RACHNA
RESILIENT, AFFORDABLE AND COMFORTABLE HOUSING THROUGH NATIONAL ACTION

Building Physics and Thermal Comfort

Session 1

13th July 2022

-Vishal Garg

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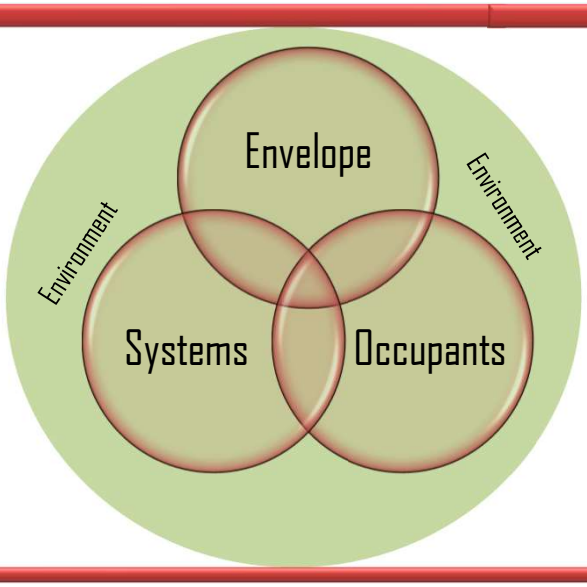
Building Physics



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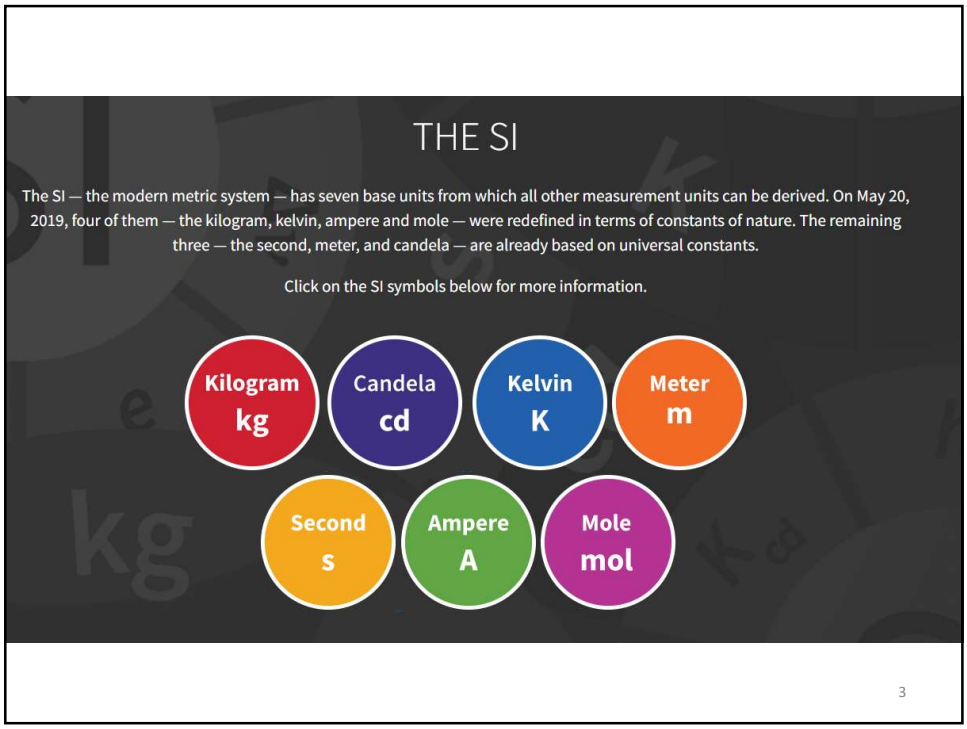
THE SI
The SI — the modern metric system — has seven base units from which all other measurement units can be derived. On May 20, 2019, four of them — the kilogram, kelvin, ampere and mole — were redefined in terms of constants of nature. The remaining three — the second, meter, and candela — are already based on universal constants.
Click on the SI symbols below for more information.
Kilogram kg
Candela cd
Kelvin K
Meter m
Second s
Ampere A
Mole mol
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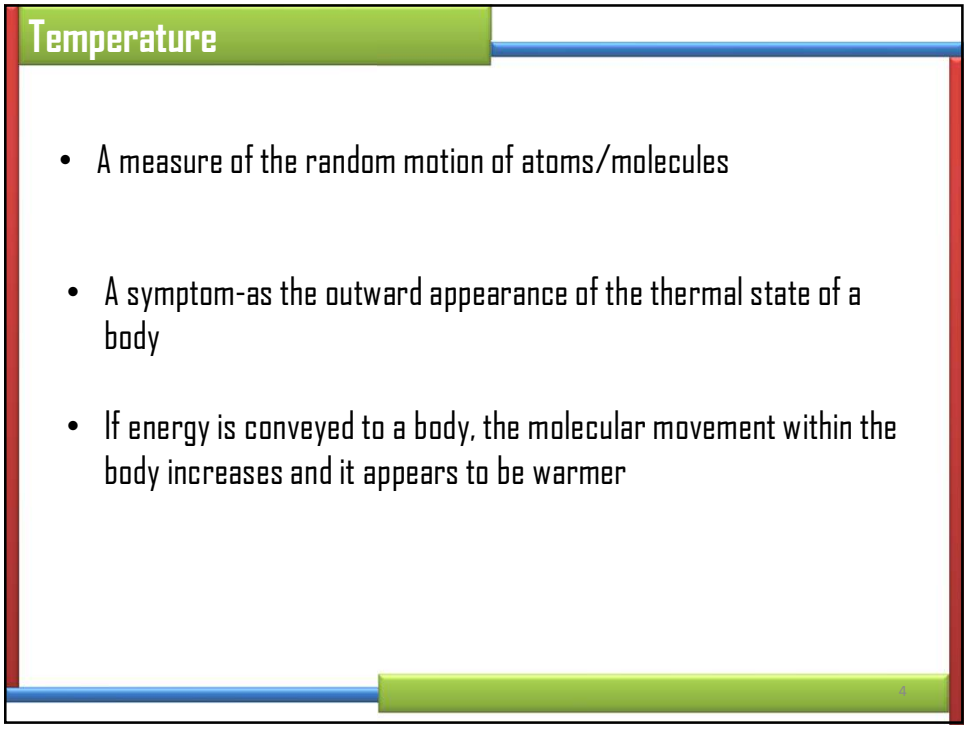
Temperature
• A measure of the random motion of atoms/molecules
• A symptom-as the outward appearance of the thermal state of a body
• If energy is conveyed to a body, the molecular movement within the body increases and it appears to be warmer
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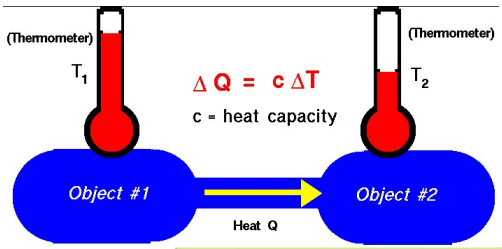
Heat transfer

- Flow of heat from hot body to a cold body
- Heat is thermal energy.
- It is transferred between bodies of different temperature.
- It is expressed in units of Joules (J) or kilowatthours (kWh).
- 1 Joule corresponds to 0.278 x 10^{-6} kWh.
- 1 kWh corresponds to 3.6 MJ (Mega Joules).



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Specific heat capacity

- The energy content of a substance depends on its:
  - temperature
  - mass
  - specific heat
- The specific heat capacity c of a substance denotes the amount of needed heat to raise the temperature of a unit mass of a substance 1 K. The unit of specific heat is thus: $J \cdot kg^{-1} \cdot K^{-1}$

Material	C_p [J/kg K]
Brick	800
Concrete	840
Limestone	910
Plaster	1000
Light weight concrete	1000
Mineral wool	1000
Wood	1200
Water	4187
Air	1006

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Laws of Thermodynamics

- First law of thermodynamics: Energy can neither be created nor be destroyed
- Second law of thermodynamics: Heat cannot pass spontaneously
  - Heat tends to distribute itself evenly
  - Flow from high temperature to lower temperature bodies
  - Directly proportional to temperature difference

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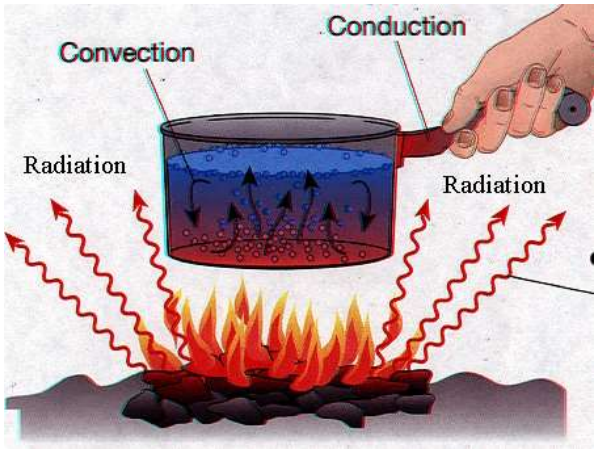
Modes of heat transfer

- Conduction
- Convection
- Radiation



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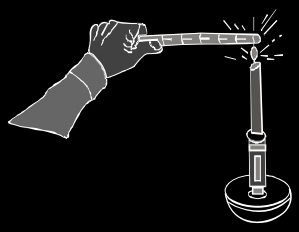
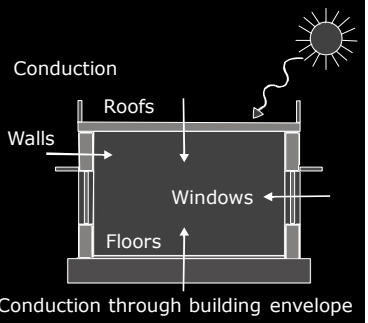
Conduction





- The flow of heat through a material by direct molecular contact
- Conduction take place when a temperature gradient exists in a solid (or stationary fluid) medium
- Energy is transferred from the more energetic to the less energetic molecules when neighbouring molecules collide
- Reduces with increase in thickness and reduction in thermal conductivity

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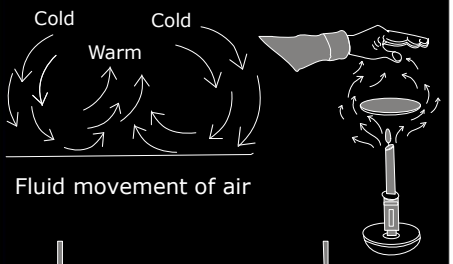
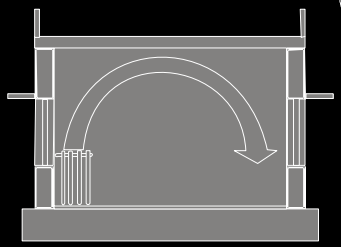
Convection





- The transfer of heat by the movement or flow of molecules (liquid or gas) with a change in their heat content
- Convective heat transfer may take the form of either in Buildings
  - Forced convection
  - Natural convection

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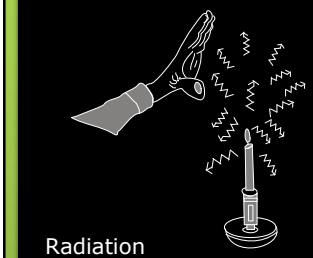
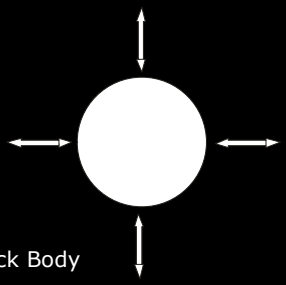
Radiation



Radiation



Black Body

- Radiation is the transfer of heat by electromagnetic waves through a gas or vacuum.
- It requires a line of sight connection between the surfaces involved
- A black body is defined as a body that absorbs all radiation that falls on its surface.

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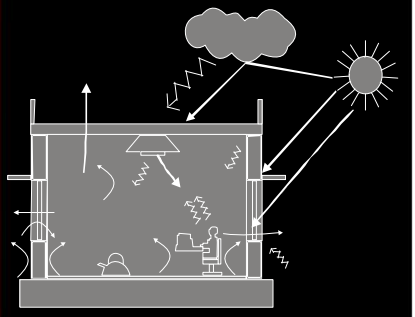
Heat gain and heat loss



Heat Gain and Heat Loss

- Heat tends to flow from higher temperatures to lower temperature zones by conduction, convection and radiation
- The rate of heat flow by any of the three forms is determined by the temperature difference between the two zones or areas considered. The greater the temperature difference, the faster the rate of heat flow

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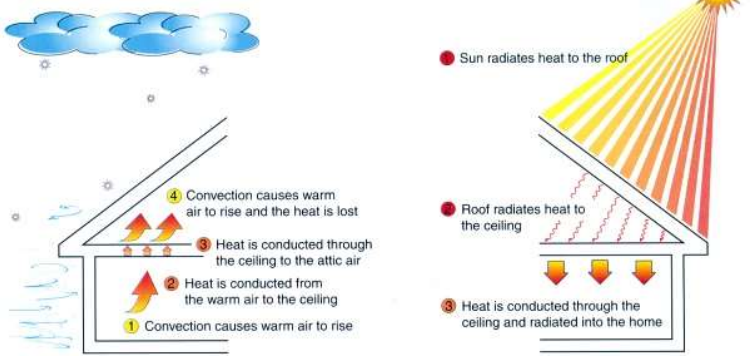
Heat transfer in buildings

Your Home Loses and Gains Heat in 3 Ways

	Convection	Conduction	Radiation
Definition:	The transfer of heat by moving air.	The transfer of heat through a solid material.	The transfer of heat in the form of electromagnetic waves.
Example:	Warm air rises and transfers heat to the ceiling	Heat is transferred from warmer sections of the walls and ceilings to cooler sections.	Heat is transferred from the roof to the ceiling.



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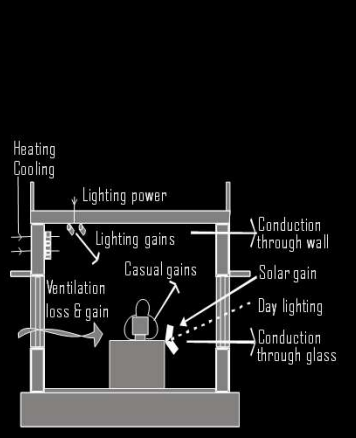
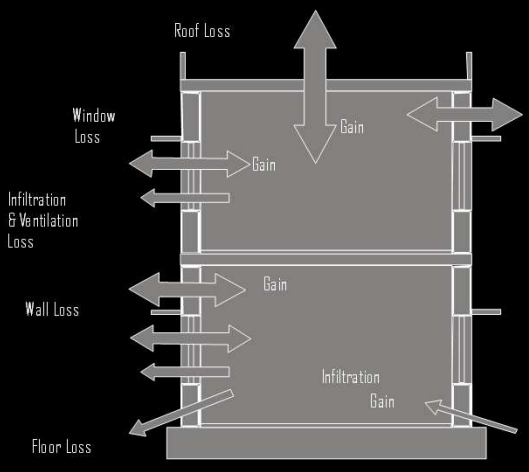
Heat flow in buildings



Heat Transfer through Envelope



Seasonal Heat Gain and Heat Loss

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Heat flow in buildings

Mode of Heat Transfer	Affected By	ECBC's role in regulating Heat Transfer
CONDUCTION	Thermal Properties of Materials & Effectiveness of Insulation	U-factors/ R-values of roofs & walls
CONVECTION	Air movement at the surface	Building Envelope Sealing Requirements
RADIATION	Indirect and direct solar radiation	• R-values of roofs & walls • Cool Roofs

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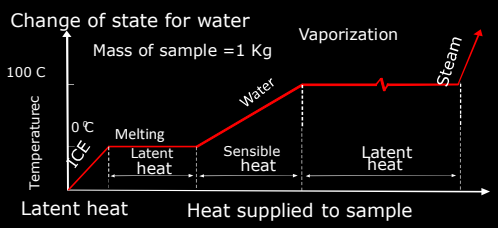
Sensible & Latent heat

Sensible Heat

- Heat that results in a temperature change is said to be "sensible" and sensed by humans

Latent Heat

- Latent Heat is the energy needed to change a substance to a higher state of matter
- No temperature change and thus no change in the kinetic energy of the particles in the material



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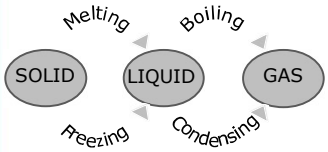
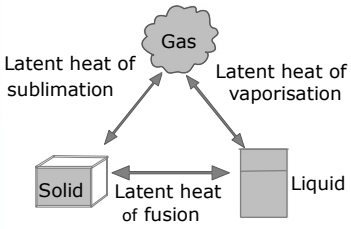
Change of State





- Science: Change in the physical state of a material (solid, liquid, or gas)
- State change occurs at a constant temperature but still entails the movement of energy
- Ex. Evaporation absorbs energy and condensation releases energy
- It involve the absorption or release of heat energy, called latent heat, without change in temperature of the material

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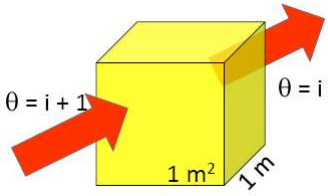
Thermal Conductivity

- Thermal conductivity in W/m K



Thermal conductivity of various materials

Material	l [W·m⁻¹·K⁻¹]
Brick	0.6
Concrete	1.7
Granite	3.5
Gypsum	0.22
Iron	84
Light-weight concrete	0.14
Mineral wool	0.04
Wood	0.14

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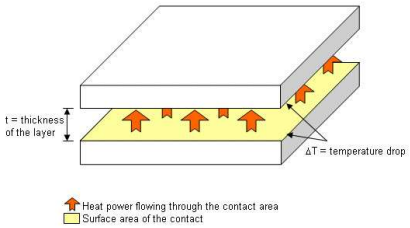
Thermal Resistance

- The value of the thermal resistance is the temperature difference across the material required to produce one unit of heat flow per unit area
- Unit : m^2-K/W

Air Space Resistance



Factors that affects air-surface resistance:

- Thickness of the airspace
- Flow of air in the air-space
- Lining of air-space (normal/reflected)

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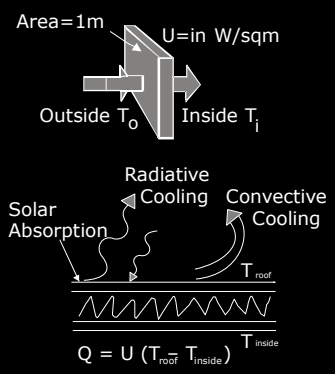
Thermal Transmittance



- Thermal transmittance from thermal resistance can be expressed as
  - U = 1 / R where
  - U = thermal transmittance (W/m^2 K)
  - R = thermal resistance (m^2 K/W)
  - Overall thermal transmittance can be expressed as U = 1 / (Σ R)

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Roof compliance example

Type	U-factor (W/m²-°K)	U-factor (Btu/h-ft²-°F)
RCC slab with mud phuska and clay tiles	2.797	0.493
RCC slab with foam concrete or perlite	0.069	0.012
Inverted clay/pots with mud phuska	2.244	0.396

- Taking case of RCC with mud-phusca
- Default U=2.797, Target U=0.261 (e.g. call centre/IT/hotel building)
- $R_{assembly} = R_{roof} + R_{insulation}$
- $(1/0.261) = (1/2.797) + R_{insulation}$
- $R_{insulation} = 3.47$, $R_{insulation} = L/k$
- $K_{perlite} = 0.04 W/mK$, $L = 0.14m$
- $K_{PUF} = 0.03$, $L = 0.1m$
- $K_{air} = 0.024$, $L = 0.08m$, (caution!!! Insulation of air cavity does not increase linearly for ever)

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Wall compliance example

Type	Description	U-factor (W/m²-°K)	U-factor (Btu/h-ft²-°F)
Mass single wall	Single wall with no insulation, plaster on both sides	1.99	0.351
Mass double wall	Double brick wall with air gap	1.23	0.216
Curtain wall	Curtain wall	2.11	0.371

- Double brick wall with air gap is not sufficient
- Taking case of single brick wall
- Default U=1.99, Target U=0.44)
- $R_{assembly} = R_{wall} + R_{insulation}$
- $(1/0.44) = (1/1.99) + R_{insulation}$
- $R_{insulation} = 1.77$, $R_{insulation} = L/k$
- $K_{hardboard} = 0.16 W/m\text{-}K$, $L = 0.28m$
- $K_{PUF} = 0.03$, $L = 0.05m$
- $K_{air} = 0.024$, $L = 0.04m$

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Surface Resistance

- It is the resistance is offered by a thin layer of air film separates the body from the surrounding air.
- The measure of this phenomenon is the 'surface or film resistance' expressed in units of resistance and reciprocal of it being film-conductance (f) with units $W/m^2\ ^0C$.

