



VOCATIONAL TRAINING

Innovative Construction Technologies for Affordable Housing

Climate Smart Buildings (CSB)

Cluster cell Ranchi, Jharkhand under Global Housing Technology Challenge - India (GHTC-India)

Training #20: Two Day Vocational Training Program at AHP, Bhubaneswar on 18th – 19th March 2023



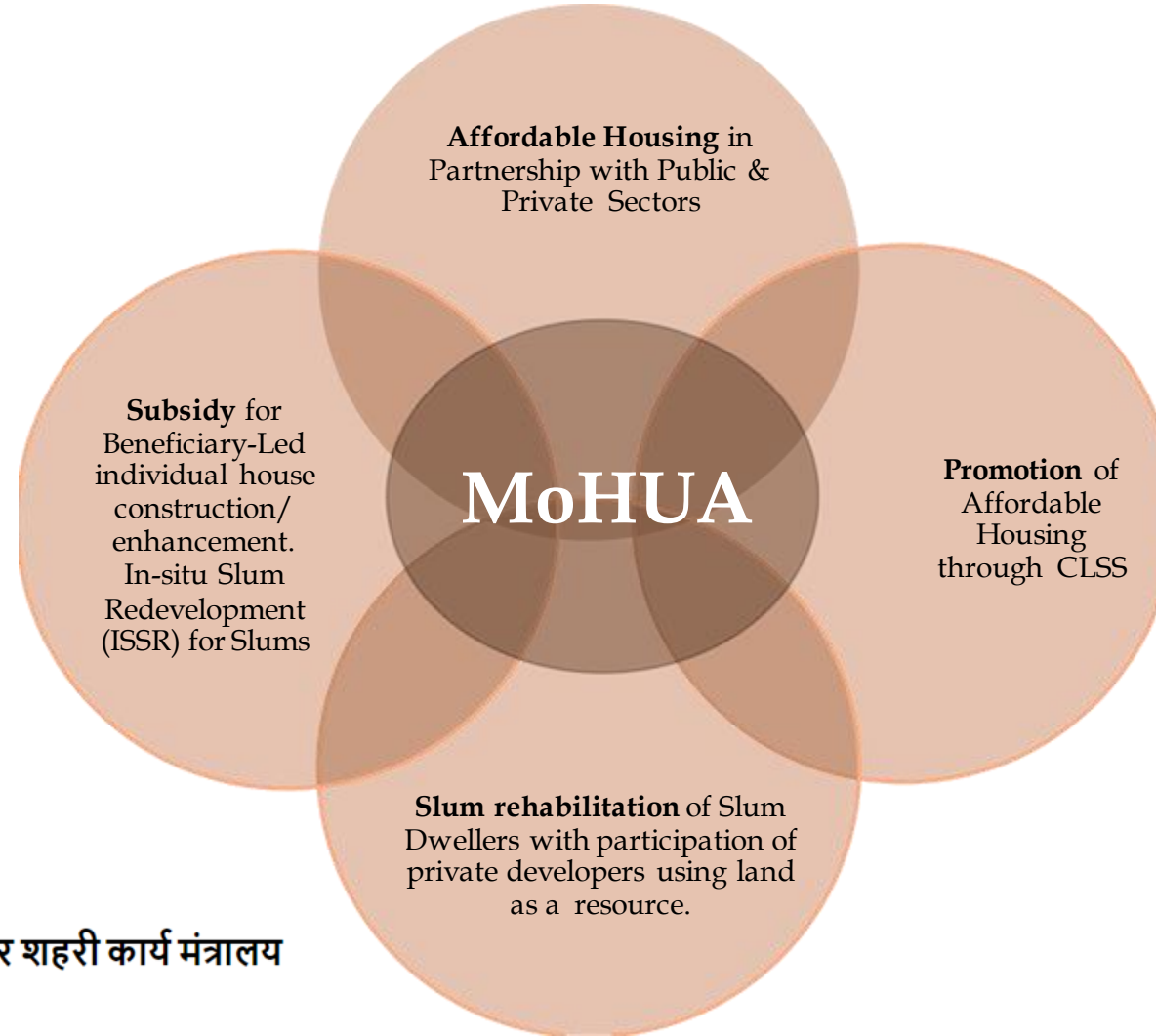
Introduction

INTRODUCTION - MoHUA

'Housing for All' by 2022.

Under the Mission, Ministry of Housing and Urban Affairs (MoHUA), provides Central Assistance to implementing agencies through States and Union Territories for providing houses to all eligible families/beneficiaries by 2022.

Addressing the affordable housing requirement in urban areas through:



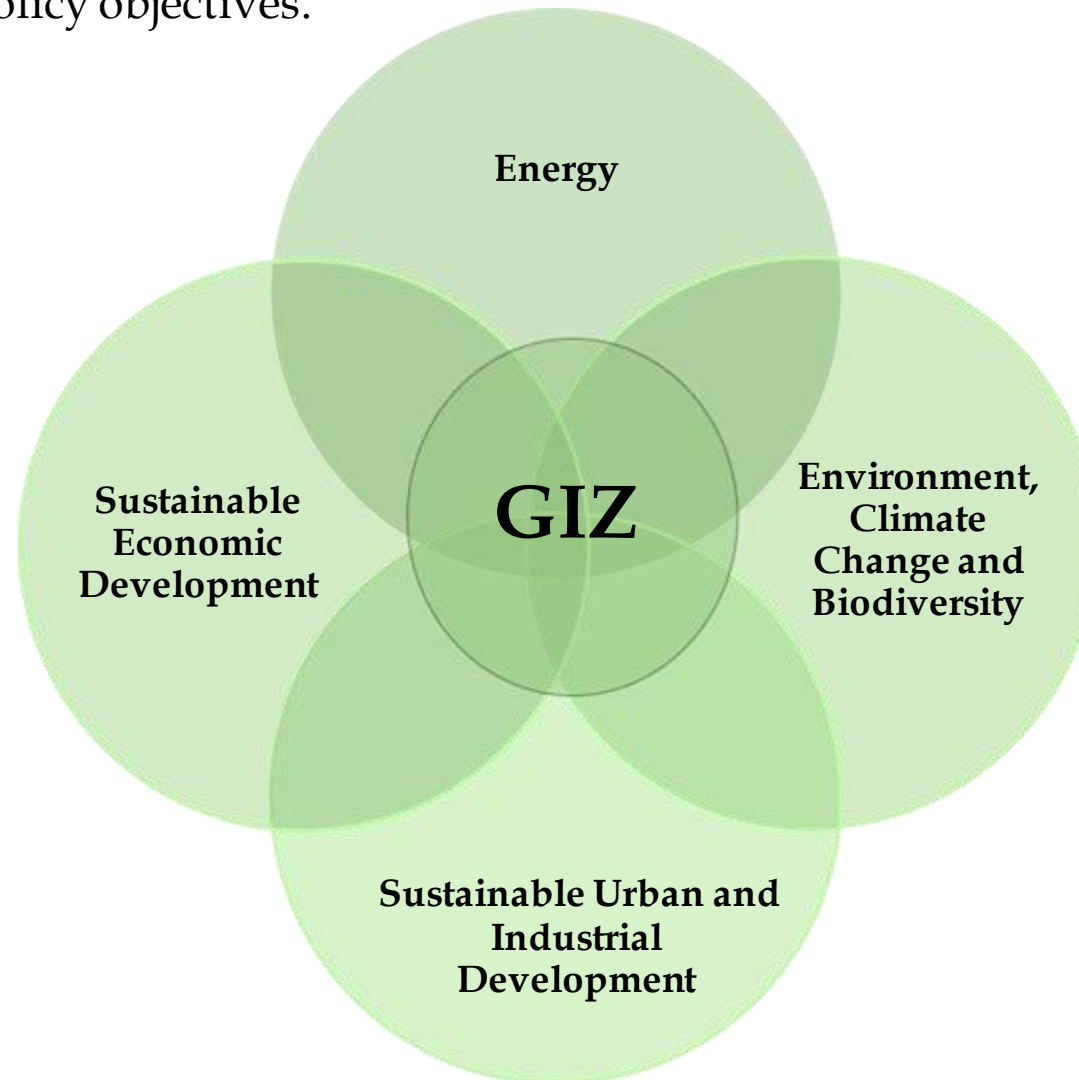
भारत सरकार

आवासन और शहरी कार्य मंत्रालय

सत्यमेव जयते

INTRODUCTION - GIZ

- GIZ is an international cooperation enterprise for sustainable development which operates worldwide, on a public benefit basis.
- GIZ is fully owned by the German Federal Government, GIZ implement development programs in partner country on behalf of the German Government in achieving its development policy objectives.

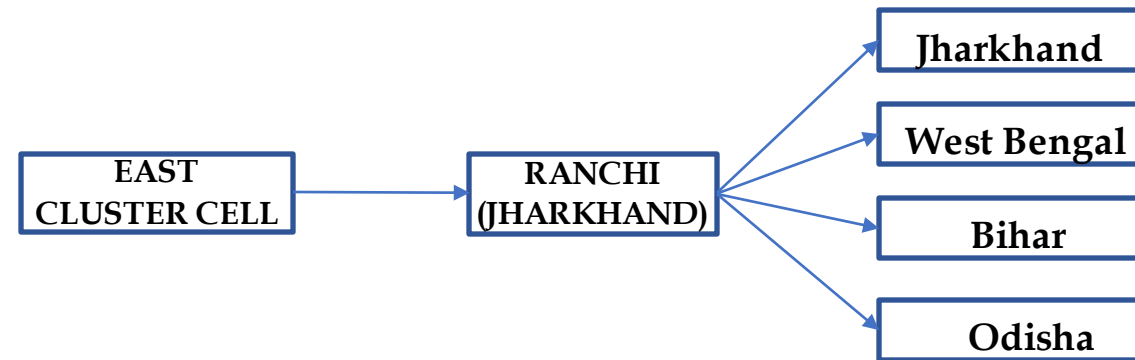


TASKS PLANNED WITH MoHUA

CLIMATE SMART BUILDING

- Technical assistance in developing thermal comfort action plan for climate resilience building for mass scale application in selected states for Affordable Housing
- Technical support in implementation of Global Housing Technology Challenge-India (GHTC-India)

States and UT's under central cluster cell established at Ranchi



भारत सरकार

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सत्यमेव जयते

AIM & CONCEPT



7 AFFORDABLE AND CLEAN ENERGY

Ensure access to affordable, reliable, sustainable, and modern energy for all

9. INDUSTRY, INNOVATION AND INFRASTRUCTURE

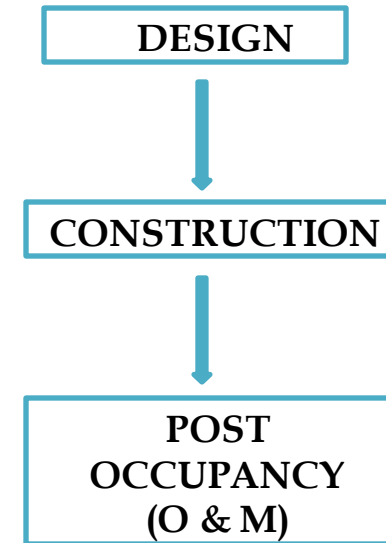
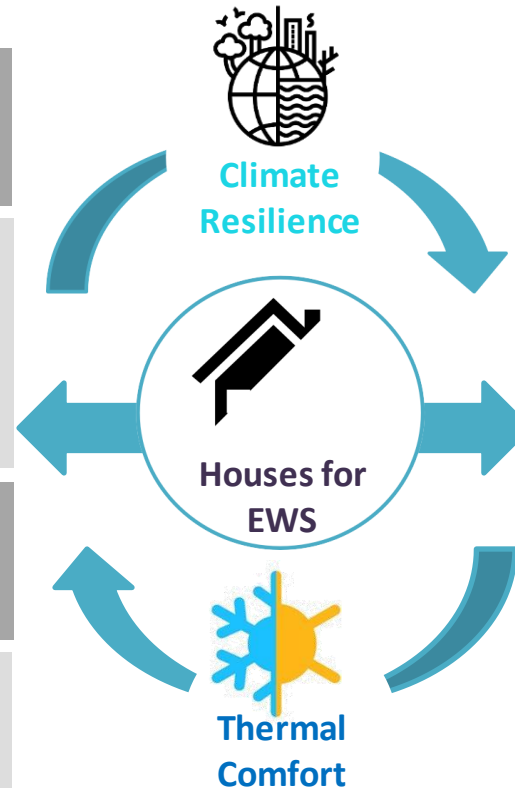
Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation

11. SUSTAINABLE CITIES AND COMMUNITIES

Make cities and human settlements inclusive, safe, resilient, and sustainable

13. PROTECT THE PLANET

Take urgent action to combat climate change and its impacts



INTEGRATION IN BY-LAWS

Session 1

- LHP & its Construction Technology
- GHTC Brief on other LHP Construction Technologies (Video & Presentation)



LHP & its Construction Technology

Light House Project (LHP) at Ranchi, Jharkhand

(Technology: Precast Concrete Construction System - 3D Precast volumetric)



- There are 7 blocks in G+ 8 configuration with 1008 houses along with basic and social infrastructure.
 - Ground coverage of the project is 29.3% and FAR is 2.21.
 - Green space is 20%.
- 16 dwelling units at each floor of building block with provision of lifts and staircases.

Conventional Construction Systems

The prevalent construction systems in India are:

Load bearing Structure

In this system, walls are constructed using bricks/stone/block masonry and floor/roof slabs are of RCC/stone/composite or truss. It is cast in-situ system and called load bearing system as load of structure is transferred to foundation and then to ground through walls.

RCC Framed Structure

In this cast in-situ system, the skeleton of a structure is of RCC column and beam with RCC slab. The infill walls can be of bricks/blocks/stone /panels. The load of the structure is transferred through beam and column to the foundation.



Prevalent Construction Systems

Load bearing Structure

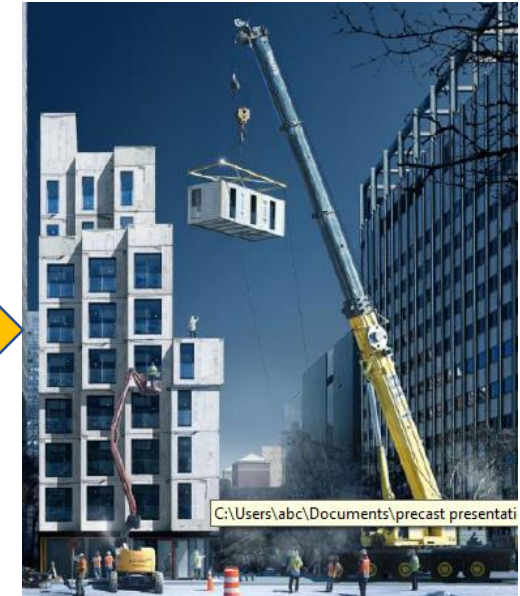


RCC Framed Structure



Technology being Used

Precast Concrete Construction - 3D Volumetric



It is the modern method of building by which precast concrete structural modules like room, toilet, kitchen, bathroom, stairs etc. & any combination of these are cast monolithically in Plant or Casting yard in a controlled condition.

These Modules transported, erected & installed using cranes and are integrated together in the form of complete building unit.

LHP-RANCHI (Precast Concrete Construction System – 3D Volumetric)

Advantages

- Upto 90% of the building work including finishing is complete in plant/casting yard leading to significant reduction in construction & occupancy time
- The controlled factory environment brings resource optimization, improved quality, precision & finish
- The required concrete can be designed using industrial by-products such as Fly Ash, Ground granulated blast furnace slag (GGBS), Micro silica etc. resulting in improved workability & durability, while also conserving natural resources. In this project Ground granulated blast furnace slag & silica fume is proposed in concrete.
- With smooth surface it eliminates use of plaster
- The monolithic casting of walls & floor of a building module reduces the chances of leakage
- The system has minimal material wastage (saving in material cost), helps in keeping neat & clean construction site and dust free environment
- Use of optimum quantity of water through recycling
- Use of shuttering & scaffolding materials is minimal
- All weather construction & better site organization



GHTC Brief on other LHP Construction Technologies (Video & Presentation)

6 LHP ACROSS INDIA



Map showing six different LHP Locations

LHPs shall serve as **LIVE Laboratories** for different aspects of **Transfer of technologies**

Light House Project (LHP) at Chennai, Tamil Nadu

(Technology: Precast Concrete Construction System - Precast components assembled at site)



No. of Dwelling Units : 1152 Nos. (G+5)
No. of Block / Tower : 12 Blocks
Units in each Block / Tower : 96 Nos.



2D Precast Concrete Construction

- Replacing cast in situ RCC structural frame with factory made structural components – 2D planar elements
- Customized Factory made beams, columns, wall panels, slab/floors, staircases etc.



Concrete components prefabricated in precast yard or site and installed in the building during construction



LHP-CHENNAI (Precast Concrete Construction System-Precast Components Assembled at Site)

Advantages

- Quality of construction is enhanced significantly due to pre-casting of components by using sophisticated moulds and machineries in factory like environment, assured curing, assured specified cover to reinforcement, proper compaction of concrete results in to dense and impermeable concrete etc. Thus lesser maintenance cost during lifetime of project.
- Inbuilt eco-friendly method of construction in terms of more off-site works in controlled factory like environment results in to significant reduction in wastage of water, natural resources, air pollution and noise pollution.
- Safety of workforce achieved automatically as most of the works are carried out at ground floor in factory like environment, which ultimately enhances the work efficiency and quality.
- Wooden shuttering material is completely avoided and wastage of other construction materials reduced significantly; which results in to conservation of scarce natural resources like soil, sand, aggregate, wood etc.
- Advance procurement of major construction materials, advance pre-casting of structural components and assured completion of work within stipulated completion period will save cost towards escalation & early returns on investments, thus Substantial cost benefit to the client.

Light House Project (LHP) at Agartala, Tripura

(Technology: Light Gauge Steel Structural System & Pre-Engineered Steel Structural System)



No. of Dwelling Units : 1000 Nos. (G+6)
No. of Block / Tower : 7 Blocks
Units in each Block / Tower : A(112), B(154), C(118),
D(168), E(168), F(168) & G(112)



PRE-ENGINEERED STEEL STRUCTURAL SYSTEM

- Replacing cast in situ RCC structural frame with factory made steel (hot rolled) structural system





Steel skeleton with Aerocon panel infills

LIGHT GAUGE STEEL STRUCTURAL SYSTEMS

- Replacing cast in situ RCC structural frame with factory made light gauge steel (cold rolled) structural system



LHP-AGARTALA (Light Gauge Steel Structural System & Pre-engineered Steel Structural System)

Advantages

- Due to light weight, significant reduction in design earthquake forces is achieved. Making it safer compared to other structures.
- Fully integrated computerised manufacturing of LGSF sections provide very high precision & accuracy.
- Speedier
- Structure being light, does not require heavy foundation
- Structural elements can be transported to any place including hilly areas/ remote places easily
- Structure can be shifted from one location to other with minimum wastage of materials.
- Steel used can be recycled multiple times
- The system is very useful for post disaster rehabilitation work.

