THERMAL INSULATION OF GREEN & SMART BUILDINGS

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MODERN SOCIETY EXPECTANCE
OFFICE / RESIDENCE

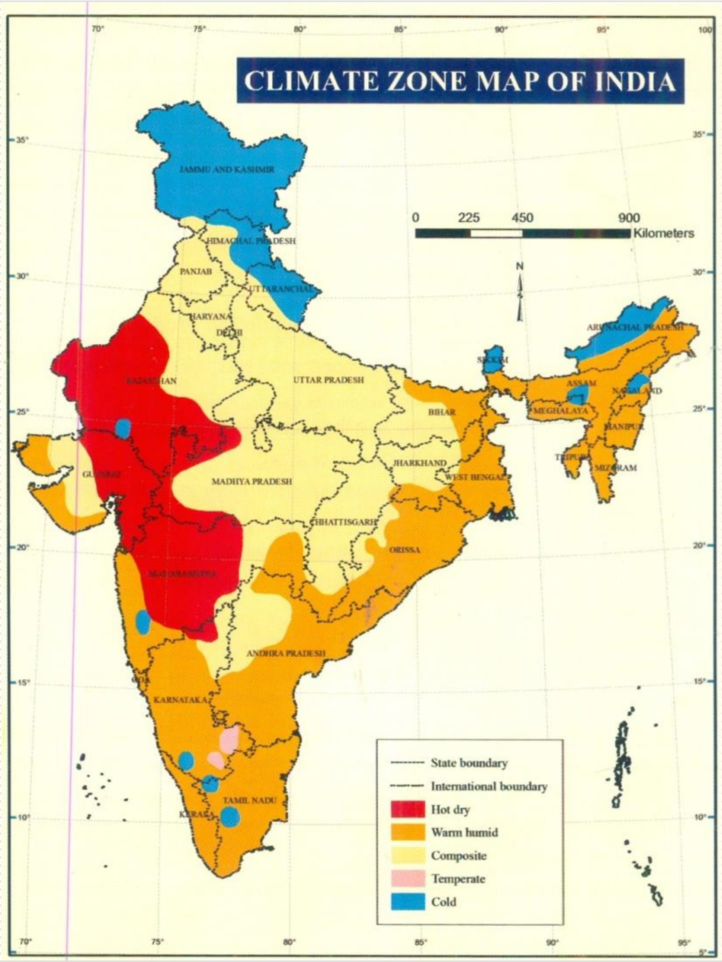
HOT & SCORCHING
SUMMER $45^{0}C$

HUMAN COMFORT

VALUE FOR LIFE

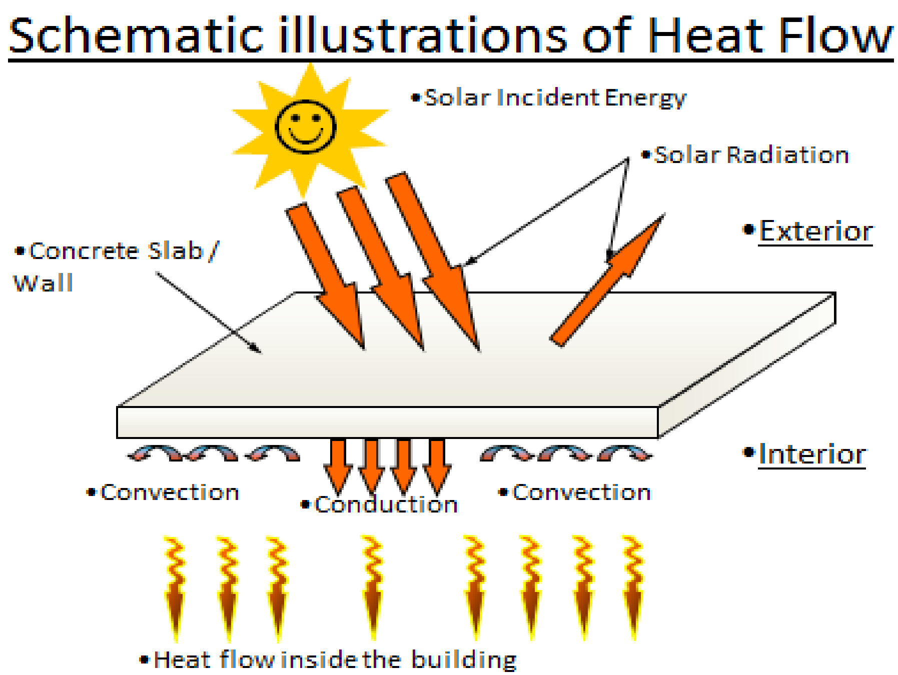
COLD & CHILLING
WINTER $0\text{-}4^{0}C$

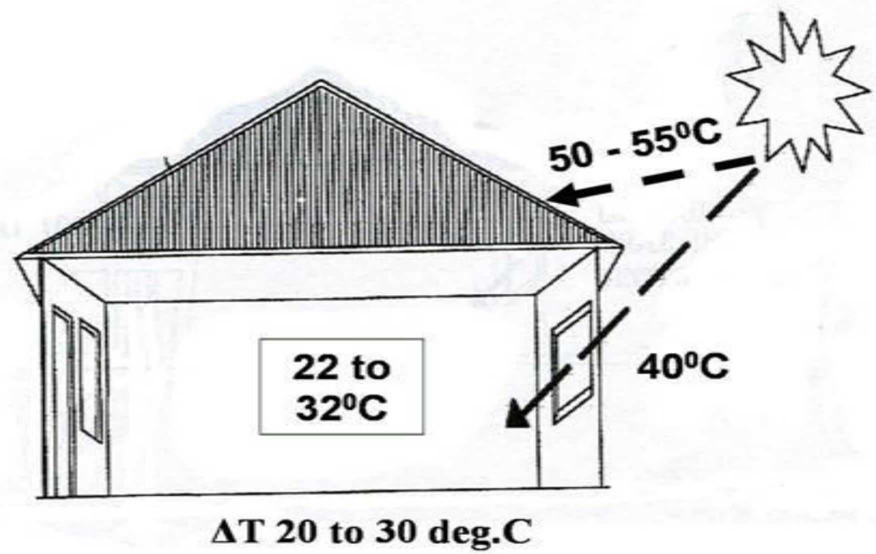
ENVIRONMENT HEAT IMPACT ON BUILDING



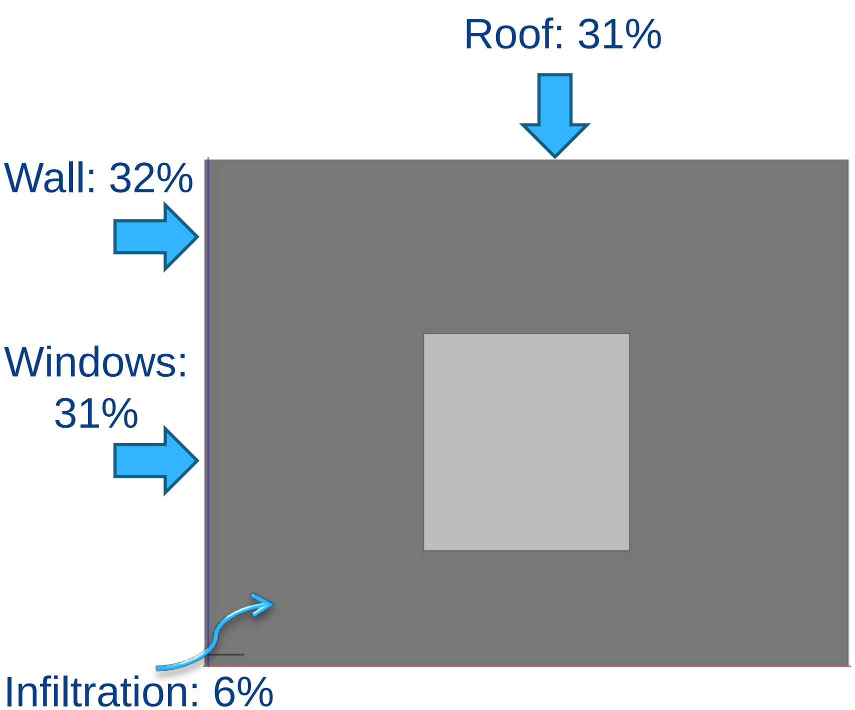
- **High ambient affects roof continuously with heat ingress**
- **High ambient heats up at least 2 walls facing afternoon sun**
- **Low ambient conditions always affects walls with cold ingress**

