winters.
2. Use of low e-glass, window tints or reflective coatings in warm climate zones.

However, consideration of VLT levels to ensure adequate use of Day lighting is relevant to maintain low energy consumption. Visible Light Transmittance factor determines the visual performance of windows. Visible Light Transmittance indicates the percentage of the visible portion of the solar rays that is transmitted through the glass. Clear glass transmits nearly 80-90% of visible light while blue and green tinted glasses provide VLT levels in the range of 35% to 80%.

Glazing units engineered with microscopically thin coatings that render low emissivity properties (Low e-coatings) can cut transmission of IR and UV radiations without any interference to visible light transmission.

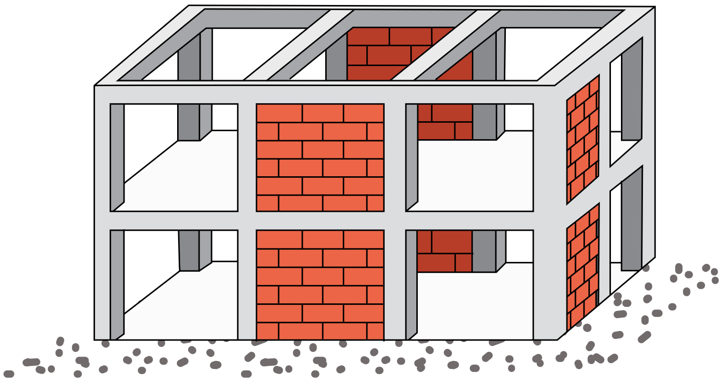
Technological advancements such as low e-coatings make minimizing solar heat gains possible while higher amount of daylight is experienced by the buildings.



भाग ४: Walling

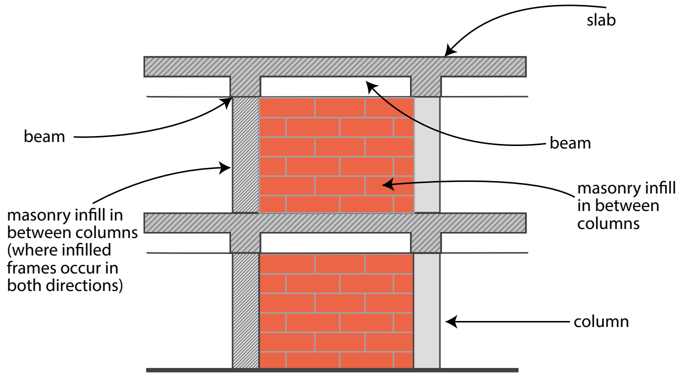
Walling and roofing have two functions, providing the structure/skeleton for the building and forming the envelope that contains the built volume. Selection of building materials in building envelope is significant as it affects the thermal comfort of the occupants and energy consumption.

STRUCTURAL SYSTEM



Most multi-family buildings are built using an RCC frame structure. The infill walling materials are chosen according to considerations of availability and cost. This choice has a major impact on the thermal performance of the building. An RCC frame with Aerated Lightweight concrete block as infill walling is found to be optimal for warm climates.

An increasing trend toward monolithic RCC construction has been noticed. Pre-cast RCC panel systems are also being proposed for speedy construction. These systems incur higher embodied energy of construction. External envelope walls of solid concrete require an integrated or added layer of insulation in order to meet the minimum energy efficiency requirement and thermal comfort requirements.



THERMAL PERFORMANCE OF WALLING MATERIALS

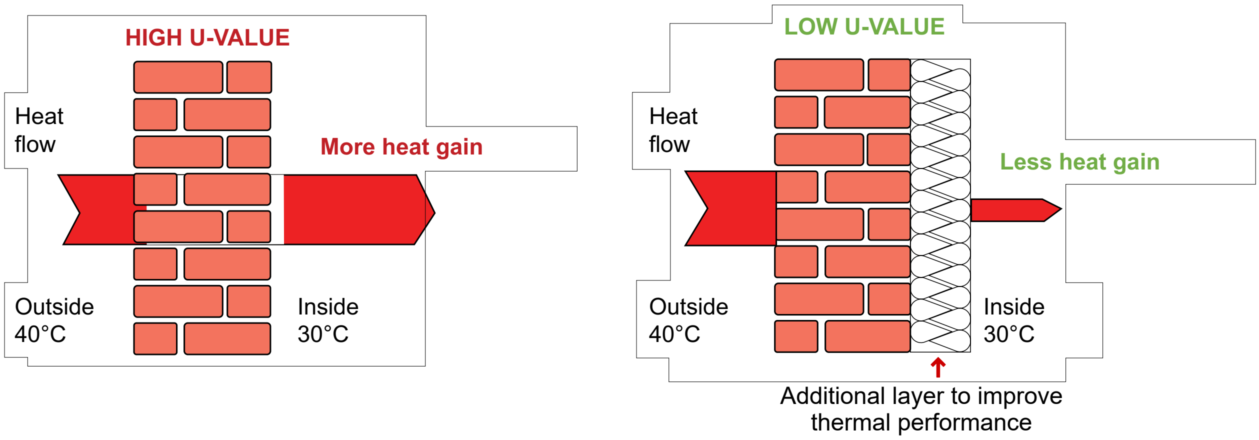
How effectively the enclosing walls of a house protect the house from the uncomfortably hot and cold weather outside, is the measure of their thermal performance. Two properties of a wall affect its thermal performance:

1. **Thermal conductivity –** The ability or the capacity of the material to conduct heat.

2. **Thermal capacity (or Thermal mass)** – The capacity of the material to absorb the heat and store it.

U-factor (Thermal Transmittance): The rate of transfer of heat through a structure (which can be a single material or a composite), divided by the difference in temperature across that structure. It depends on the thermal property as well as the thickness of the material. The lower the u-value, the lower is the flow of heat and therefore the heat gain.

Figure 3.s Dependence of U-value and heat transfer on wall thickness and assembly



Thermal Conductivity and Density

It is seen that the thermal conductivity of the walling material increases with its density. For external walls that are exposed to the outside heat or cold, it is desirable to use a walling method that has low thermal conductivity with a reasonable density. Lightweight concrete blocks or lower density fired clay bricks would be the preferred choices.

Selection of walling materials and wall construction type

The current common practice for building walls in multistorey residential buildings uses blockwork masonry. The wall thickness provides a measure of insulation and thermal capacity. Fired clay brick has been the most common material for walls. The properties of the brick vary considerably from region to region depending on the type of soil available and the method of manufacture and the density of the brick. Other options are also available like fly ash blocks, solid or hollow concrete blocks and lightweight aerated concrete blocks, etc.