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Surface Conductance

- If the layer of air on both sides of wall is considered as per the concept of surface conductance, heat transfer from air on one side to air on other side takes place. Hence the overall 'air-to-air resistance (R)' will be the sum of the body's resistance and the surface resistance on both sides of wall: $R = 1/f_o + R_b + 1/f_i$
- The value of surface or film conductance (f) is a function of surface qualities such as smoothness and of the velocity

$1/f_o$ is film resistance on outer side of wall

$1/f_i$ l s film resistance on inner side of wall

R_b is the resistance of wall or body

unit m^2 K/W.

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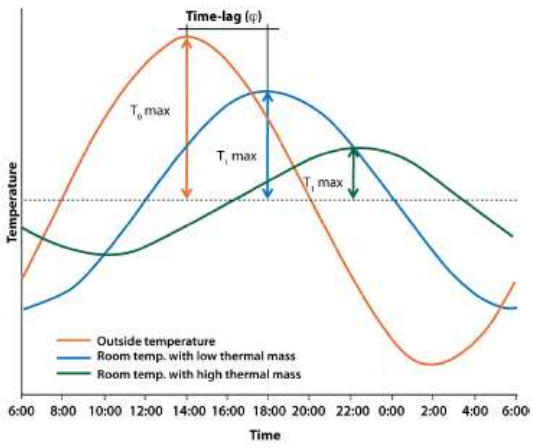
Transient behavior of building

- Each particle of the wall material absorbs certain amount of heat depending upon its mass and specific heat jointly known as heat capacity.

Decrement factor $\mu = \frac{\text{Ti max.}}{\text{T max.}}$



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Transient heat flow estimation

$$Q = U A [(Tm - Ti) + \mu (T\phi - Tm)]$$

q is momentary heat transfer rate in W

A is area in m^2

U is U-value in $W/m^{2\,0}C$

Tm is daily mean outdoor temperature

Ti is indoor temperature (assumed to be constant)

Tϕ is outdoor sol-air temperature φ hours earlier than the time of investigation

μ is decrement factor

φ is time lag in hours

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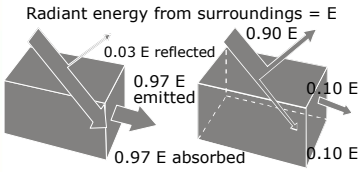
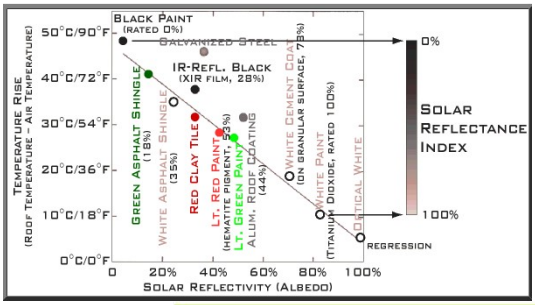
Emissivity



Lampblack and Silver coated block

- The ratio of the radiant energy emitted from a surface at a given temperature to the energy emitted by a black body at the same temperature
- The lower the emissivity rating, the better the insulation characteristic



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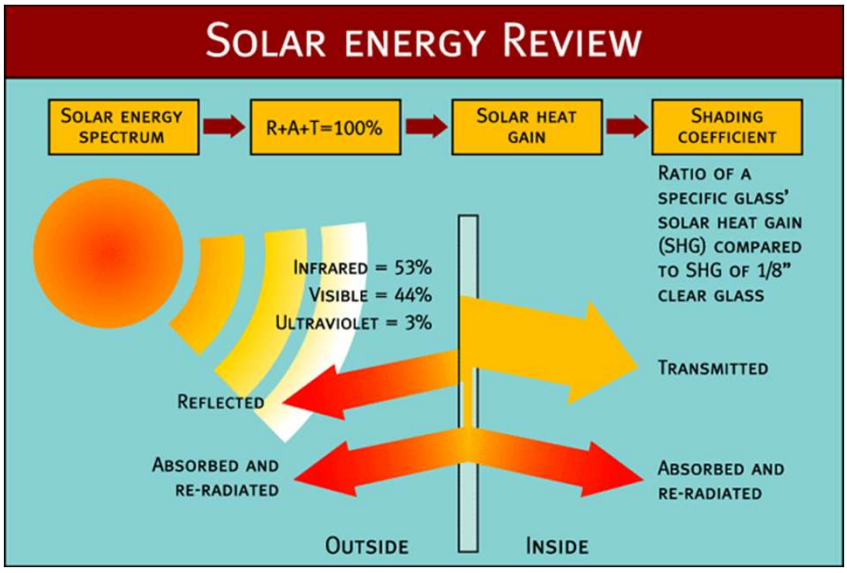
Transparent Components



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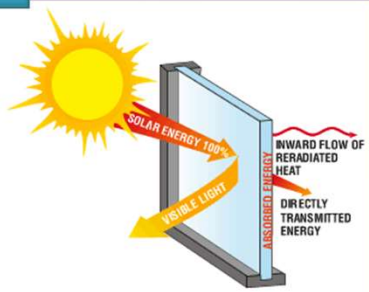
Solar Heat Gain Coefficient

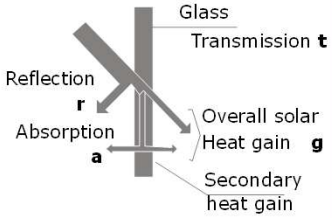
Solar Heat Gain

- Heat gain from the sun, entering a room through transparent surfaces (kW/m²)

Solar Heat Gain Coefficient

- The percentage of solar energy directly transmitted or absorbed and re-radiated into a building
- Ratio of the sum of directly transmitted solar radiation and the amount of absorbed radiation entering the space through a window to the external solar radiation





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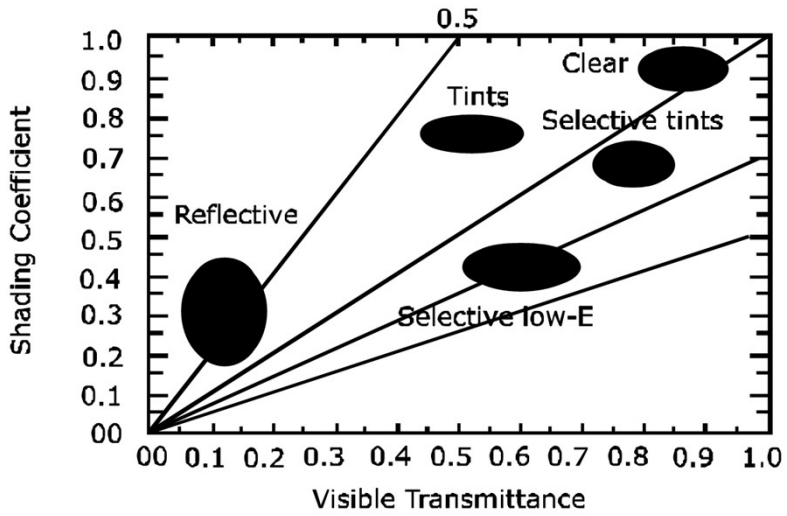
SHGC vs VLT



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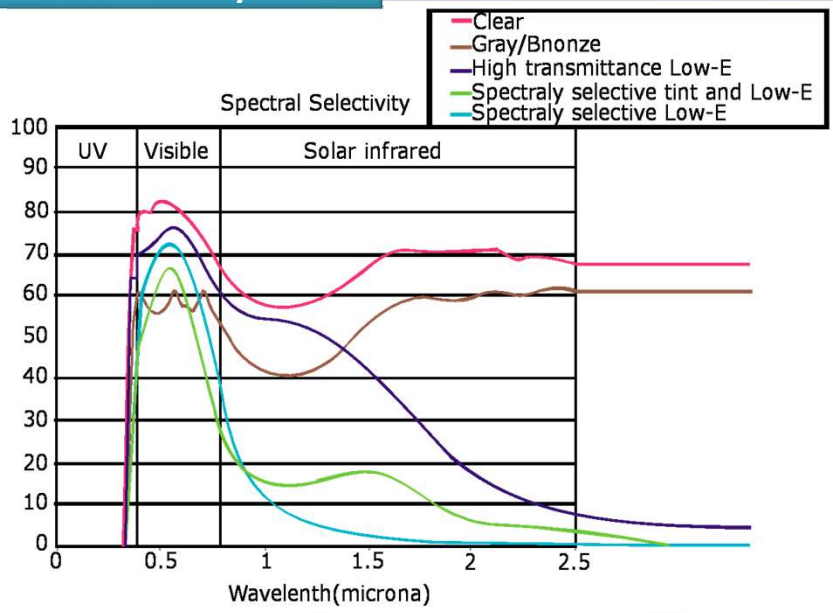
Spectral Selectivity



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Effective SHGC

Same glass but different SHGC

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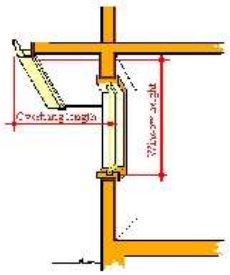
Effective SHGC

Same glass but different SHGC



Overhang

Louvers Awnings Shutters

Drapes and curtains Venetian blinds Roller shades

Shading devices (external and internal)

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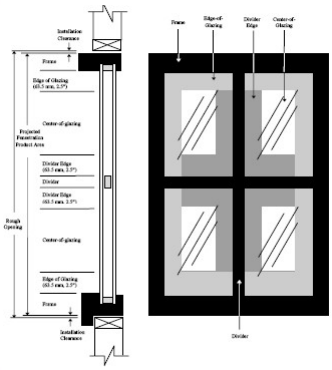
U value of Fenestration



Total Product U-factor

- Insulating values of the glazing assembly
- The edge effects in the IG Unit
- The insulating value of the frame & sash

Center-of-Glazing U-factor

- Total number of glazing layers, the dimension separating the various layers of glazing,
- Type of gas that fills the separation, Characteristics of coatings on the various surfaces.

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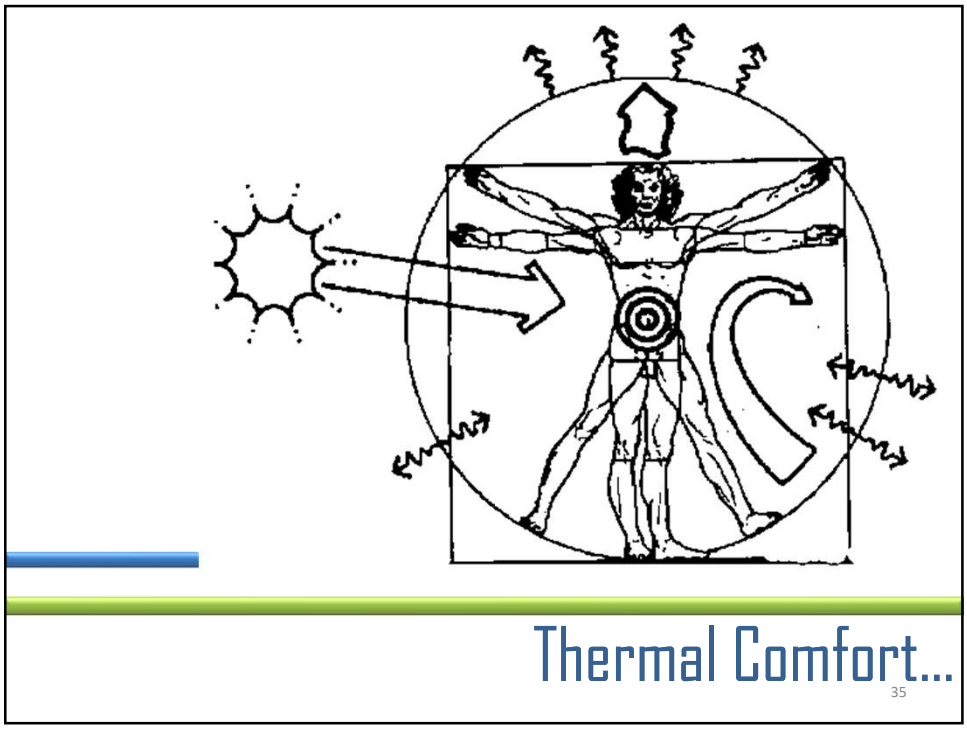

Thermal Comfort...

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Thermal Comfort

- That condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation"

PERSONAL PARAMETERS
personal choices

- Activity (Metabolic rate)
- Clothing

ENVIRONMENTAL PARAMETERS
Building envelope and HVAC

- Air temperature
- Mean Radiant temperature
- Air speed
- Humidity

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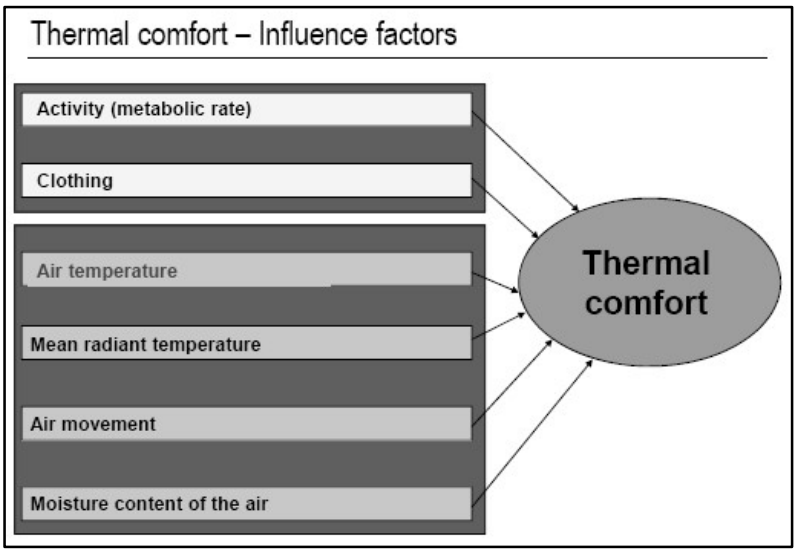
Comfort Parameters



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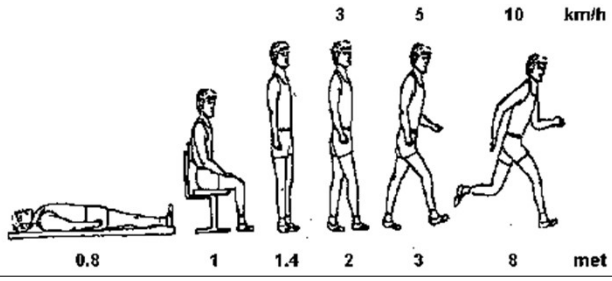
Activity



- M(metabolic rate): the rate of transformation of chemical energy into heat and mechanical work by metabolic activities within an organism, usually expressed in terms of unit area of the total body surface or met units
- 1 met = 58.2 W/m2, which is equal to the energy produced per unit surface area of an average person, seated at rest

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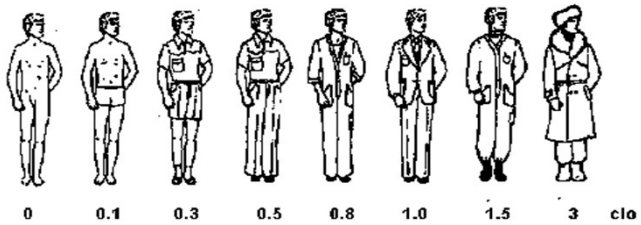
Clothing

- clo: a unit used to express the thermal insulation provided by garments and clothing ensembles
- 1 clo = 0.155 m2·K/W

Ensemble Description	I_{cl} (Clo)
Trousers + short-sleeved shirt	0.57
Long-sleeved coveralls + T-shirt	0.72
Sweat pants + sweat shirt	0.74
Trousers + long-sleeved shirt + suit jacket	0.96
Insulated coveralls + long-sleeved thermal underwear (+ bottoms)	1.37



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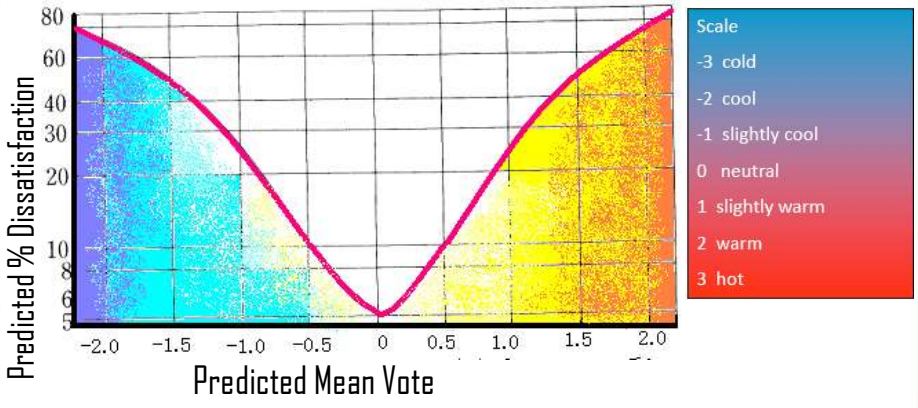
PMV & PPD



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Radiative temperature

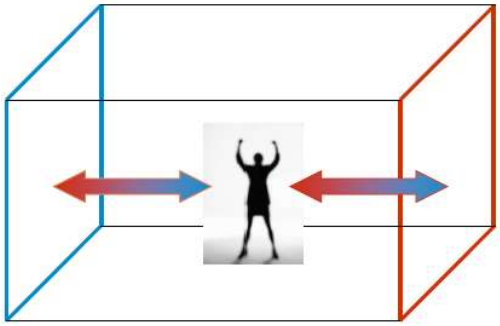
Radiation exchange

θ_U mean radiant temperature (MRT)

Rough approximation:

$$\theta_U \approx \frac{(\sum A_i \theta_i)}{\sum A_i}$$

θ Surface temperature
A Area



41

41

Operative temperature

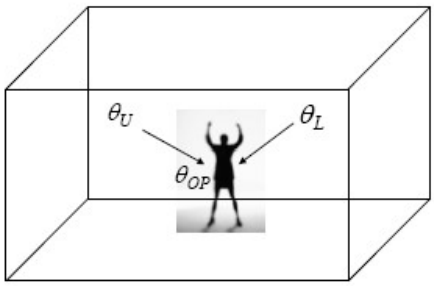
Operative Temperature

Operative Temperature (dry resultant or perceived temperature)

q_L Air temperature

q_U Mean radiant temperature

$$\theta_{OP} \approx \frac{\theta_L + \theta_U}{2}$$



42

42


GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA
Ministry of Housing and Urban Affairs
Government of India
आज़ादी का अमृत महोत्सव
giz
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
Thank you
RACHNA
asci
Leadership through Learning

43

RACHNA
RESILIENT, AFFORDABLE AND COMFORTABLE HOUSING THROUGH NATIONAL ACTION

One-Day Online Training Program on Thermal Comfort in Affordable Housing

Session 2

13th July 2022

1

Importance of Passive Design for Comfort and Energy Efficiency in Residential Buildings

Ashok Lall

2

Sustainable Development Goals

Affordable homes at locations of employment and economic opportunity with access to public transport and social amenities. Livelihoods in an inclusive construction economy

Resilience of urban living in cases of infrastructure breakdown and disasters, with sufficiency of habitable space and environmental security – water, air, recycled waste.