‘HEAT TRANSFER FROM HIGHER TO LOWER TEMPERATURE’





Heat Load Components: Composite Climate (New Delhi)



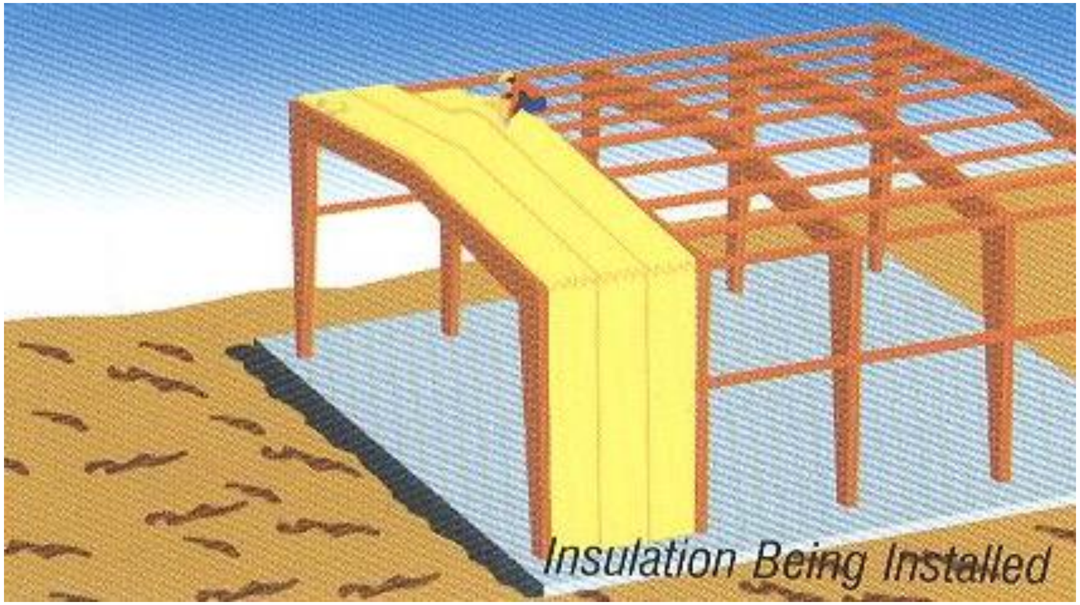
**Direct heat gain from windows not accounted*

Summer Heat Flow (May)	
Weather Conditions	
Temperature	Min.: 18.7°C, Max.: 42.6°C, Avg.: ~32°C
Relative Humidity	Min.: 13%, Max.: 97%, Avg.: ~50%

Net heat flow per unit area	
Roof (15 m²)	24.6 kWh/m²
Wall (47.6 m²)	8.1 kWh/m²
Window (8.4 m²)	43.3 kWh/m²
Infiltration (based on floor area 15 m²)	5.0 kWh/m2

WHAT THERMAL INSULATION CAN DO

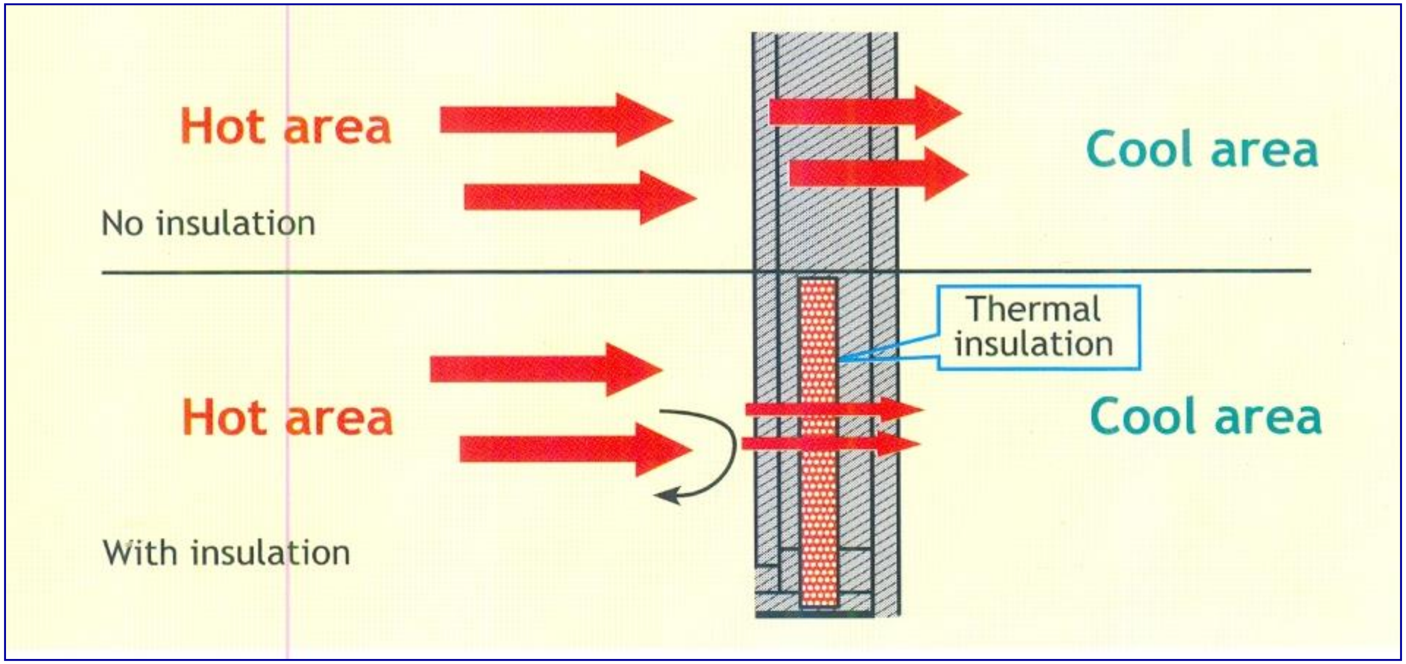
* Creates an envelope outside the building
* Stop heat / cold ingress from outside
* Thermal Resistance ‘R’ = L/K
* Maintains at least 8-9 degrees temp. difference
* Maintains controlled temp. for longer periods
* Human comfort
* High Quality of Life



Role of Thermal Insulation

The Science :

1. **Heat always flows from high to low temperature**
2. **Insulation materials do not transfer heat well; thus reduce the heat transfer.**

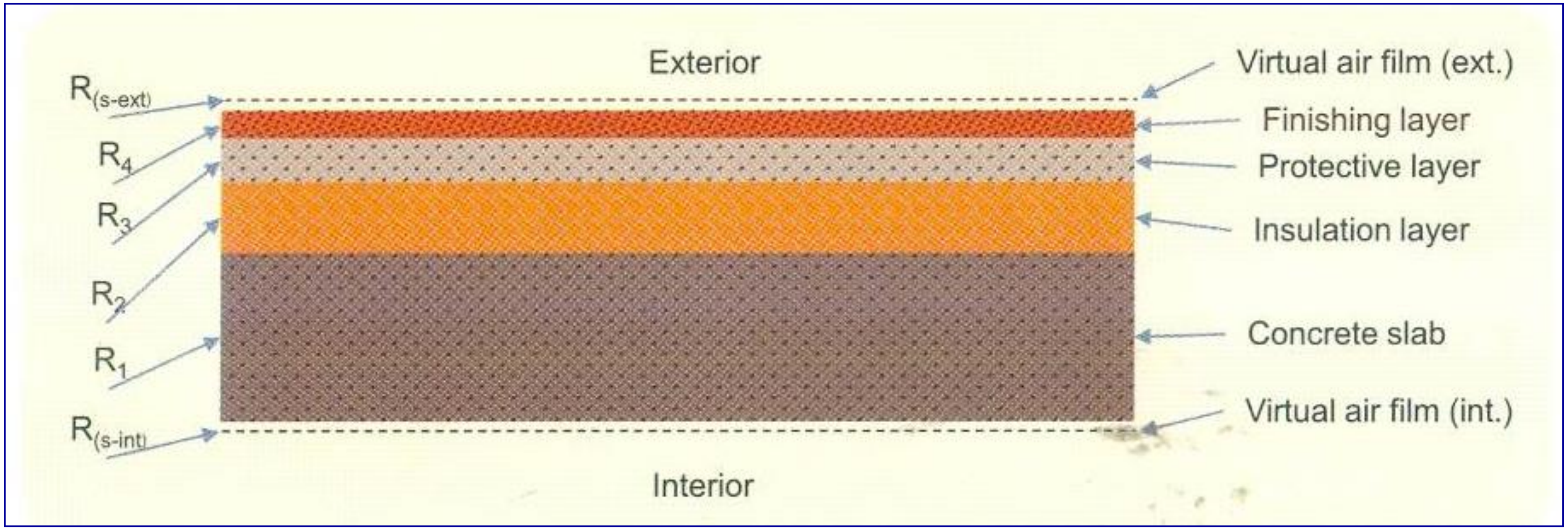


Role of Thermal Insulation

Thermal Resistance :