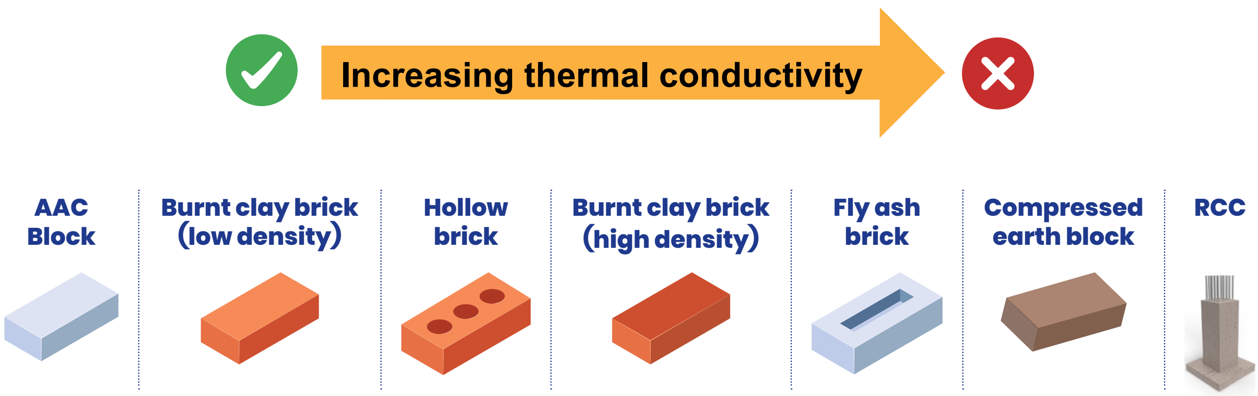
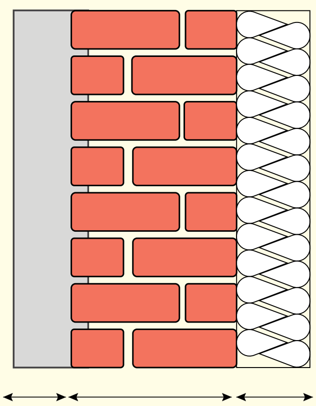


Table 6: Table showing thermal conductivity and density of various materials

S. no.	Types of materials	Density (kg/m³)	Thermal conductivity (W/m².K)
1.	Solid Burnt Clay brick	1440	0.620
2.	Solid Burnt Clay brick	1600	0.740
3.	Solid Burnt Clay brick	1760	0.850
4.	Solid Burnt Clay brick	1920	0.980
5.	Resource efficient (hollow) brick	1520	0.631
6.	Fly ash brick	1660	0.856
7.	Solid concrete block 25/50	2427	1.396
8.	Solid concrete block 30/60	2349	1.411
9.	Aerated autoclaved concrete (AAC) block	642	0.184
10.	Cement stabilized Earth block (CSEB)	1700	0.926
11.	Dense concrete	2410	1.740
12.	Reinforced concrete cement	2288	1.580

WORKING EXAMPLE

Wall Assembly



$$R_1 = \frac{t_1}{k_1} \qquad R_2 = \frac{t_2}{k_2} \qquad R_3 = \frac{t_3}{k_3}$$

U-value of the wall assembly = $\frac{1}{R_1 + R_2 + R_3}$
(Unit: W/m².K)

Where

- R is thermal resistance of each construction layer (unit: m².K/W)
- t is the thickness of each material layer (unit: m)
- k is the thermal conductivity of each material (unit: W/m².K)

Table 7: Table showing U value of various building materials

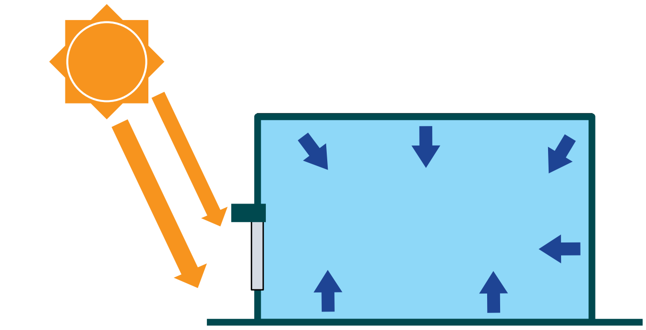
S.N.	Test phase	Wall types	Thickness (in mm)	U value (W/m².K)
1	1	Base case: Burnt clay brick wall	250	2.41
2	1	Rattrap bond wall	250	2.11
3	1	Light gauge framed steel structure with EPS	136	1.37
4	1	Light gauge framed steel structure with PPGI sheet	150	2.12
5	1	Reinforced EPS core panel system	150	0.56
6	1	Glass fibre reinforced gypsum panel – unfilled	124	2.06
7	1	Glass fibre reinforced gypsum panel – with RCC and non-structural filling	124	2.12
8	1	Glass fibre reinforced gypsum panel – with partial RCC filling	124	2.13
9	1	Structural stay-in-place formwork system (Coffer) – insulated panel	230	0.44
10	2	Bamboo Crete	65	2.71
11	2	Wattle and Daub	45	3.61
12	2	Stabilized Adobe	230	2.11
13	2	Laterite Block Wall	205	2.17
14	2	Unstabilized Adobe	230	2.05
15	2	CSEB	230	2.79
16	2	Unstabilized CEB	230	2.74

Thermal Insulation

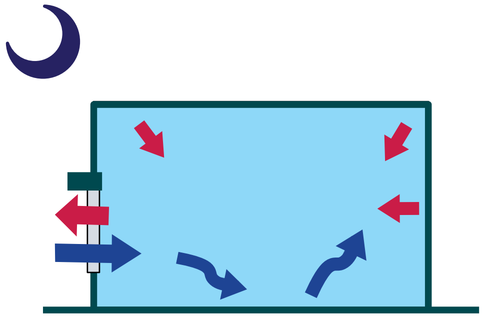
Thermal insulation in building envelope components restricts the heat exchange between indoor and outdoor temperatures. Thermal insulation in building envelope can be added as an additional layer over and above the structural material.