Light House Project (LHP) at Indore, M.P.

(Technology: Prefabricated Sandwich Panel System & Pre-Engineered Steel Structural System)

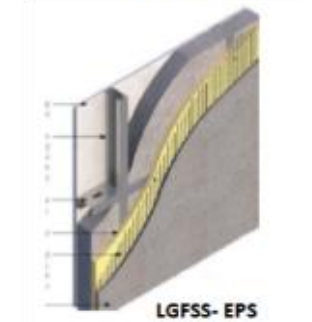
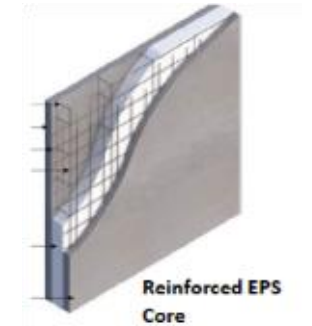
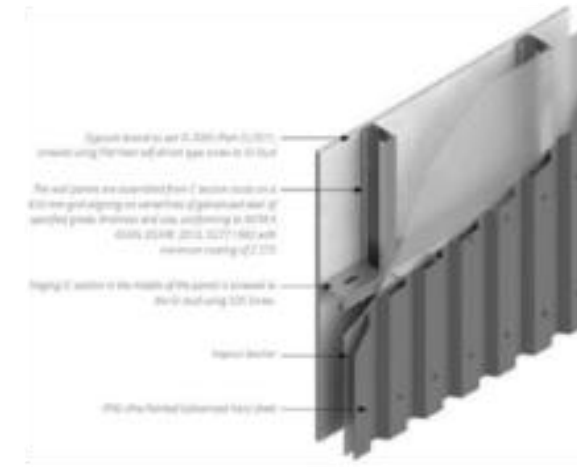
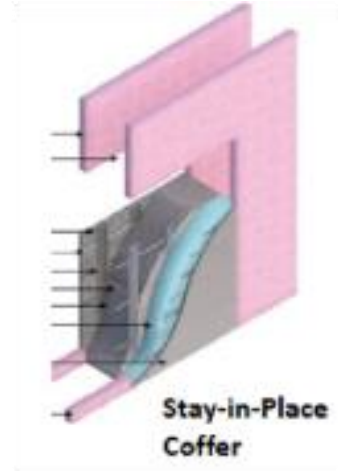
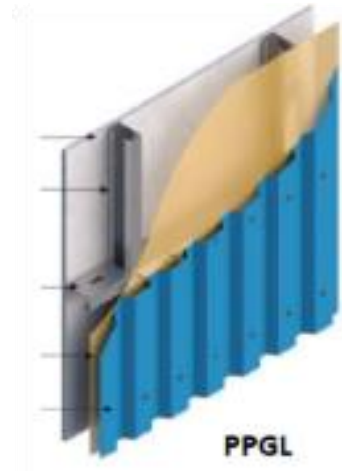


No. of Dwelling Units : 1024 Nos. (S+8)
No. of Block / Tower : 8 Blocks
Units in each Block / Tower : 128 Nos.



PREFABRICATED SANDWICH PANEL SYSTEMS

- EPS Core Panel Systems
- Other Sandwich Panel Systems
 - Fibre cement board
 - MgO Board
 - AAC panels



- **Replacing brick and mortar walls with dry customized walls made in factory**



LHP-INDORE (Prefabricated Sandwich Panel System)

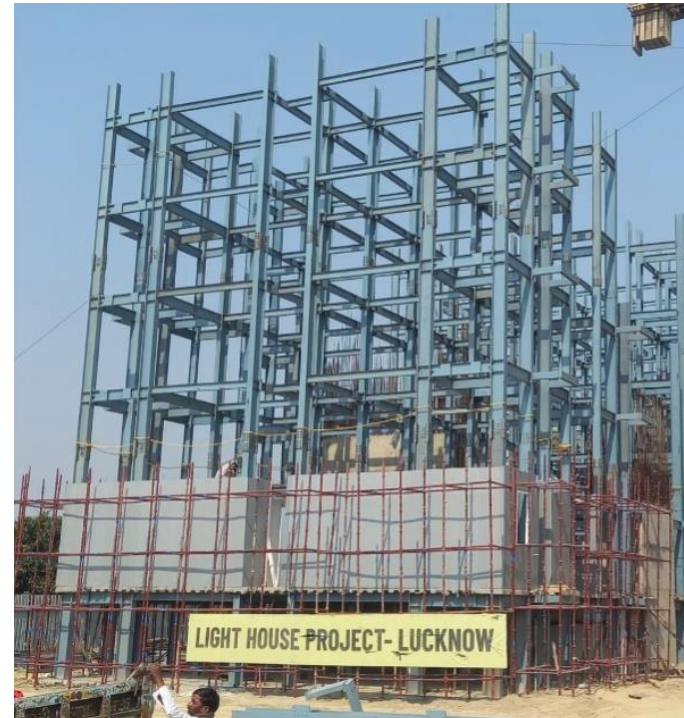
Advantages

- The system is dry walling system, brings speed in construction, water conservation (no use of water for curing of walling components at site).
- The sandwich panels have light weight material as core material, which brings resource efficiency, better thermal insulation, acoustics & energy efficiency
- Being light in weight, results in lower dead load of building & foundation size.

Light House Project (LHP) at Lucknow, U.P.

(Technology: Stay in-place Formwork System & Pre-Engineered Steel Structural System)

No. of Dwelling Units : 1040 Nos. (S+13)
No. of Block / Tower : 4 Blocks
Units in each Block / Tower : A(494),
B(130), C(208) & D(208)



STAY-IN-PLACE FORMWORK SYSTEM

- Replacing cast-in-situ Formwork with factory made formwork systems
- It is sacrificial formwork or lost formwork means formwork is left in the structural system to later act as insulation or reinforcement cage



LHP-LUCKNOW (Stay in Place PVC formwork System)

Advantages

- Having formwork already as part of system, the construction of building is faster as compared to conventional buildings. The formwork needs some support only for alignment purpose.
- The formwork consists of rigid PVC components, which do not corrode, chip or stain & resistant to UV, bacteria, fungi etc., thus ensuring long life of the structure.
- The polymer content used in manufacturing of formwork is up to 55% recycled content and are further recyclable, making it an eco-friendly material.
- The form work system has specific advantage for use in coastal areas as due to polymer encasement it offers higher durability.
- With concrete as filling material, the curing requirement of concrete is significantly reduced, thus saving in precious water resources.
- The formwork system does not have plastering requirement & gives a aesthetic finished surface in different color options.
- The system provides advantages in terms of structural strength, durability enhancement, weather resistance, flexural strength, thermal insulation and ease of construction.

Stay-In-Place PVC Wall Forms

- This is a prefinished wall formwork from M/s Novel Assembler Pvt. Ltd. comprising of rigid Poly-Vinyl Chloride (PVC) based polymer components that serve as a permanent stay-in-place durable finished form-work for concrete walls.
- The extruded components slide and interlock together to create continuous formwork with the two faces of the wall connected together by continuous web members forming hollow rectangular components. The web members are punched with oval-shaped cores to allow easy flow of the poured concrete between the components.
- The hollow Novel Wall components are erected and filled with concrete, in situ, to provide a monolithic concrete wall.



Rising EPS (Beads) Cement Panels



- Rising EPS (Beads) Cement Panels are patented panels from M/s Rising Japan Infra Pvt. Ltd. These are lightweight composite wall, floor and roof sandwich panels made of thin fiber cement/calcium silicate board as outer and inner faces with a core of EPS granule balls, adhesive, cement, sand, fly ash and other bonding materials in mortar form.
- The core material in slurry state is pushed under pressure into preset molds. Once set, it shall be moved for curing and ready for use with RCC or steel framed structure.
- These panels are presently manufactured by the firm in China and shortly a plant will be installed in India.

Light House Project (LHP) at Rajkot, Gujarat

(Technology: Monolithic Concrete Construction System)



No. of Dwelling Units : 1144 Nos. (S+13)
No. of Block / Tower : 11 Blocks
Units in each Block / Tower : 104 Nos.



MONOLITHIC CONCRETE CONSTRUCTION

- Replacing cast-in-situ Formwork with factory made customized formwork systems
- Formwork material is Aluminium / composites / steel having 100 to 500 repetitions
- Assembly line construction i.e. placing the formwork, pouring the concrete, moving the formwork to upper level



Modular Tunnel form



- Tunnel formwork is a mechanized system for cellular structures. It is based on two half shells which are placed together to form a room or cell. Several cells make an apartment. With tunnel forms, walls and slab are cast in a single day.
- The formwork is set up for the day's pour in the morning. The reinforcement and services are positioned and concrete is poured in the afternoon. Once reinforcement is placed, concrete for walls and Slabs shall be poured in one single operation. The formwork is stripped the early morning and positioned for the subsequent phase.
- Here the walls and slabs are cast in a form of a tunnel leaving two sides open whereas in monolithic concrete construction the entire room is cast in a single pour..

LHP-RAJKOT (Monolithic Concrete Construction using Tunnel Formwork)

Advantages

- Facilitates rapid construction of multiple/ mass modular units (similar units)
- Results in durable structure with low maintenance requirement
- The precise finishing can be ensured with no plastering requirement
- The concrete can use industrial by-products such as Fly Ash, Ground granulated blast furnace slag (GGBFS), Micro silica etc. resulting in improved workability & durability, while also conserving natural resource
- Being Box type structure, highly suitable against horizontal forces (earthquake, cyclone etc.)
- The large number of modular units bring economy in construction.

Summary of Light House Project (LHP)

| LHP Location | | | Chennai (Tamil Nadu) | Rajkot (Gujarat) | Indore (Madhya Pradesh) | Ranchi (Jharkhand) | Agartala (Tripura) | Lucknow (Uttar Pradesh) |
|--------------|--------------------------------------|---------------|--|--|-------------------------------------|--|---|-------------------------------|
| Sl. No | Particulars | Units | | | | | | |
| 1 | Name of Technology | Name | Precast Concrete Construction System- Precast Components | Monolithic Concrete Construction using Tunnel Formwork | Prefabricated Sandwich Panel System | Precast Concrete Construction System – 3D Volumetric | Light Gauge Steel Frame System (LGSF) with Pre-Engineered Steel Structural System | Stay in Place Formwork System |
| 2 | No. of Houses | No. | 1,152 | 1,144 | 1,024 | 1,008 | 1,000 | 1,040 |
| 3 | No. of Floors | No. | G+5 | S+13 | S+8 | G+8 | G+6 | S+13 |
| 4 | Plot Area | Sqm | 33,596 | 39,599 | 41,920 | 31,160 | 24,000 | 20,000 |
| 5 | Per House Carpet Area | Sqm | 26.58 | 39.77 | 29.04 | 29.85 | 30.00 | 34.50 |
| 6 | Project Cost | INR (in Cr) | 116.27 | 118.90 | 128.00 | 134.00 | 162.50 | 130.90 |
| 7 | Per House cost (with infrastructure) | INR (in Lakh) | 10.09 | 10.39 | 12.50 | 13.29 | 16.25 | 12.58 |

Session 2

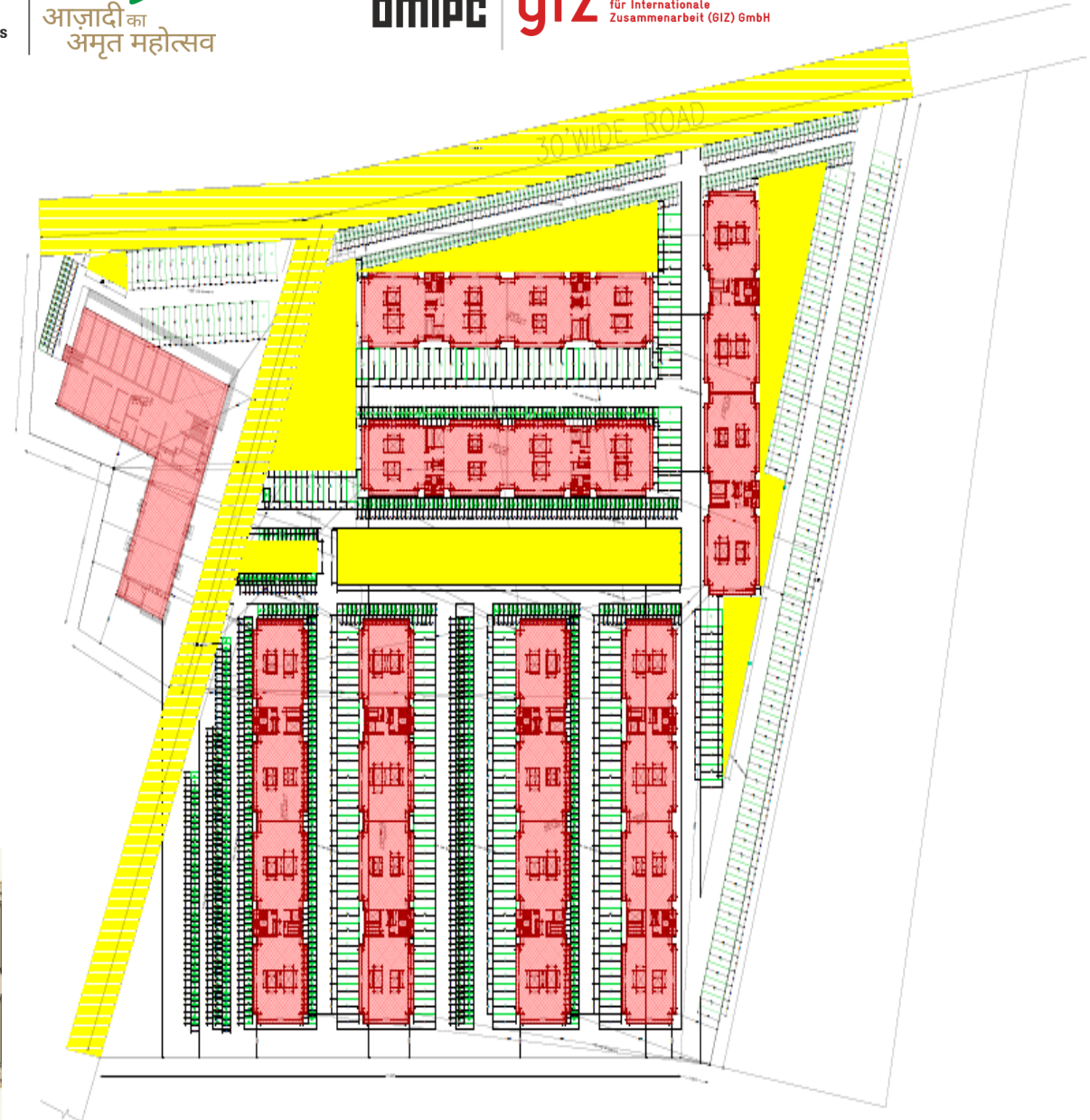
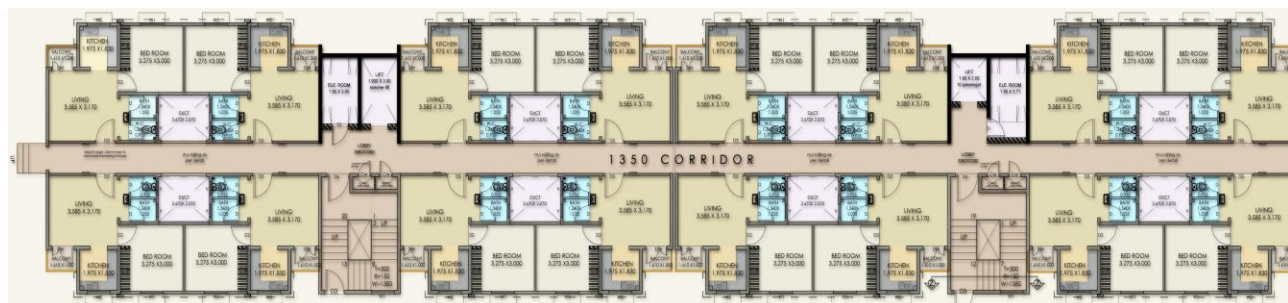
- Construction Process at LHP Ranchi
- Basic of thermal Comfort and Passive Design Strategies for Affordable Housing



Construction Process

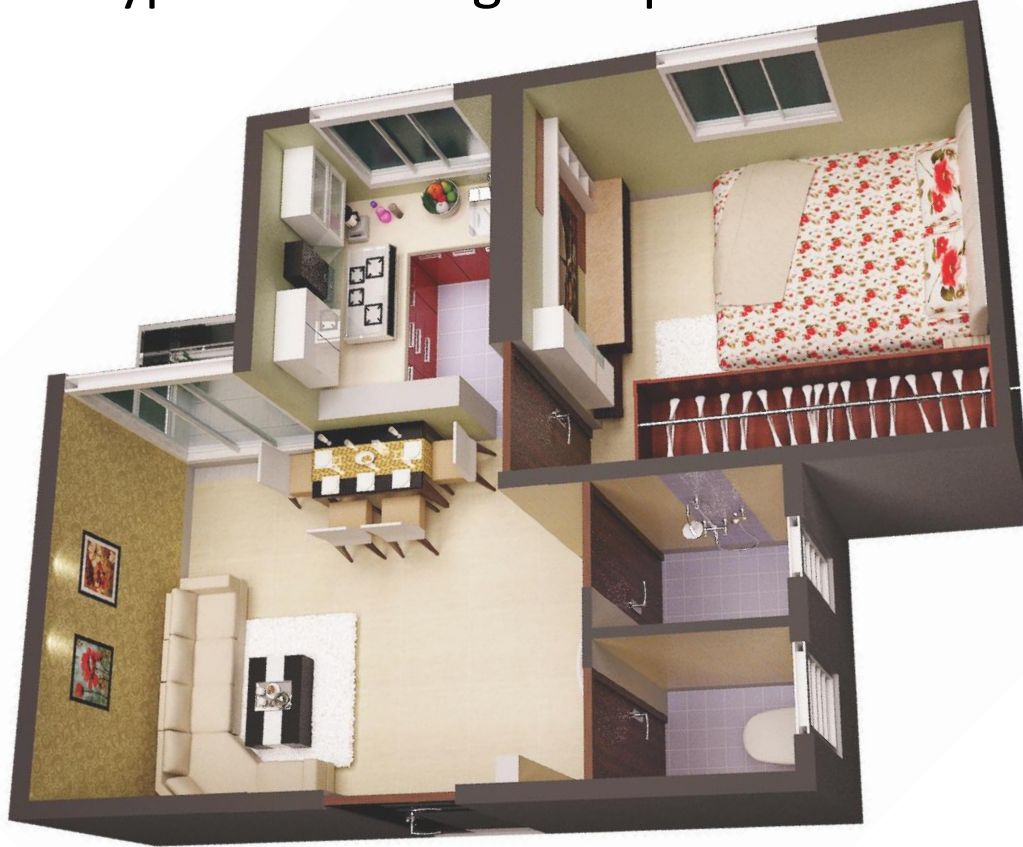
- There are 7 blocks in Ground + 8 configuration with 1008 houses along with basic and social infrastructure.
- Ground coverage of the project is 29.3% and FAR is 2.21.
- Green space is 20%.