$$R_{T(Roof)} = R_1 + R_2 + R_3 + R_4 + R_{(s\text{-}ext)} + R_{(s\text{-}int)}$$

$$R_{T(Wall)} = R_1 + R_2 + R_{(s\text{-}ext)} + R_{(s\text{-}int)}$$



Thermal resistances of layers of different building materials in roof

Impact of Insulation: Composite Climate (New Delhi)

Summer: Heat in-flow (May)

<u>Business-as-usual construction</u>
Roof U-value: 4.2 W/m^2.K
Wall U-value: 2.1 W/m^2.K

<u>ECBC compliant roof & wall</u>
Roof U-value: 0.261 W/m^2.K
Wall U-value: 0.44 W/m^2.K

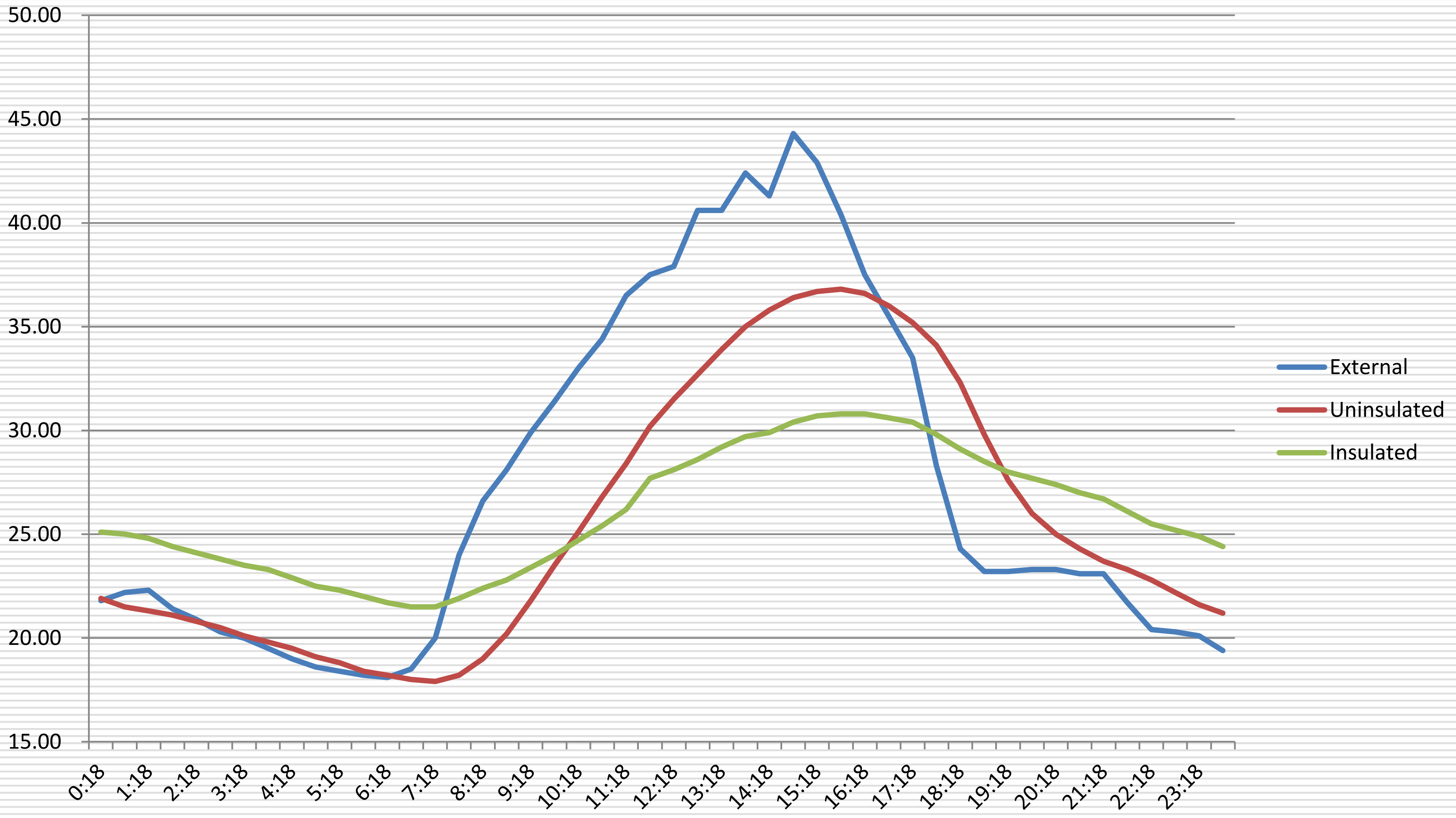
Reduction in heat in-flow through roof ~ 90%
Reduction in heat in-flow through walls ~ 70%

Source: BEEP analysis

Impact of Roof & Wall Insulation

- **Typical summer day in Composite climate (Delhi)**
- **With a 50mm Envelop insulation.**

Maximum Temperature Difference is 13.9°C @ 14:hrs



WHAT THERMAL INSULATION CAN DO

TYPICAL HOT SUMMER ROOF SITUATION

DAYTIME	AMBIENT TEMP. (DEG.C)	WORKING FLOOR TEMP. (DEG.C)	INSULATED ROOF WORKING FLOOR TEMP. (DEG.C)
10 AM – 12PM	39	35	30
12PM -2PM	41	37	32
2PM-4PM	41	37	32
4PM-6PM	40	36	31