Thermal capacity (or thermal mass)

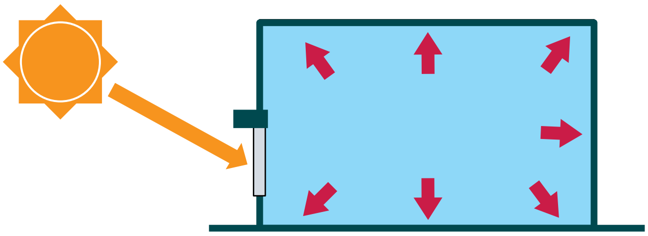
Materials also have capacity to absorb some part of the incident heat. This is quantified as the specific heat capacity of the material. High specific heat of the material also known as high thermal mass, results in more amount of heat storage within the material and consequently less transmission. This can also be achieved by increasing the thickness of the walls and roof, thereby increasing the thermal mass. Heavy and thick walls take longer to heat up and cool down than light and thin walls. High thermal mass has a dampening effect on the temperature variation outdoors during a day and night cycle.



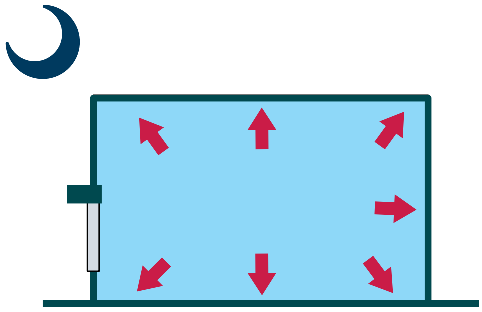
Summer Day: thermal mass will ensure delay in heat transfer to the inside



Summer Night: ventilation at night will help cool the building mass down



Winter Day: Solar heat gets stored in the build mass



Winter Night: the heat stored during the day is radiated inside

This strategy is effective in areas where the difference between the day and night temperatures is substantial.

WORKING EXAMPLE

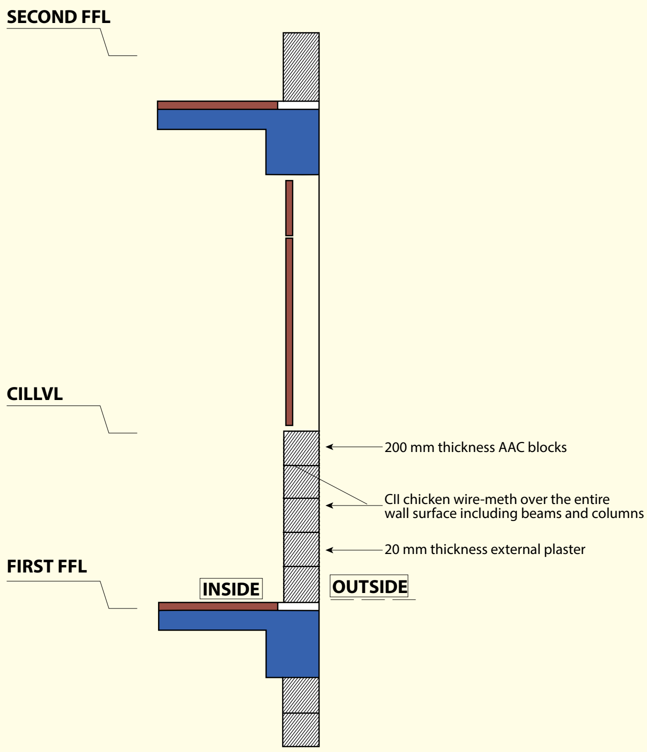
Walling Solution Example (200 mm thick autoclaved aerated concrete blocks)

Description: Autoclaved aerated concrete (AAC) block is a lightweight, load-bearing, and high insulating block that comes in various thickness of 100 mm, 150 mm, and 200 mm. For the construction of external walls, a 200-mm-thick AAC block is recommended. For carrying out masonry work, a non-shrink grout should be added to the mortar. This should be used between the blocks as well as at all junctions of mortar and RCC work.

The internal and external surfaces of the 200-mm-thick AAC wall should be provided with a GI chicken wire-mesh over entire AAC block masonry including overlap at concrete-masonry junctions. This would help in avoiding shrinkage cracks in the future.

U-value: 0.77 W/m².K

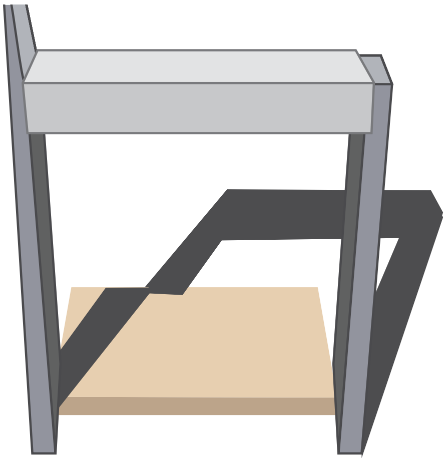
Effect of thermal mass and solar in heat transfer



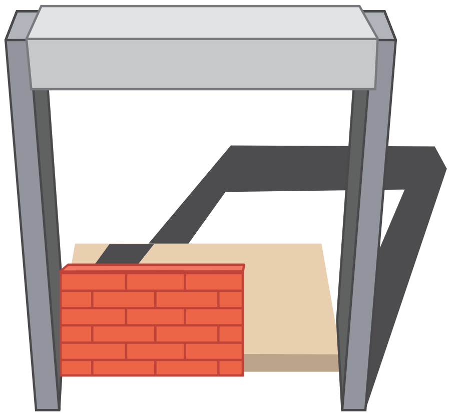
Item description of BOQ for Overdeck insulation:

Providing and constructing AAC Block masonry conforming to IS 2185 Part 3 with approved quality factory made Grade 1 AAC blocks of dry density of 551-650 kg/cum, compressive strength of 4 N/sq.mm, water absorption is less than 15%, thermal conductivity less than 0.24 $W/m^2.K$ and as approved by EIC and approved method statement.