Use of low-carbon and resource-efficient modes of production for construction of housing and selecting building types for minimum operational energy.

Build-in resilience against extreme events, shade and green for a habitable outdoors against heat waves, aggregate rain harvest and water efficiency, minimize hard ground and motor vehicles for low UHI

Housing for all
Ministry of Housing & Poverty Alleviation

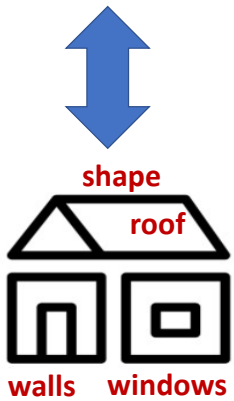
SUSTAINABLE DEVELOPMENT GOALS

PARIS2015 UN CLIMATE CHANGE CONFERENCE COP21.CMP11

3

The climate and its seasonal and diurnal patterns vary from place to place

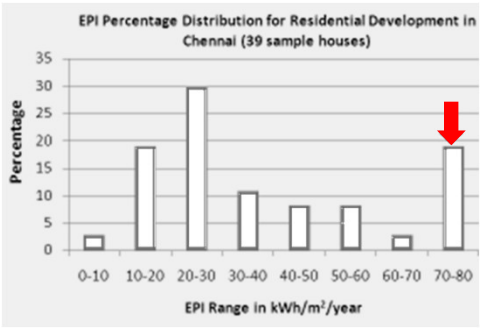
Passive design strategies would be climate responsive

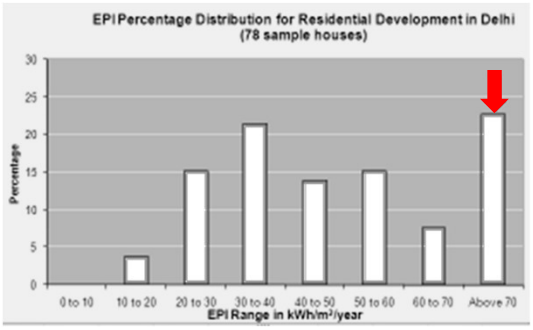


Building design would respond to seasonal and diurnal variations

4

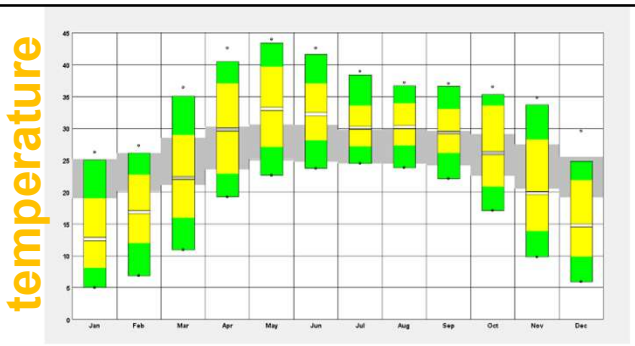
ELECTRICITY CONSUMPTION PATTERN : sample household survey

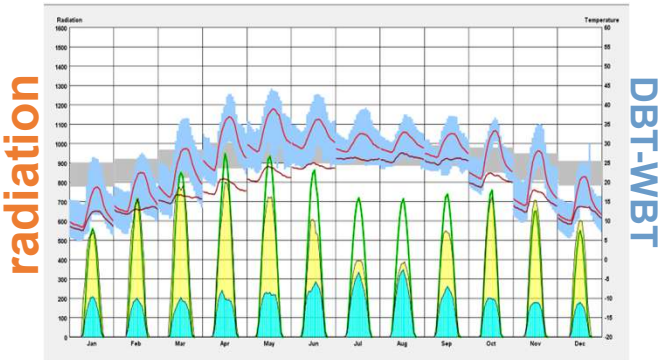




There is an emerging trend of houses with EPI above 80 kWh/sq.m./year which are typically houses with 2 or more air conditioners and 4 or more occupants. This trend is visible in both climate types.

5

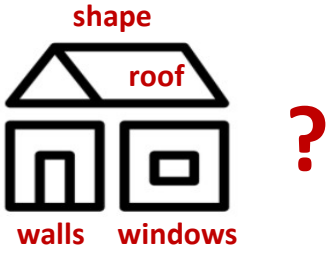




Delhi

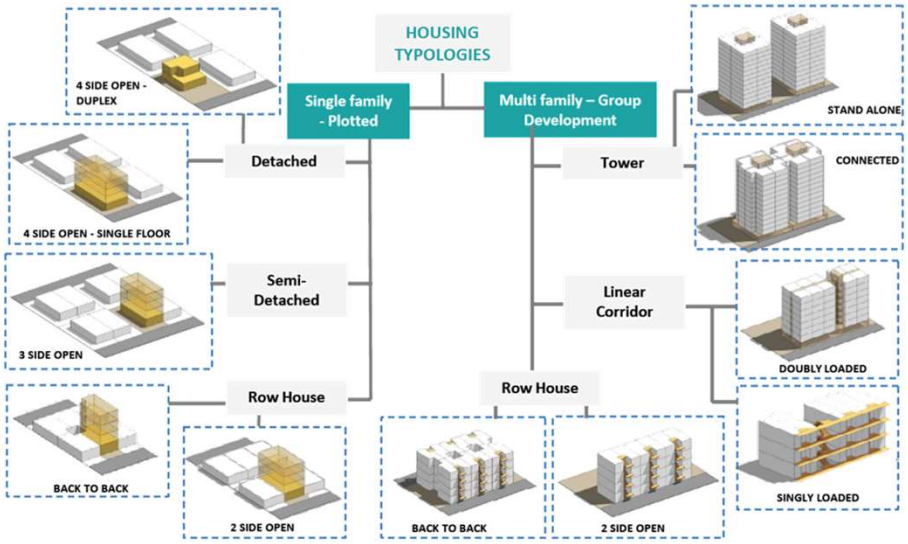
cold..pleasant...hot...humid...pleasant..

Note diurnal range variation!



6

Residential Typologies



7

STRATEGIES

- EXPOSURE to Solar, ambient air and wind Adjacent microclimate
- INSOLATION
- HEAT TRANSFER
- HEAT EXCHANGE
- HUMIDITY CONTROL
- HEAT SINKS / SOURCES

ENGINES

TECHNIQUES

– Shape, surface area

– Orientation / shading,

– Shading device/system

–Thermal mass, insulation, surface reflectance

– Ventilation, infiltration control

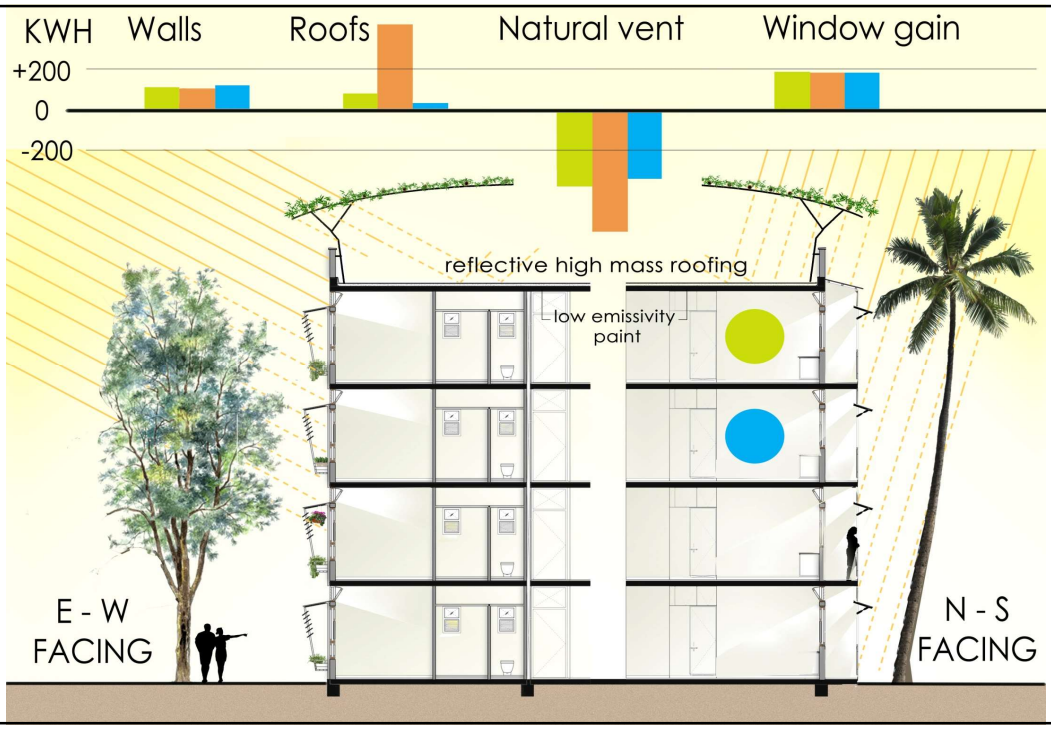
– Vapour barrier

– Evapo-transpiration, Sky, Earth, Water body

- Passive engines

- Low energy cooling/heating systems

8



9

EXPOSURE

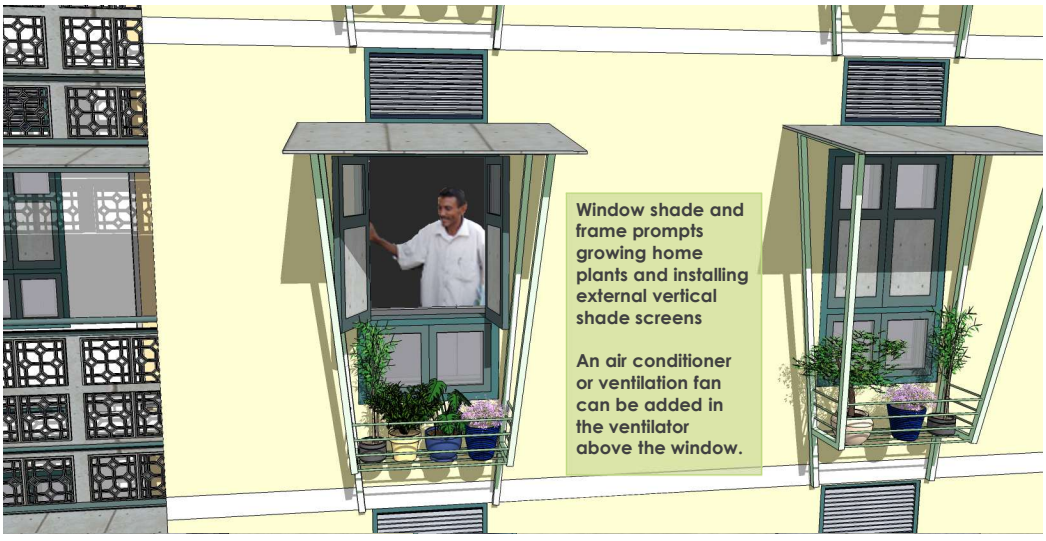
- Row housing to reduce peripheral wall exposure.
- External shading system – balconies and sun shade frames.
- End wall shading

10

SITE LEVEL STRATEGY – ORIENTATION and MICROCLIMATE FOR THERMAL COMFORT

11

BUILDING LEVEL STRATEGY – WINDOWS AND BALCONIES



Afternoon

12

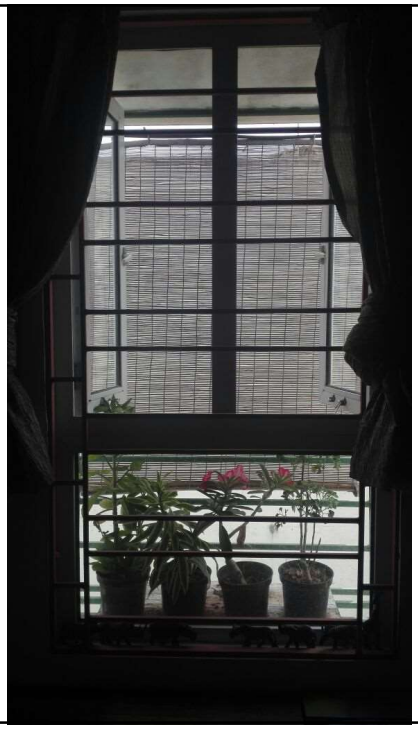
BUILDING LEVEL STRATEGY – WINDOWS AND BALCONIES

13

14

Happinest Avadi, Chennai

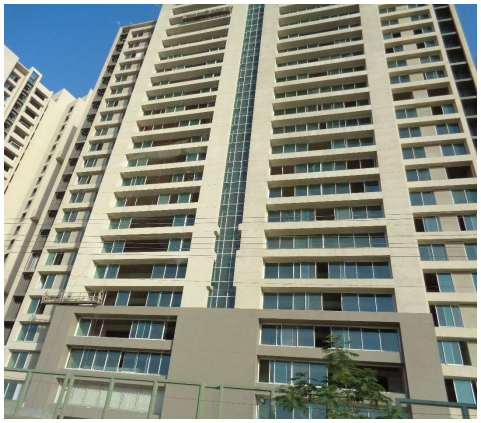
15



16

Design recommendations for thermal comfort

- **Reduce heat gains from the sun through windows**
  - Optimize the size of windows, as *glass* transfers **3-6** *times more heat* than walls
  - Shade the window- **use external movable shading** or **partially opaque shutters**



17

TYPICAL SHADING DEVICE FRAMEWORK

BRIEF DESCRIPTION

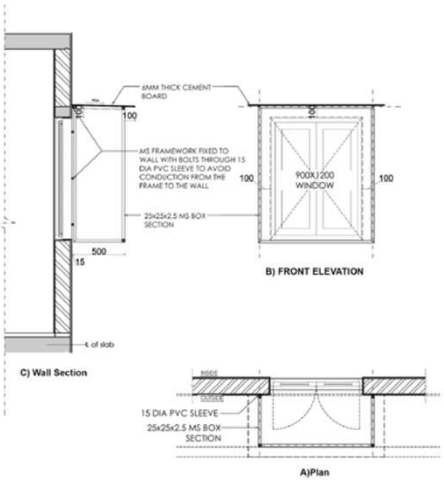
If a projected frame of light metal section is fixed on the wall surrounding the window opening is provided (as shown in the wall section), it will help to attach the shading panels or screens conveniently. This frame would allow the user to easily install shading screens/chiks/cloth, etc. These screens can be either fixed or movable type. The extent of the shading panel would depend on the orientation of the window. (See illustrations)

Framework: The framework is a support system designed to easily fix shading screens corresponding to the orientation. This typical box frame is made up of MS sections; other alternative options include aluminium, stainless steel, and GI. However, the box frame cost is provided for MS section.

The chhajja projection at the top should ideally be a lightweight, non-porous material such as cement board. One may also use stone or any other waterproof boards. The frame should be attached to the external wall with minimum surface area in contact with the wall. PVC sleeves can be used to separate the frame and wall and limit the conduction heat gains from the shading device to the envelope.

The fixed shading elements may be provided by the builder at the time of making the building, whereas roll-up/pull-down screens may be left to the user to install. Figure A provides the sketch of the assembly. The construction steps are shown in Figures 1 to 4. The details of the front elevation and wall section are shown in Figures B and C, respectively.

₹3000
Cost/m²



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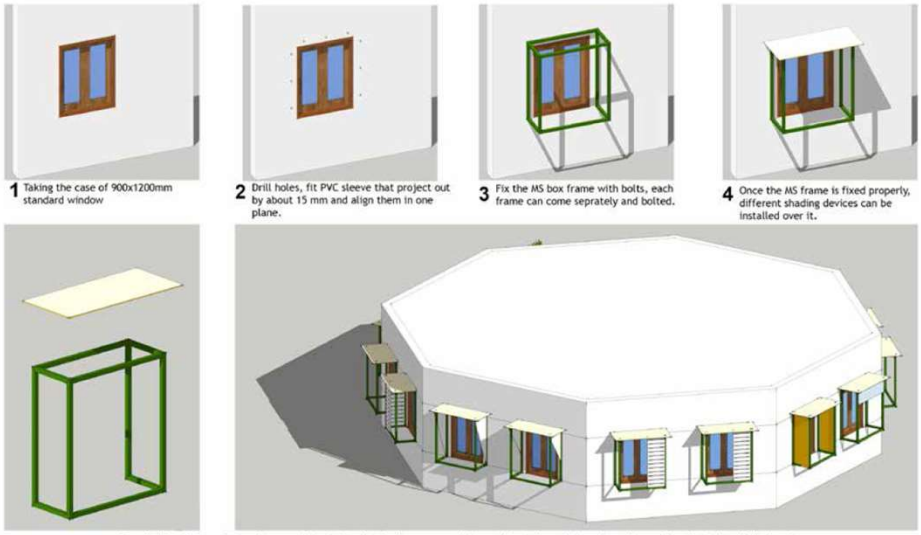
18

CONSTRUCTION STEPS



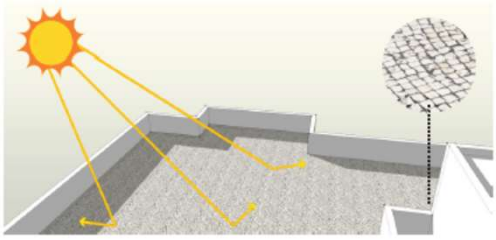
The shading device acts as a framework to further fix shading screens, chiks, perforated panels etc. depending on the orientation of the facade.