Typical floor plan

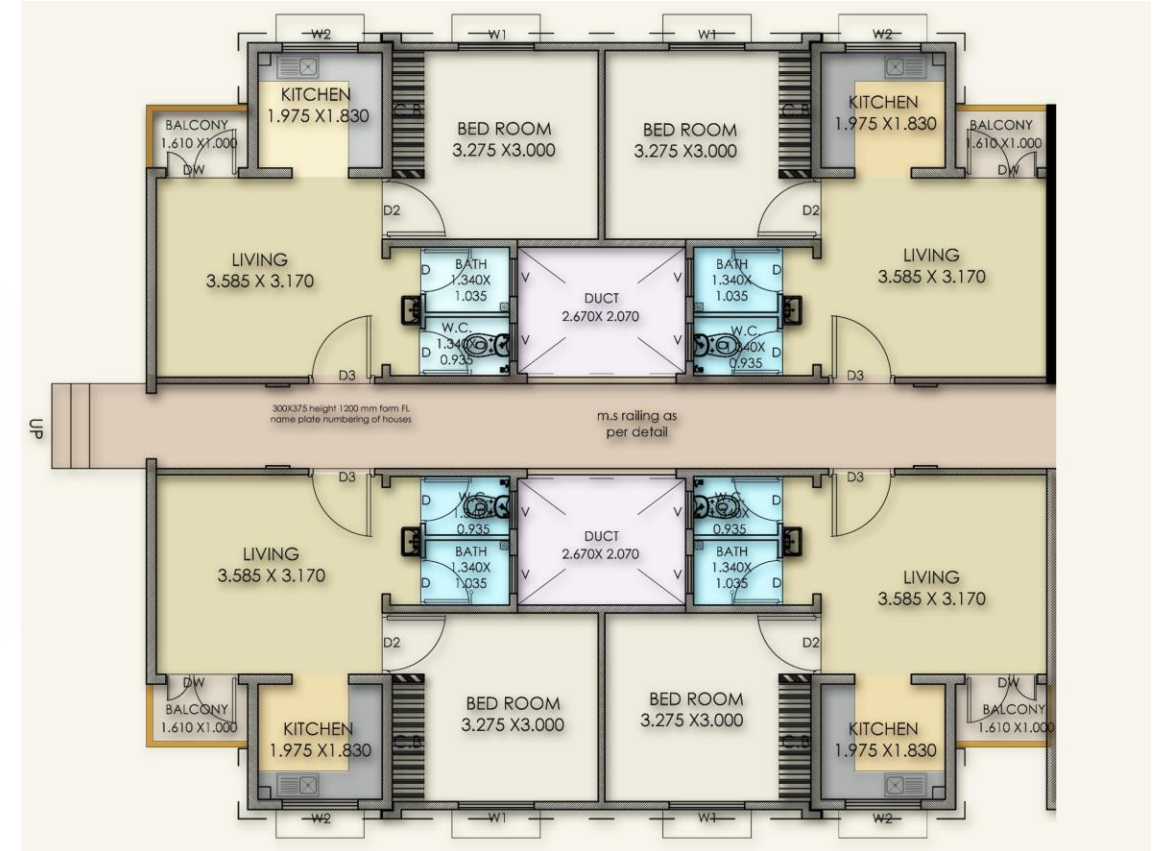


- 16 dwelling units at each floor of building block with provision of lifts and staircases.

• Typical Dwelling Unit plan



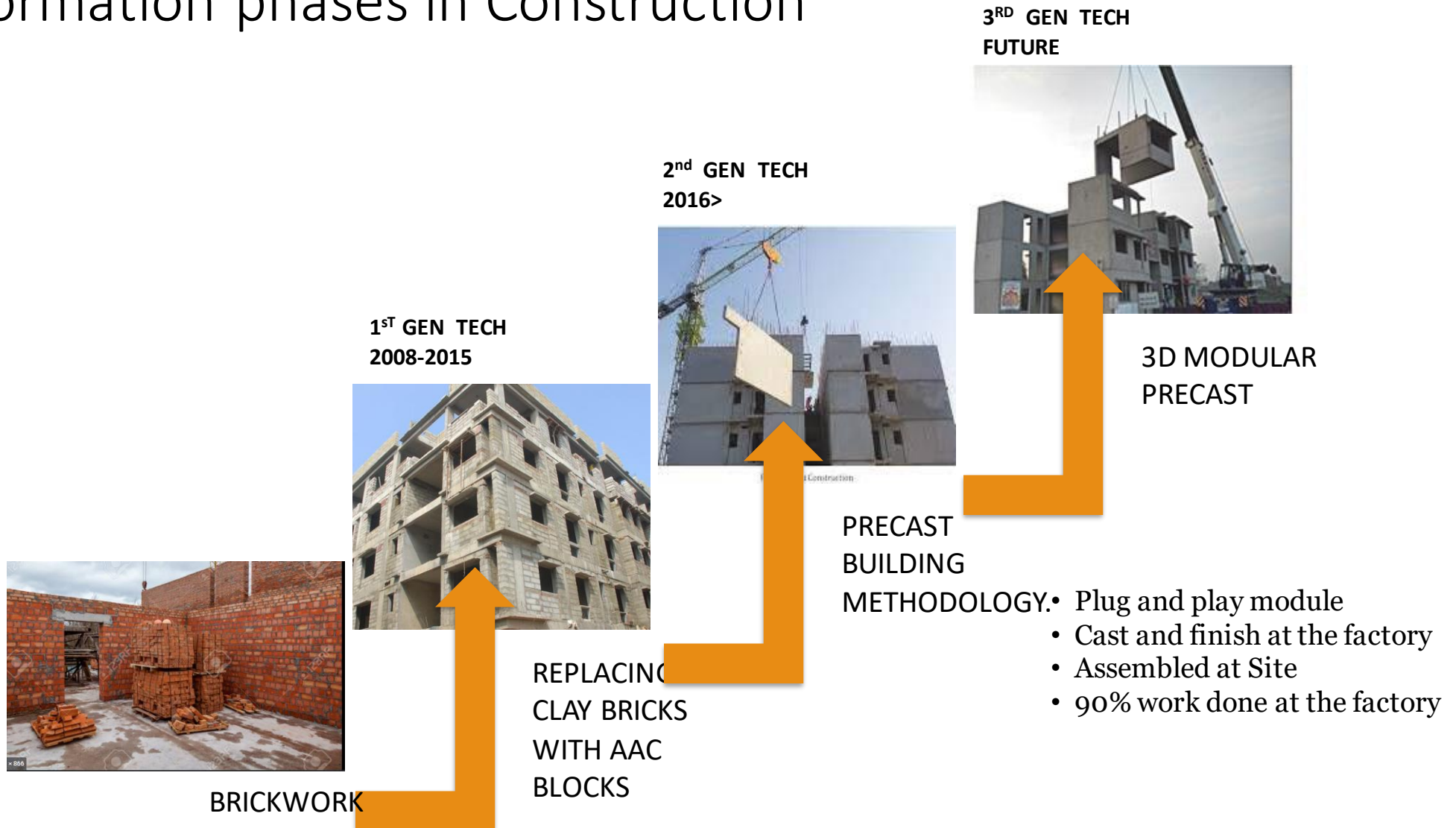
Each dwelling unit consists of one hall, one bed room, a kitchen, WC, Bath and a balcony. The carpet area of each unit is 29.85 Sq.mt. The sizes of individual rooms & service areas conform to NBC norms.



Other special features:

- Green rating as per GRIHA
- Use of renewable resources:
 - Rain water harvesting
 - Solar lighting
- Solid waste management
- STP with recycling of waste water
- Fire Fighting System conforming to NBC

Transformation phases in Construction



Construction Methodology & Special Features of 3D Modular precast

3D Modular precast

- ❑ Lego like plug and play modules
- ❑ Cast and finished in factories
- ❑ Assembled on site
- ❑ 90% work done in Factory



Thermal Comfort

Transportation

- ❑ Reduce labor cost
- ❑ Minimal material waste
- ❑ Better quality structures
- ❑ Lesser site disturbance
- ❑ Flexible and adaptable
- ❑ Movable and permanent building options

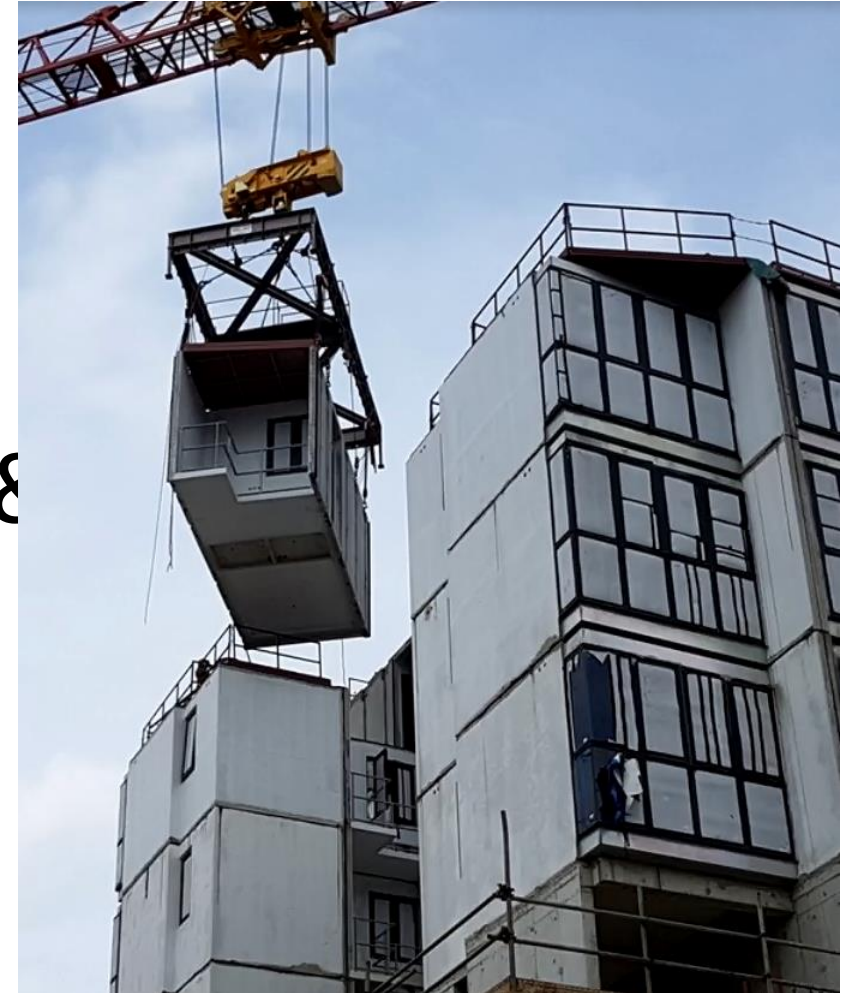
Installation



* Source: Magicrete, Volert

Structural Elements

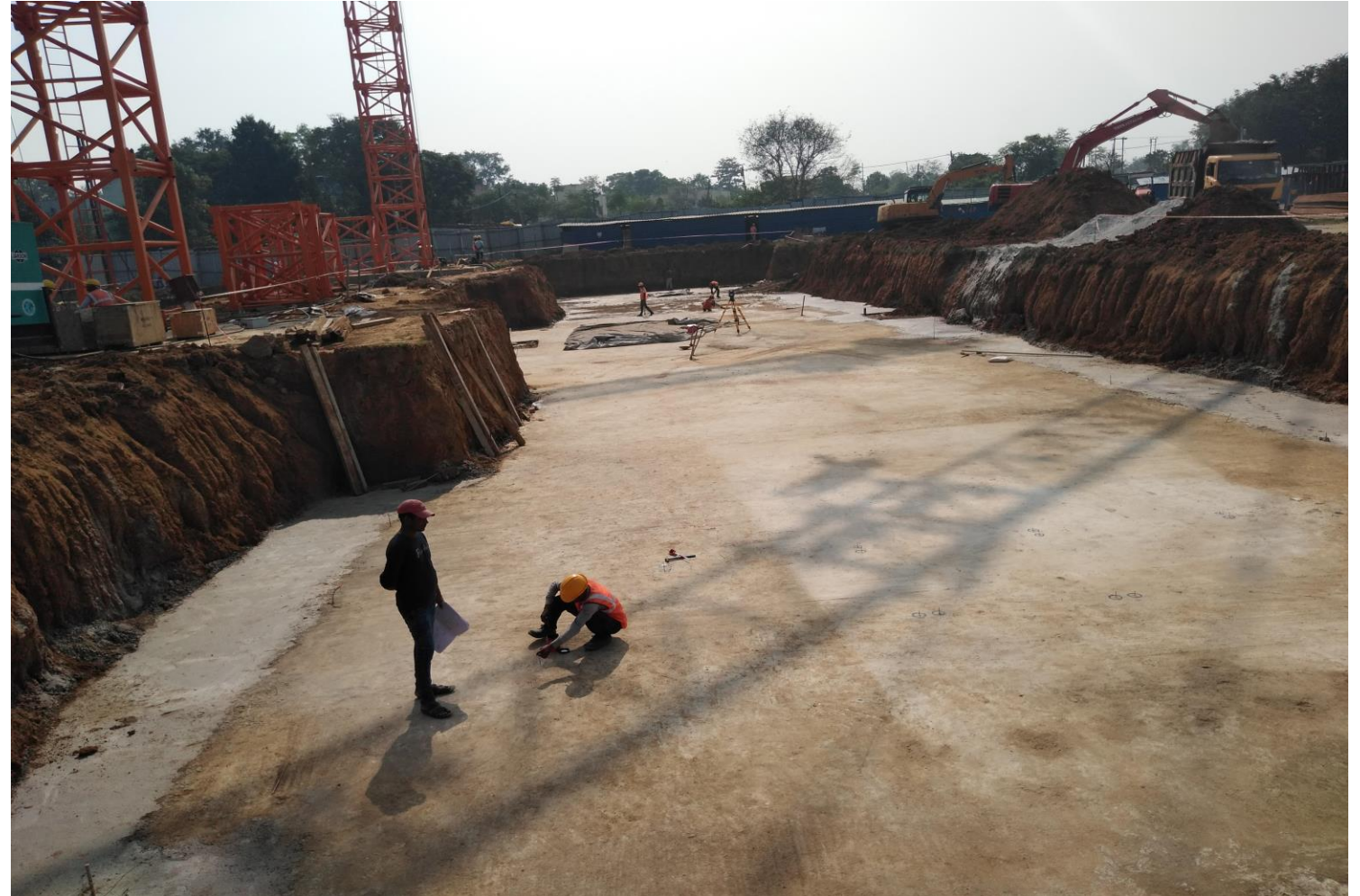
- Foundation
- Structural System comprising of 3D modules, walling panels & solid core pre-stressed slab



Construction Sequence

- Sub-Structure: Foundation
- Super-structure: Structural System comprising of 3D modules, walling panels & solid core pre-stressed slab
- MEP: Plumbing & Electrical
- Finishing

EXCAVATION



- The project starts with layout and excavation.
- After the layout at site, the excavation of each block is done using mechanical excavators up to the required depth of foundation which is 2.0 m for blocks

FOUNDATION



- The foundation work starts with the PCC of 100 mm thickness (M10 Grade)



- Reinforcement and shuttering for raft foundation



- All building blocks have Raft foundation with 700 mm thick M-30 Concrete.

FOUNDATION



- Shear wall of M30 Grade Concrete are being cast upto plinth height over already laid cured raft.

FOUNDATION



- Desnuttering from wall.

Structural Elements

Foundation

- Conventional as per geo-technical investigations, bearing capacity, soil strata, water table, etc.
- Raft foundation with RCC shear wall upto plinth level.
- Grade slab at plinth level.



Structural system

Structural Elements

Manufacturing of structural modules

- 3D Steel Moulds are created as suiting to various sizes of Building units (Pods).
- High strength steel as per the structural design is placed inside 3D moulds.
- Electrical and plumbing lines are set up. Block outs for doors and windows are also set up at the same time.
- The pods are cast into their final shape using high-performance concrete.
- Strict quality checks are taken for each pod before they are transported for erection and assembly at the site.



Casting Yard at Site



Casting Yard at Site



Casting Yard at Site



Advantages of the System

Structural Elements

- Upto 90% of the building work including finishing is complete in plant/casting yard leading to significant reduction in construction & occupancy time
- The controlled factory environment brings resource optimization, improved quality, precision & finish
- The required concrete can be designed using industrial by-products such as Fly Ash, Ground granulated blast furnace slag (GGBS), Micro silica etc. resulting in improved workability & durability, while also conserving natural resources. In this project Ground granulated blast furnace slag & silica fume is proposed in concrete.
- With smooth surface it eliminates use of plaster
- The monolithic casting of walls & floor of a building module reduces the chances of leakage
- The system has minimal material wastage (saving in material cost), helps in keeping neat & clean construction site and dust free environment
- Use of optimum quantity of water through recycling
- Use of shuttering & scaffolding materials is minimal
- All weather construction & better site organization

Essential requirements

- Space for casting yard is required in addition to site for actual construction. The project is not viable if the factory is located far away. Setting up of casting yard requires time in month/(s) depending on project size & delivery schedule
- Approach road to site for movement of high capacity trailers, Cranes etc.
- Site should have space for proper leveraging & functioning of cranes
- Requires skilled labour & strict supervision
- Plumbing & electrical services need to be pre-planned

Structural Elements



Construction Sequence

Construction sequence in the project;

- Making the designed foundation of the building ready, while manufacturing of precast concrete structural modules are taking place at the factory.
- Factory finished building units/modules are installed at the site with the help of tower cranes.
- Gable end walls are positioned to terminate the sides of building.
- Pre stressed slabs are installed as flooring elements.
- Rebar mesh is finally placed for structural screed thereby connecting all the elements together. Consecutive floors are built in similar manner to complete the structure.