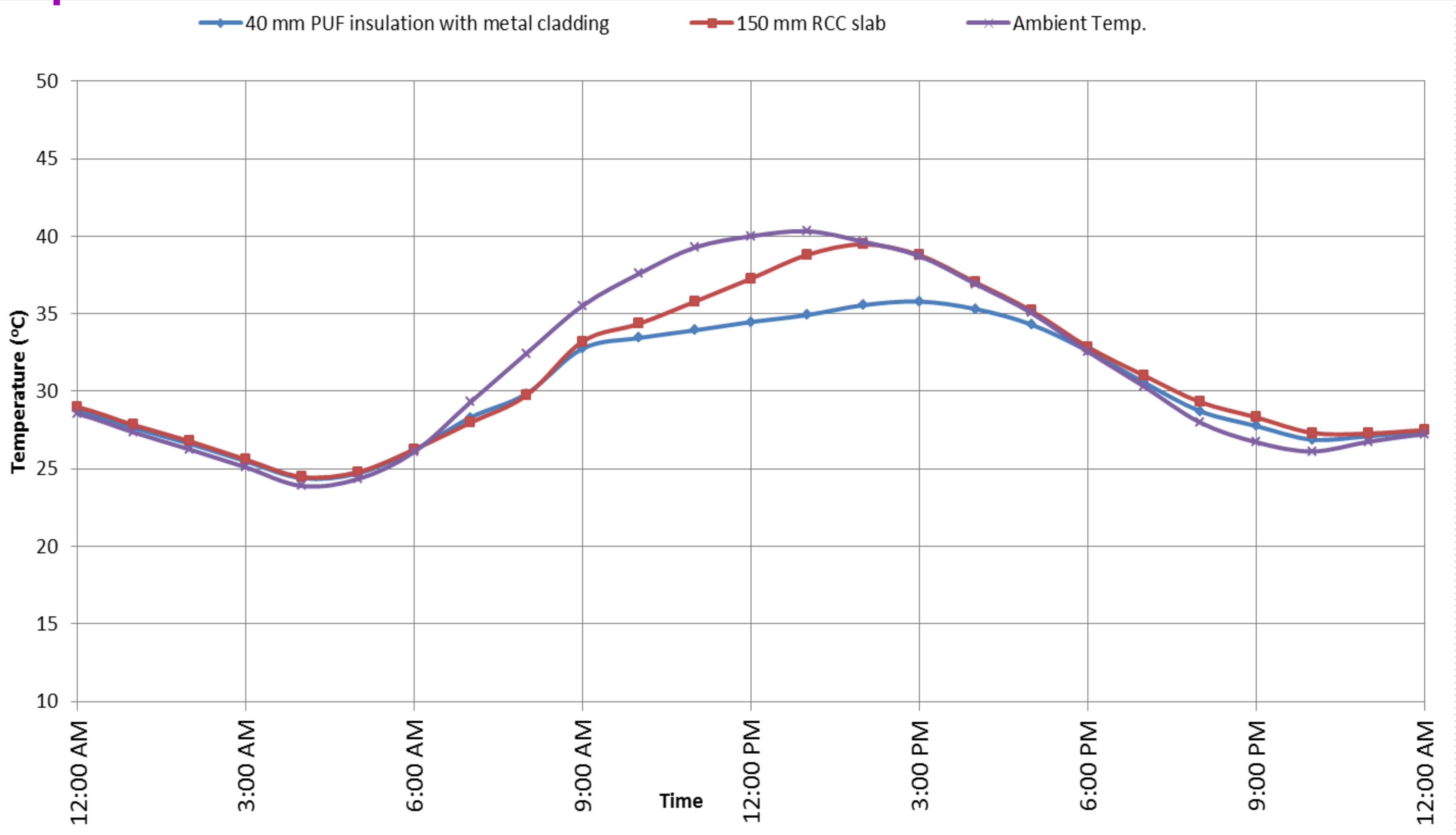
Normal building with 150mm RCC, Water Proofed, Brick Wall

WHAT THERMAL INSULATION CAN DO

- In a tropical country with high ambient conditions roof is mostly heated up so roof insulation is prevalent.
- In a cold country wall is critical as cold remains at ground level, so wall insulation plays major roll in cold ingress.
- Roof & wall insulation creates a major impact on indoor temperature and comfort in a building

IMPACT OF ROOF INSULATION

- Up to 6-7^{o}C cooler than ambient
- Up to 4-5^{o}C cooler than RCC



HEAT INGRESS CALCULATION

Design Conditions	
Ambient Temperature	40°C
Outside Surface Temperature	42°C
Indoor Temperature	35°C
Component Area	10 m2
Thermal Conductivity of Fibrous / Rockwool	0.035 W/mK
Thermal Conductivity of Rigid / PUF	0.023 W/mK

S. No.	Building Assembly	Heat Gain (W/m2)	Percentage Reduction in Heat Gain
1	Metal Sheet - 0.5mm	7.27	-
2	Metal Sheet - 0.5mm + Fibrous / Rockwool 50mm	1.174	84%
3	Metal Sheet - 0.5mm + Rigid / PUF 50mm	0.816	89%

HEAT INGRESS CALCULATION

S. No.	Building Assembly	Heat Gain (W/m2)	Percentage Reduction in Heat Gain
1	RCC - 150 mm	5.532	-
2	RCC - 150mm + Fibrous / Rockwool 50mm	1.117	80%
3	RCC - 150mm + Rigid/ PUF 50mm	0.7888	86%
Note:	Thermal Conductivity of RCC	1.73 W/mK	

S. No.	Building Assembly	Heat Gain (W/m2)	Percentage Reduction in Heat Gain
1	Brick - 150mm	4.343	-
2	Brick - 150mm + Fibrous / Rockwool 50mm	1.058	76%
3	Brick - 150mm + Rigid / PUF 50mm	0.759	82%
Note :	Thermal Conductivity of Brick	0.808 W/mK	

Thermal Insulation of Buildings

Buildings consume more than 40% of the Global Energy Use

- This major energy demand in a building is due to lack of Building Envelope which contributes to 60-75% of heat gain / loss.
- Insulation of Building envelope (Roof & Wall) is a key factor to reduce heat gain / loss and reduce energy cost.
- LEED India & GRIHA advocate Building Envelope Insulation.
- Any savings on Building Energy Consumption is beneficial

Insulation Benefits

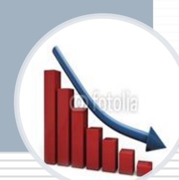
Industry & Society require Low-emission Buildings, Energy-Efficient Architecture & Sustainable solutions

- Stop heat / cold ingress from outside
- Saves on fossil fuel
- Reduces emission of GHG.
- Lower energy losses; avoid the danger of oversized heating or cooling systems that works hard to compensate for the heat or cold losses through the building envelope.

Environmental

- Effective insulation lowers heating or cooling bills, thus no longer being affected by rising energy costs
- Maintains controlled temp. for longer periods.

Economical



- Human Comfort – improves the efficiency of occupier/user.
- Provides fungus-free and microbe-free healthier environ, due to absence of cold walls

Social

Various Application Methods

External Wall Insulation with Fibrous / Rockwool slabs

Rigid / PU External Roof & Wall Spray Insulation

Various Application Methods

Rigid External Thermal Insulation Composite System

Rigid Roof Insulation with water proofing membrane

THERMAL INSULATION FOR BUILDINGS

ROOF UNDERDECK INSUALTION

Fibrous / Rockwool Insulation

Rigid / PIR Insulation

THERMAL INSULATION FOR BUILDINGS

ROOF OVERDECK INSULATION

FIXING OF PRE- FORMED RIGID / POLYURETHANE SLABS OVER RCC

THERMAL INSULATION FOR BUILDINGS

ROOF

OVERDECK INSULATION WITH SPRAYED SYSTEM OVER RCC

SPRAYED / RIGID PUF 42$\pm$2 KG/M3

THERMAL INSULATION FOR BUILDINGS

ROOF

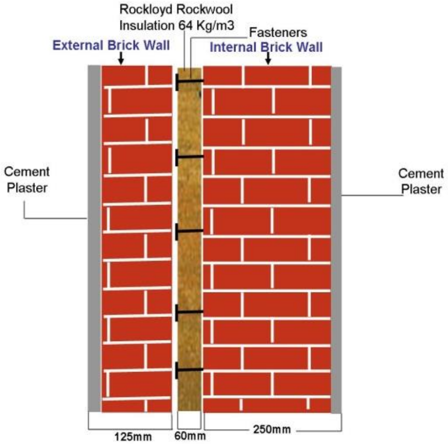
OVERDECK INSULATION WITH SPRAYED SYSTEM OVER RCC