29

19

Design recommendations for thermal comfort

- **Reduce heat gains through the roof and walls**
  - Insulate / shade roof. Reflective roof finish
  - Insulate / shade walls



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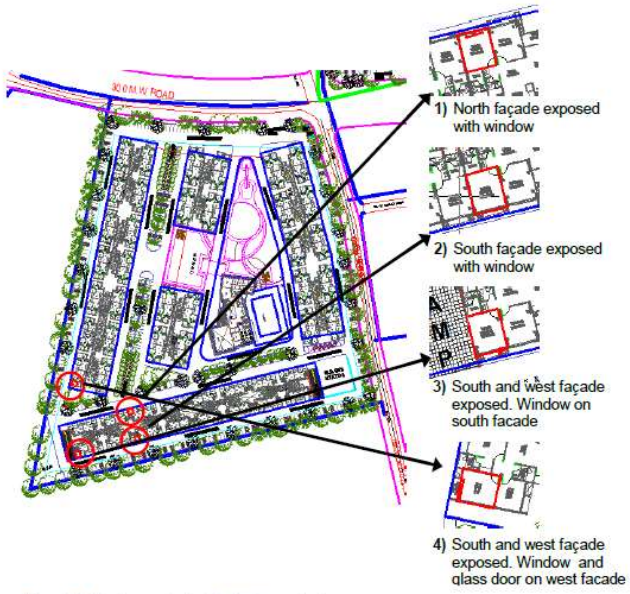

Figure 12: 4 bedrooms taken for further analysis

Energy simulation was carried out in these sample bedrooms to calculate peak temperature inside the flats on a typical summer day as well as cooling loads.

22

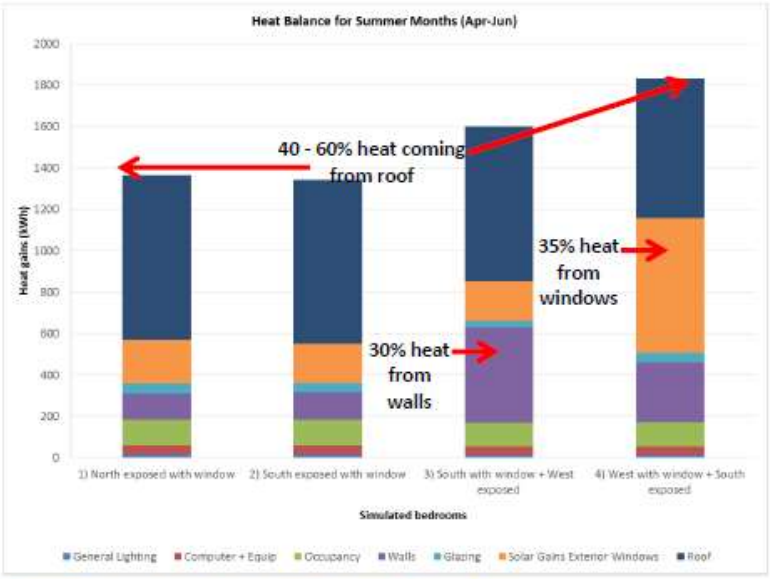

Figure 17: Heat balance for summer months for top floor

23

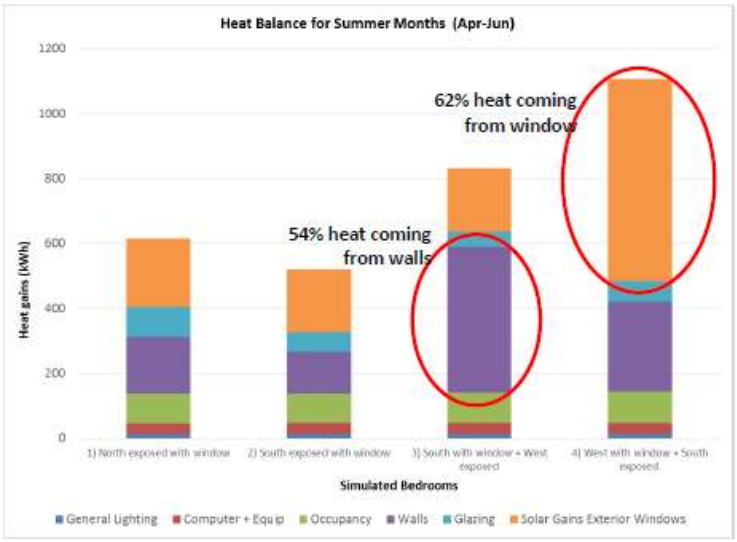

Figure 16: Heat balance for summer months for intermediate floor

24

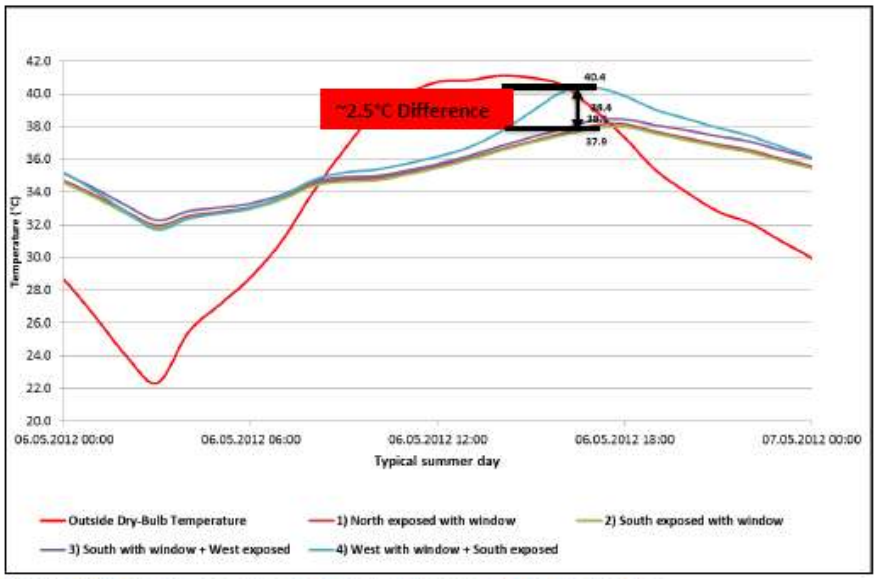

Figure 14: Inside temperatures on a typical summer day on the top floor

25

Description of Base Case

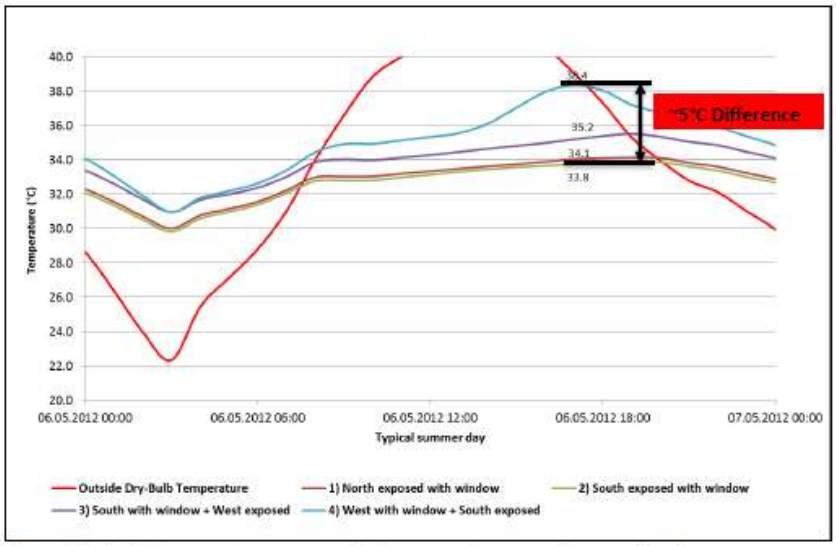

Figure 13: Inside temperatures on a typical summer day on an intermediate floor

26

6.2.1.4 Insulated walls: AAC blocks

The analysis of the base case also showed that the exposed walls facing the west also allow significant heat gains into the building. Using insulating walling material will reduce the transfer of heat through walls. Autoclaved Aerated Concrete (AAC) Blocks are good insulating material. They are also lightweight, reducing load on the structure and thus reducing the structural steel requirement.

Constructing with AAC blocks requires skilled labour and careful handling of the blocks. Some care also needs to be after building occupation. AAC blocks must be procured from known and reliable manufacturers.

Figure 22: AAC block

6.2.1.5 Roof insulation

For the top floor, the highest heat gains are from the roof. It is thus very important to insulate the roof and this leads to considerable reduction in inside temperature for the top floor. Figure 23 shows the detail of the roof with insulation.

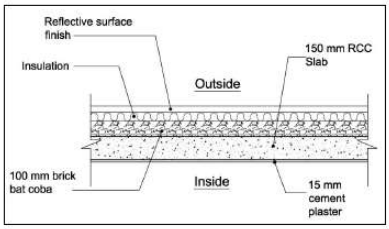

Figure 23: Roof detail with insulation

27

6.2.1.1 Window shading

Currently all windows have a 600mm overhang or open into a 1300mm balcony. The following addition is proposed in all windows facing east and west.

1) Fixed louvred screen above lintel height. This is proposed to be added by the developer.
2) Movable screens or "chiks" below lintel height. It is suggested that some vertical framing be provided by the developer. This would provide the occupants some way of attaching "chiks" later.

The additional shading is shown in Figure 18, Figure 19 and Figure 20.

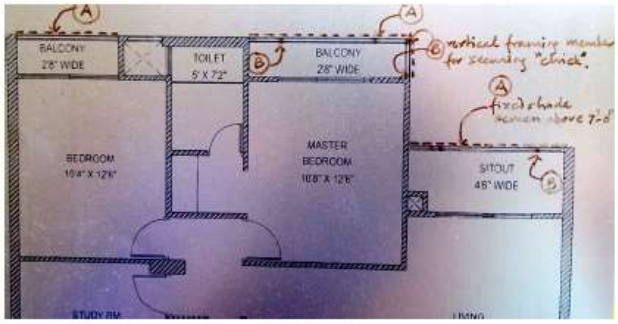

Figure 18: Proposed shading: 2.5 BHK unit

28

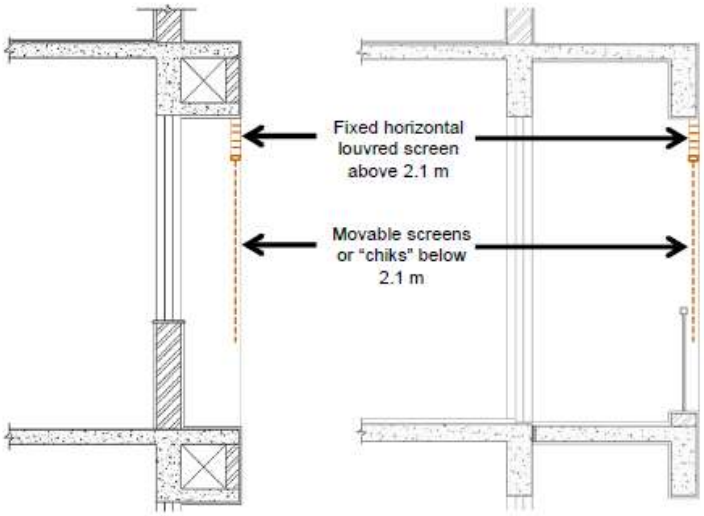

Figure 20: Section showing proposed shading

29

These strategies were simulated for the worst of the sample bedrooms, i.e. Bedroom 4 (Bedroom with south and west façade exposed with window / glass door on west façade) on the top floor.

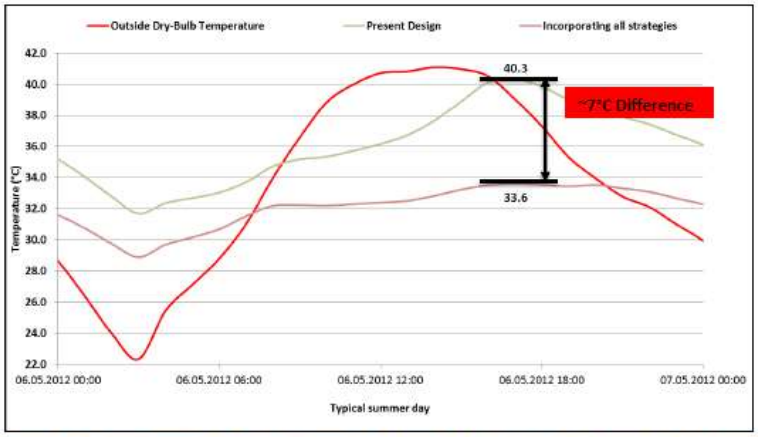

Figure 25: Inside temperature of Bedroom 4 on the top floor with and without the passive strategies

30

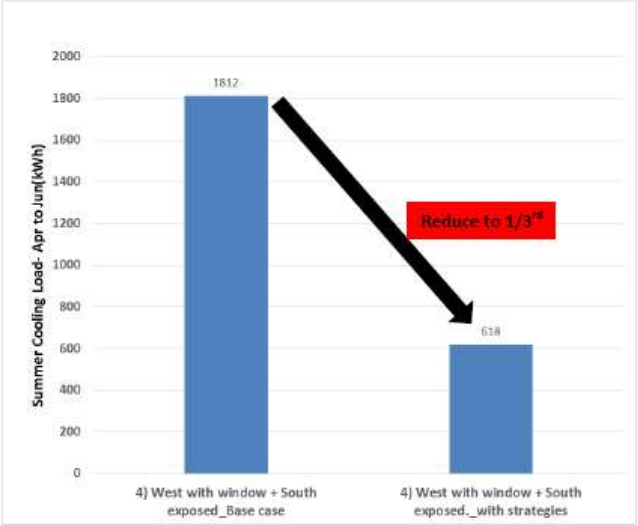

Figure 26: Cooling load of Bedroom 4 on the top floor with and without the passive strategies

31

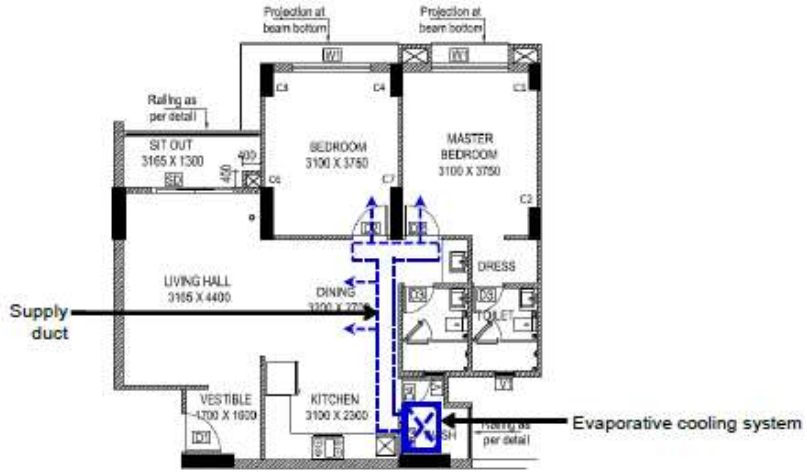

Figure 28: Possible scheme for evaporative cooling in flats

32

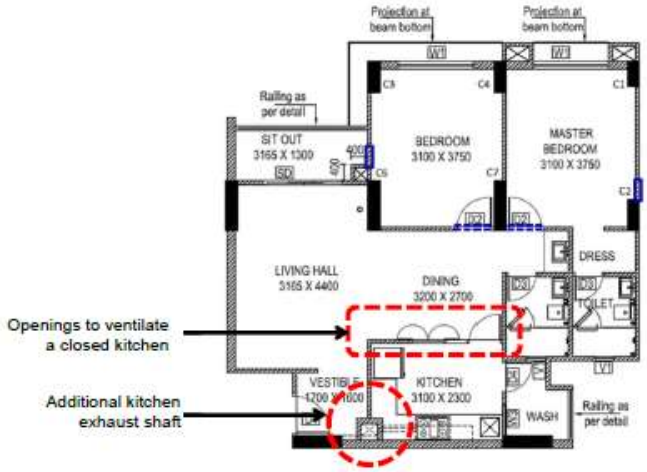

Figure 31: Additional shaft and openings for kitchen ventilation

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Impact of window / shading design on window heat gains, ventilation, cooling electricity and thermal comfort

Analysis done for Mahindra Life Spaces by Indo-Swiss BEEP

08 June 2020

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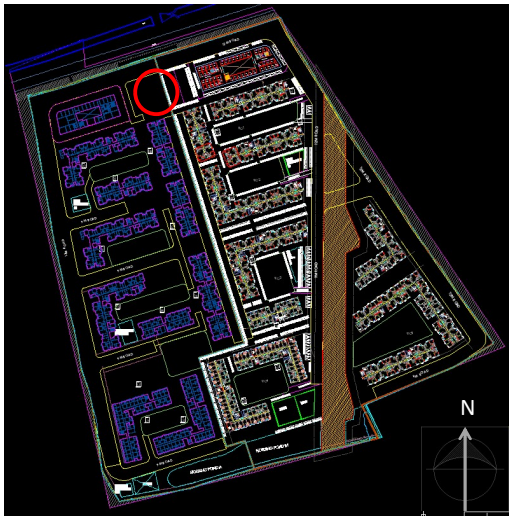
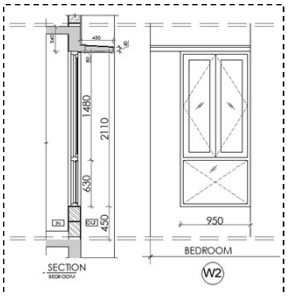
Selection of unit for detailed simulation



35

35

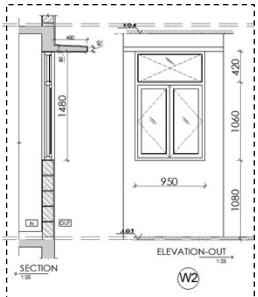
Design alternatives for comparison



Case 1:

Window size: As per current design

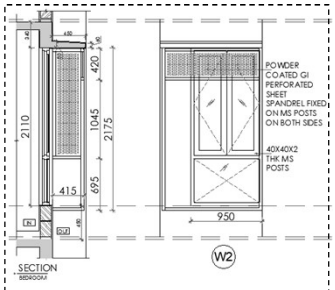
Shade: As per current design



Case 2:

Window size: As per Part 1 design (Fixed part of Glass at bottom is removed)

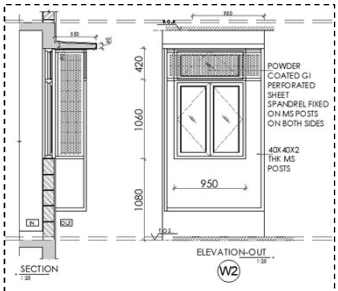
Shade: As per current design



Case 3:

Window size: As per current design

Shade: As proposed (side fins – up to 1.48 m from top, front screen – up to 0.42 from top of window)



Case 4:

Window size: As per Part 1 design (Fixed part of Glass at bottom is removed, while top part of the window in Bedroom and Living room is also openable)

Shade: As proposed (side fins – up to 1.48 m from top, front screen – up to 0.42 from top of window)

Case 5: Assisted ventilation is added in Case.4

36

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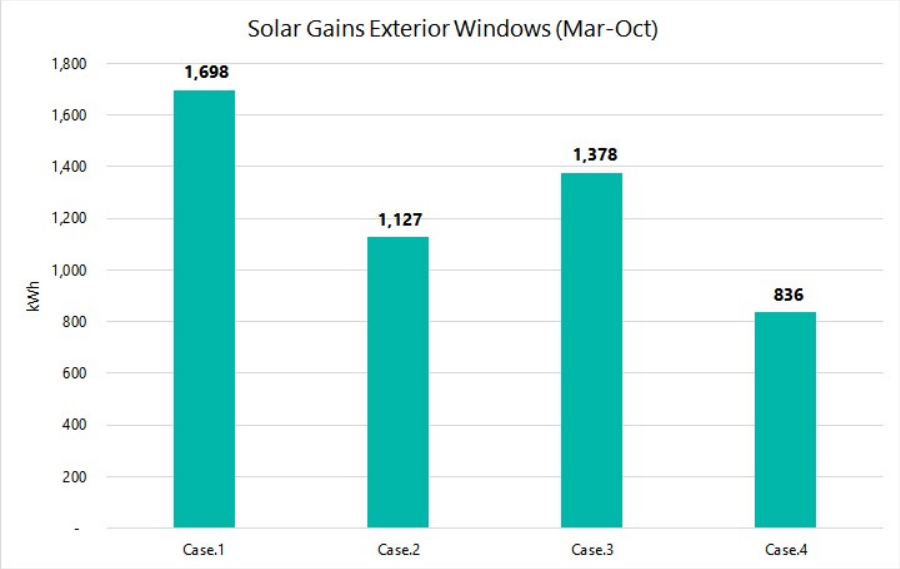
Result 2: Impact on direct solar gains