Concrete & Reinforcement Steel Specifications

| Item | Concrete Grade |
|---|----------------|
| Raft foundation, Precast Shear wall, Precast Partition walls (Non-Load bearing) | M30 |
| Precast Pre-stressed solid slab | M50 |
| Structural Screed | M35 |

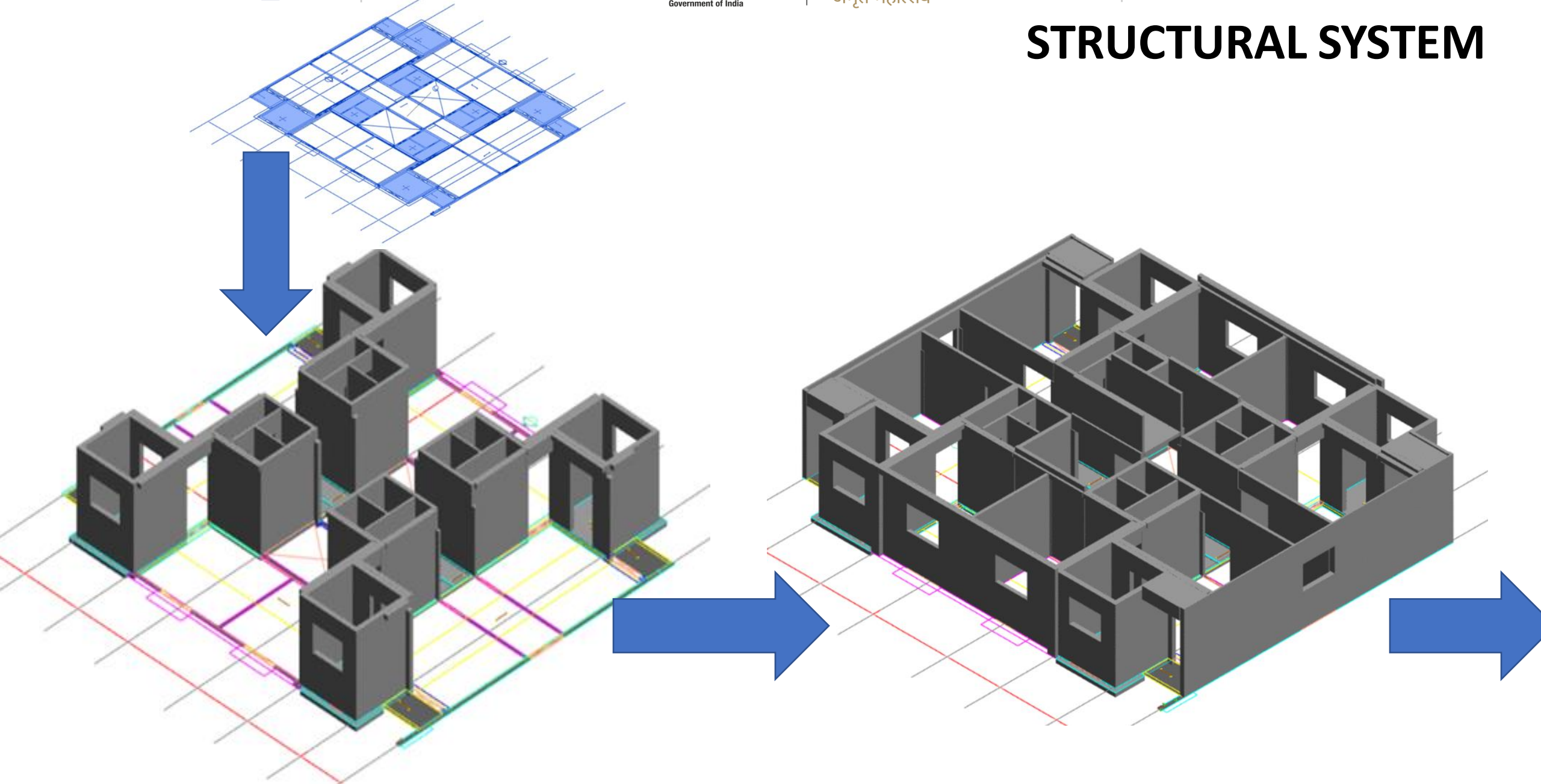
- Mix design for concrete and all Concrete work shall conform to IS 456-2000 & Liquid retaining structures shall conform to IS 3370:2009
- All Super structure precast walls, Reinforcement Steels are to be HYSD/TMT bars of Fe 500 as per IS 1786-2008.
- Flooring Pre-stressed solid slabs: $f_{pu} = 1860 \text{ N/mm}^2$
- Structural Screed: Fe 500 of wire mesh

Batching Plant

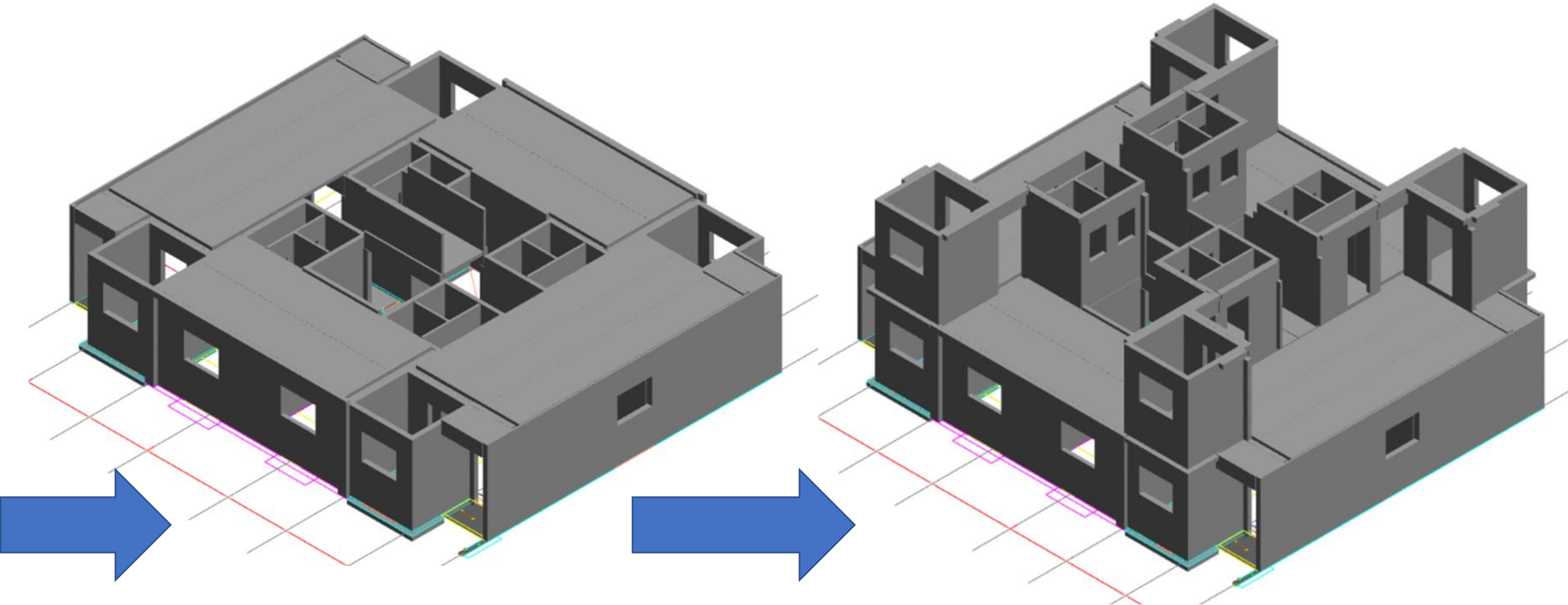
To bring resource efficiency, optimization of building materials and for quality control, a computerized batching plant has been established at site.



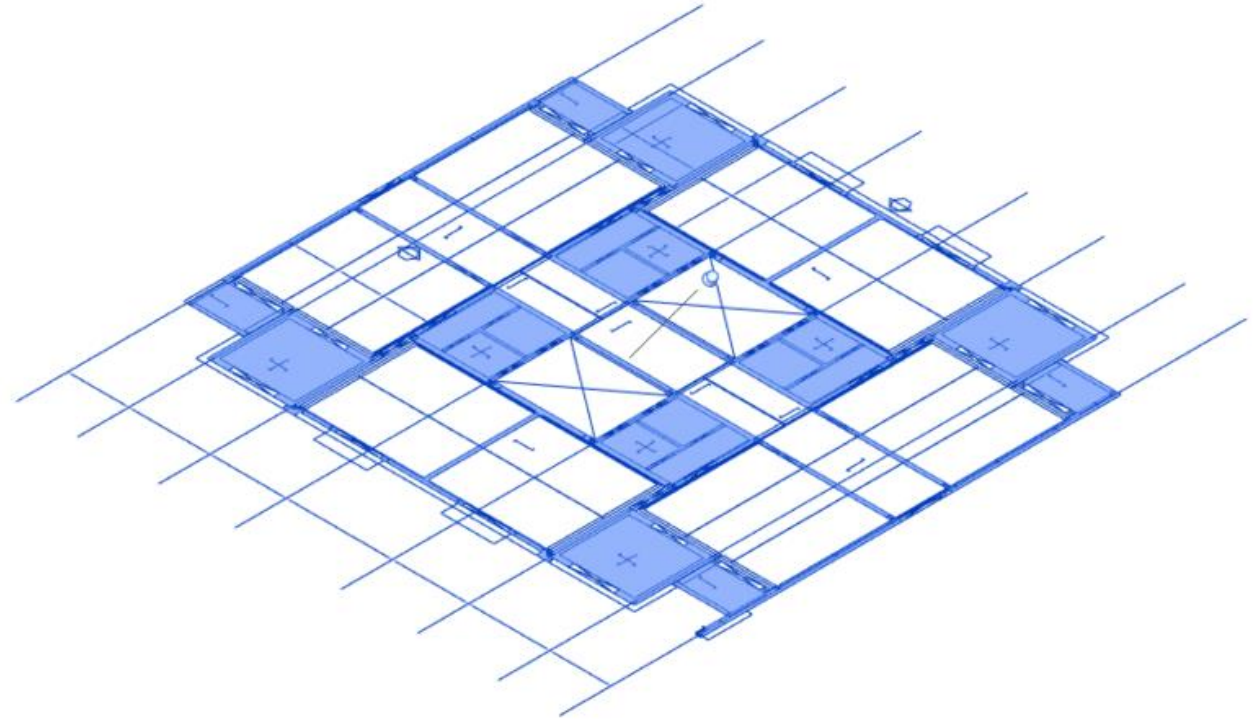
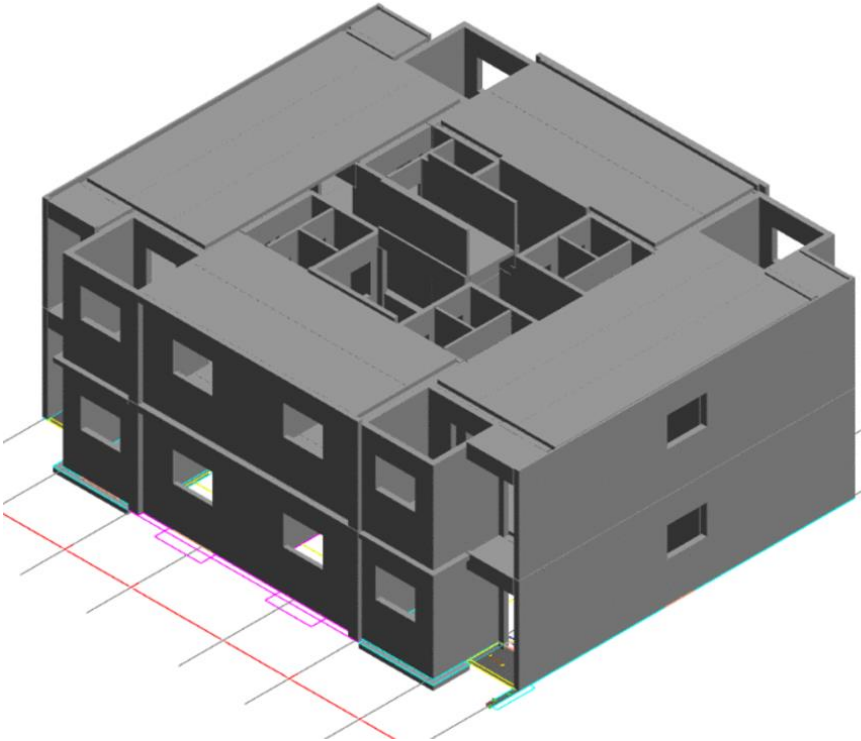
STRUCTURAL SYSTEM



STRUCTURAL SYSTEM



STRUCTURAL SYSTEM



Animation



- Erection of Components

Erection



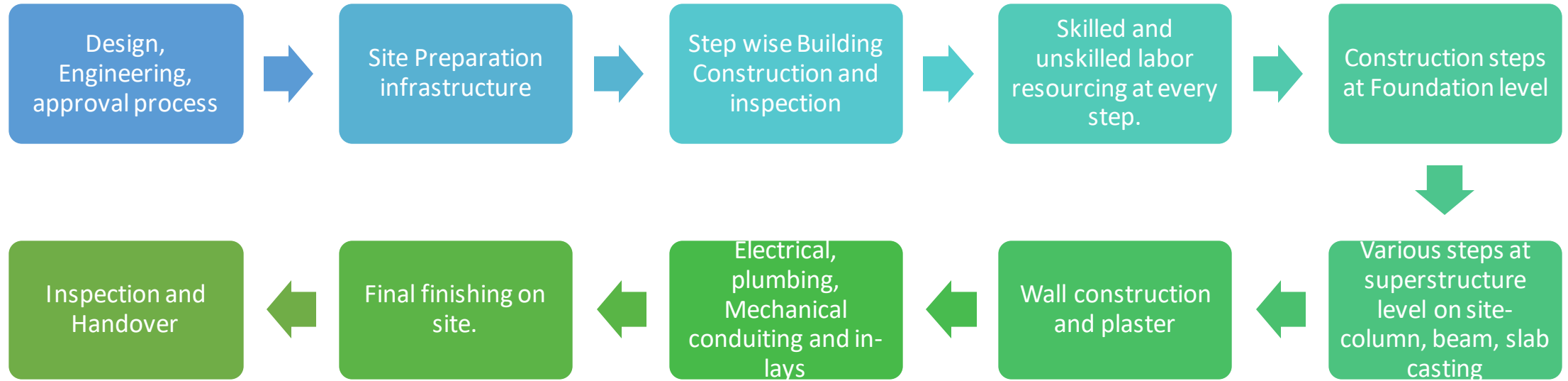




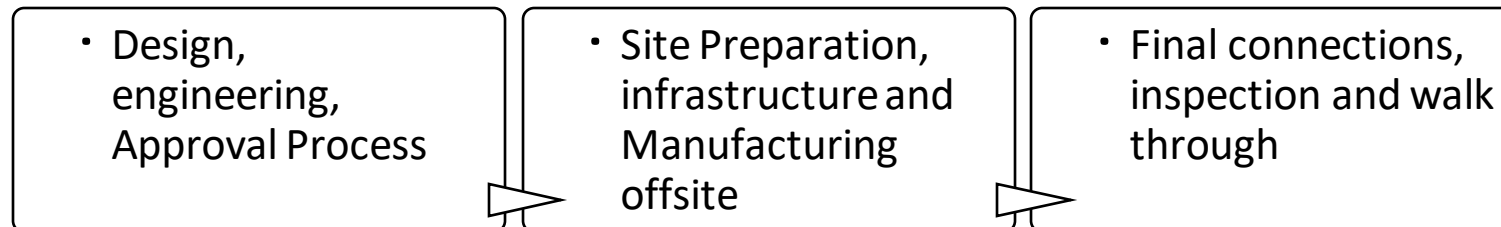


Construction Methodology

Traditional Construction timeline



Pods Construction timeline





Basic of thermal Comfort and Passive Design Strategies for Affordable Housing



Thermal comfort is a mental state that reflects happiness with the thermal environment and is measured by subjective assessment.



Importance of Thermal Comfort

2

People adjust their behavior to cope with their thermal environment, such as by adding or removing clothing, changing their posture unconsciously, selecting a heating source, moving closer to or farther away from cooling/heating sources, and so on.

3

When this option (removing a jacket or moving away from a heat source) is gone, issues develop since people are no longer able to adjust. People are unable to adapt to their environment in some cases because the environment in which they work is a product of the processes of the task they are doing.

1. You can increase morale and productivity while also enhancing health and safety by regulating thermal comfort. Because their capacity to make decisions and/or do manual tasks deteriorates in excessively hot and cold conditions, people are more prone to behave unsafely



Importance of Thermal Comfort – Body Requirements



- Homo sapiens primate order of the class of mammals
- Body heat is a by-product of metabolism
- A normal core temperature of $\sim 37^{\circ}\text{C}$ and skin at $\sim 34^{\circ}\text{C}$



Source: Sunil Kumar Singh. (2016). Alert to heatwaves [Image]. Retrieved 12 April 2022, from <https://www.downtoearth.org.in/news/climate-change/alert-to-heat-waves-53459>

The Telegraph Online. (2020). Cold conditions continue in Delhi [Image]. Retrieved 12 April 2022, from <https://www.telegraphindia.com/india/cold-conditions-continue-in-delhi/cid/1732019>

PHYSICAL FACTORS

AIR TEMPERATURE – the temperature of the air surrounding a body

The ideal temperature for sedentary work is usually between **20°C and 26°C**

RADIANT TEMPERATURE – the heat that radiates from a warm object

Heat can be generated by equipment, which raises the temperature in a specific region.