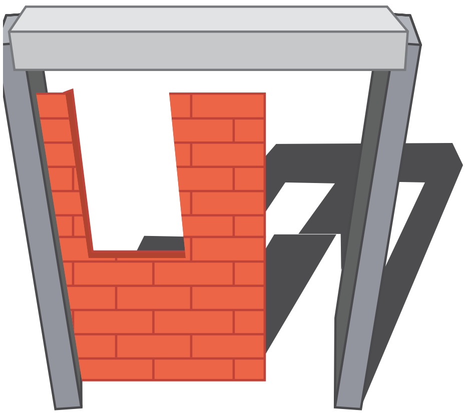
WORKING EXAMPLE



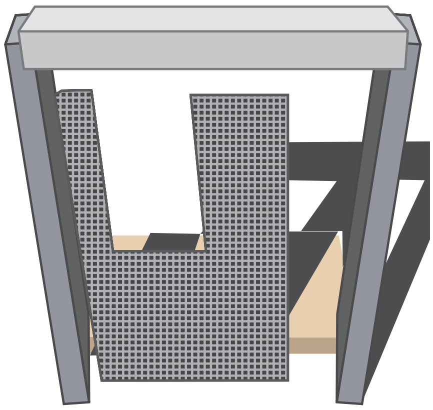
1 Laying leveling course (about 40 mm) to begin brickwork from a flat surface



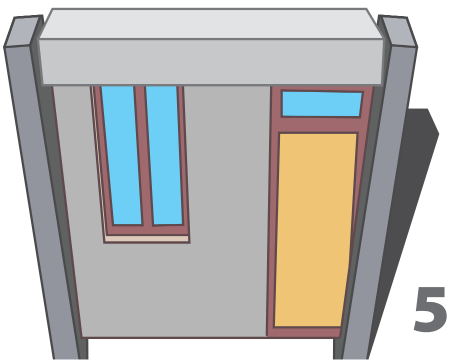
2 Laying 200 mm x 200 mm x 400 mm AAC blocks



3 Raise the wall and provide openings for doors and windows



4 Fix GI chicken wire-mesh over the entire surface of blocks and structure overlap



5 Plaster the wall and fix door and windows

भाग ५: Cool Roofs

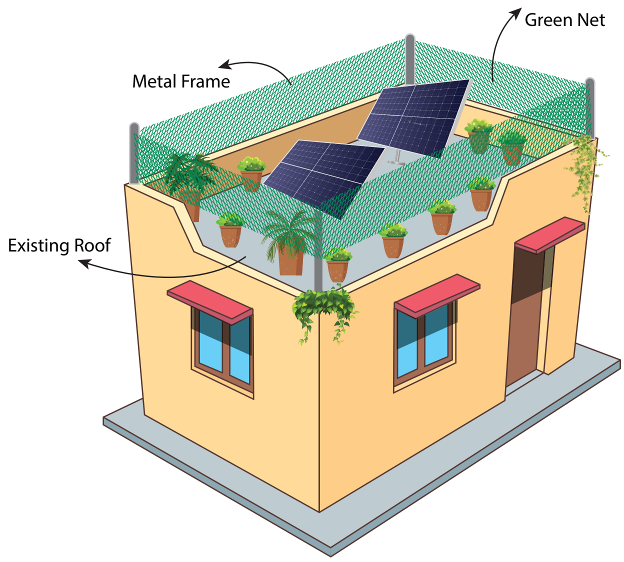
The roof experiences maximum heat gain from the Sun's direct rays. The top floors suffer the most during summers as they get additional heat from the roof. If the roof is of a dark finish, it will absorb the heat of the Sun's rays and become extremely hot. The hotter the surface of the roof the more heat will be transferred to the room below.

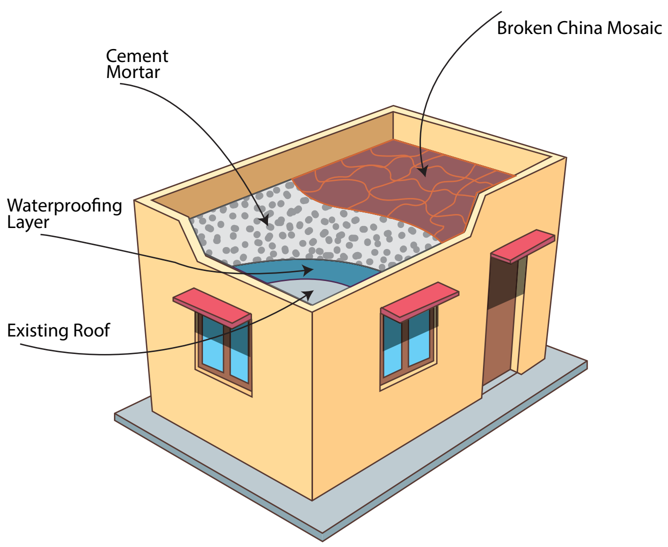
Cool roofs are helpful in reducing heat gain, providing thermal comfort, reduce the air-conditioning requirement and help in mitigation of carbon.

Strategies like orientation do not play any role in preventing heat gain through the roof. For preventing heat gains through the roof, the strategies can be threefold:

1. Shade

Shading the roof surface using light weight framed structures. Installing solar PV over the roof also helps shade the roof surface. Vegetation can also be used to cover the roof surface and protect from Sun's rays.



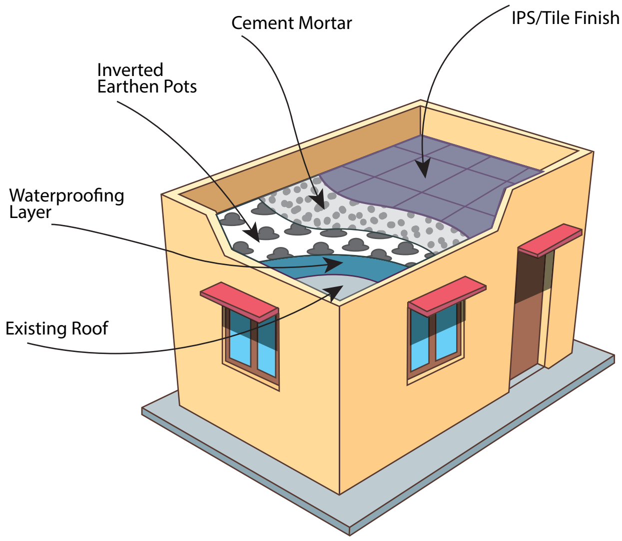


2. Reflect

Reflect majority of the direct Sun rays falling on the surface. This can be achieved by using a light-coloured roof finish such as china mosaic/tiles, or lime wash, or a heat reflective paint to reflect the sun's rays.

3. Insulate

Use layers in the roof assembly that prevent heat transfer to the inside. Using insulation material such as Extruded polystyrene (XPS) or EPS insulation layer or mud phuska or air cavities created using inverted earthen pots are all ways of achieving insulation on the roof.



Why a cooler roof?

Roofs receive the maximum heat from the sun out of all the surfaces of a building. For cooler buildings, we need to prevent this heat from transferring inside the building.