- **51% less direct heat gain from window by reducing glass area and adding shading (Case.4 vs Case.1)**
- 34% & 19% less direct heat gain from window by reducing glass area (Case.2 vs Case.1) & by adding shading (Case.3 vs Case.1)
- May lead to selection of lower TR of AC for the flat

37

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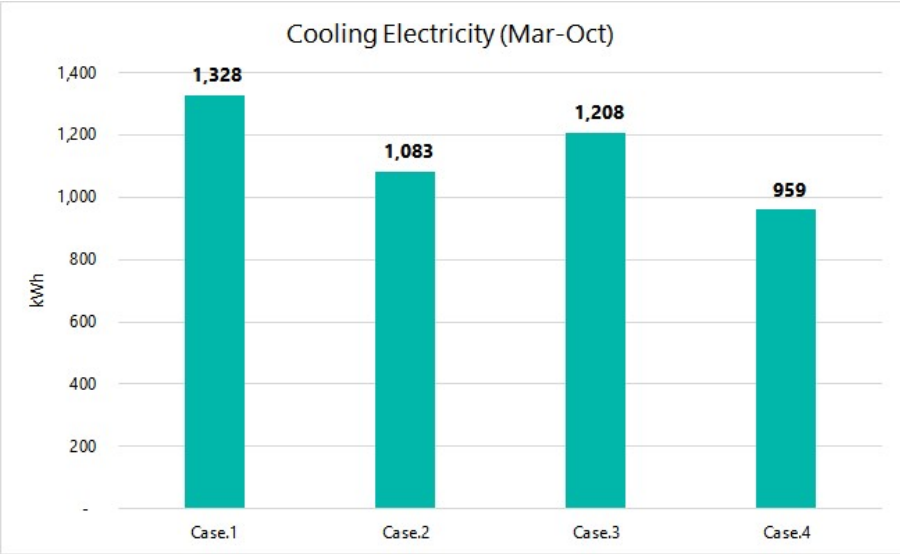
Result 3: Impact on cooling electricity



- **28% less cooling electricity required by by reducing glass area and adding shading (Case.4 vs Case.1)**
- 18% less cooling electricity required by reducing glass area (Case.2 vs Case.1)
- 9% less cooling electricity required by adding shading (Case.3 vs Case.1)

38

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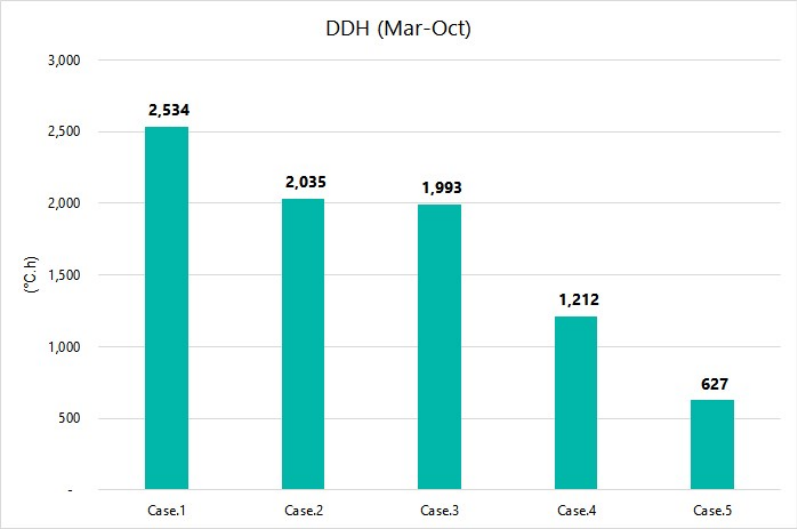
Result 4: Impact of window/shading design on Discomfort Degree Hour (DDH)



- **52% reduction in DDH** by reducing glass area and adding shading (Case.4 vs Case.1);
  75% reduction by adding assisted ventilation with improved design (Case.5 vs Case.1)
- ~20% reduction in DDH due to either reducing glass area (Case.2 vs Case.1) or by adding shading (Case.3 vs Case.1)
- Significant reduction in the operational time (hours per day and operating days per month) for the AC with Case.4 or Case.5

39

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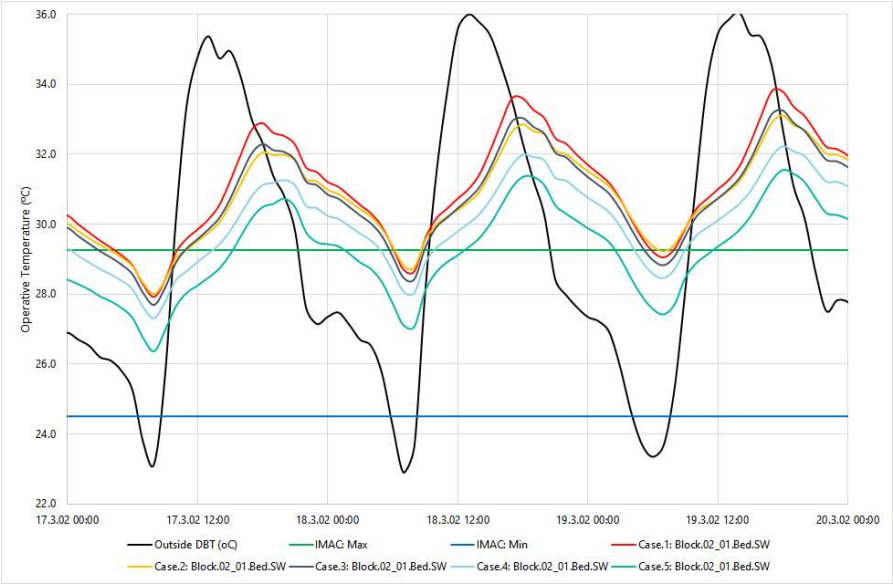
Result 5: Indoor operative temperature

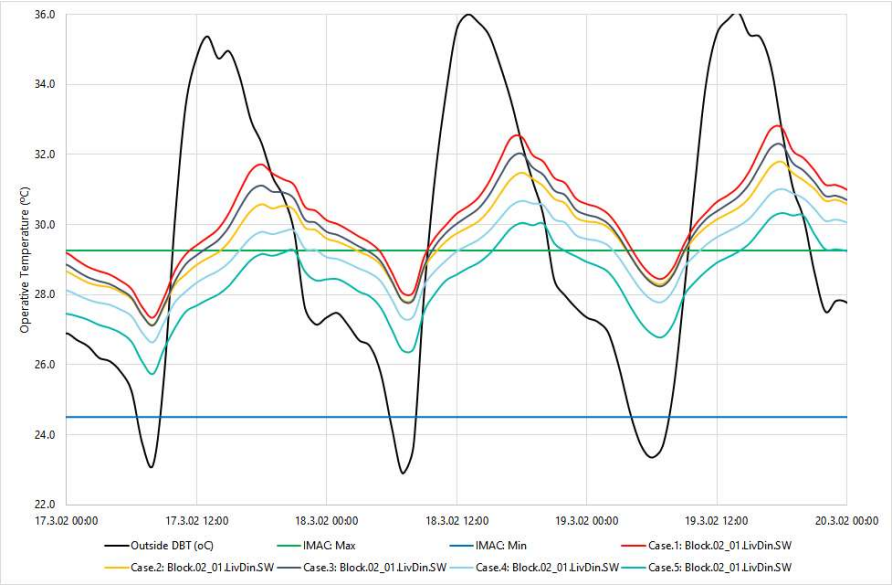


- 2-2.5°C reduction by adding assisted ventilation (Case.5 vs Case.1); **Can comfortably sleep without AC**
- 1.5-2°C reduction by reducing glass area and adding shading (Case.4 vs Case.1)
- ~1°C reduction with either reduced glass area (Case.2 vs Case.1) or by adding window shading (Case.3 vs Case.1).

40

40

Result 5: Indoor operative temperature

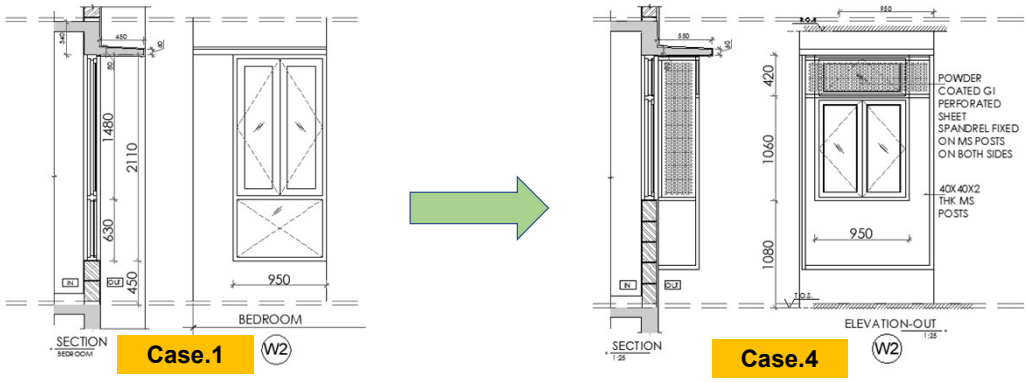


- ~2.5˚C when assisted ventilation is added with improved design (Case.5 vs Case.1); **Most of hours come within IMAC band**
- ~2˚C reduction in peak inside operative temperature with reduced glass area and shading (Case.4 vs Case.1)
- ~0.5 and ~1˚C reduction in peak inside operative temperature by adding window shading (Case.3 vs Case.1) and with reduced glass area (Case.2 vs Case.1), respectively.

41

41

Key recommendations for improving Case 1



- **Replace the lower glass part with (or add) opaque material.**
- **Add vertical shading on side and top.**
- **Shading frame enables residents to install rollup screens conveniently.**
- **Give suitable openings for installing ventilation/exhaust fans.**

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Key inferences from simulation results

- **Huge impact of window design** on solar gains and hence on DDH (in naturally ventilated mode) and cooling electricity (in air-conditioned mode).
- **28% reduction in cooling electricity and 52% reduction in DDH** for Case.4.
- **~2.5°C reduction in peak indoor operative temperature** for Case.4 and Case.5. Will lead to reduced AC operational time (hours per day and operating days per month).
- **75% reduction in DDH with improved design with assisted ventilation (Case.5). This means, one may not buy an AC. Nights become comfortable and one can sleep comfortably without AC as well.**

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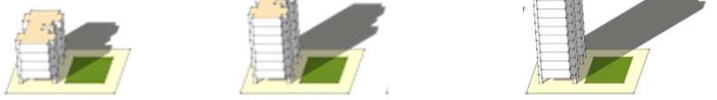
Methodology for Evaluation

In this study, the buildings are classified in 3 typologies :



Low rise(<16.5m), **Medium rise**(16.5-25m) **High Rise**(>25m)

This study has evaluated the potential of Low Carbon resource-efficient affordable housing on various parameters over 3 scales:

Building Level **Neighbourhood Level** **City Level**

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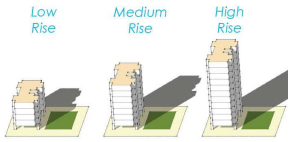
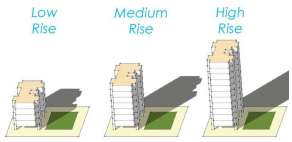
Comparison of Building Typologies



Criteria of Comparison	Low Rise	Medium Rise	High Rise
Sustainability	**High**	**Medium**	**Low**
Environmental Impact	**Low**	**Medium**	**High**
Suitability for Housing Category	**EWS/LIG** (<50m²)	**LIG/MIG** (50-90m²)	**MIG/HIG** (>90m²)
Demand	Maximum **70%**	Moderate 20%	Least 10%

The high rise development is least suitable from a Low Carbon perspective and thus should be avoided.

The preferred typology should be Low rise but if Land Cost are very high one may go for a Medium Rise.



Criteria of Comparison	Most	Less	Least
Affordability			
Open Area per Person	●	●	●
Embodied Energy efficiency	●	●	●
Operational Energy efficiency	●	●	●
Solar-Roof Potential	●	●	●
(Carpet Area)/ (Built Up area)	●	●	●
Construction Cost affordability	●	●	●
Quick Construction Time	●	●	●
Maintenance affordability	●	●	●
Disaster/ Break-down resilience	●	●	●

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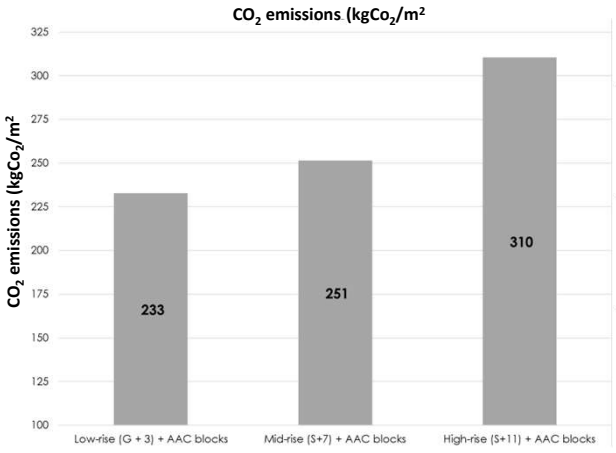
Embodied Energy Efficiency



- **Given the same walling material, the taller our buildings are, greater will be the CO_2 emissions, due to higher steel and cement content.**
- **As we go from low-rise to mid-rise and high-rise buildings, CO_2 emissions will increase around 15% and 35% respectively.**
- **The CO_2 emissions are higher if we use brick and monolithic concrete instead use AAC/Hollow-core/Fly ash bricks/ Hollow-core/ Hollow burnt- clay brick**

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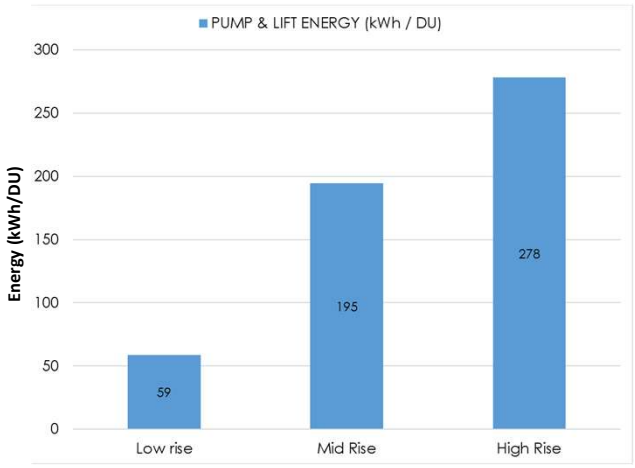
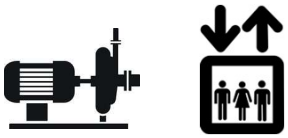
Operational Energy Efficiency





- Increase in common service energy (pump + lift) by 4 to 5 times as we go from low-rise to high rise

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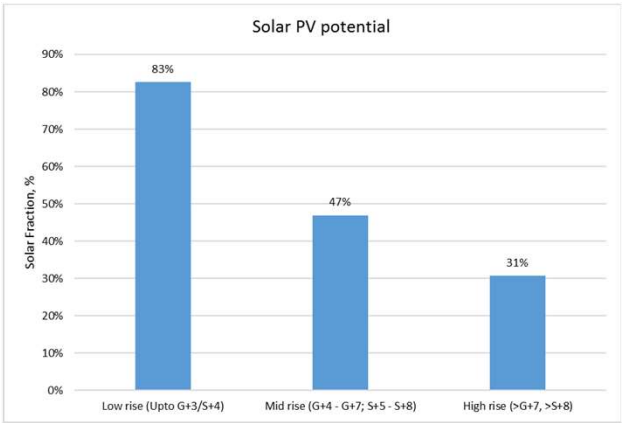
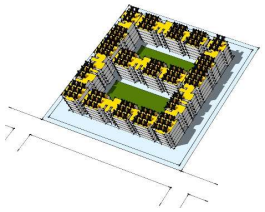
Rooftop Solar Potential





- 80% of the energy requirement in a low-rise building can be met by rooftop solar energy. Low rise buildings have the potential to be Net Zero due to better Rooftop Area to Electricity Demand Ratio.
- Building higher decreases Solar potential.

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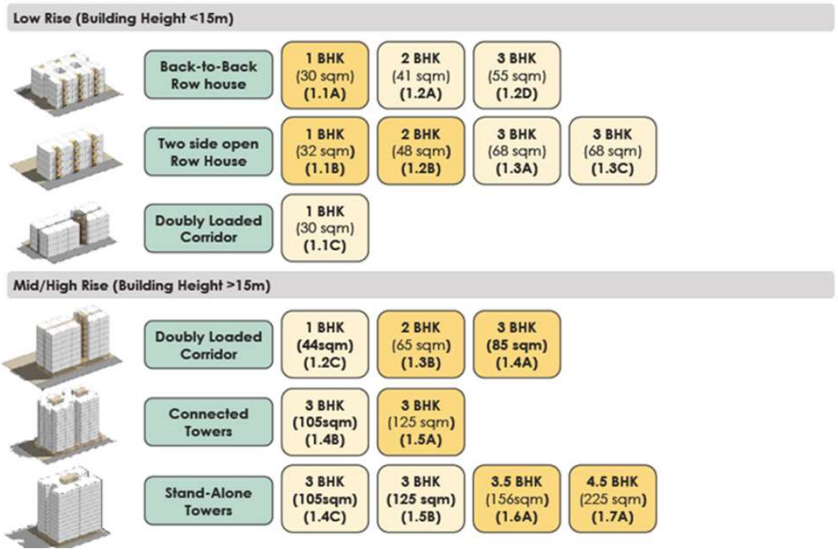
Residential Typologies & House sizes



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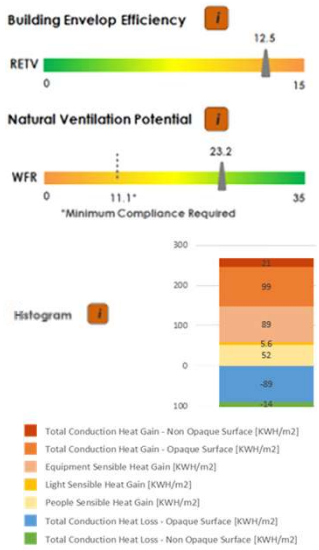
Energy performance

Energy Simulation
The building design - architectural, mechanical and electrical systems are replicated in the energy simulation software to analyze the energy data, design effectiveness and energy demand. **Software used:** Design builder/Energy plus **Outputs:** Energy performance Indicators, Life cycle cost, Payback No. of hours of Natural Ventilation



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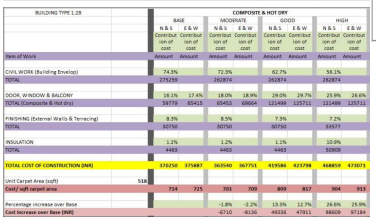
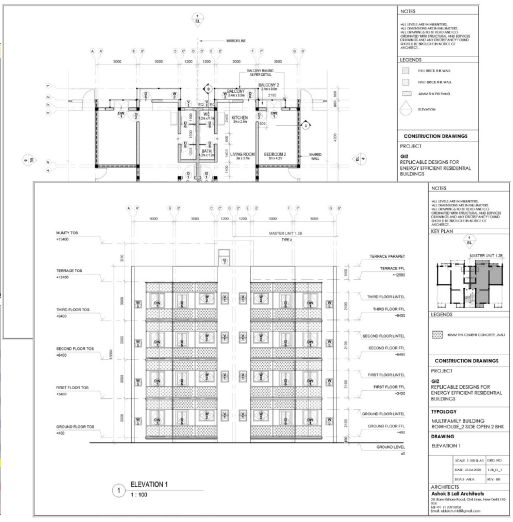
Master Set-Design & Construction data

Windows & Shading design



Bill of quantities



Working Drawings

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Sustainable Development Goals

Affordable homes at locations of employment and economic opportunity with access to public transport and social amenities. Livelihoods in an inclusive construction economy

Resilience of urban living in cases of infrastructure breakdown and disasters, with sufficiency of habitable space and environmental security – water, air, recycled waste.