HOMOGENOUS JOINTLESS SURFACE

THERMAL INSULATION FOR BUILDINGS

EXTERNAL WALL INSULATION

WITH RIGID / RW INSULATION BOARDS



CAVITY FILL, HOLLOW BLOCKS FINISH

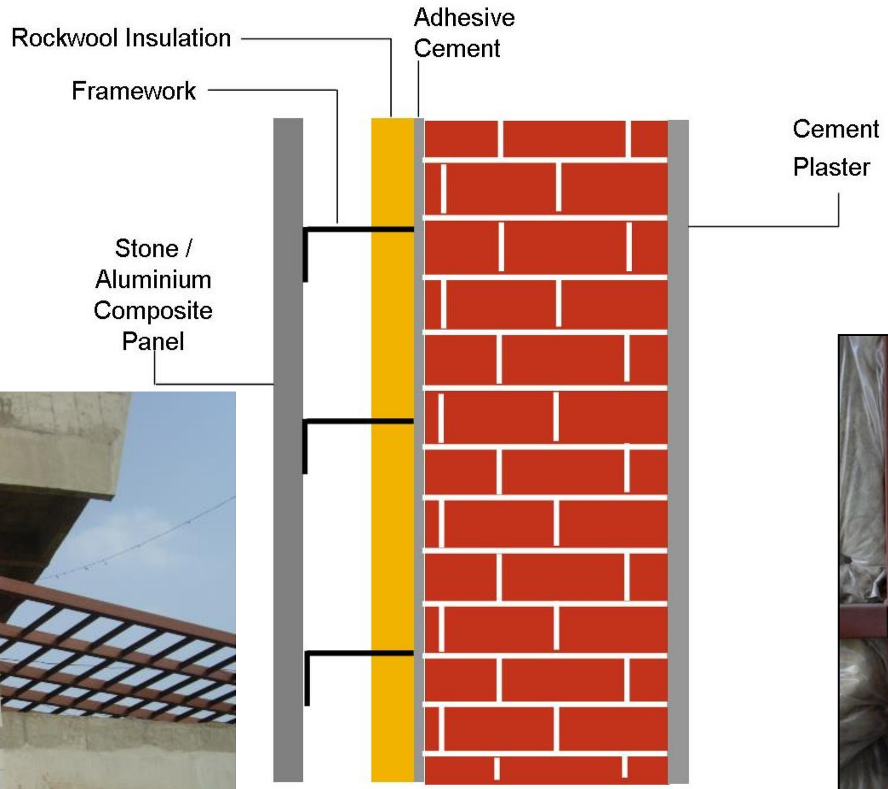
THERMAL INSULATION FOR BUILDINGS

INTERNAL WALL INSULATION

WITH RIGID / RW INSULATION BOARDS

THERMAL INSULATION FOR BUILDINGS

WALL INSULATION BEHIND STONE / ALUMINIUM COMPOSITE PANEL



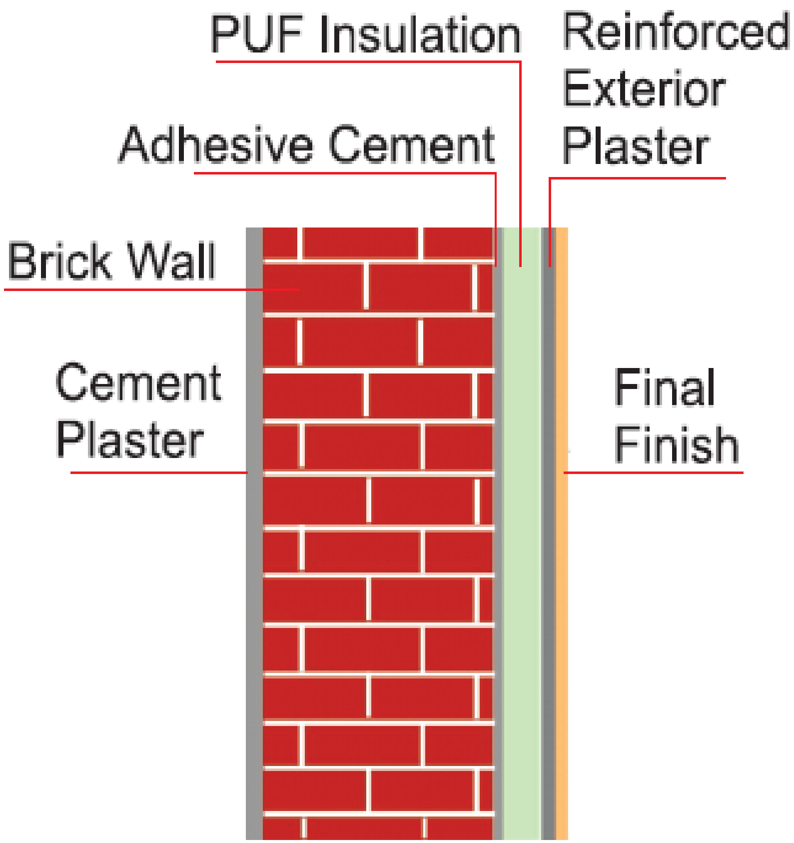
THERMAL INSULATION FOR BUILDINGS

OUTSIDE WALL INSULATION WITH ROCKWOOL BOARDS AND FINISHED WITH DECORATIVE PANELS

DECORATIVE PANEL ABSORBS HEAT & CONDUCTED INSIDE – RW STOPS HEAT PASSAGE

THERMAL INSULATION FOR BUILDINGS

EXTERIOR WALL INSUALTION



LATEST CONCEPT

LARGELY PRACTISED IN CHINA

THERMAL INSULATION FOR BUILDINGS

WALL INSULATION WITH PUF / PIR SLABS

THERMAL INSULATION FOR BUILDINGS

CAVITY WALL INSULATION WITH PUF CAST-IN-SITU

THERMAL INSULATION FOR BUILDINGS

PUF SPRAY INSULATION WITH STONE CLADDING

THERMAL INSULATION FOR BUILDINGS

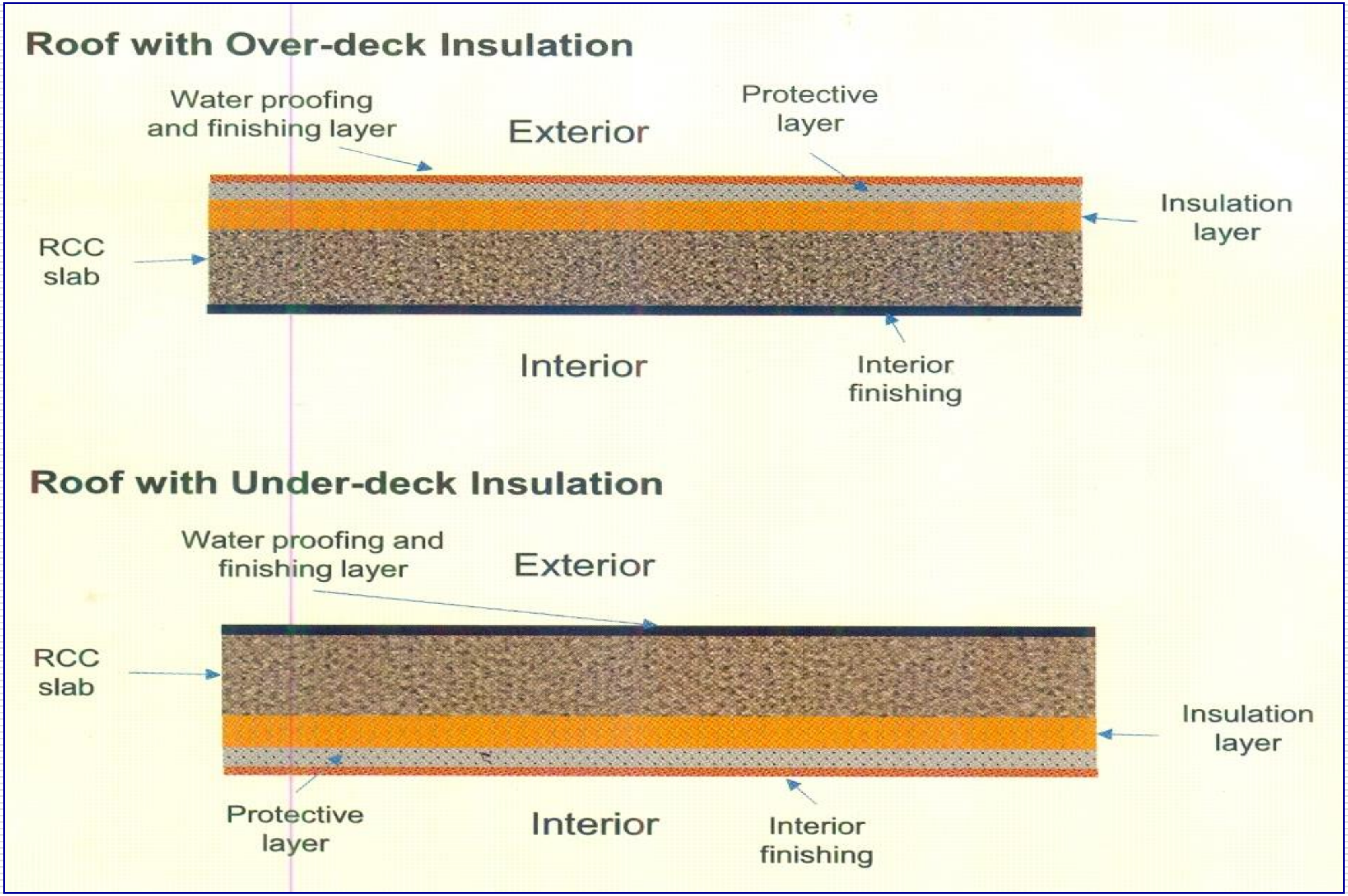
Type of Insulation Application preferably for Commercial Buildings, Central AC