Blocking. *Blocking the sun rays from falling on the roof*

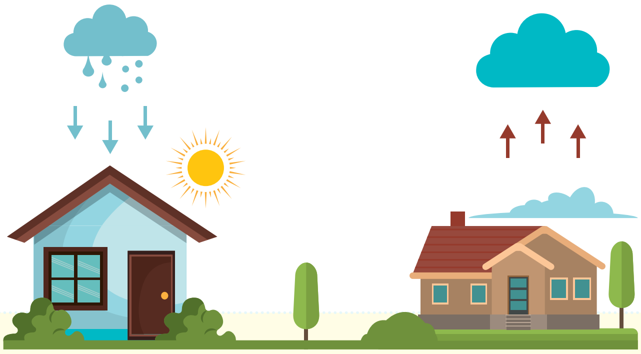
What is a cool roof?

Cool roofs prevent rooftops of buildings from heating up due to the sun rays. Cooler roofs keep the indoor temperatures of the housing at comfortable levels.

Reflecting. *Reflects the sun rays away from the building*

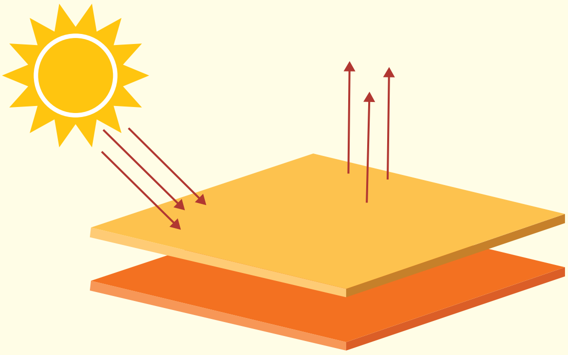
How do they work?

Roofs become cool roof by **blocking, reflecting or stopping** the heat from the sun.



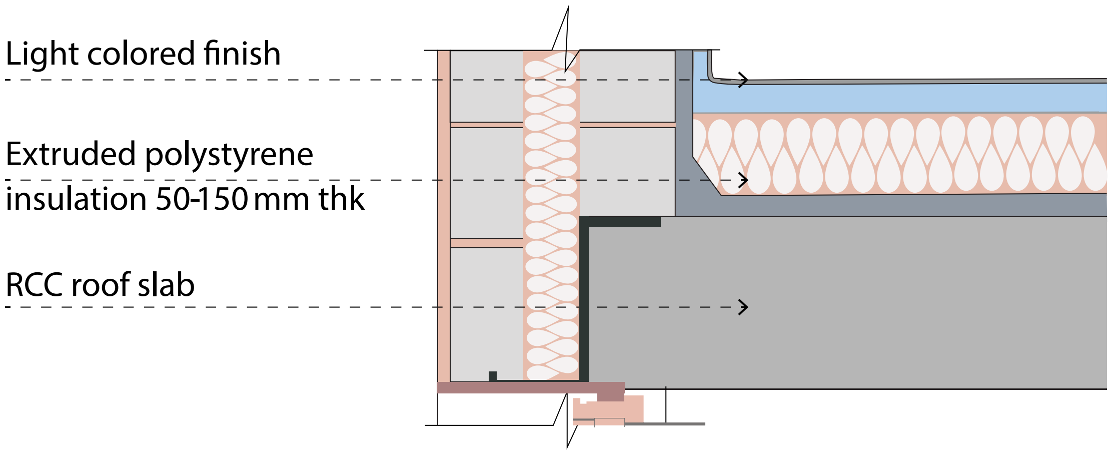
Cool roofs essentially **reflect** the sun away from the buildings, keeping the indoor spaces of buildings cooler. Also, the small amount that is absorbed by the roof is also **emitted** back to atmosphere.

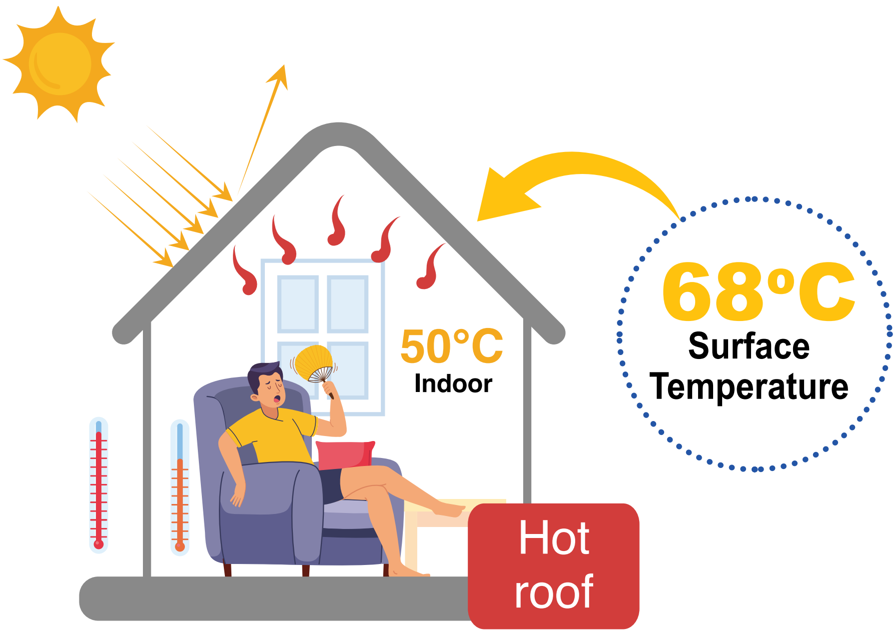
Roofing materials that have high reflectance and high emittance are termed as having high SRI (Solar reflectance Index). Aged SRI considers the effect of weathering due to environmental factors and is measured on a scale of 0-100.