Use of low-carbon and resource-efficient modes of production for construction of housing and selecting building types for minimum operational energy.

Build-in resilience against extreme events, shade and green for a habitable outdoors against heat waves, aggregate rain harvest and water efficiency, minimize hard ground and motor vehicles for low UHI

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Thank you!

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RESILIENT, AFFORDABLE AND COMFORTABLE HOUSING THROUGH NATIONAL ACTION

One-Day Online Training Program on Thermal Comfort in Affordable Housing

Session 3
13th July 2022

1

RESILIENT, AFFORDABLE AND COMFORTABLE HOUSING THROUGH NATIONAL ACTION

Building Codes, Affordable Housing and Thermal Comfort

Aviruch Bhatia

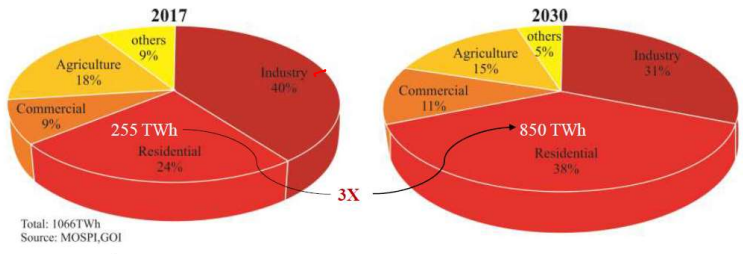
2

Outline

- Introduction
- Affordable Housing
- Thermal Comfort
- Energy Codes
- ENS Tool
- Conclusions

3

Energy Consumption in Residential Buildings



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Affordable Housing Programs in India

- Address the vision of 'AatmaNirbhar Bharat' by creating affordable rental housing for urban migrants/ poor
- Provide dignified living with necessary civic amenities near their workplace on affordable rent
- Create conducive ecosystem for Public/ Private Entities to leverage investment in rental housing

Pradhan Mantri Awas Yojana - Urban (PMAY-U)
Affordable Rental Housing Complexes (ARHCs)

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Thermal Comfort

Environment	Personal
➢ Air temperature	➢ Clothing ensembles
➢ Mean radiant temperature	➢ Metabolic rate or activity
➢ Relative humidity	
➢ Air movement	

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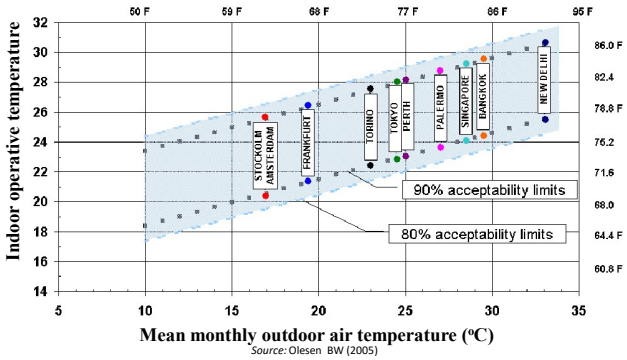
Acceptable Temperature Ranges



Source: Olesen BW (2005)

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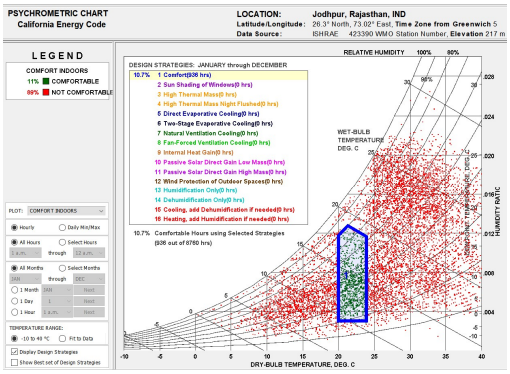
Context: Affordable Housing



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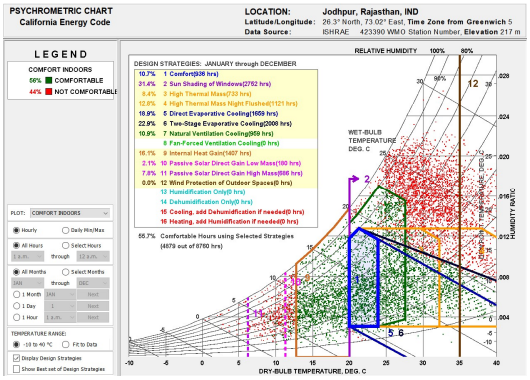
Context: Affordable Housing



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Types of Building Energy Codes

- Prescriptive codes
- Trade-off codes
- **Performance codes**
- Outcome-based codes

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Types of Building Energy Codes

- Prescriptive codes
- Trade-off codes
- Performance codes
- Outcome-based codes

ECBC – R
Eco Niwas Samhita – 1

Eco Niwas Samhita - 2

ECBC 2017
ECBC
ECBC+
Super ECBC

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ECO NIWAS SAMHITA

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Eco Niwas Samhita (ENS, ECBC-Residential) (Part-I Building Envelope)

PROVISIONS FOR BUILDING ENVELOPE

Reduce Heat Gain/Loss
Improve Natural Ventilation & Daylighting

Improved thermal comfort & reduced energy consumption

Source: Bureau of Energy Efficiency, Government of India, & Ministry of Power. (2018). Eco-Niwas Samhita- Part I: Building Envelope. Retrieved from

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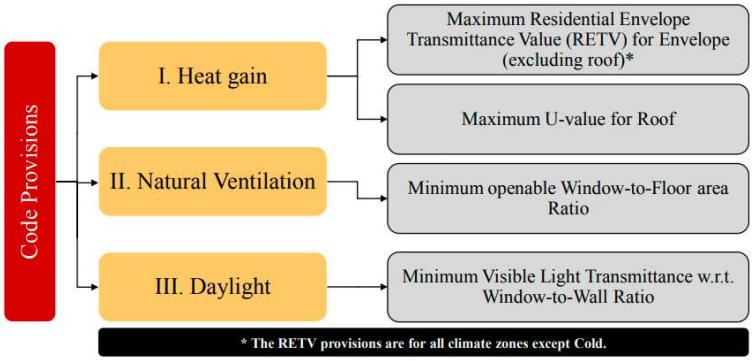
Overview of Code Provisions



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Code Provision: Heat Gain

Source: Bureau of Energy Efficiency, Government of India, & Ministry of Power. (2018). Eco-Niwas Samhita- Part I: Building Envelope. Retrieved from

Reducing Heat Gain:

Maximum RETV for building envelope (except roof)	$RETV \leq 15\ W/m^2$ For all climate zones except Cold
Roofing material's maximum thermal transmittance value (for all climate zones)	$U_{roof} \leq 1.2\ W/m^2K$

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Residential Envelope Transmittance Value (RETV)

The net heat gain rate (over the cooling period) through the building envelope, walls, and windows (excluding the roof) divided by the area of the building envelope (excluding the roof), is measured in W/m^2.

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Observations and Calculations

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RETV: Formula and Calculations

$$RETV = \frac{1}{A_{envelope}} \times \left[\left\{ a \times \sum_{i=1}^{n} \left(A_{opaque_i} \times U_{opaque_i} \times \omega_i \right) \right\} + \left\{ b \times \sum_{i=1}^{n} \left(A_{non-opaque_i} \times U_{non-opaque_i} \times \omega_i \right) \right\} + \left\{ c \times \sum_{i=1}^{n} \left(A_{non-opaque_i} \times SHGC_{eq_i} \times \omega_i \right) \right\} \right]$$

- Wall Conductive Heat Gains
- Window Conductive Heat Gain
- Window Radiation Heat Gain

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Code Provisions: Natural Ventilation

The openable window-to-floor ratio (WFR_{op}) is the ratio of openable area to the built-up area of the dwelling units.

$$WFR_{op} = \frac{A_{openable}}{A_{built-up}}$$

Climate Zone	Minimum WFR_{op} %
Composite	12.5
Hot-Dry	10.0
Warm-Humid	16.6
Temperate	12.5
Cold	8.3

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Openable Window-to-Floor Area Ratio

- Higher WFR_{op} helps in enhancement in
- Natural Ventilation
- Thermal comfort
- Cooling Energy Savings

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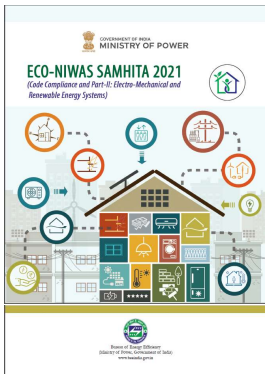
Eco-Niwas Samhita 2021 (Code Compliance and Part-II)



- Scope
- Code Compliance
- Mandatory Requirements
- Prescriptive Requirements
- Point System Method

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Mandatory Requirements

- All requirements for building envelope under mandatory section as mentioned in Chapter 4 of ENS Part I.
- Power Factor Correction
- Energy Monitoring
- Electric Vehicle Charging System
- Electrical Systems

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Point System Method

Section	Components	Minimum points	Additional Points	Maximum Points
6.4	Building Envelope			
	Building Envelope	47	40	87
6.5	Building Services			
	Common area and exterior lighting	3	6	9
	Elevators	13	9	22
	Pumps	6	8	14
	Electrical Systems	1	5	6
6.6	Indoor Electrical End-Use			
	Indoor Lighting		12	12
	Comfort Systems		50	50
	ENS Score	70	130	200

Section	Components	Minimum Points	Additional Points	Maximum Points
6.7	Renewable Energy Systems			
	Solar Hot Water Systems		10	10
	Solar Photo Voltaic		10	10
	Additional ENS Score		20	20

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ENS Score

Thermal transmittance of roof (U_{roof})

Maximum Score	7 Points

Score breakup for the thermal transmittance of roof is as mentioned in the Table 10

Table 10: Points for Thermal Transmittance of Roof (U_{roof})

Minimum, if opted: Thermal transmittance of roof shall comply with the maximum Uroof value of 1.2 W/m²·K.	Up to 3 Points
Additional: 1 Point for every reduction of 0.23 W/m²·K in thermal transmittance of roof from the Minimum requirement prescribed under §6.1(a).	Up to 4 Points

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Residential Envelope Transmittance Value (RETV)

The RETV for the building envelope (except roof) for four climate zones, namely, Composite Climate, Hot-Dry Climate, Warm-Humid Climate, and Temperate Climate, shall comply with the maximum RETV of 15 W/m^2.	44 Points
For RETV less than 15 and up to 12 W/m^2, score will be calculated by following equation: 74 – 2 x (RETV)	Up to 50 Points
Additional: For RETV less than 12 and up to 6 W/m^2, score will be calculated by following equation: 110 – 5 x (RETV)	Up to 80 points
Additional: For RETV less than 6 W/m^2	80 Points

Building Services

Minimum:

The Lighting power density (LPD) and Luminous efficacy (LE) of permanently installed lighting fixtures in common area of the ENS building shall meet the requirements of either maximum LPD or minimum luminous efficacy given in Table 13, Table 14 and as mentioned in section 6.5.1 (ii) and 6.5.1 (iii) for all the areas/ zones applicable for the building for which compliance is sought. — 3 Points

If a particular area/ zone is not applicable to a building for which compliance is sought, the performance requirement of the respective zone/ area is not required.

Additional:

Installing all the permanently installed lighting fixtures with lamp luminous efficacy of 95 lm/W in areas mentioned below — Up to 3 Points

Area/ Zones	Points
Corridor lighting and stilt parking	1
Basement Lighting	1
Exterior Lighting Areas	1

Additional:

Lamps for all exterior applications apart from emergency lighting shall be controlled by photo sensor or astronomical time switch that is capable of automatically turning off the exterior lighting when daylight is available, or the lighting is not required.

Installing all the permanently installed lighting fixtures in all corridor lighting, stilt parking, basement lighting and exterior lighting with lamp luminous efficacy of 105 lm/W. — Up to 6 Points

Area/ Zones	Points
Corridor lighting and stilt parking	2
Basement Lighting	2
Exterior Lighting Areas	2

Building Services - Points for Air Conditioners

Minimum, if opted: Unitary Type: 5 Star Split AC: 3 Star VRF: 3.28 EER Chiller: Minimum ECBC Level values as mentioned in ECBC 2017	20 Points
Additional : Split AC: 4 Star VRF: Not Applicable as on date, however, whenever BEE Star labelling for VRF is launched, Star 4 will be applicable Chiller: Minimum ECBC+ Level values as mentioned in ECBC 2017	9 Points
Additional : Split AC: 5 Star VRF: Not Applicable as on date, however, whenever BEE Star labelling for VRF is launched, Star 5 will be applicable Chiller: Minimum SuperECBC Level values as mentioned in ECBC 2017	21 Points

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Building Services - Points for Renewable Energy Systems

Minimum, if opted: The ENS compliant building shall provide a solar water heating system (SWH) of minimum BEE 3 Star label and is capable of meeting 100% of the annual hot water demand of top 4 floors of the residential building. or 100% of the annual hot water demand of top 4 floors of the residential building is met by the system using heat recovery	5 Points
Additional: Additional points can be obtained by installing SWH system as per as per following: 100% of the annual hot water demand of top 6 floors of the residential building (2 points) 100% of the annual hot water demand of top 8 floors of the residential building (5 points)	Up to 5 Points

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Building Services - Points for Renewable Energy Systems

Minimum, if opted:	
The ENS compliant building shall provide a dedicated Renewable Energy Generation Zone (REGZ) –	
Equivalent to a minimum of 2 kWh/m².year of electricity; or	5 Points
Equivalent to at least 20% of roof area.	
The REGZ shall be free of any obstructions within its boundaries and from shadows cast by objects adjacent to the zone.	
Additional:	
Additional points can be obtained by installing solar photo voltaic as per following:	
Equivalent to a minimum of 3 kWh/m².year of electricity or Equivalent to at least 30% of roof area (2 points)	Up to 5 Points
Equivalent to a minimum of 4 kWh/m².year of electricity or Equivalent to at least 40% of roof area (5 points)	

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Affordable Housing

- Affordable houses are Dwelling Units (DUs) with Carpet Area less than 60 sqm. It also includes Economically Weaker Section (EWS) category and Lower Income Group (LIG) category (LIG-A: 28-40 sq. m. and LIG-B 41- 60 Sq.m.).
- Projects using at least 60 percent of the FAR/ FSI for dwelling units of Carpet Area not more than 60 sqm will be considered as Affordable housing projects.
- This definition could be changed time to time by Ministry of Housing & Urban Affairs and respective states and latest definition for the respective state shall be considered.

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Minimum ENS Score Requirement

Project Category	Minimum ENS Score
Low rise buildings	47
Affordable Housing	70
High rise buildings	100

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ENS Tool

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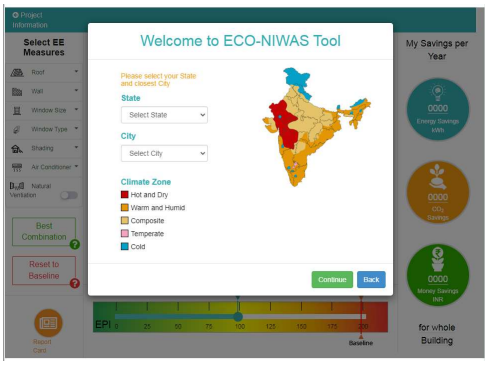
ENS Tool: https://www.econiwas.com/tool/



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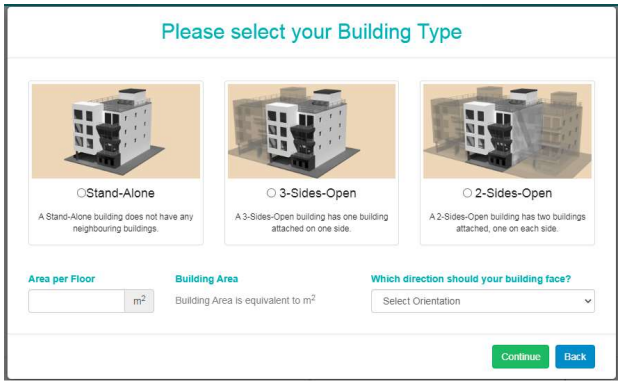
ENS Tool



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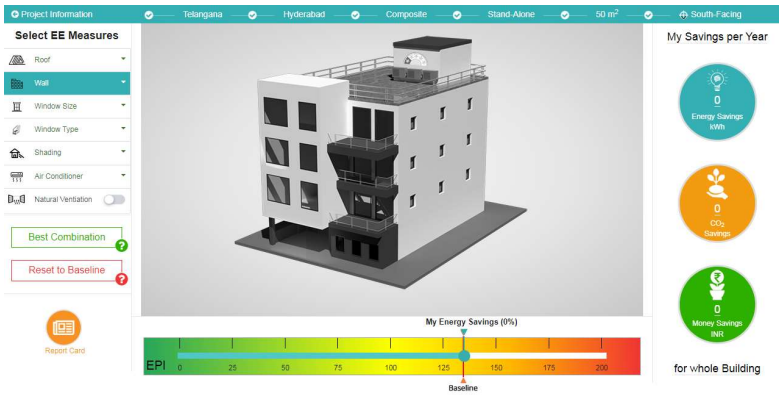
ENS Tool



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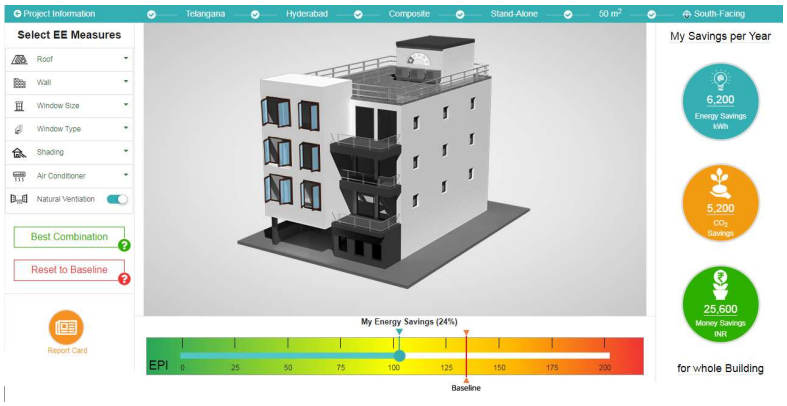
ENS Tool



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ENS Tool

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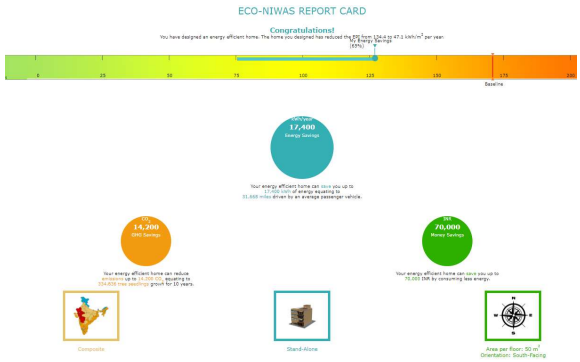
ENS Tool



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Conclusions

- Affordable Housing
- Thermal Comfort
- Energy Codes
- ENS Tool

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Thank you!