PHYSICAL FACTORS

AIR VELOCITY – the speed of air moving across the worker

It's best if the air flow rate is between **0.1 and 0.2 m/s.**

HUMIDITY – the amount of evaporated water in the air

Air-conditioning can easily attain ideal relative humidity values of **40 percent to 70 percent.**

Factors affecting Thermal Comfort - Others

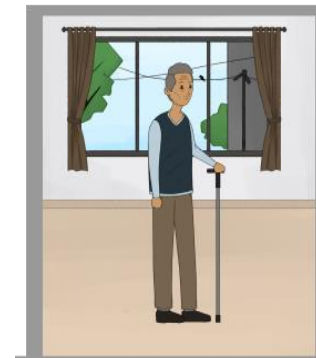
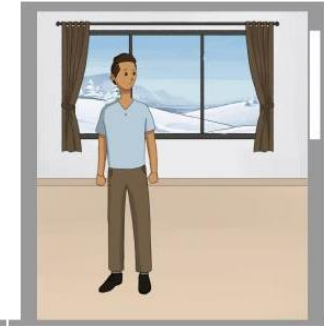
- **Acclimatization**
 - Short-term physiological adjustments
 - Long-term endocrine adjustments
- **Body shape and fat**
- **Age and gender**
- **Status of health**



Short term
physiological
adjustments



Long term physiological
adjustments



Age

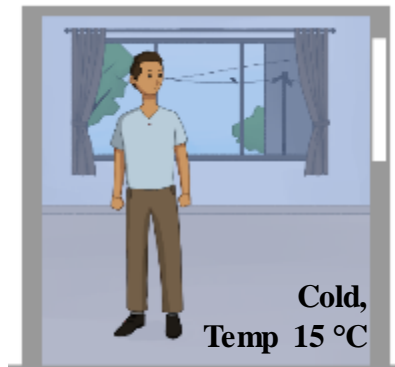
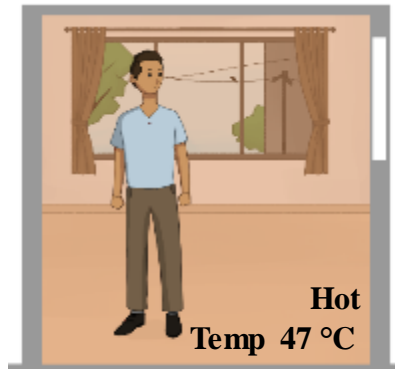


Gender

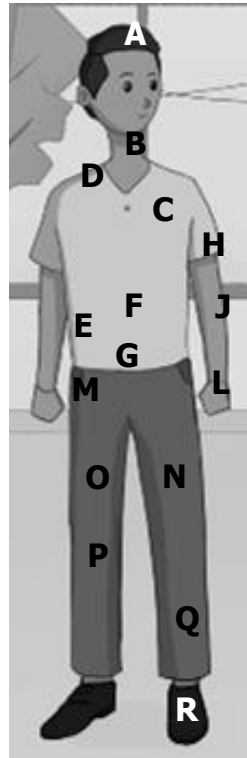


Health &
Wellbeing

Thermal Comfort – Cold – Neutral - Warm

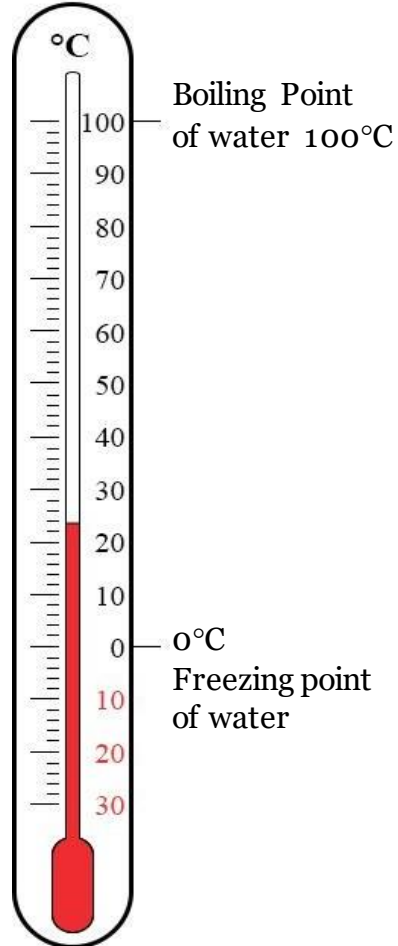


Air Temp 27 °C



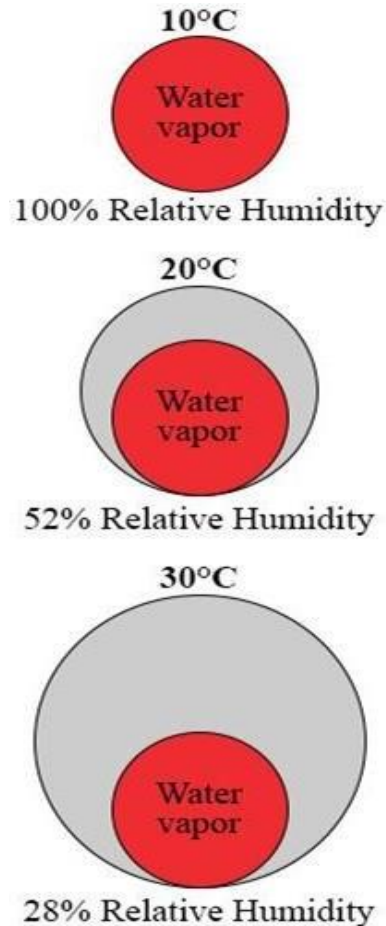
| Body Part | Skin Location | Cold (15 °C) | Neutral (27°C) | Hot (47 °C) |
|-----------|---------------|--------------|----------------|-------------|
| A | Forehead | 31.7 | 35.2 | 37 |
| B | Back of Neck | 31.2 | 35.1 | 36.1 |
| C | Chest | 30.1 | 34.4 | 35.8 |
| D | Upper Back | 30.7 | 34.4 | 36.3 |
| E | Lower Back | 29.2 | 33.7 | 36.6 |
| F | Upper Abdomen | 29 | 33.8 | 35.7 |
| G | Lower Abdomen | 29.2 | 34.8 | 36.2 |
| H | Tricep | 28 | 33.2 | 36.6 |
| J | Forearm | 26.9 | 34 | 37 |
| L | Hand | 23.7 | 33.8 | 36.7 |
| M | Hip | 26.5 | 32.2 | 36.8 |
| N | Side thigh | 27.3 | 33 | 36.5 |
| O | Front thigh | 29.4 | 33.7 | 36.7 |
| P | Back thigh | 25.5 | 32.2 | 36 |
| Q | Calf | 25.1 | 31.6 | 35.9 |
| R | Foot | 23.2 | 30.4 | 36.2 |

Factors Affecting Thermal Comfort – Air Temperature



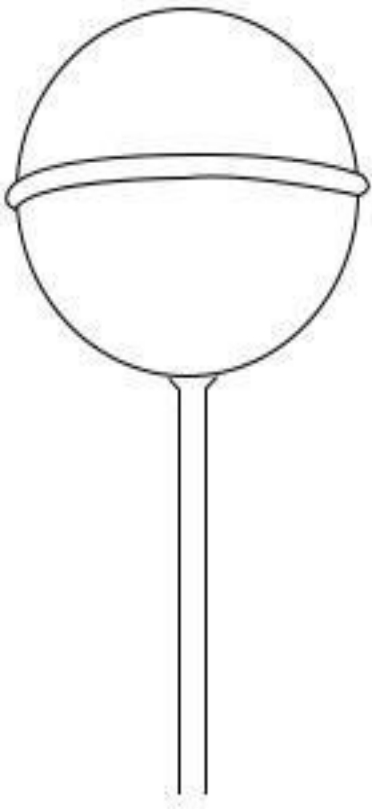
- Temperature of the air surrounding the body (Dry Bulb Temperature) – DBT)
- Temperature of air measured by a thermometer freely exposed to the air, but shielded from radiation and moisture.
- Degrees Celsius (°C)

Factors Affecting Thermal Comfort – Relative Humidity



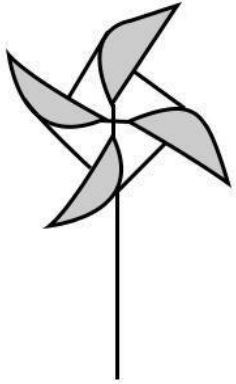
- Moisture Content of the air
- The amount of moisture in the air depends upon
- Air Pressure
- Air Temperature
- Percentage (%)

Factors Affecting Thermal Comfort – Mean Radiant Temperature



- Uniform temperature of an imaginary enclosure
- Measure of the effect of Radiant interchanges at a point in space
- Calculated using (T_g), (T_a) and air velocity

Factors Affecting Thermal Comfort – Air Speed



- Air Speed is the rate of air movement at a point, without regard to direction
- Average air speed, height and directions
- Calculated using (T_g), (T_a) and air velocity
- Meter per second (m/s)

Factors Affecting Thermal Comfort – Clothing Value



- The resistance to sensible heat transfer provided by clothing ensemble
- Clothing Insulation Value (clo - I_{cl})
- Impact of furniture such as chair and beddings

Factors Affecting Thermal Comfort – Metabolic Rates



- The rate at which metabolism occurs in a living organism.
- Rate of energy expenditure per unit time
- Average adult 1.8 square meter
- Energy per unit areas, watts per square meter (W/m^2)

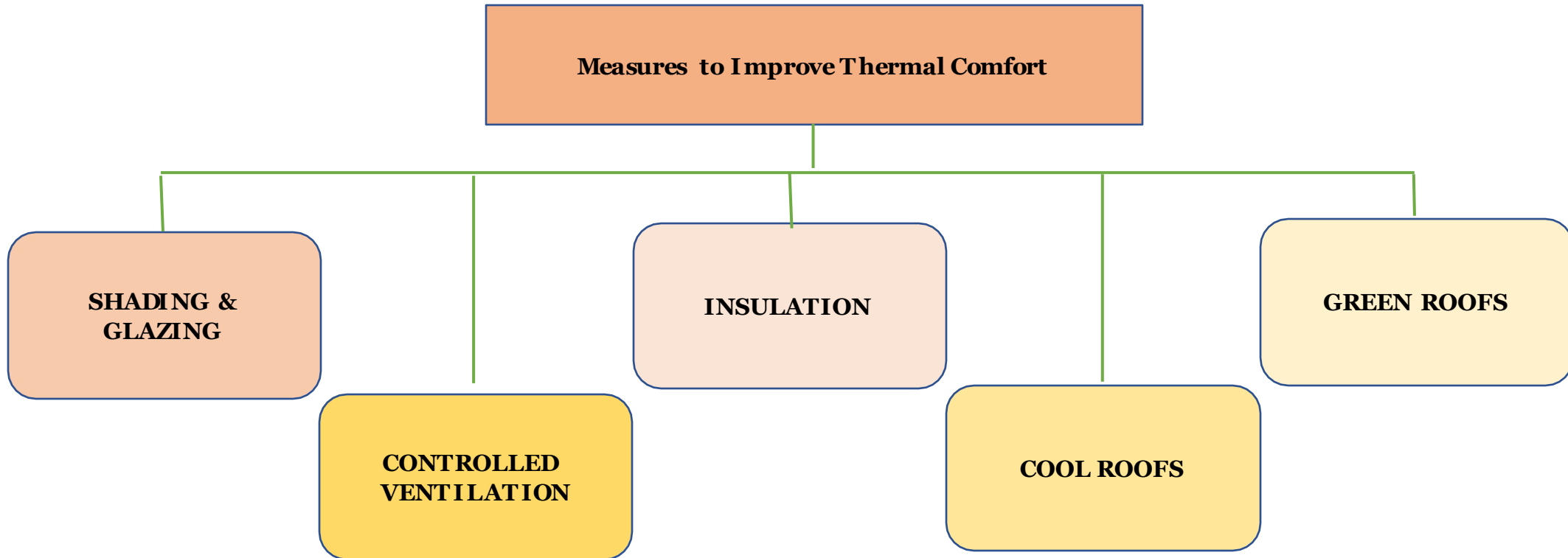
| CLOTHING | Clo |
|--|------|
| T-shirts, shorts, Light socks, Sandals | 0.30 |
| Shirt, Trousers socks, Shoes | 0.70 |
| Jacket, Blouse, Long skirt, stockings | 1.00 |
| Trousers, Vest, Jacket Coat, Socks Shoes | 1.50 |

CLOTHING LEVELS & INSULATION

| ACTIVITY | Met |
|---|-----|
| Seated, Relaxed | 1.0 |
| Sedentary Activity (office, dwelling, school, laboratory) | 1.2 |
| Standing, Light Activity (shopping, laboratory, light industry) | 1.6 |
| Standing, Medium activity (shop assistant, domestic work, machine work) | 2.0 |

METABOLIC RATE

Measures to Improve Thermal Comfort



Shading & Glazing

Shading reduces internal heat gain through coincident radiation.

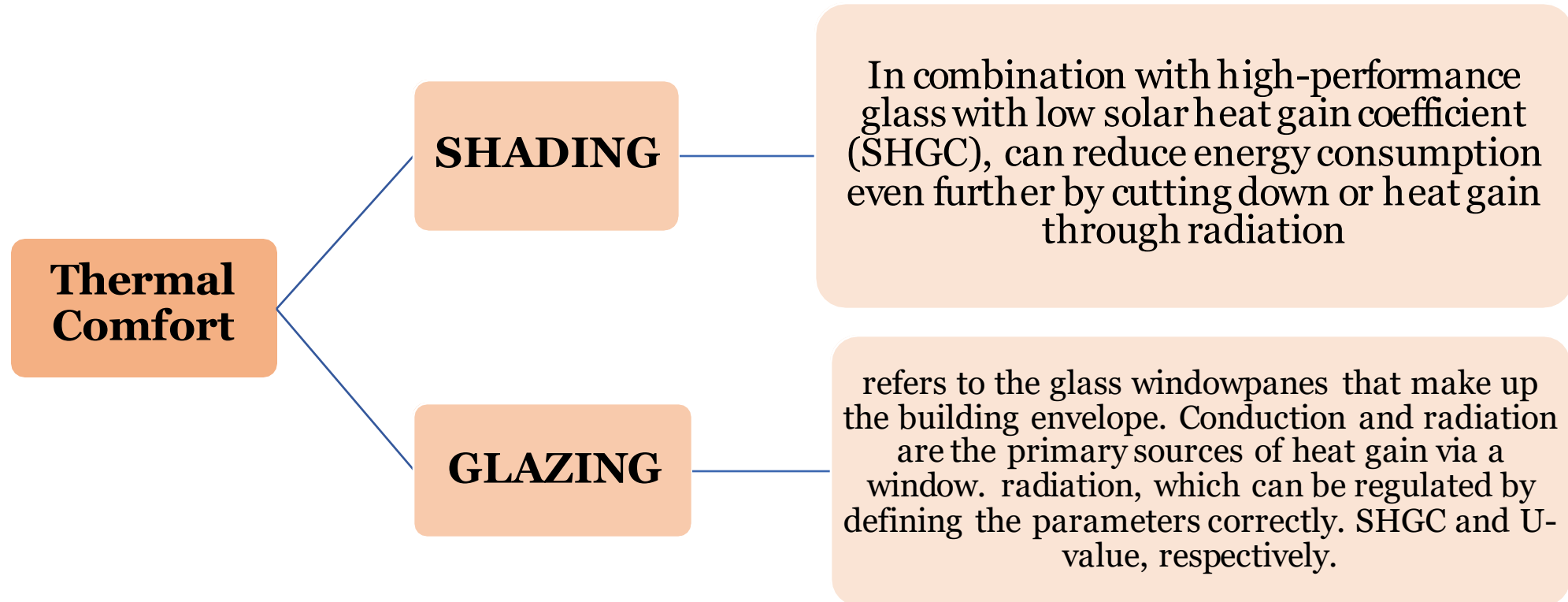
| VARIOUS METHODS TO SHADE WINDOWS | | | | | |
|----------------------------------|---------|---------|---------------|---------------|--------------------|
| Overhangs | Awnings | Louvers | Vertical Fins | Light Shelves | Natural Vegetation |

These can reduce cooling energy consumption by 10-20%

The shading mechanism can be fixed or movable (manually or automatically) for allowing varying levels of shading based on

- 1. the sun's position and**
- 2. movement in the sky**

Shading & Glazing



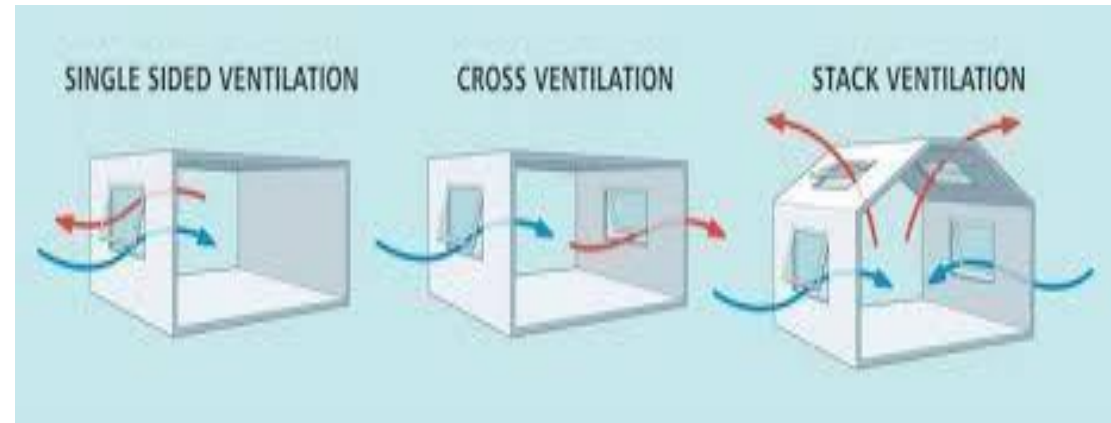
Controlled Ventilation

**BUILDING CAN BE
DESIGNED AS**

**CROSS
VENTILATION**

**STACK
VENTILATION**

**SINGLE-SIDED
VENTILATION**



Controlled Ventilation

Designing windows and vents to dissipate warm air and allow the ingress of cool air can reduce cooling energy consumption by 10-30%

Air Velocity range between 0.5 to 1 m/s **Drops temperature at about 3 °C at 50% relative Humidity**

AIR VELOCITY OF 1 m/s

Office Environment

Too High

Home Environment

Acceptable (Especially if there is no resource to active air conditioning.)