- **Roof Overdeck Insulation and Exterior Wall Insulation**

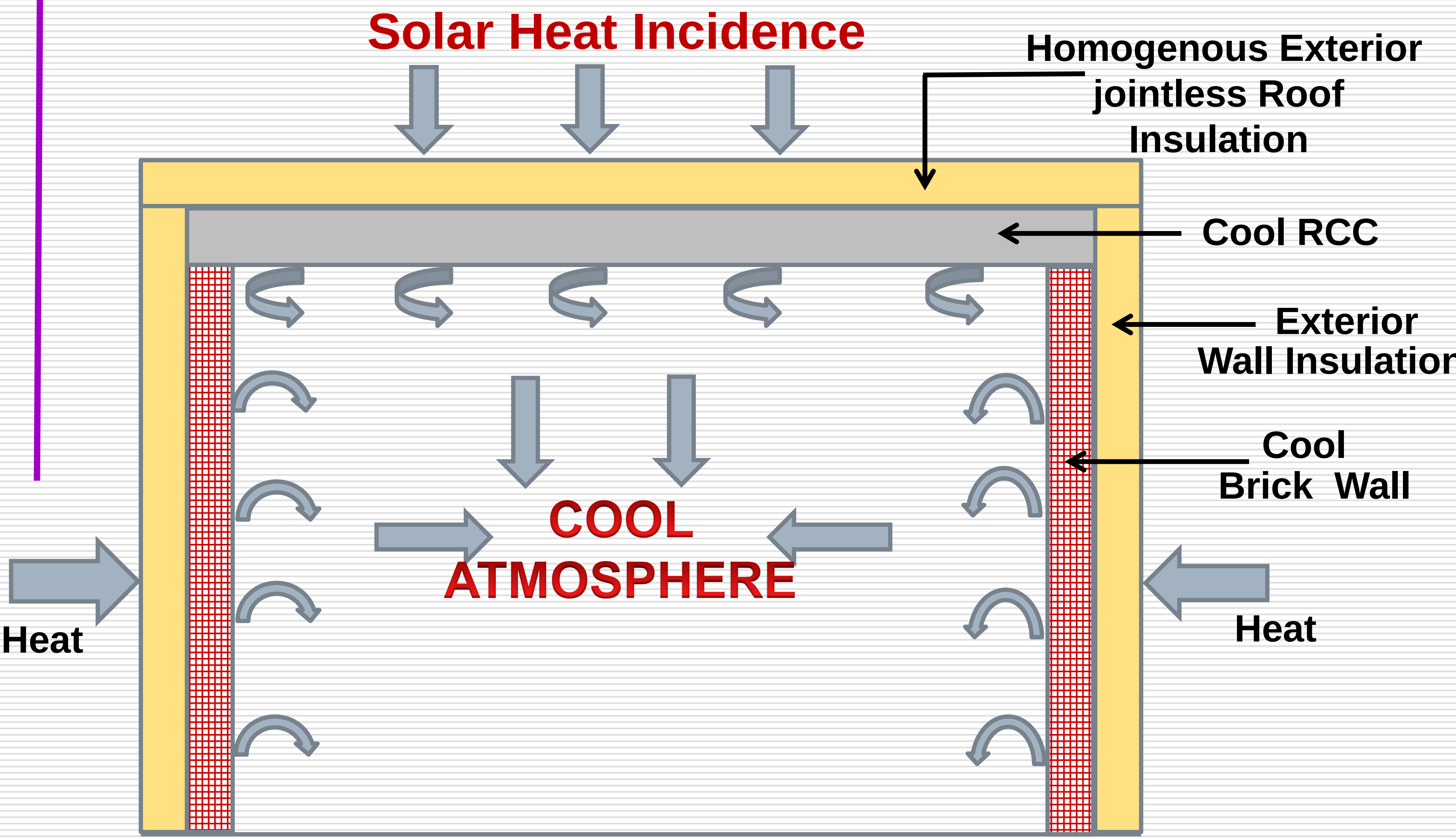
Type of Insulation Applictaion for Residential House

- **Individual rooms with Window AC**
- **Roof Underdeck & Interior Wall Insulation for instant cooling effect**