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RESILIENT, AFFORDABLE AND COMFORTABLE HOUSING THROUGH NATIONAL ACTION

One-Day Online Training Program on Thermal Comfort in Affordable Housing

Session 4

Dr. Shivraj Dhaka

13th July 2022

Building Materials and Methods of Construction for Affordable Housing and Case Studies

One-Day Online Training Program on Thermal Comfort in Affordable Housing

13 July 2022

Dr Shivraj Dhaka
Senior Counsellor, Indian Green Building Council (IGBC)
| 9177577288 shivraj.dhaka@cii.in

Contents

- **Building Materials in affordable houses**
  - **Background**
  - **Building materials**
  - **Key approaches**
  - **Method of construction for affordable housing**
  - **Case studies**

Passive Building Material/Products

1) Glazing
2) Insulation
3) Paints & Coatings
4) Adhesives & Sealants
5) Flyash blocks
6) Cement
7) Concrete
8) Certified new wood
9) Housekeeping chemicals
10) False ceiling materials,
11) Flooring materials
12) Furniture
13) Gypsum based products
14) High reflective materials & coatings

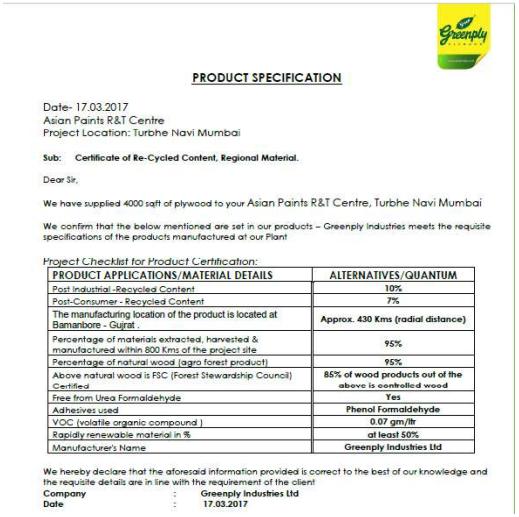
Flyash Bricks

Paints

Adhesives & Sealants

Materials with Recycled Content

- **To encourage the use of products (materials other than plant machinery) which contain recycled materials to reduce environmental impacts associated with the use of virgin materials.**



PRODUCT SPECIFICATION

Date- 17.03.2017
Asian Paints R&T Centre
Project Location: Turbhe Navi Mumbai

Sub: Certificate of Re-Cycled Content, Regional Material.

Dear Sir,

We have supplied 4000 sqft of plywood to your Asian Paints R&T Centre, Turbhe Navi Mumbai

We confirm that the below mentioned are set in our products – Greenply Industries meets the requisite specifications of the products manufactured at our Plant

Project Checklist for Product Certification:

PRODUCT APPLICATIONS/MATERIAL DETAILS	ALTERNATIVES/QUANTUM
Post Industrial -Recycled Content	10%
Post-Consumer - Recycled Content	7%
The manufacturing location of the product is located at Bamanbore - Gujrat .	Approx. 430 Kms (radial distance)
Percentage of materials extracted, harvested & manufactured within 800 Kms of the project site	95%
Percentage of natural wood (agro forest product)	95%
Above natural wood is FSC (Forest Stewardship Council) Certified	85% of wood products out of the above is controlled wood
Free from Urea Formaldehyde	Yes
Adhesives used	Phenol Formaldehyde
VOC (volatile organic compound)	0.07 gm/ltr
Rapidly renewable material in %	at least 50%
Manufacturer's Name	Greenply Industries Ltd

We hereby declare that the aforesaid information provided is correct to the best of our knowledge and the requisite details are in line with the requirement of the client

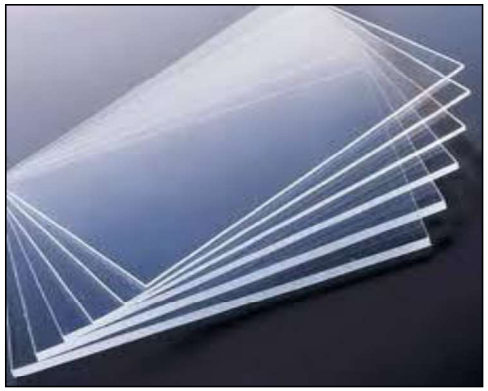
Company : Greenply Industries Ltd
Date : 17.03.2017

Composite Wood

Materials with Recycled Content

- **Use materials with recycled content such that the total recycled content constitutes atleast 15% of the total cost of the materials used in the project.**

% of materials with recycled content
≥ 15%
≥ 25%

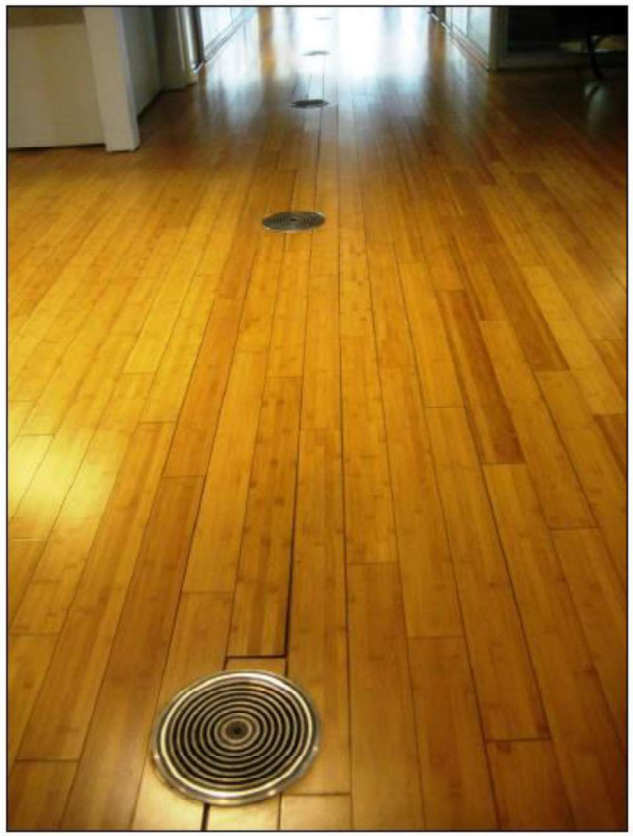


Material Cost= Total Cost – (Labour + Installation Cost)

Typical Materials with High Recycled Content

Materials	% Recycled content
Fly ash blocks	30-40
Glass	10-15
Ceramic tiles	20-30
MDF	30-50
Steel	25
Cement	20-30

Flooring



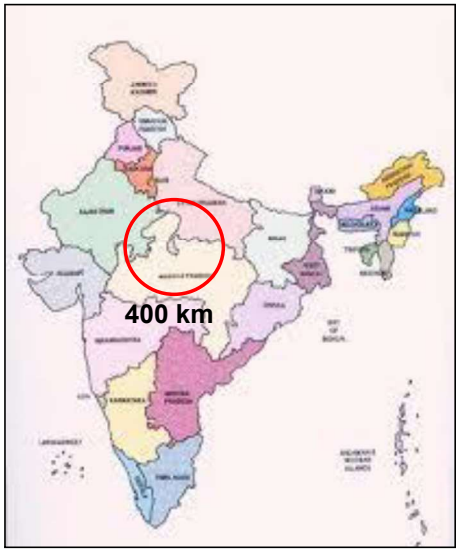
Bamboo Flooring

Recycled Carpet
Eicher Corporate Office, Noida, Platinum

Local Materials

- **Encourage the use of building materials available locally to minimise the associated environmental impacts**

Percentage of local materials sourced
≥ 50%
≥ 75%



Local Materials

- **Ensure that atleast 50% of the total factory building materials by cost used in the factory building are manufactured within a radius of 400 Km.**

Calculations:

Product name	Vendor	Product Cost (Rs)	Distance between project & manufacturer (Km)	Local Materials information source
Steel		832,089,970		Letter
Cement		240,242,518	392	Letter
Fly ash Bricks		204,206,140	50	Letter
Sand		102,103,070	47	Letter
Stone		71,472,149	47	Letter
Galvanum Sheet		25,808,120	440	Letter
Puff Panels		77,424,361	440	Letter
Total cost of materials manufactured locally (Rs.)		1,553,346,328		
Total Materials cost			1,932,959,908	
Percentage of local materials			80.36	

Factory, Halol, Platinum

Material Reuse

- **Encourage the use of salvaged building materials and products to reduce the demand for virgin materials to minimize the impacts associated with extraction and processing of virgin materials.**

Percentage of salvaged materials used
≥ 5 %
≥ 10 %

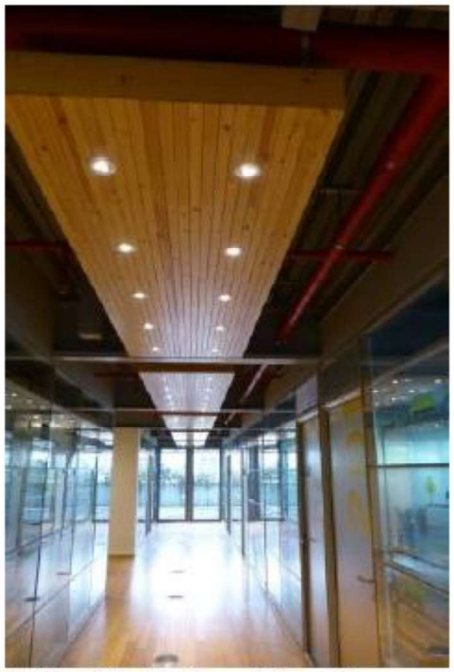

Salvaged Door

Material Reuse

Use of Railway sleepers bought from railway auction

Eicher Corporate Office, Gurgaon, Platinum

Material Reuse– Salvaged Materials



Use of scrap Swedish pine wood in false ceilings.

Eicher, Gurgaon Platinum

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Certified Wood / Rapidly Renewable Building Materials and Furniture

- **To minimise the usage of virgin wood thereby encouraging responsible forest management**

Approach towards "Cradle to Cradle"

Certified Wood / Rapidly Renewable Building Materials and Furniture

- **Ensure atleast 50% (by cost) of all wood based products used in the building will be FSC (Forest Stewardship Council) or the local Forest Department certified wood or rapidly renewable based products.**

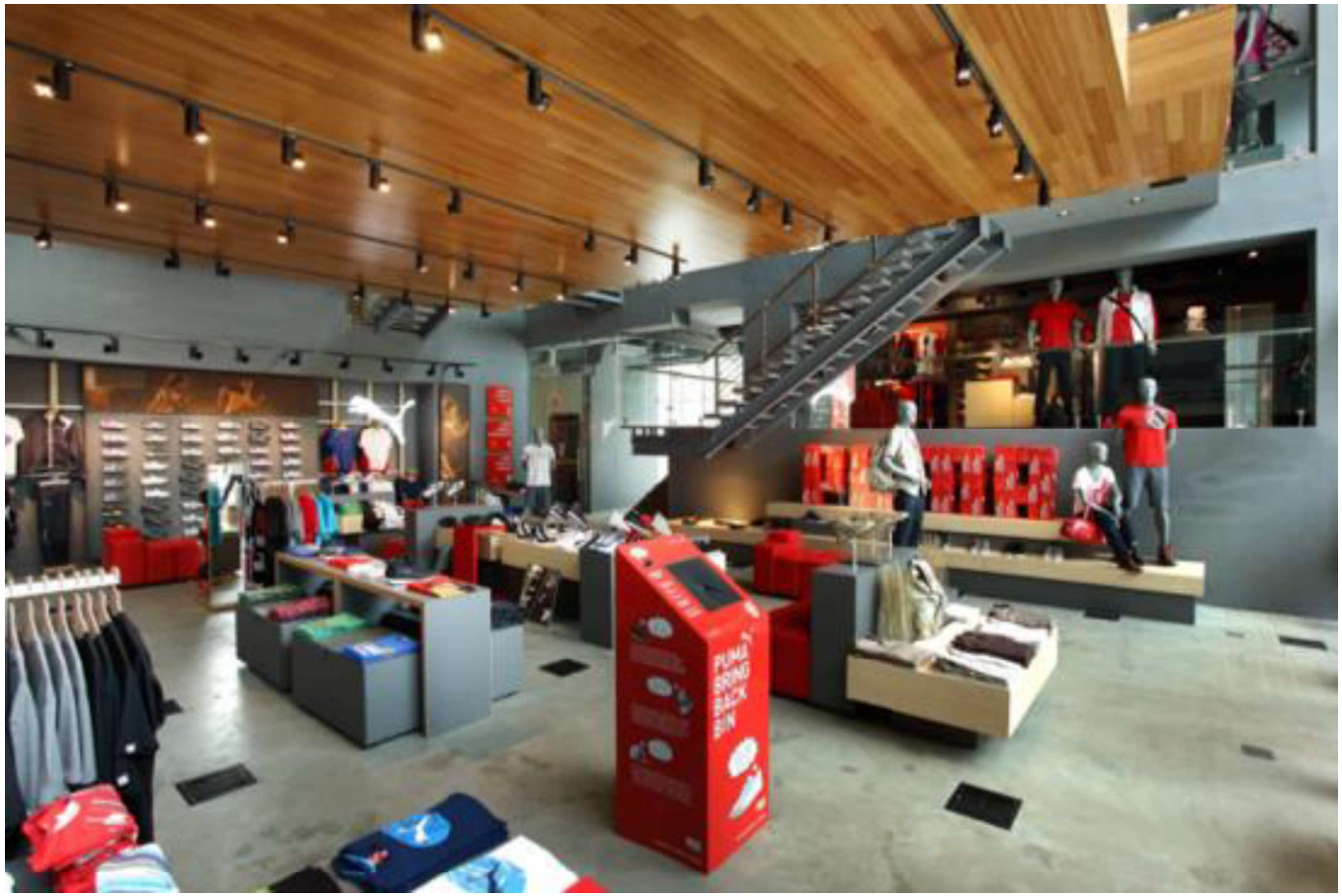
Percentage of FSC / Forest Department certified wood / Rapidly renewable
> 50%
> 75%

Green Building Materials

- Assess 'How Green is a Product' based on its Life Cycle
- Highlights the way forward to achieve environmental excellence
- International standards and protocols followed for product testing and evaluation

'GreenPro' Framework for Certification

Rapidly Renewable materials



PUMA Store, Bangalore

Use of Bamboo panels for cladding the suspended ceiling

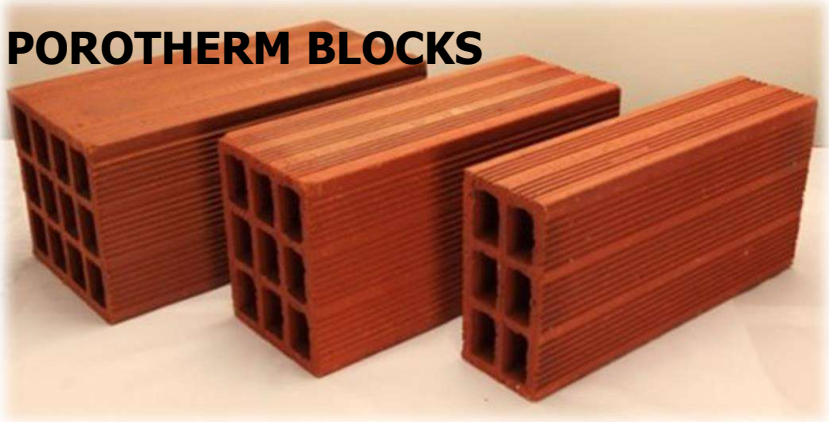
Optimisation on Structural Design

- **Optimum use of construction materials to reduce dependence on natural resources**
- **Design to conserve steel, concrete, water and cement as compared to standard practices, while maintaining structural integrity**

Optimisation on Structural Design

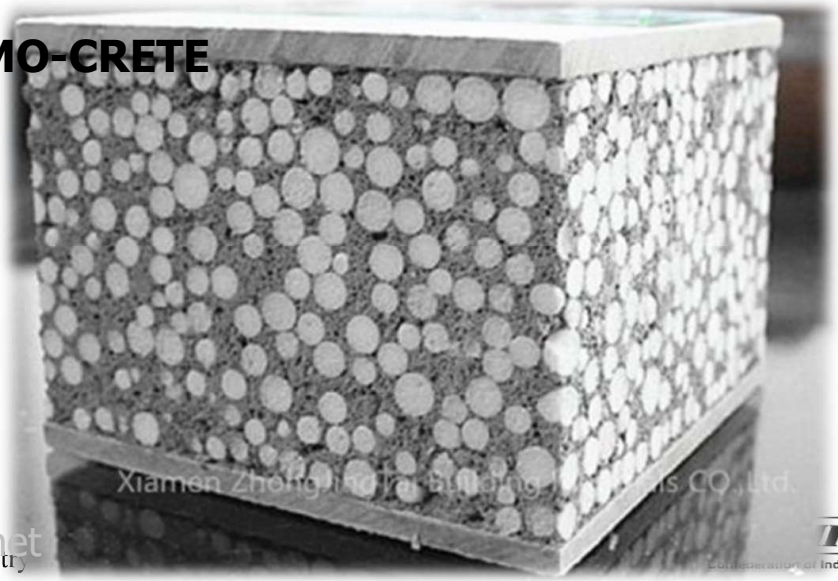
- **Reduction in Dead Load – Use of Light weight materials**