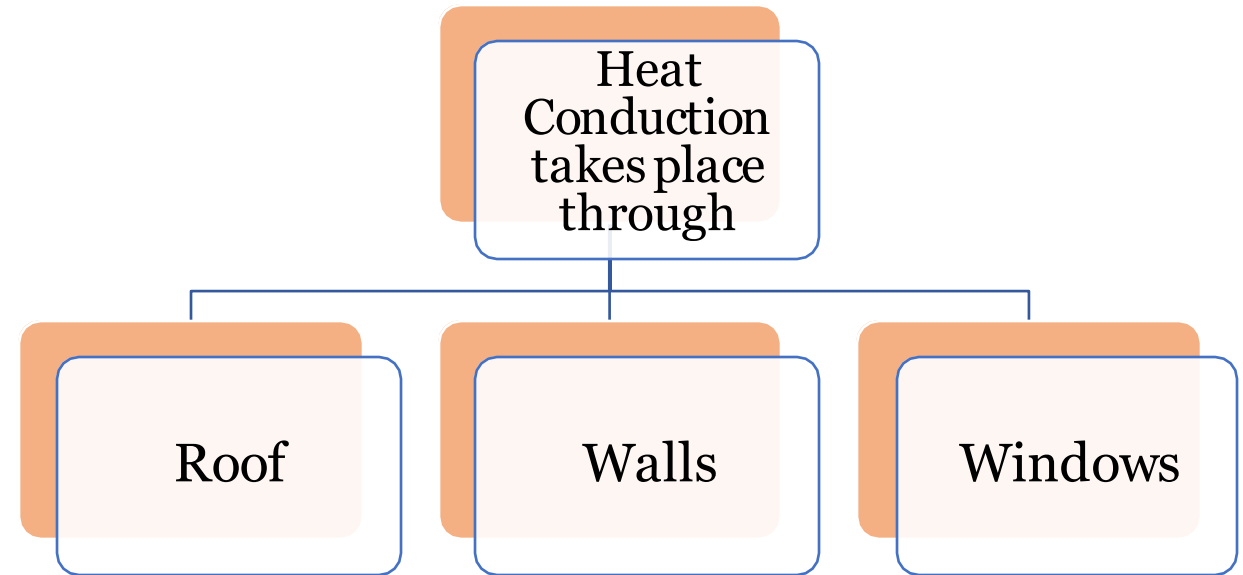
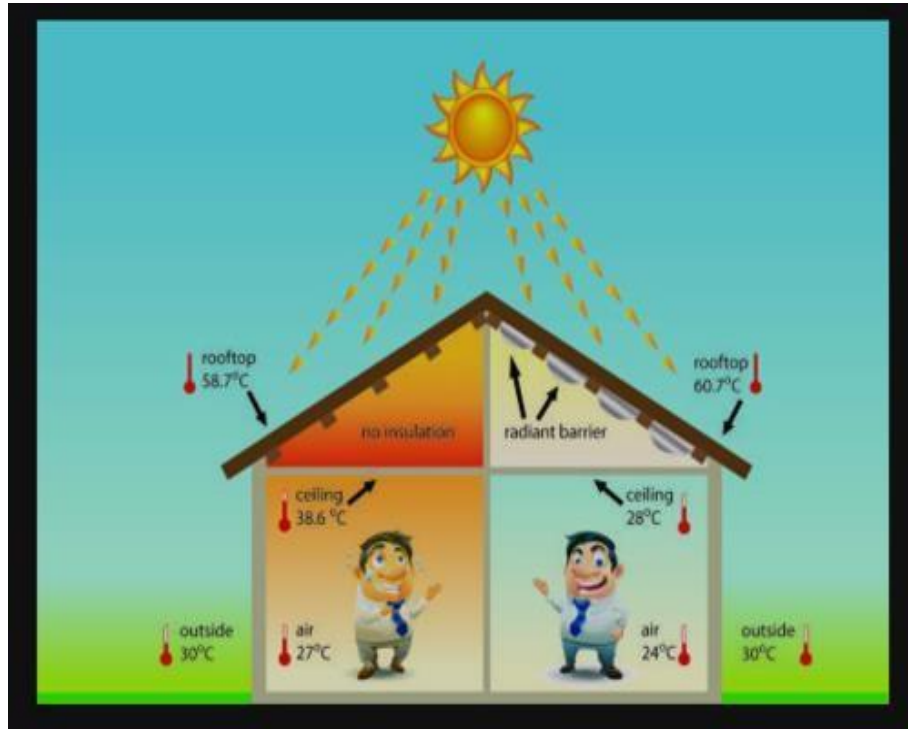
Controlled Ventilation

Natural ventilation takes advantage of the differences in air pressure between warm air and cool air, as well as convection currents, to remove warm air from an indoor space and allow fresh cooler air in.

This also has the added advantage of cooling the walls and roofs of the buildings that hold significant thermal mass, further enhancing the thermal comfort of the occupants

| NATURAL VENTILATION | | Even in hot-dry and warm-humid climate zones where some air-conditioning may be required during peak Thermal Comfort for All summer, buildings can be designed to operate in a mixed mode to enable night ventilation and natural ventilation during cooler seasons |
|---|--|---|
| With Breeze Air | Works Best | |
| Absence of natural breeze | Fans can be used to improve the flow of cool air | |
| Natural ventilation promotes the occupants' adaptation to external temperature, called adaptive thermal comfort | | |

Insulation

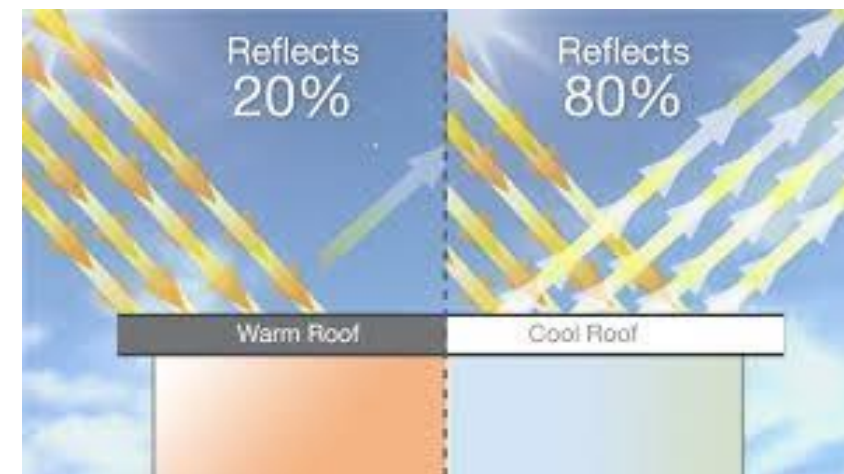


An insulating material can resist heat transfer due to its low thermal conductivity. Insulating walls and the roof can reduce cooling energy loads by up to 8%

Cool Roofs

Cool roofs are one of the passive design options for reducing cooling loads in buildings. Cool roofs reflect most of the sunlight (about 80% on a clear day)

| When sunlight is incident on a dark roof | When Sunlight is incident on a cool roof |
|--|--|
| 38% heats the atmosphere | 10% heats the environment |
| 52% heats the city air | 8% heats the city air |
| 5% is reflected | 80% is reflected |
| | 1.5% heats the building |



Cool Roofs

In the summer, a typical cool roof surface temperature keeps 25-35°C cooler than a conventional roof, lowering the internal air temperature by roughly 3-5°C and improving the thermal performance.

The comfort of the inhabitants is improved, and the roof's lifespan is extended.

Cool roofs increase the durability of the roof itself by reducing thermal expansion and contraction.

Apart from helping enhance the thermal comfort in the top floor and helping reduce air-conditioning load, cool or white roof or pavements also offer significant reduction in urban heat island effect



The cities of Jodhpur and Jaipur is the extremely hot state of Rajasthan, where most of the city homes are painted in light blue and light pink colours, are examples of practical application of this age-old traditional design style.

Green Roofs

A green roof is a roof of a building that is partially or completely covered with vegetation

GREEN ROOFS PURPOSE

Absorbing Rain Water

Providing Insulation

Helping lower urban air temperatures

Mitigating the urban heat island effect



Green Roofs

Reduction in Energy use is an important feature of Green Roofing

GREEN ROOFS IN BUILDINGS ALLOWS

During cooler Winter Months

Retain their heat

During hotter Summer Months

Reflecting and absorbing solar radiations

Passive Strategies & Building Physics

Passive Measures

Climatic Zone Level

Temperature, rainfall, wind direction, sun radiation, humidity, and other environmental factors are taken into consideration when designing.

Site Level

To take advantage of the positive aspects of the site and its microclimatic features while minimising the negative aspects.

Level of Response

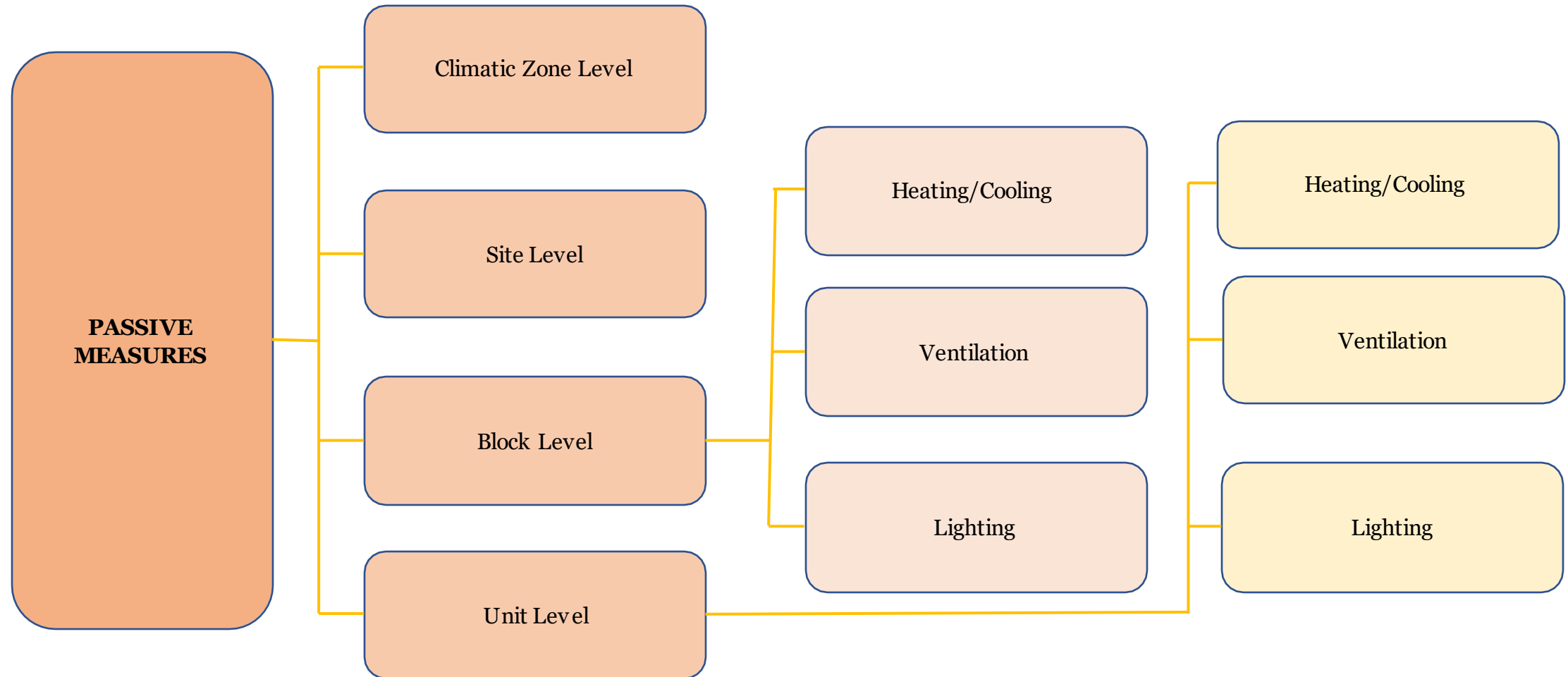
Block Level

Interaction of the block with its surroundings and plants to ensure that it has adequate heating, ventilation, and lighting.

Unit Level

Design solutions that influence heat, light, and ventilation based on climatic variables at the unit level.

Passive Strategies & Building Physics



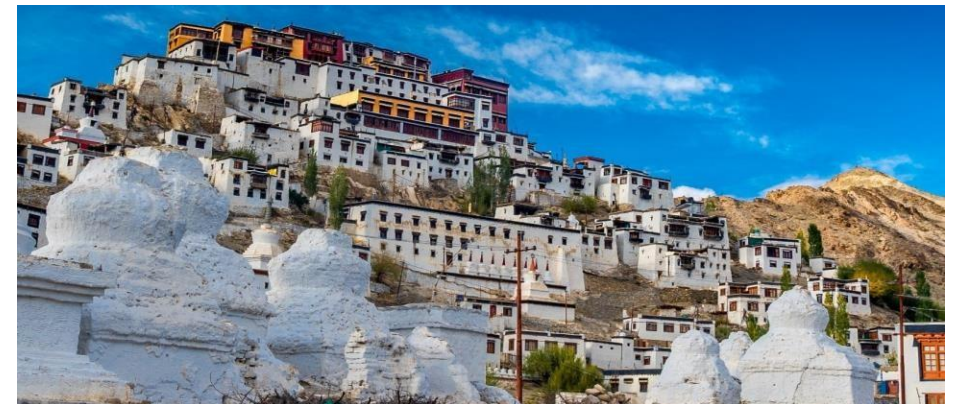
Passive Strategies & Building Physics

Passive Measures – Climatic Zone Level

Vernacular / traditional architectural typologies that respond to the region's distinct environment are best exemplified.

Example

- In Ladakh, earth architecture with thick walls and limited windows provides optimal insulation.
- In Rajasthan, courtyard havelis take advantage of pressure differences and reciprocal shading to provide natural cooling and ventilation.
- In Kerala, sloping roofs are used to guard against severe rains.



Passive Strategies & Building Physics

Passive Measures – Site Level

Reducing the 'heat island' effect with approaches like:

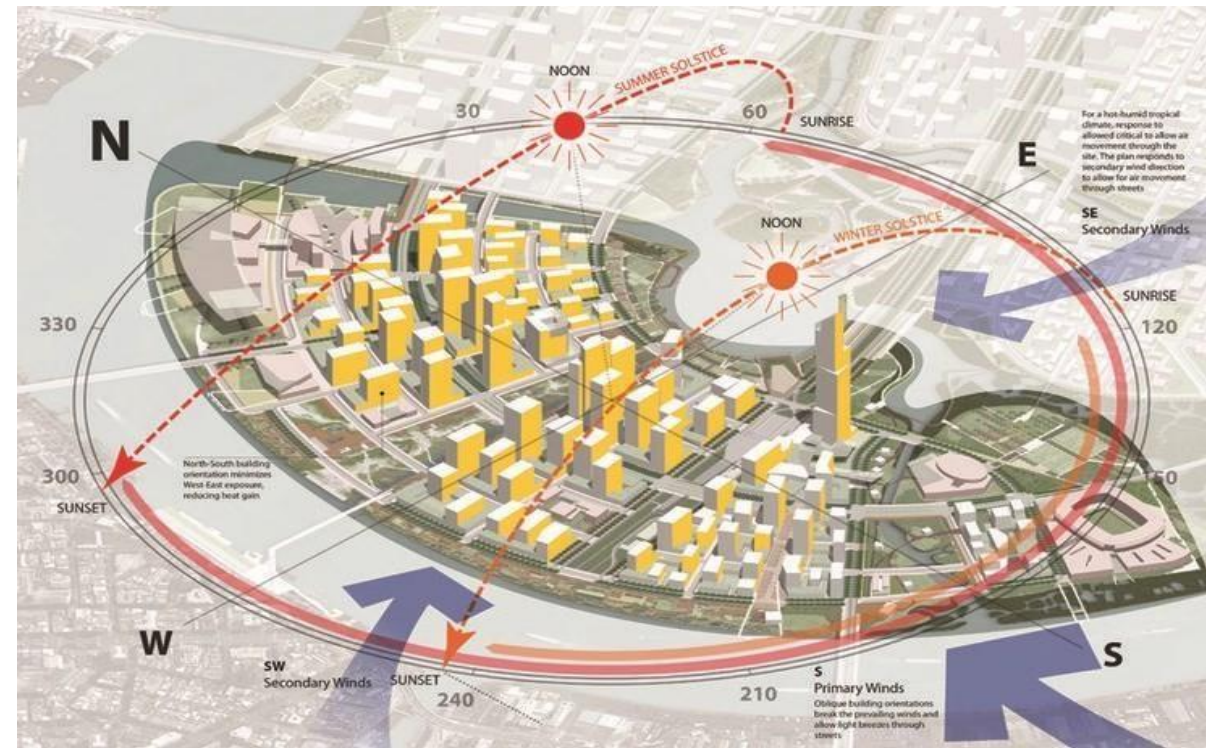
Courtyards / open courts are often surrounded by construction.