THERMAL INSULATION FOR BUILDINGS

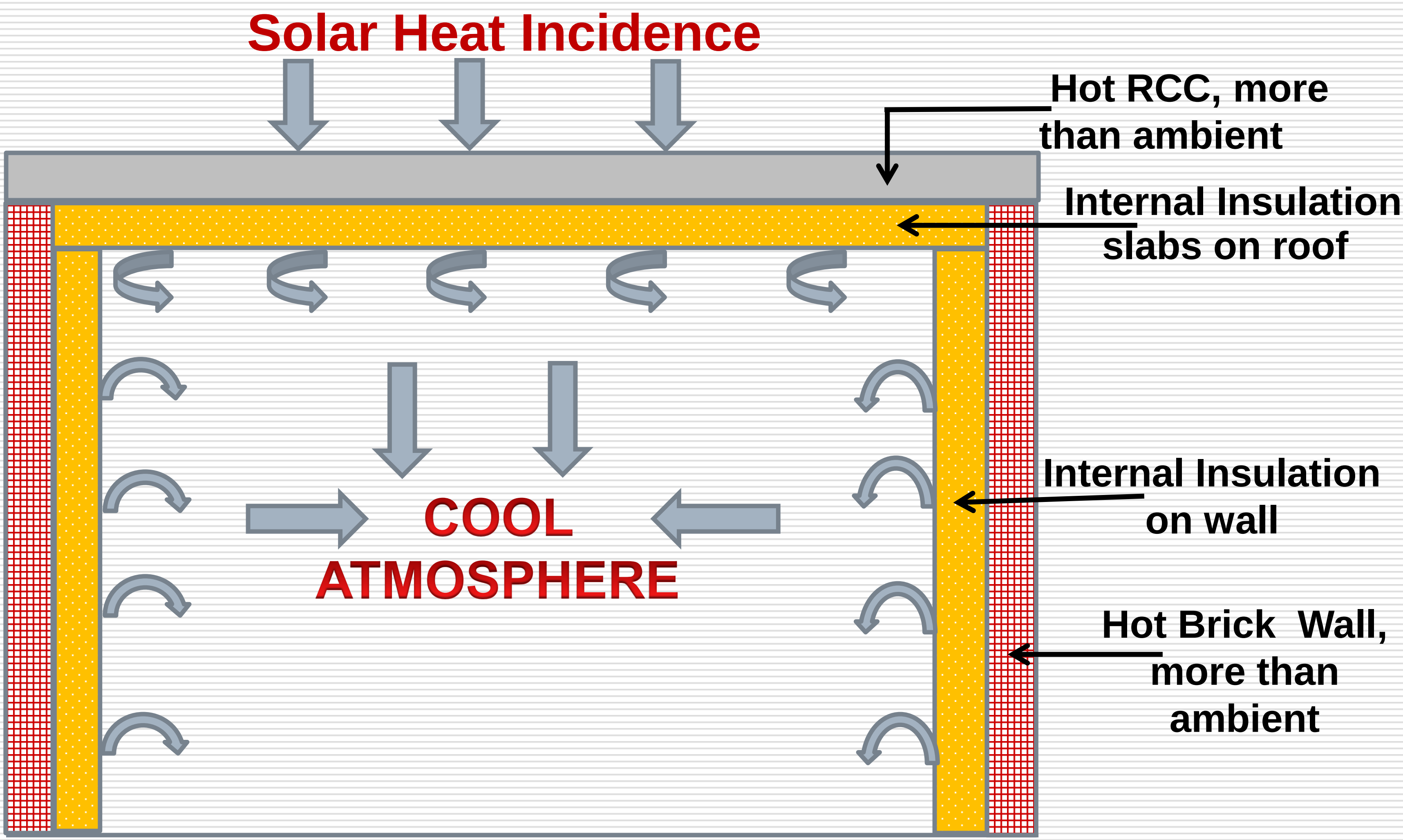


THERMAL INSULATION FOR CENTRALLY AIR-CONDITIONED BUILDINGS



RCC Roof & Brick wall acts as Cold Storage, emits out cold, Energy Savings

THERMAL INSULATION FOR INDIVIDUAL CHAMBERS IN BUILDINGS



Instant Cooling Effect

THERMAL INSULATION FOR BUILDINGS

EXTERNAL INSULATION FOR CENTRALLY AIR CONDITIONED BUILDINGS

When Heat Stopped at source

- RCC & Brick wall not heated up / exposed to environment
- Central AC will cool down the roof & wall through absorption
- After some time Roof & Wall will act as cold storage
- Cold will be radiated back inside
- More effective AC
- Energy conservation, Electricity saving
- Life of RCC & Brick wall increases

THERMAL INSULATION FOR BUILDINGS

INTERNAL INSULATION OF RESIDENTIAL HOUSES

- RCC & Brick wall heated up and during winter wall is cooled down
- Insulation stops spread of conducted heat & cold
- Individual chambers / rooms get cooled down faster
- Window AC system will have cooling effect faster as the cool air will not come in contact with the solid brick / RCC roof.
- Insulation reverts back and circulates the air

THERMAL INSULATION FOR BUILDINGS

FLOOR INSUALTION

Rockwool Board Insulation

THERMAL INSULATION FOR BUILDINGS

INSULATED ROOF, WALL, FLOOR

BAYERS ZERO ENERGY BUILDING AT NOIDA
SMART BUILDING INFRASTRUCTURE

Typical R&U Value Chart

POLYURETHANE FOAM SLAB / SPRAY

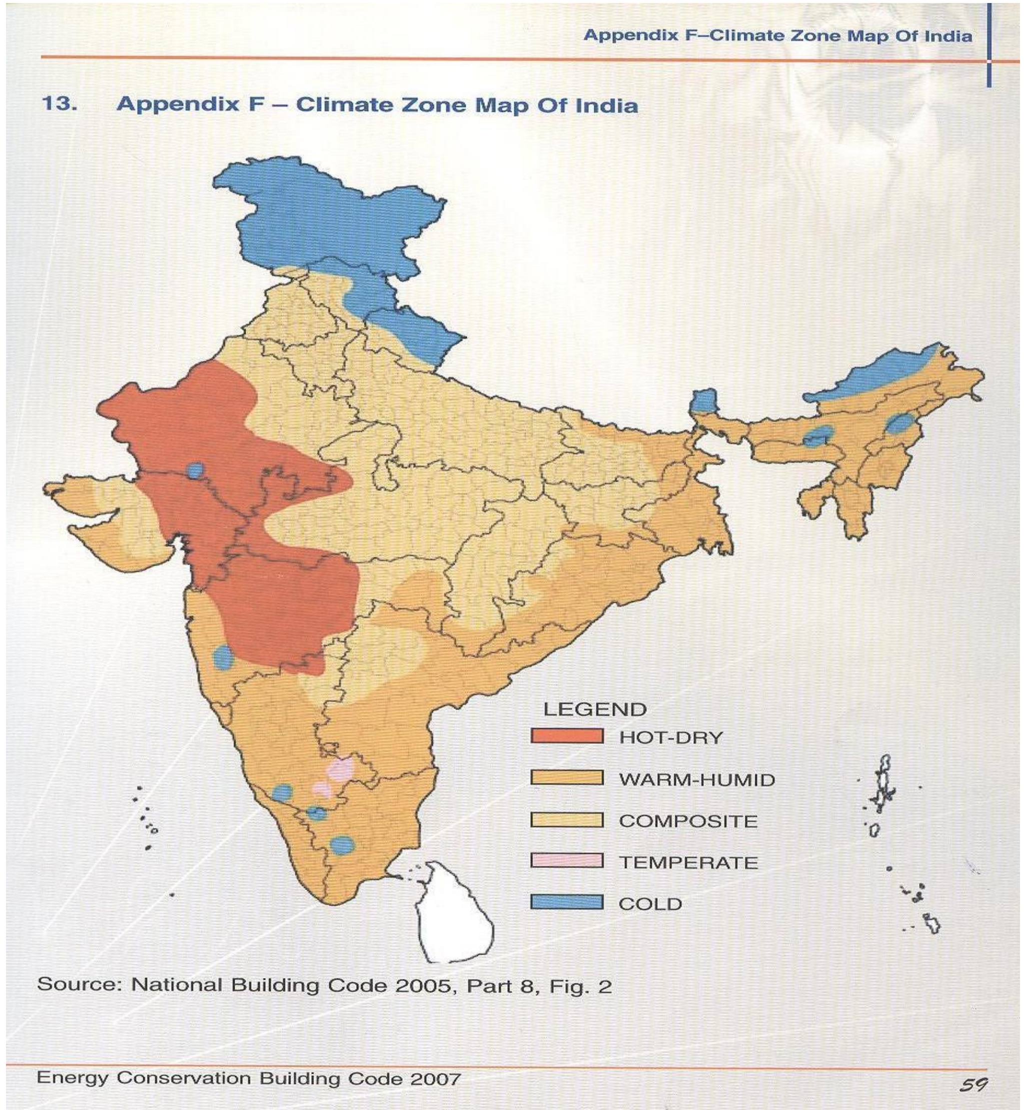
Thickness (mm)	R-Value		U-Value	
	(m2-Deg.C/W)	(Ft.2Hr.Deg. F/ Btu-in)	W/m2-deg.C)	(Btu-in/ ft.2Hr.Deg.F)
30	1.43	8.11	0.700	0.123
50	2.38	13.52	0.420	0.074
65	3.10	17.58	0.323	0.057
75	3.57	20.28	0.280	0.049

Typical R&U Value Chart

ROCKWOOL

Thickness (mm)	R-Value		U-Value	
	(m2-Deg.C/W)	(Ft.2Hr.Deg.F/ Btu-in)	W/m2-deg.C)	(Btu-in/ ft.2Hr.Deg.F)
50	1.72	9.79	0.580	0.102
65	2.24	12.73	0.446	0.079
75	2.59	14.69	0.387	0.068
120	4.14	23.50	0.242	0.043

ECBC 2007 – GUIDE TO SELECTION OF INSULATION MATERIALS



EXTENT OF INSULATION

CLIMATE ZONE

City	Climate Zone	City	Climate Zone
Ahmedabad	Hot & Dry	Kota	Hot & Dry
Allahabad	Composite	Kurnool	warm& Humid
Amritsar	Composite	Lucknow	Composite
Aurangabad	Hot & Dry	Madras	warm& Humid
Bangalore	Temperate	Manglore	warm& Humid
Barmer	Hot & Dry	Mumbai	warm& Humid
Belgaum	Warm & Humid	Nagpur	Composite
Bhagalpur	Warm & Humid	Nellore	warm& Humid
Bhopal	Composite	New Delhi	Composite
Bhubaneshwar	Warm & Humid	Panjim	warm& Humid
Bikaner	Hot & Dry	Patna	Composite
Calcutta	Warm & Humid	Pune	warm& Humid
Chitradurga	Warm & Humid	Raipur	Composite
Dehradun	Composite	Rajkot	Composite

CLIMATE ZONE

City	Climate Zone	City	Climate Zone
Dibrugarh	Warm & Humid	Ramgundam	warm& Humid
Gauhati	Cold	Ranchi	Composite
Gorakhpur	Composite	Ratnagiri	warm& Humid
Gwalior	Composite	Raxaul	warm& Humid
Hissar	Composite	Saharanpur	Composite
Hyderabad	Composite	Shillong	warm& Humid
Imphal	Warm & Humid	Sholapur	Hot & Dry
Indore	Composite	SunderNagar	cold
Jabalpur	Composite	Surat	Hot & Dry
Jagdelpur	Warm & Humid	Tezpur	warm& Humid
Jaipur	Composite	Tirucchirapali	warm& Humid
Jaisalmer	Hot & Dry	Trivandrum	warm& Humid
Jamnagar	Warm & Humid	Tuticorin	warm& Humid
Jodhpur	Hot & Dry	Veraval	warm& Humid
Jorhat	warm& Humid	Vishakhapatnam	warm& Humid