POROTHERM BLOCKS



CLC BLOCKS

THERMO-CRETE



Source: Internet

Composite/Agri-based/Recycled Wood

Rice Husk Particle Board

Ceiling in Class Room

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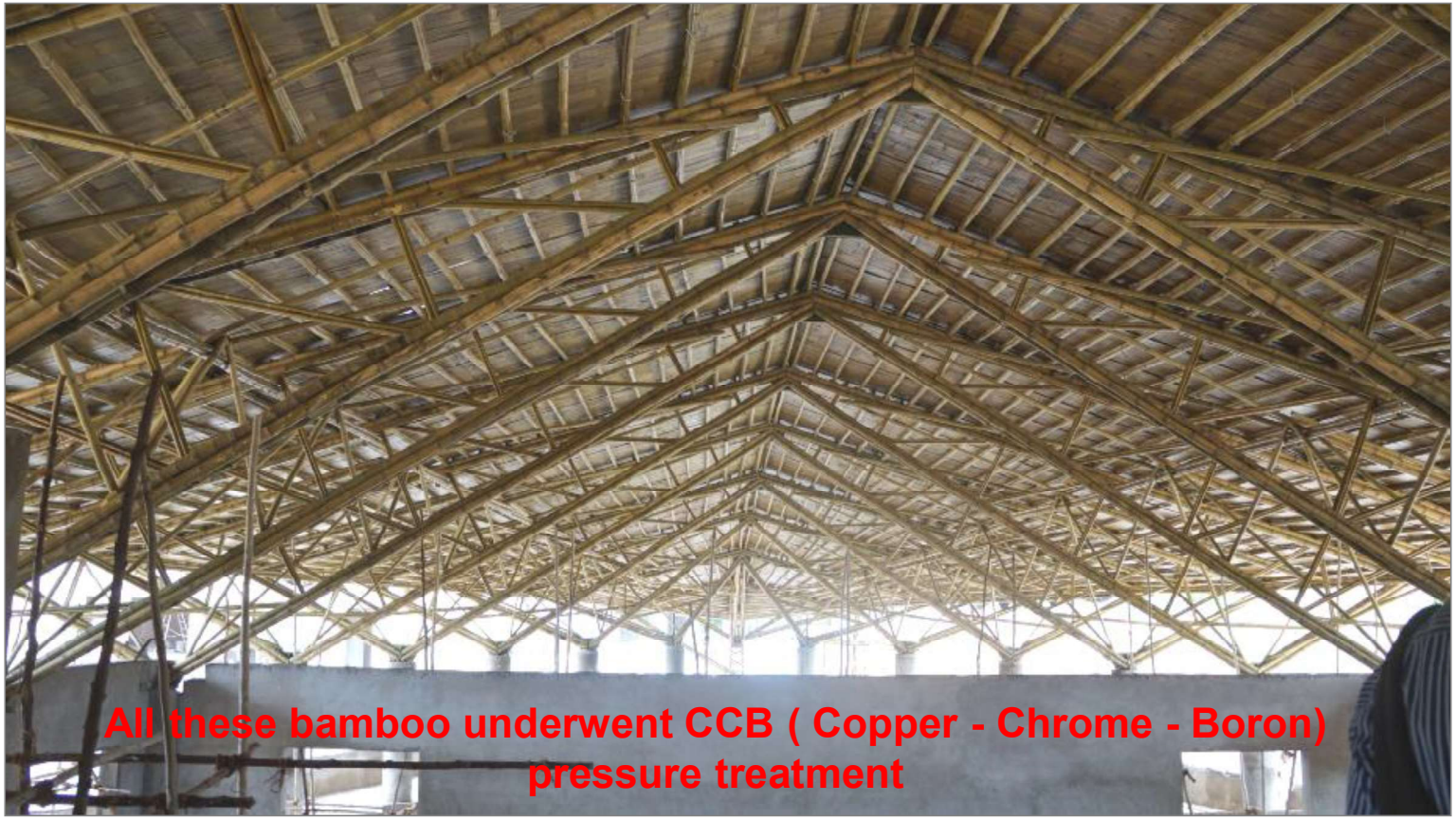
The clubhouse is India's largest Bamboo structure (made with Indian bamboo)



Naandi Rurban Commune, Hyderabad
Platinum Rated

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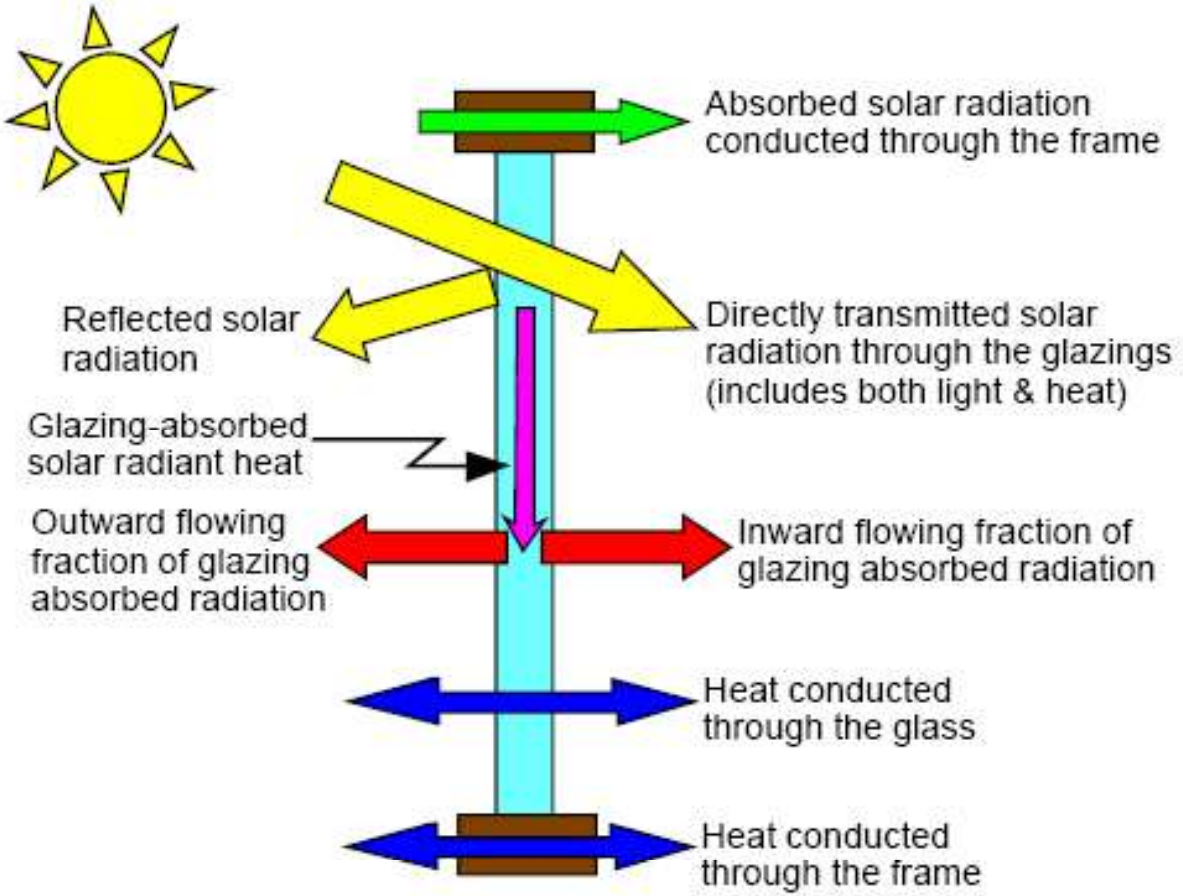
Master Material Sheet

MASTER MATERIALS TRACKING SHEET

Material Name and Type	Manufacturer	Total Materials Quantity & Cost				MR C3 Certified Green Products		MR C6 Alternative Construction Material		MR C4 Local Materials			Information Source
		Quantity	Units	Cost per unit	Total Cost (Rs)	Certified Yes/No	Certified Material Value (Rs)	% of Alternate Content	Recycled Content Value (Rs)	Quantity	Total Cost (Rs)	Distance to manufacturing (km)	
Cement (ACC F2R)	ACC Ltd	24,849	Nos	400	9,939,600	Yes	9,939,600	28.00%	2,783,088	100%	9,939,600		Manufacturer Brochure
Porotherm Blocks	Weinerberger	106,424	Nos	75	7,981,800	Yes	7,981,800	25.00%	1,995,450	100%	7,981,800		Manufacturer Brochure
Fly Ash Brick	ACC Ltd	337,000	Nos	8	2,696,000	No	0	40.00%	1,078,400	100%	2,696,000		Manufacturer Letter
M Sand	Local	6,424	cu.m	1,225	7,869,400	No	0	100.00%	7,869,400	100%	7,869,400		Manufacturer Letter
20mm Metal	Local	1,266	cu.m	1,050	1,329,300	No	0	0.00%	0	100%	1,329,300	56	Manufacturer Letter
Contruction Debris	Local	1,549	cu.m	3,150	4,879,350	No	0	100.00%	4,879,350	100%	4,879,350		Manufacturer Letter
Refilling of construction Debris	Local	91	sq.m	3,150	286,650	No	0	100.00%	286,650	100%	286,650		Manufacturer Letter
Gravel	Local	813	cu.m	3,150	2,560,950	No	0	0.00%	0	100%	2,560,950		
RMC Concrete	Ultratech Duracon	1,924	cu.m	4,900	9,427,600	Yes	9,427,600	35.00%	3,299,660	100%	9,427,600		Manufacturer Brochure
Steel	Local	458	Tons	60,000	27,480,000	No	0	15.00%	4,122,000	100%	27,480,000		
Laterite Stone	Local	94,955	Nos	90	8,545,950	No	0	100.00%	8,545,950	100%	8,545,950		Vendor letter
Structural Steel Fabrication	Tata Structura	51,405	Kg	90	4,626,450	Yes	4,626,450		0	100%	4,626,450		Manufacturer Brochure
Flush Doors	Local	1,244	sq.m	3,300	4,105,200	No	0	0.00%	0	100%	4,105,200		
UPVC Windows	Gadil Windows	1,549	sq.m	2,845	4,406,905	No	0	0.00%	0	100%	4,406,905		Manufacturer Letter
Italin Marble	Maheshwary Marble	3,920	sq.m	2,166	8,490,720	No	0	0.00%	0	0%	0		
Granite	Local	796	sq.m	1,550	1,233,800	No	0	0.00%	0	100%	1,233,800		
Toilet Tile	Nitco	3,862	sq.m	753	2,908,086	Yes	2,908,086	0.00%	0	0%	0		
Laminate Wooden Flooring	Subh Woods	2,537	sq.m	1,200	3,044,400	Yes	3,044,400	0.00%	0	0%	0		Manufacturer Brochure
Glass Handrail	Guardian Glass	1,390	sq.m	3,595	4,997,050	No	0	18.00%	899,469	100%	4,997,050		
Foam Concrete	Ultratech Litecon	1,964	sq.m	950	1,865,800	Yes	1,865,800	45.00%	839,610	100%	1,865,800		
Terrace Tile	ABC Ceramics	1,964	sq.m	645	1,266,780	Yes	1,266,780	0.00%	0	100%	1,266,780		
Paver Blocks	Nippon	1,724	sq.m	384	662,016	Yes	662,016	0.00%	0	100%	662,016		
Painting	Dulux	41,059	sq.m	160	6,569,440	Yes	6,569,440	0.00%	0	0%	0		
Glass (Windows)	Guardian Glass	1,450	sq.m	1,500	2,175,000	Yes	2,175,000	18.00%	391,500	100%	2,175,000		Manufacturer Letter
				Total Cost	129,348,247		50,466,972		36,990,527		108,335,601		

Total Construction Cost (excluding MEP)	221,331,000	1765.80	125343.24	Sqft
Default Total Material Cost (60% of Total Cost)	132,798,600			
% of Certified Green Products	38.00%	Meets requirement	5 points	
% of Alternate Construction Material	27.85%	Meets requirement	2 points	
% of Materials Procured Locally	81.58%	Meets requirement	2 points	

Heat Flows Through Windows



U-value

- U value – (W/m2.deg K)
- Heat transfer due to temperature difference (conduction)
- Typical U values
  - Single glazed glass (6mm) : 5-6
  - High Performance glass : 1.7 – 3.0 (6mm+airgap+6mm)

Shading coefficient

- **Shading coefficient**

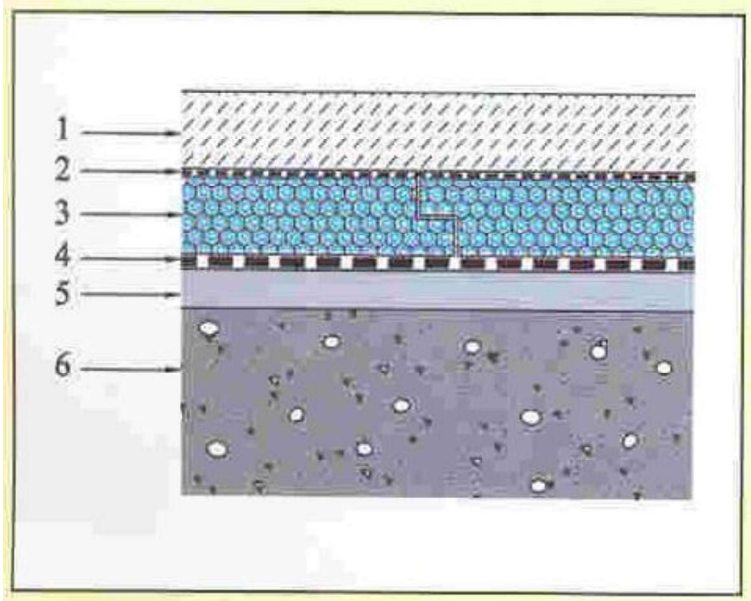
  Heat gain thru' a given glazing (SHGC)

  Heat gain thru' 3 mm clear glass (0.87)

- **Solar heat gain coefficient (SHGC)**
  - Also called as Solar factor by manufacturers
  - Indicates direct heat gain
- **Typical values**
  - Single glazed 6mm glass : 0.5 – 0.8
  - High performance glass : 0.1 – 0.4

Roof Insulation

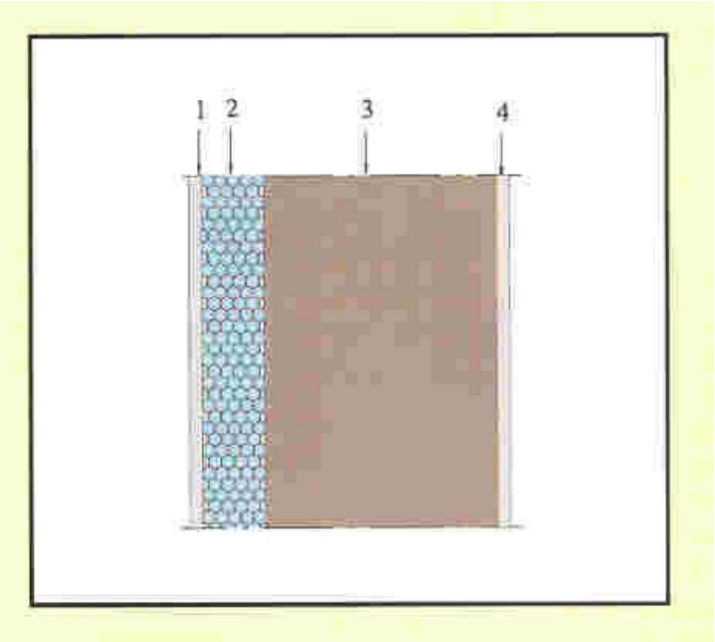
- Over-deck ?
- Under-deck ?
- Insulation sandwiched
- Saving potential
  - 3-8 % depending on extent of roof



1: Reinforced concrete
2: Separation layer
3: Insulation
4: Water proof membrane
5: Screed
6: Concrete roof deck

Wall Insulation

- **External or Internal**
- **Internal if brick exterior required**
- **Saving potential**
  - **3 – 8 %**



1: Cement plaster / Gypsum wall board
2: Insulation
3: Brick or concrete wall
4: Interior gypsum or plaster

Autoclaved Aerated Concrete Blocks

- **AAC blocks**
  - Composed of fly ash, cement, lime, Aluminum powder and water
- **Unique properties**
  - Low U value: 0.67 W/m^2 ^ok
  - Reduction in temp possible : 4-5^oC
- **Economic Benefits**
  - 15-20% savings in A/c Load
  - Savings in Cement

Insulation Materials-Relative U-values
(75 mm thick)

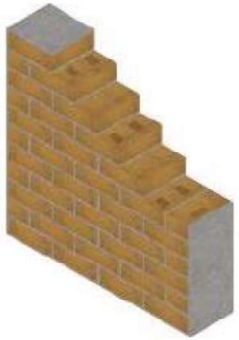
- **Glass wool stuffed**
  - U value : 0.53 W/m^2 deg K
- **Thermocol**
  - U-Value : 0.47 W/m^2 deg K
- **Extruded Polysterene**
  - U-Value : 0.37 W/m^2 deg K
- **Polyurethane**
  - U-Value : 0.35 W/m^2 deg K

Walling Technologies

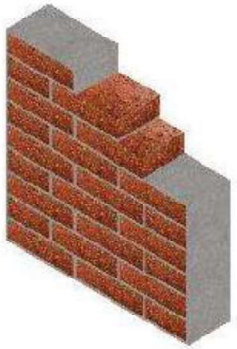
Bamboo-Crete
U - VALUE (W/m ^{2}K)= 1.82

Wattle and Daub
U - VALUE (W/m ^{2}K)= 2.09

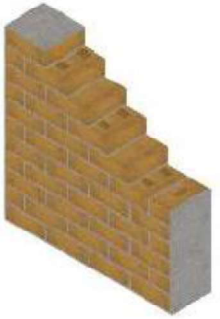
Stabilized Adobe
U - VALUE (W/m ^{2}K)= 1.50



Laterite block wall
U - VALUE (W/m ^{2}K)= 1.61

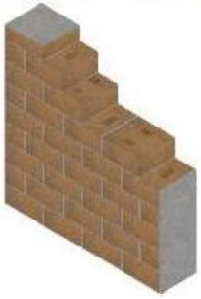


Unstabilized Adobe
U - VALUE (W/m ^{2}K)= 1.57



Compressed Stabilized Earth block wall
U - VALUE (W/m ^{2}K)= 1.59

Unstabilized Compressed Earth block wall
U - VALUE (W/m ^{2}K)= 1.42



AAC block wall
U - VALUE (W/m ^{2}K)= 0.45

Unstabilized Rammed Earth Wall assembly
U - VALUE (W/m ^{2}K)= 1.68

Stabilized Rammed Earth Wall assembly
U - VALUE (W/m ^{2}K)=

Reuse of Debris of AAC Blocks and Concrete

Reuse of materials Godrej Tress Phase 3, Mumbai

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Use of Excavated soil as Alternate Material

VKM Goldfields, Coimbatore

Envelope measures : Typical saving potential

- AAC wall : 3-8 %
- Brick wall with 75mm extruded polysterene insulation : 3-8 %
- High Albedo roofing material : 2-3 %
- Roof garden : 1-2 %
- Low-U glass & glazing : 6-8 %
- Thermal break : 1-2 %
- Roof insulation (extr.polyst) : 5-6 %

Pre Fab Construction

IGBC Green Homes Platinum rated - Prefab Homes - Karnataka State Police Housing Corp

Day 1

Day 7

Day 10

Day 2

Day 11

Day 5

Day 9

Day 14

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Sum-up

- Development of 'Green Procurement Policy'
- Capacity building for organization's staff
- Development of 'Green Procurement Guidelines'
  - Incorporate Green specifications for products and materials
- Implementation of Green Procurement
  - High Value, High volume and High Impact
- Monitor the impact
  - Financial Benefits

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Thank you

प्रधान मंत्री आवास योजना-शहरी
Pradhan Mantri Awas Yojana-Urban

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

Ministry of Housing and Urban Affairs
Government of India

आज़ादी का अमृत महोत्सव

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Thank you!

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Leadership through Learning