Taking advantage of block mutual shading

Using site massing to create wind passageways

lowering the amount of hard paving to allow for water absorption

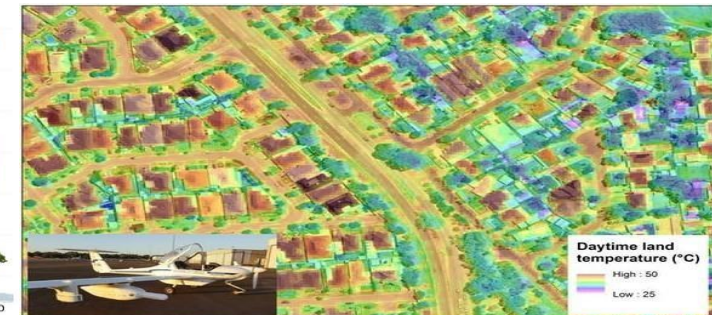
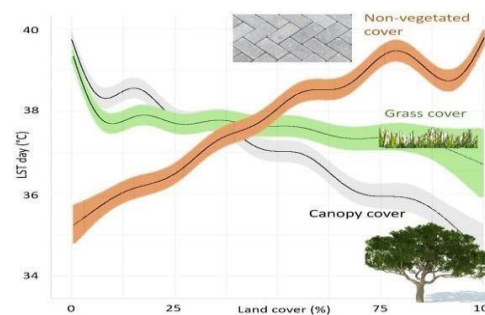
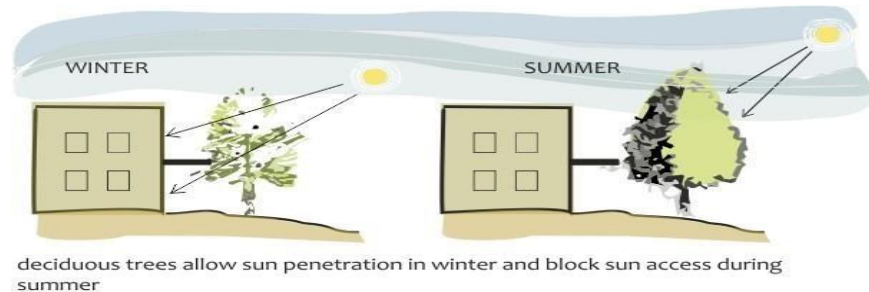
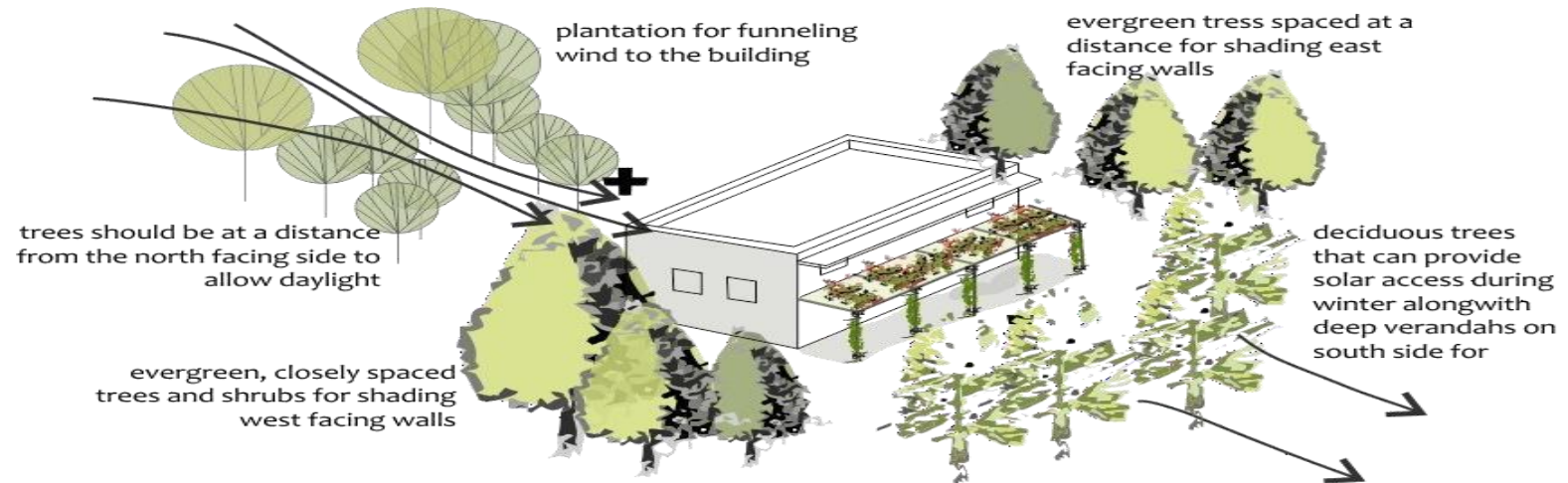
Using complementary vegetation to manage the amount of sunlight that gets through as the seasons change



Passive Strategies & Building Physics

Passive Measures – Leveraging Plantation

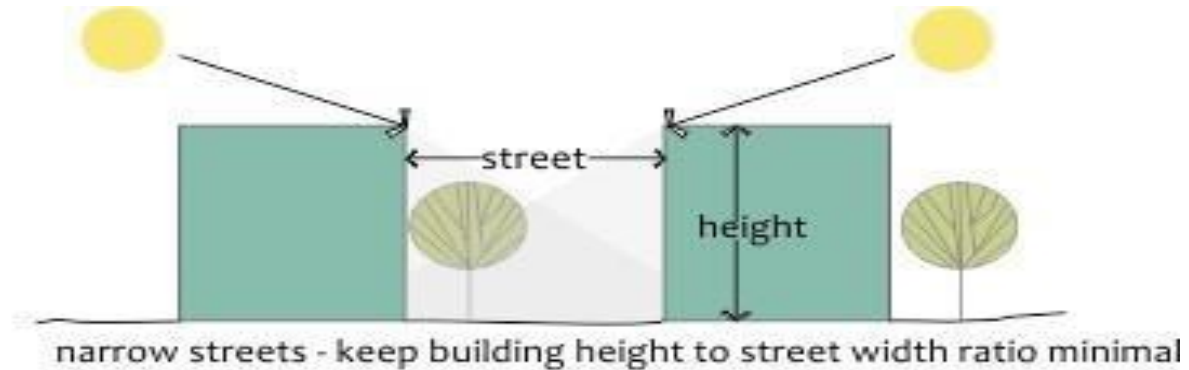
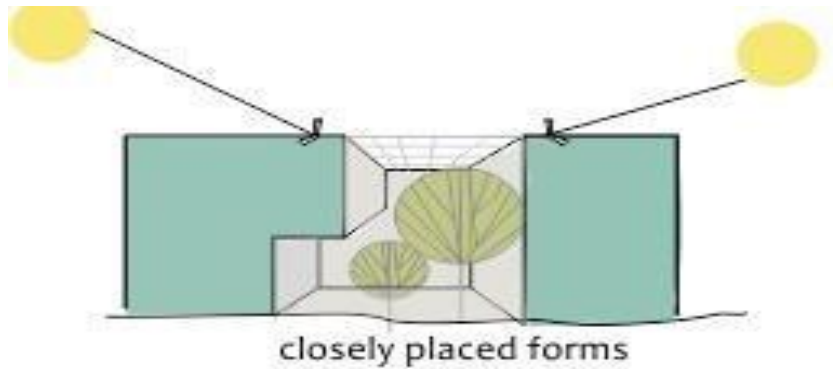
Planting trees in the right places to provide shade and ventilation can significantly reduce the severity of intense weather. During heatwaves in Adelaide, a research found that districts with more vegetation cover remained cooler by up to 6°C.



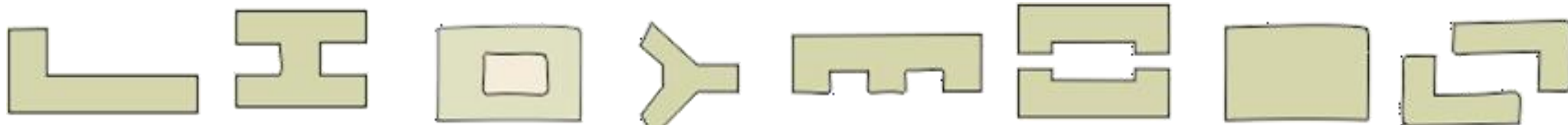
Passive Strategies & Building Physics

Block Level

Arrange the blocks so that mutual shade is obtained, avoiding solar heat buildup throughout the summer.



HEATING/
COOLING

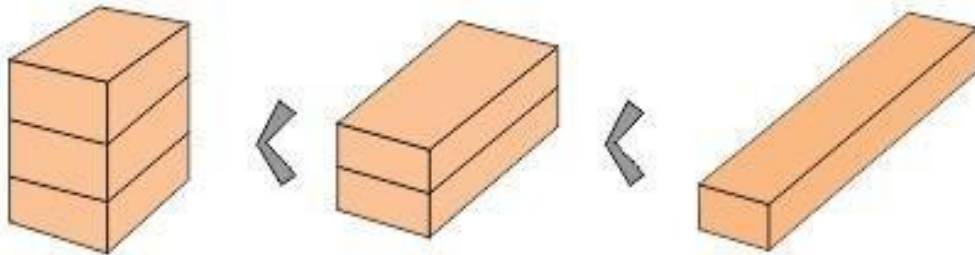


Passive Strategies & Building Physics

Block Level

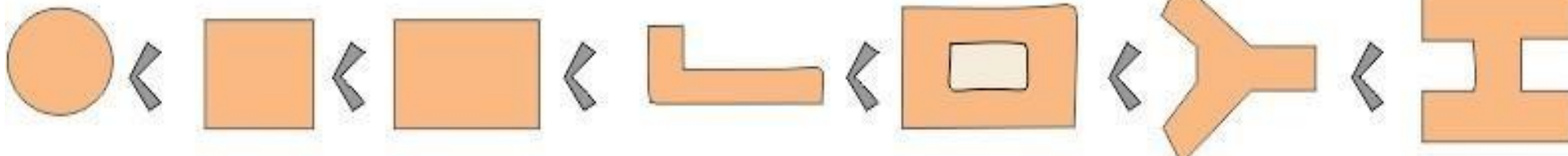
In harsh climate zones, reduce the surface area to building volume and perimeter to area ratios to reduce solar radiation exposure.

Minimise S/V ratio in extreme climates



increase compactness by reducing
surface area for the same volume

Minimise P/A ratio in extreme climates

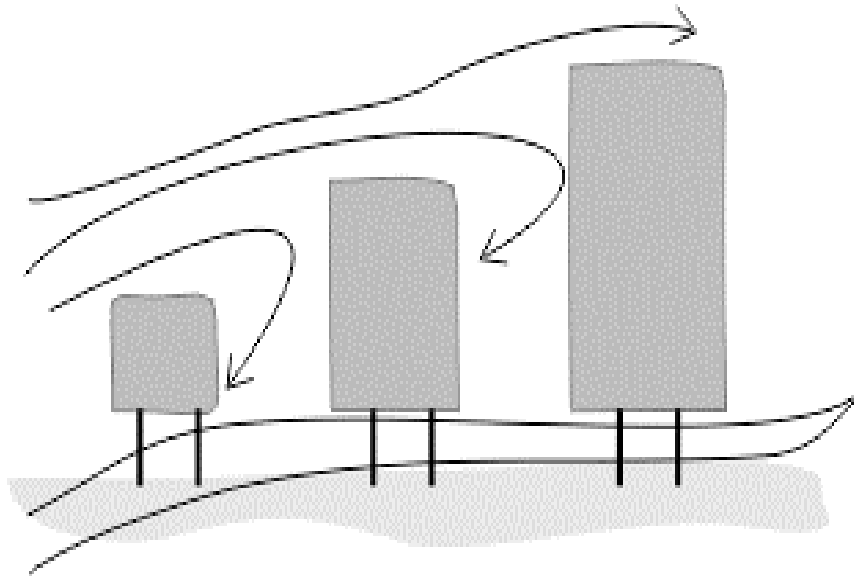


HEATING/
COOLING

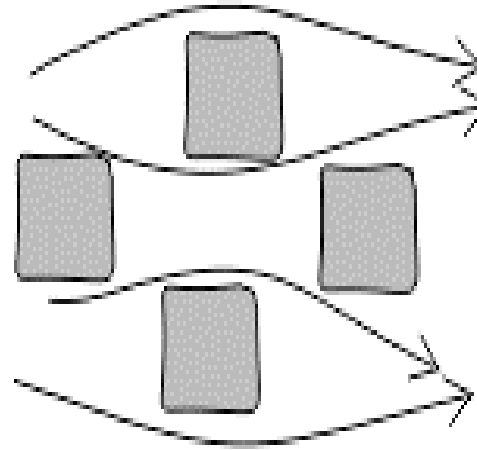
Passive Strategies & Building Physics

Block Level

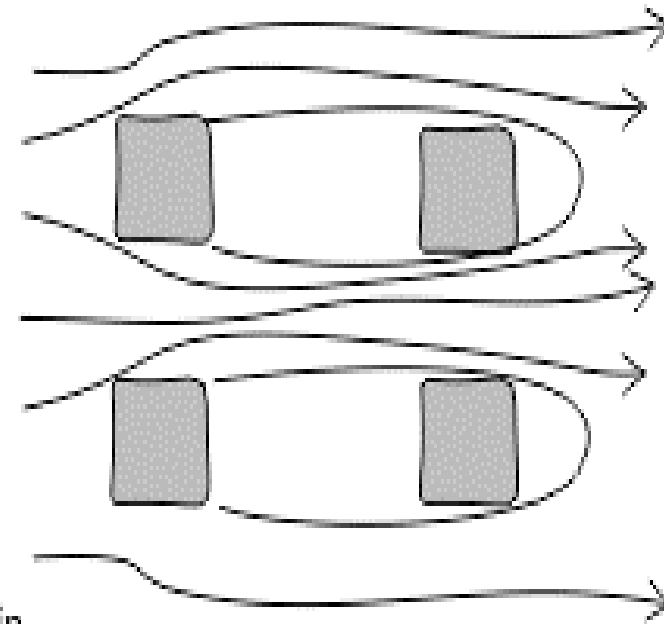
Wind shadows should be avoided by building orientation.



if a site has multiple buildings, they should be arranged in ascending order of their heights and be built on stilts to allow ventilation



staggered layout helps in accentuating wind movement

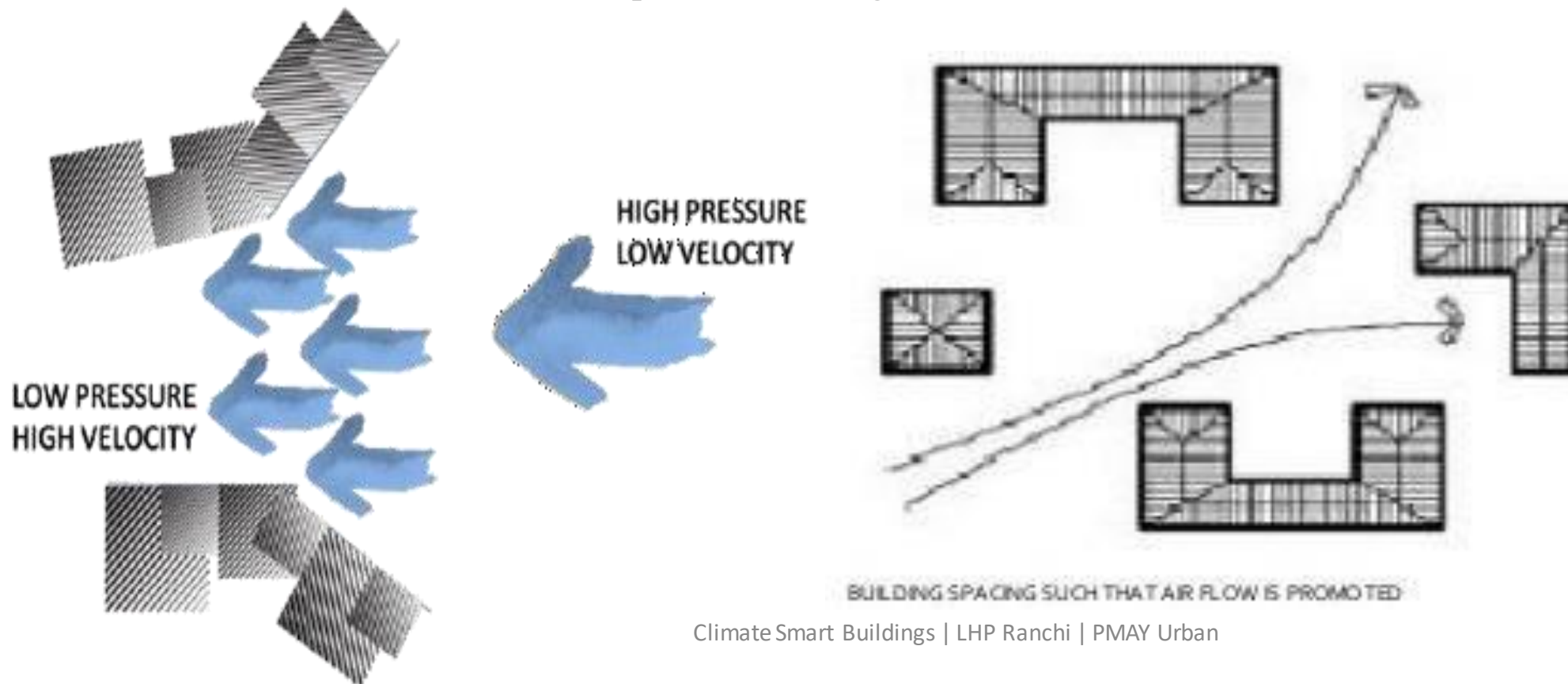


VENTILAT
ION

Passive Strategies & Building Physics

Block Level

Wind flows can be harnesses by constructing courts and catchment zones of various sizes. This can help to improve airflow and provide a cooling effect for the blocks.



VENTILATION

Passive Strategies & Building Physics

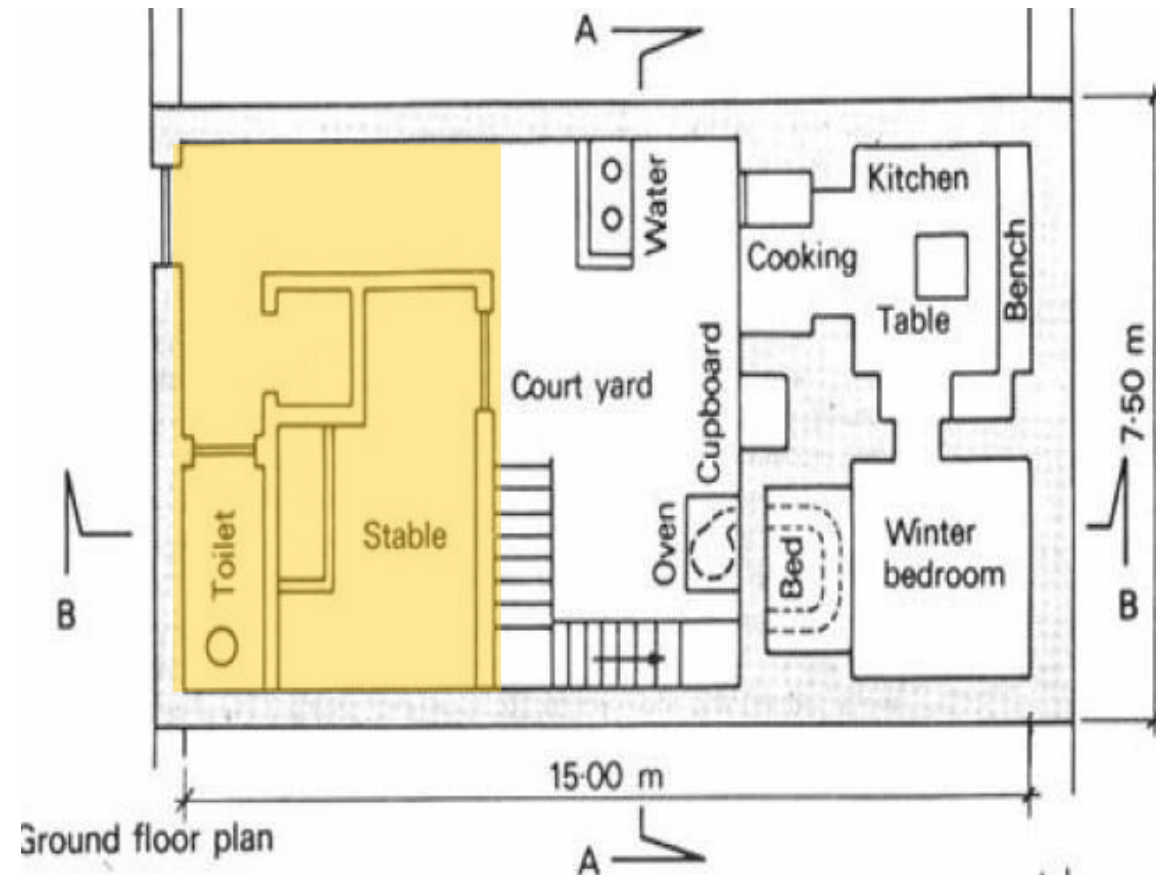
Unit Level

FORMS AND ORIENTATION:

Sun radiation penetration patterns and, as a result, heat uptake and loss in a building are affected by changes in solar route during different seasons.