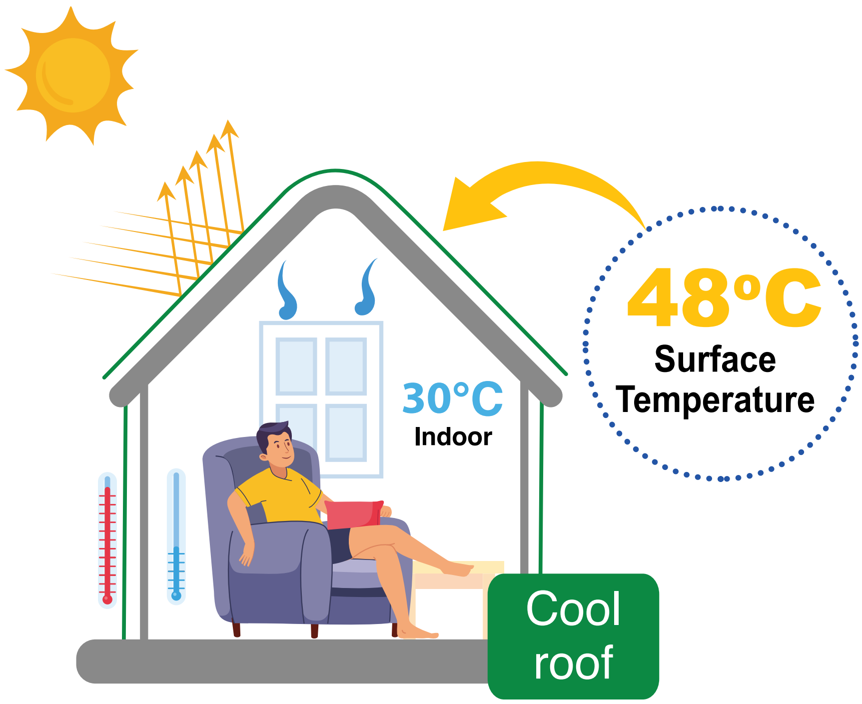


Variety of materials and colours are available for both newer buildings and older buildings. **Cool roof paints and coatings** are one of the easiest and cost-effective way to achieve cool roofs with low investments.

Insulation can also be added in the roof, such as XPS or coated with concrete with EPS balls. The final coating can then be covered with cool roof paints for added advantage.

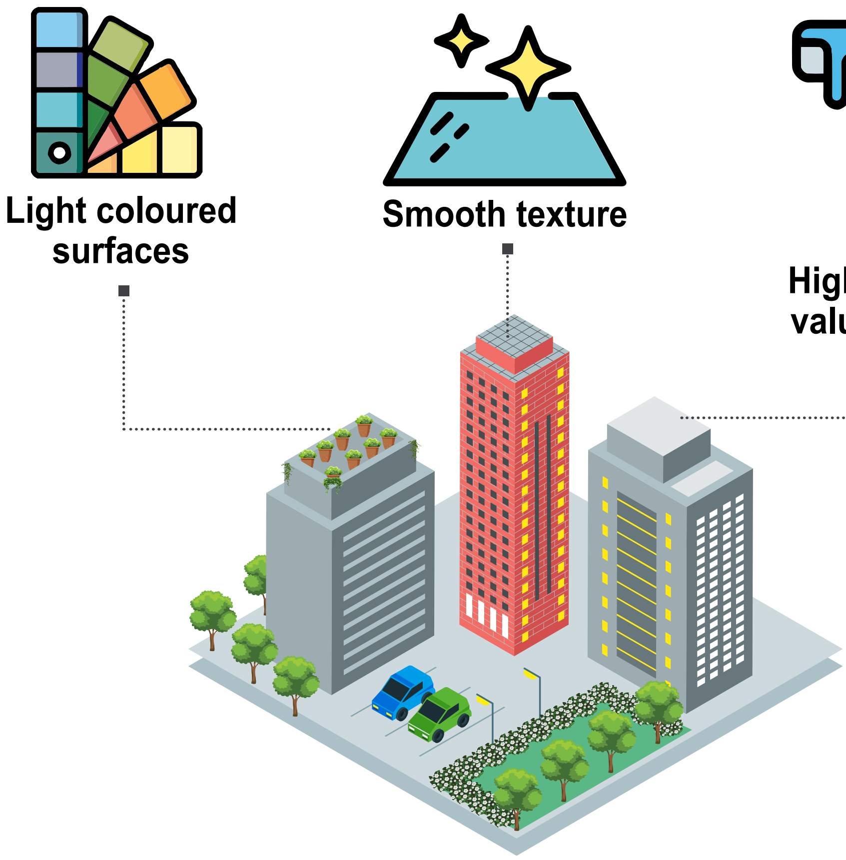






Strategies for Cool Roofs

Implementing cool roof strategies can significantly reduce the heat gain in buildings, lower energy consumption for cooling, and contribute to a more comfortable indoor environment. It's important to consider factors like local climate, building design, and specific roofing requirements when selecting and implementing cool roof strategies. Some strategies are as following.

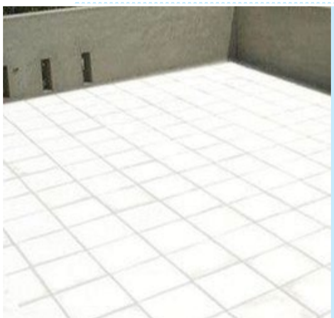


China Mosaic

Colour- White
Texture - Smooth
SRI - High

Cool roof tiles

Colour- White
Texture - Smooth
SRI - High



Cool roof paint

Colour- White
Texture - Smooth
SRI - High

Thermocrete

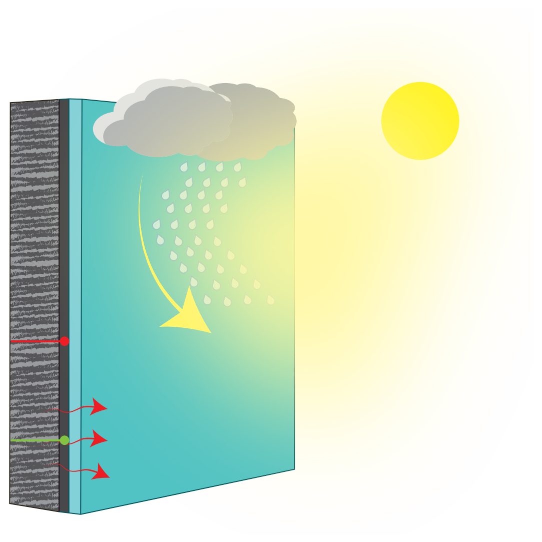
U-value - Low

COOL WALLS

A "cool" wall is a type of exterior wall that stays cool in the sun by reflecting sunlight and emitting heat.

Exterior walls are closer to the ground and receive roughly half as much sunlight as roofs. A city may have far more wall space than roof space. As a result, just like dark roofs, dark walls can heat up buildings, compromising thermal comfort and exacerbating the urban heat island effect.

A cool wall is similar to a cool roof in that both have high reflectivity and emissivity, which helps to keep the building cooler and reduce energy use.