Internal layout is of the courtyard type, which is rather compact. Reduced sun exposure on East-West external walls to reduce heat gain.

If planned and situated on the east and, especially, the west end of the structure, non-habitable rooms (stores, bathrooms, etc.) can be efficient thermal barriers.



Climate Smart Buildings | LHP Ranchi | PMAY Urban

HEATING/
COOLING

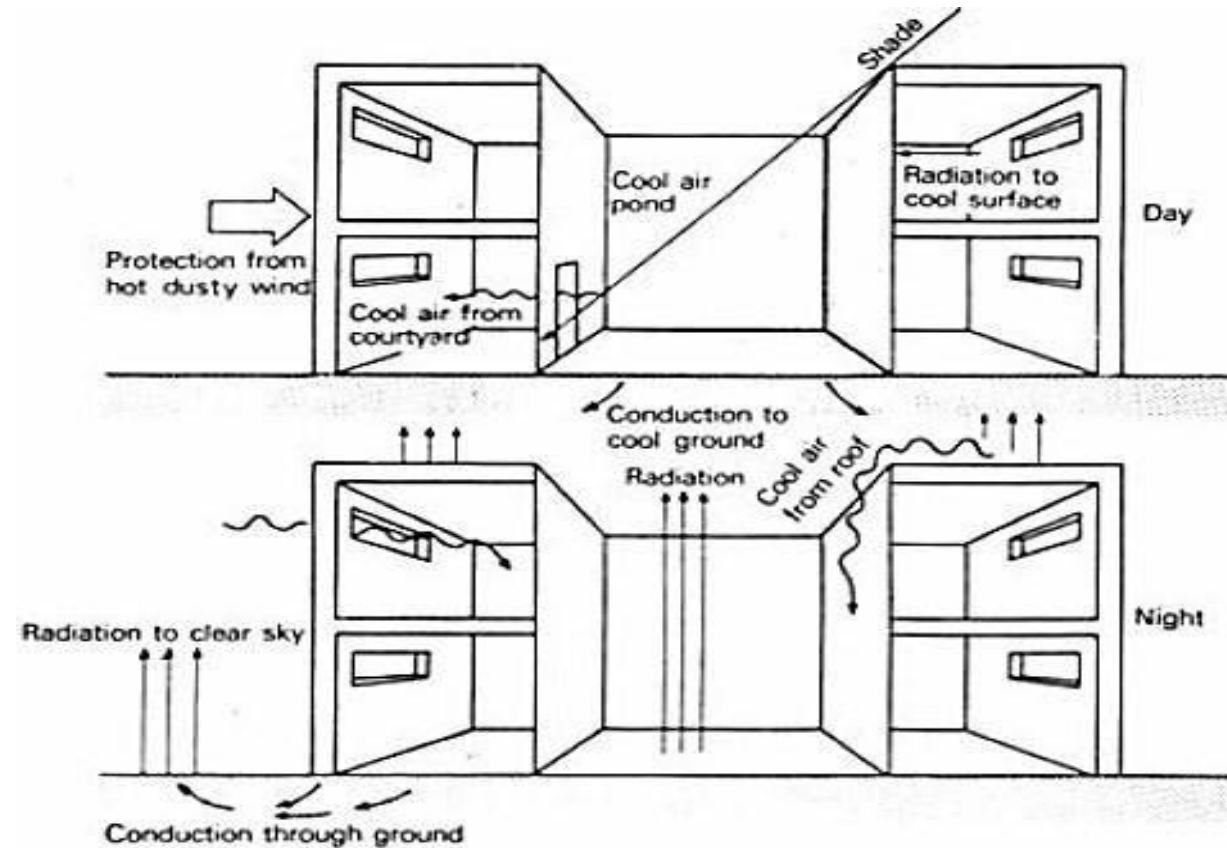
Passive Strategies & Building Physics

Unit Level

FORMS AND ORIENTATION:

High walls block the sun, resulting in significant portions of the inner surfaces and courtyard floor being shaded during the day.

The dirt beneath the courtyard will extract heat from the surrounding places and remit it to the open sky during the night, resulting in cooler air and surfaces.



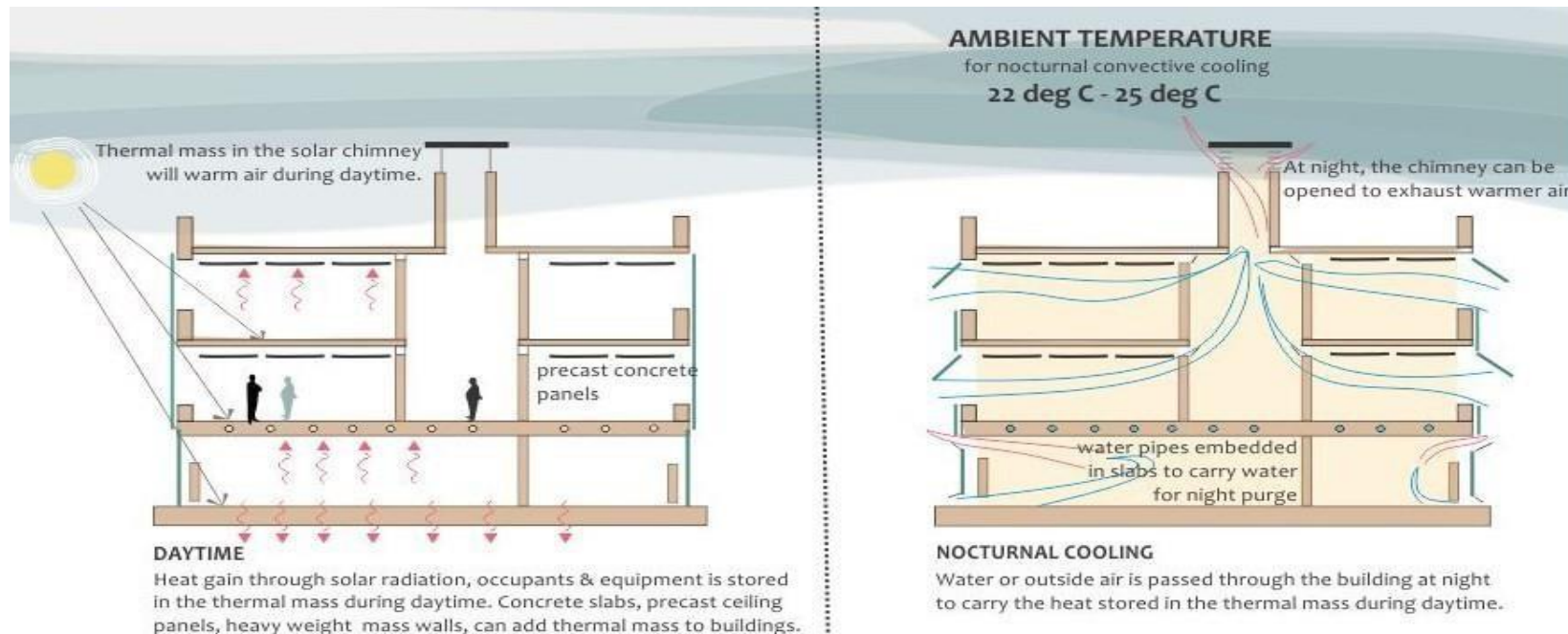
HEATING/
COOLING

Passive Strategies & Building Physics

Unit Level

THERMAL MASS:

Thermal mass can be combined with night-time convective cooling, sometimes known as "night cooling," to passively cool buildings. Thermal mass as a passive cooling and heating approach requires a large diurnal swing.



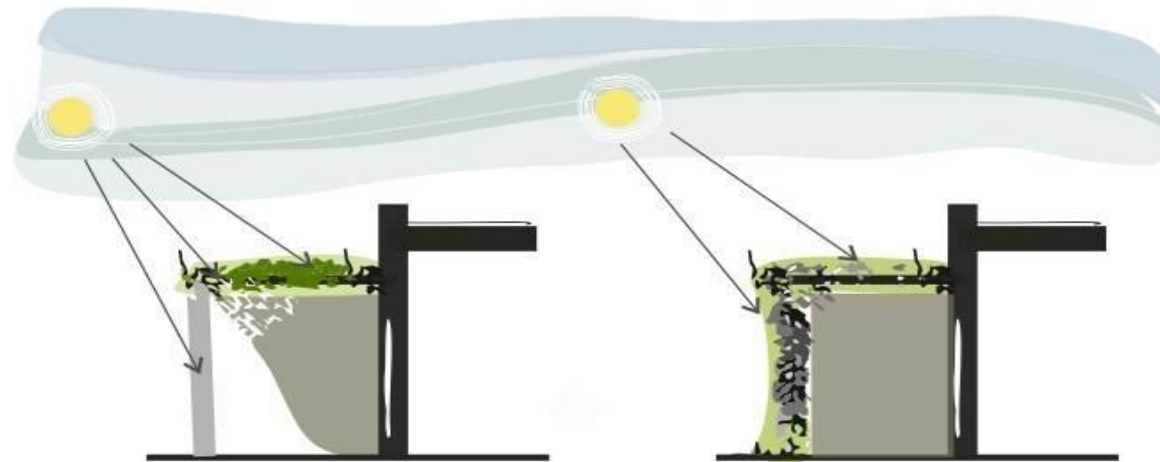
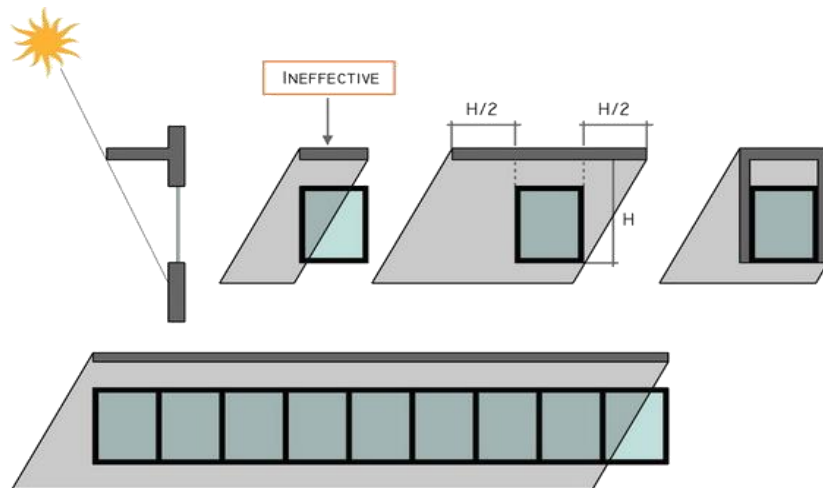
Passive Strategies & Building Physics

Unit Level

SHADING:

Shade-producing plants, such as creepers, can be used.

Fenestrations and shades/chajjas can be built to maximise solar radiation depending on the environment.



HEATING/
COOLING

Passive Strategies & Building Physics

Unit Level

ORIENTATION:

Buildings can be orientated in relation to the prevailing wind direction at angles ranging from 0° to 30° .

In buildings with a courtyard, positioning the courtyard 45 degrees from the prevailing wind maximises wind flow into the courtyard and improves cross ventilation in the building (in climates where cooling is required).

CREATING PRESSURE DIFFERENCES:

A 'squeeze point' occurs when wind enters through a smaller opening and escapes through a larger opening. This generates a natural vacuum, which speeds up the wind.

The total area of apertures should be at least 30% of the total floor space.

The window-to-wall-ratio (WWR) should not exceed 60%.

VENTILATION

CASE STUDIES

INFOSYS – POCHARAM CAMPUS

LOCATION

HYDERABAD,
TELANGANA

COORDINATES

17° N, 78° E

OCCUPANCY TYPE

OFFICE

TPOLOGY

NEW CONSTRUCTION

CLIMATE TYPE

HOT AND DRY

PROJECT AREA

27,870 m²



Given the high-standards in terms of building design achieved at the SDB1 in Hyderabad, it has now been showcased in the 'Best Practices Guide for High Performance Indian Office Buildings' by Lawrence Berkeley National Lab, a U.S. Department of Energy (DoE) National Laboratory.

GODREJ PLANT 13 ANNEXE

LOCATION

MUMBAI, MAHARASHTRA

COORDINATES

19° N, 73° E

OCCUPANCY TYPE

OFFICE – PRIVATE

TPOLOGY

NEW CONSTRUCTION

CLIMATE TYPE

WARM AND HUMID

PROJECT AREA

24,443 m²



GODREJ PLANT 13 ANNEXE

The Plant 13 Annexe Building at Godrej & Boyce (G&B) in Mumbai has been designated as India's first CII-IGBC accredited Net Zero Energy Building. The structure is a mixed-use office/convention center (with office spaces, conference and meeting rooms, auditoriums (90 to 250 seats), banquet hall, 300-person eating facilities, and an industrial kitchen), making certification extremely difficult.

In 2015, the building received an IGBC Platinum grade in the EB (Existing Building) category, which was recertified in 2019. In 2016, it was also awarded the BEE 5 Star Rating. In 2019, he received the 'Energy Performance Award' for meticulous energy measuring and monitoring. At the CII National Energy Management Award event in 2020, it was named "Excellent Energy Efficient Unit."

**EPI –
75kWh/m²/yr**

INDIRA PARYAVARAN BHAWAN, MoEF

LOCATION

NEW DELHI

COORDINATES

29° N, 77° E

OCCUPANCY TYPE

OFFICE & EDUCATIONAL

TYOLOGY

NEW CONSTRUCTION

CLIMATE TYPE

COMPOSITE

PROJECT AREA

9565 m²



The Indira Paryavaran Bhawan is now India's most environmentally friendly structure. GRIHA 5 Star and LEED Platinum certifications were awarded to the project. The structure has already received accolades, including the MNRE's Adarsh/GRIHA Award for Outstanding Integration of Renewable Energy Technologies.

The new office building for the Ministry of Environment and Forest (MoEF), Indira Paryavaran Bhawan, is a significant departure from traditional architectural design

To reach net zero criterion, several energy saving measures were implemented to lower the building's energy loads, with the residual demand being satisfied by producing energy from on-site installed high efficiency solar panels.

The project team focused on measures for lowering energy demand, such as ample natural light, shade, landscape to reduce ambient temperature, and energy-efficient active building technologies

When compared to a conventional building, Indira Paryavaran Bhawan utilizes 70% less energy. The project used green building principles, such as water conservation and optimization through site waste water recycling.

EPI –
44kWh/m²/yr

Renewable Energy Integration 930 kW PV panels with a total area of 4650m² for on-site generation, tilted at 23° facing south to generate equivalent to 70kWh/m²/yr

JAQUAR HEADQUARTERS

LOCATION

MANESAR HARYANA

COORDINATES

28° N, 77° E

OCCUPANCY TYPE

CORPORATE AND
MANUFACTURING

TPOLOGY

NEW CONSTRUCTION

CLIMATE TYPE

COMPOSITE

PROJECT AREA

48000 m²



JAQUAR HEADQUARTERS

The building is a perfect blend of modern design sensibilities, biophilic inspiration, and a brand ambition of soaring high.

The Jaguar Headquarters in Manesar is not only a stunning structure, but also a painstakingly constructed complex with cutting-edge technology that has resulted in a net zero campus with a LEED Platinum (USGBC) rating. This project is known for its complex organic design and space arrangement, making it a visual pleasure.

Through its characteristic wing-shaped architecture, the design redefines a business workplace by giving it a memorable experience. The spreading wings of a symbolic eagle, poised to take flight, are atop the horizontal glass edifice, suggesting a firm with worldwide ambitions.

ST. ANDREWS BOYS HOSTEL BLOCK, GURUGRAM

LOCATION

GURUGRAM HARYANA

COORDINATES

28° N, 76° E

OCCUPANCY TYPE

HOSTEL

TPOLOGY

NEW CONSTRUCTION

CLIMATE TYPE

HOT AND DRY

PROJECT AREA

5574 m²



ST. ANDREWS BOYS HOSTEL BLOCK, GURUGRAM

The goal of the design process was to increase student interaction within the indoor areas, which then spilled outdoors and interacted with the surrounding landscape.

On the south and north facades, the linear block was twisted to create a shaded entry (summer court) and an open terrace (winter court), respectively, to stimulate activities at all times of the day and season. The ramp serves as a buffer between the hot outdoors and the cooler interior, preventing kids from experiencing heat shock.

ST. ANDREWS GIRLS HOSTEL BLOCK, GURUGRAM

LOCATION

GURUGRAM HARYANA

COORDINATES

28° N, 76° E

OCCUPANCY TYPE

HOSTEL

TPOLOGY

NEW CONSTRUCTION

CLIMATE TYPE

HOT AND DRY

PROJECT AREA

2322 m²



ST. ANDREWS GIRLS HOSTEL BLOCK, GURUGRAM

Indoor and outdoor spaces that connect physically and aesthetically at different levels to encourage interactions and social activities are incorporated into the building's plan.

The entrance foyer and lobby were planned as outdoor spaces facing west and connected to the pantry so that students can enjoy their nights outside with a spill-out into the green landscape.

AKSHAY URJA BHAWAN HAREDA

LOCATION

PANCHKULA HARYANA

COORDINATES

30° N, 76° E

OCCUPANCY TYPE

OFFICE - PUBLIC

TPOLOGY

NEW CONSTRUCTION

CLIMATE TYPE

COMPOSITE

PROJECT AREA

5100 m²



AKSHAY URJA BHAWAN HAREDA

Mechanical air conditioning is used to guarantee thermal comfort in apical zones at all times.

Zones are created based on the intended temperature set points. 25.1 °C for apex offices, 25.3 °C for regulated office and public areas, and 25.5 °C for passive zones.

In the summer, controlled zones are cooled, and in the monsoon, they are chilled. In the summer, passive zones are cooled, while in the monsoon, they are aired. The centre atrium has a mist system for cooling the controlled and passive zones. Water that has been chilled to a temperature of 15°C.

Thank You