***Wall paints** are available which can reduce the surface temperature of the wall by 10–15ºC. Indoor temperatures can drop by 3–4ºC.*

*Coating exterior walls with **solar-reflective paints** can lead to substantial energy savings in hot climates while curbing pollution.*

BENEFITS AND IMPACT OF COOL ROOF

Cool roofs provide energy savings, improve comfort, extend roof lifespan, cool cities, and have environmental benefits. Cool roofs can reduce energy consumption by 20–30% of top floor, lowering the energy bills for homeowners and businesses.

Costing

	Name	Costing*/ sq.ft	Drop in indoor temperature
1	Cool roof paint	25	2–4°C
2	China mosaic	137	1–2°C
3	Shading (green mats)	175	2.5–3°C

*All these costs are indicative and estimated in 2023. Actual cost may vary from vendor to vendor.

The beneficiaries will benefit from these low-cost (mainly one-time) operational cool roof alternatives by having more thermal comfort without having to use more energy to maintain comfortable indoor temperatures.

WORKING EXAMPLE

Cool roof through High SRI paint

Many high SRI paints are available in the market which are good at keeping the rooftop cool by reflecting the sun rays. Apply SRI paints with minimum SRI value of 0.7.

Materials required: base coat, reflective paint and polymer-silicon based reflective coating

STEP ONE 01 Ensure a level surface by lightly chipping away unevenness. Wash thoroughly after.

STEP TWO 02 Mix the white coating powder with water to make a workable base coat. Apply the base coat using paint brush evenly and dry for minimum 2 hrs.

STEP THREE 03 Apply the reflective paint. Add thinner if too viscous to make it workable. Apply two coats over base coat. Dry the paint for min. 2-3 hrs on a bright sunny day.

STEP FOUR 04 Apply a final coating of polymer-silicon based reflective coating. This coating provides water proofing and is shinier hence enhancing reflection properties.

WORKING EXAMPLE

Cool roof through Shading

Being the most basic strategy, shading is an efficient strategy to provide thermal comfort and keep the roof temperatures low. Depending on the type of material used for shading, one can achieve 100% shading.

Shading options: Green mats, GI sheets or PV panels, if that is feasible for the project

Materials required: MS Hollow section, shading material

STEP ONE 01

Prepare a framing plan for the shading and ensuring the unanchored span of the shading material does not exceed 6 feet. For this span and lighter shading material, MS hollow sections of 50mmx50mmx5mm is good enough. However, this may change, and the right size be chosen based on weight of shading material. Height of the frame can be 8-10 ft. MS strips are welded to MS sections to clamp it with wall.

STEP TWO 02

Construct the MS frame and weld at necessary joints and apply corrosion resistant coatings on MS hollows sections.

STEP THREE 03

The shading material to be used can be cut into required sizes as per the availability of the raw material. Fasten the shading material on the frame using GI wires (for green mats) or bolts or screws (for GI sheets) and ensuring overlapping.

Additionally, GI sheets can be painted with cool roof paints which will prevent the material to heat up, further improving the performance of the roof. Rooftop solar is also an efficient shading strategy and should follow the procedure of qualified personnel.

Step 1

Step 2

Step 3

WORKING EXAMPLE

Cool roof through China Mosaic tiles

Using broken China mosaic tiles, the purpose is to create a reflective surface which reflects the sun rays away from the roof top and keeping it cooler. Light coloured broken tiles are tightly placed on a mortar bed and the gaps are filled with white cement.

Materials required are: Broken China mosaic tiles, white cement, Portland cement, aggregates (10-20mm), coarse sand.

STEP ONE 01 Ensure a level surface by lightly chipping away unevenness. Wash thoroughly after.

STEP TWO 02 Mix the white coating powder with water to make a workable base coat. Apply the base coat using paint brush evenly and dry for minimum 2hrs.

STEP THREE 03 Apply the reflective paint. Add thinner if too viscous to make it workable. Apply two coats over base coat. Dry the paint for min. 2-3 hrs on a bright sunny day.

STEP FOUR 04 Apply a final coating of polymer-silicon based reflective coating. This coating provides water proofing and is shinier hence enhancing reflection properties.

Step 1

Step 2

Step 3

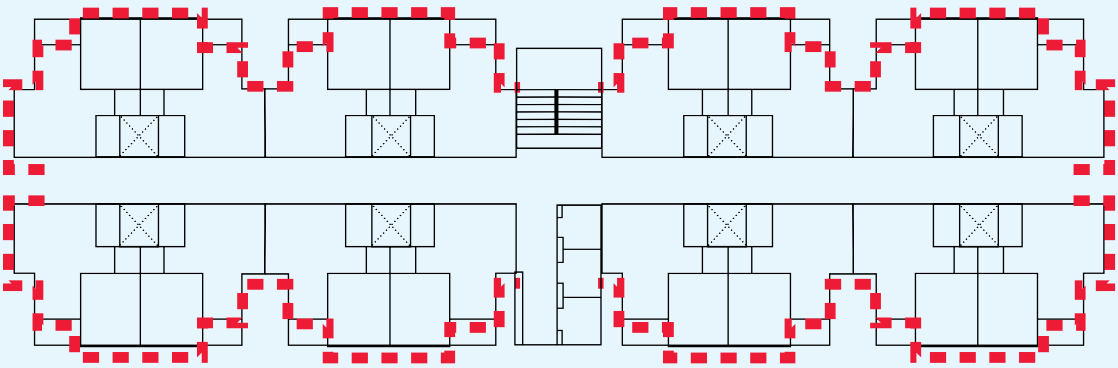
Step 4

Table 8: Summary of Recommendations

	Hot and Dry	Warm and Humid	Composite	Cold	Temperate
Massing	Compact building with shared walls and mutual shading	Open, staggered layout to promote air movement	Compact building with shared walls, open to winter sun	Living spaces oriented to capture south sun	Open layout to promote thermal comfort
Building Plan	Minimum external wall area, with elements like courtyards and cool roof	Minimum external wall area while ensuring cross ventilation with courtyards, verandahs and louvers for wind	Minimum external wall area while allowing cross ventilation, with elements like courtyards, window shading and cool roof	Minimum external wall area with living areas having openings and sun balconies facing south	Minimum external wall area while allowing cross ventilation with elements like window shading and cool roof

GLOSSARY

Building Envelope: The elements of a building that separate the habitable spaces of dwelling units from the exterior and are exposed to the ambient (i.e., exposed directly to external air and opening into balconies). It does not include walls facing open corridors and enclosed shafts, as well as walls of common services such as lifts and staircase.



Building Envelope. Dotted lines show the walls included in the definition of building envelope.

Orientation Axis Line: The orientation axis line (OAL) in building design is an imaginary line used as a reference for its orientation or direction. An OAL passes through the centre of the building and aligns with the longer side or length or façade of the building. The orientation axis line helps establish the building's alignment with respect to the cardinal directions (north, south, east, and west), to optimize factors such as solar exposure, natural lighting, and energy efficiency.

When it comes to different shapes of buildings, the orientation axis line can be defined as follows:

General form of building: For a building, the orientation axis line shall pass through the centre and align parallel with the longer side of the rectangle.

For example:

H shape: *For an H-shaped building, the orientation axis line shall pass through the centre of the building, aligning parallel with the longer side.*

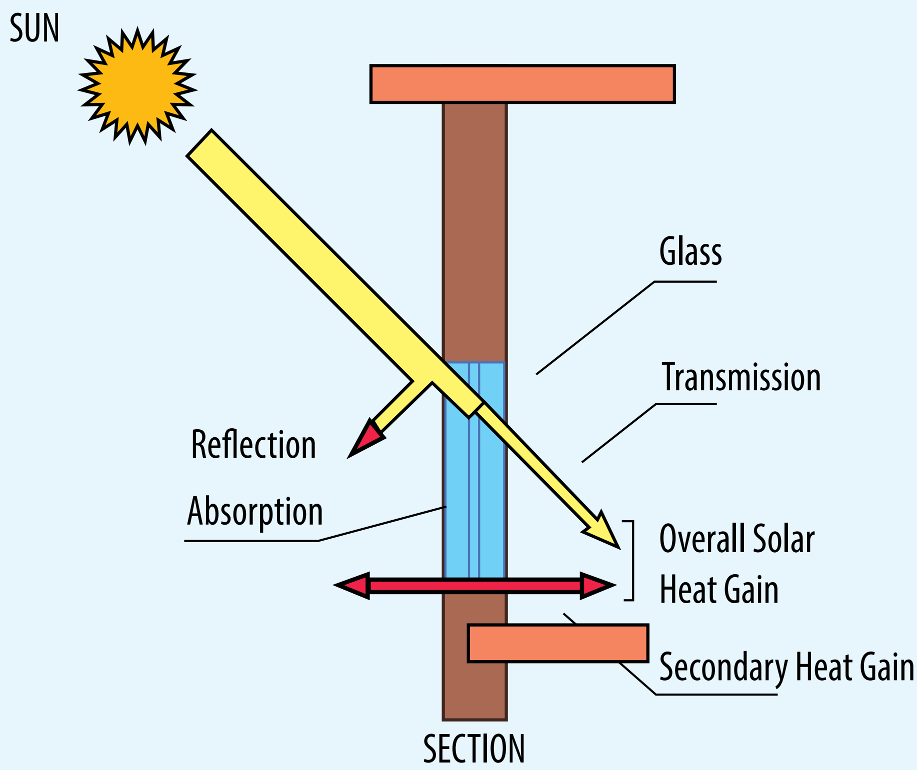
L Shape: *In an L-shaped building, the orientation axis line would pass through the centre of the building, aligning with the longer side or length of the L shape.*

E Shape: *For an E-shaped building, the orientation axis line would also pass through the centre of the building. In this case, the line would align with the longer section of the E shape, which typically connects the two vertical arms of the E. The orientation axis line would follow the length of this central section to determine the building's overall orientation.*

Solar Heat Gain Coefficient (SHGC): SHGC is the fraction of incident solar radiation admitted through non-opaque components, both directly transmitted, and absorbed and subsequently released inward through conduction, convection, and radiation.

A_{opaque}: Opaque building envelope components include walls, opaque panels in doors, windows, ventilators, etc.

$A_{non\text{-}opaque}$: Non-opaque building envelope components include transparent/translucent panels in windows, doors, ventilators, etc.



List of organizations consulted in the development process of PRiTHVi 2

1. Aliah University
2. Amity University
3. Bhubaneswar Development Authority
4. Bhubaneswar Municipal Corporation
5. Central Public Works Department, Kolkata
6. Chandigarh Administration
7. Chandigarh Housing Board
8. Chitkara University
9. Cuttack Municipal Corporation
10. Department of Housing for All, Haryana
11. District Urban Development Agency, Bhubaneswar
12. Greater Mohali Area Development Authority
13. Housing and Urban Development Corporation Limited
14. Karnataka Rajya Nirmana Kendra
15. Karnataka Slum Development Board, Bangalore
16. Kolkata Metropolitan Development Authority
17. Kolkata Municipal Corporation
18. Mahatma Gandhi State Institute of Public Administration, Government of Punjab
19. Mysore Community Biosphere
20. Nirmithi Kendra
21. Odisha Urban Housing Mission
22. Piloo Mody College of Architecture, BPUT
23. Plaksha University
24. Public Works Department, Bangalore
25. Public Works Department, BBSR
26. Punjab Energy Development Agency
27. Punjab Urban Planning and Development Authority
28. Rajiv Gandhi Housing Corporation Limited
29. State Urban Development Agency
30. West Bengal State Designated Agency

List of Private Stakeholders consulted in the development process of PRiTHVi 2

1. Aditi Architects and Planners
2. Altra Group
3. Archi Morph Design Studio
4. BG Shirke Group
5. Brigade
6. Brookefield
7. DTC Group
8. Ernst & Young
9. Ingenious Atelier
10. Mitsumi
11. Nirman Consultancy
12. Outinord Formworks
13. Plan Arch Studios
14. Salient Design Studio
15. SPD Constructions

Climate Smart Buildings Programme

About the programme

The Ministry of Housing and Urban Affairs, Government of India aims to foster sustainability in built environment by use of sustainable materials for Thermal comfort and in turn improve the environment and climate conditions.

The project extends technical assistance and cooperation making affordable housing under PMAY-U, thermally comfortable. The project aims to enhance climate resilience and thermal comfort in buildings by adopting innovative passive measures, local sustainable and low embodied energy material coupled with best available technologies for affordable housing construction.

These building constructed and operated using innovative technologies and appropriate modern products, materials and designs will lead to sustainability in buildings and mitigation of carbon emissions.


Unnamed Road, Sagar, Karnataka 577430, India
WEST COAST
ಪ್ರಧಾನ ಮಂತ್ರಿ
ಆವಾಸ್ ಯೋಜನಾ (ನಗರ)
Pradhana Mantri Awass Yojana-Urban
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