ECBC COMPLIANCE FOR ROOFS & WALLS

Prescribed minimum R-values of insulation and maximum U-factors for roofs and walls

Envelope	Climate zone	Buildings used for 24 hours (hospitals, hotels, call centres)		Buildings used at daytime and other types	
		Max. U-factor (Composite)	Min. R-value of insulation alone	Max U-factor	Min. R-value of insulation alone
		$W/(m^2K)$	m^2 K/W	$W/(m^2K)$	m^2 K/W
Roofs	Composite	0.261	3.5	0.409	2.10
	Hot and dry	0.261	3.5	0.409	2.10
	Warm and humid	0.261	3.5	0.409	2.10
	Moderate	0.409	2.1	0.409	2.10
	Cold	0.261	3.5	0.409	2.10
Walls	Composite	0.440	2.1	0.440	2.10
	Hot and dry	0.440	2.1	0.440	2.10
	Warm and humid	0.440	2.1	0.440	2.10
	Moderate	0.440	2.1	0.440	2.10
	Cold	0.369	2.2	0.352	2.35

THERMAL INSULATION FOR BUILDINGS

ACCORDING TO ECBC					
A) Roof Assembly U-factor and Insulation R-value Requirements			Thickness of Insulation Materials		
Climate Zone	24- Hour use buildings Hospitals, Hotels, Call Centers etc.		FIBROUS INSULA-TION (MM)	RIGID FOAM INSULATION (MM)	PU SPRAY (MM)
	Maximum U-factor of the overall assembly (W/m^2-°C)	Minimum R-value of insulation alone (m^2 - °C/W)			
Composite	U-0.261	R-3.5	105	75	85
Hot and dry	U-0.261	R-3.5	105	75	85
Warm & Humid	U-0.261	R-3.5	105	75	85
Moderate	U-0.409	R-2.1	65	45	50
Cold	U-0.261	R-3.5	105	75	85

THERMAL INSULATION FOR BUILDINGS

ACCORDING TO ECBC					
A) Roof Assembly U-factor and Insulation R-value Requirements			Thickness of Insulation Materials		
Climate Zone	Daytime use buildings Other Building Types		FIBROUS INSULATION (MM)	RIGID FOAM INSULA-TION (MM)	PU SPRAY (MM)
	Maximum U-factor of the overall assembly (W/m²-°C)	Minimum R-value of insulation alone (m² - °C/W)			
Composite	U-0.409	R-2.1	65	45	50
Hot and dry	U-0.409	R-2.1	65	45	50
Warm & Humid	U-0.409	R-2.1	65	45	50
Moderate	U-0.409	R-2.1	65	45	50
Cold	U-0.409	R-2.1	65	45	50

THERMAL INSULATION FOR BUILDINGS

<table>
<tr><td colspan="6">ACCORDING TO ECBC</td></tr>
<tr><td colspan="3">B) Opaque wall assembly U-factor and Insulation R- value Requirements</td><td colspan="3">Thickness of Insulation Materials</td></tr>
<tr><td rowspan="2">Climate Zone</td><td colspan="2">24- Hour use buildings
Hospitals, Hotels, Call Centers etc.</td><td rowspan="2">FIBROUS INSULATION (MM)</td><td rowspan="2">RIGID FOAM INSULATION (MM)</td><td rowspan="2">PU SPRAY (MM)</td></tr>
<tr><td>Maximum U-factor of the overall assembly (W/m^2-°C)</td><td>Minimum R-value of insulation alone (m^2 - °C/W)</td></tr>
<tr><td>Composite</td><td>U-0.440</td><td>R-2.10</td><td>65</td><td>45</td><td>50</td></tr>
<tr><td>Hot and dry</td><td>U-0.440</td><td>R-2.10</td><td>65</td><td>45</td><td>50</td></tr>
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<tr><td>Cold</td><td>U-0.369</td><td>R-2.20</td><td>65</td><td>50</td><td>55</td></tr>
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THERMAL INSULATION FOR BUILDINGS

ACCORDING TO ECBC					
B) Opaque wall assembly U-factor and Insulation R- value Requirements			Thickness of Insulation Materials		
Climate Zone	Other Building Types (Day Time)		FIBROUS INSULATION (MM)	RIGID FOAM INSULATION (MM)	PU SPRAY (MM)
	Maximum U-factor of the overall assembly (W/m^2-°C)	Minimum R-value of insulation alone (m^2 - °C/W)			
Composite	U-0.440	R-2.10	65	45	50
Hot and dry	U-0.440	R-2.10	65	45	50
Warm & Humid	U-0.440	R-2.10	65	45	50
Moderate	U-0.440	R-2.10	65	45	50
Cold	U-0.352	R-2.35	70	50	55

THERMAL INSULATION FOR BUILDINGS

TYPICAL ENERGY CONSERVATION CASES FOR BUILDING ROOF AS PER ECBC NORMS (24 HR.)							
Composite Case Study							
150 mm RCC Roof 225 mm Brick Wall For Summer Ambient Temp. = 40 Deg. C. For Winter Ambient Temp. = 4 Deg. C.				Size of Building L= Length = 50m W= Width = 20m H= Height = 3 m			
Considering Roof Area of 1000 m2							
Insulation Material	Heat Gain Through Roof	Savings	Total Heat Ingress	Cost of Energy @ Rs.5.10 KW for 300 days, 10 Hr.	Savings (at 70% efficiency of TR)	Costs of Insulation	Payback Period
	(W/m2)	(W/m2)	(KW)	(Rs/Year)	(Rs/Year)	(Rs.)	(months)
Bare RCC & Brick	68.91	-	68.91	10,54,323	Nil	-	-
75 mm PUF Spray insulation	9.51	59.4	9.51	1,45,503	6,36,174	10,50,000	20
50 mm PUF Spray	13.35	55.56	13.35	2,04,255	5,95,047	7,00,000	15
100 mm Rockwool Insulation	9.07	59.84	9.07	1,38,771	6,40,886	9,00,000	17
65 mm Rockwool Insulation	13.02	55.89	13.02	1,99,206	5,98,581	7,50,000	15

CASE STUDY

Aranya Bhawan, Jaipur

Charrette Held: December 2012

BEEP
BUILDING ENERGY EFFICIENCY PROJECT

Client

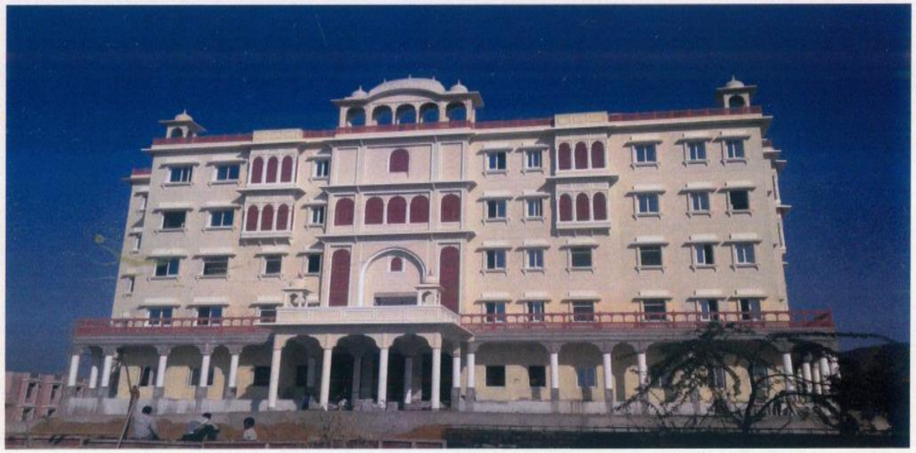
- Rajasthan Forest Department;
- Rajasthan State Road Development and Construction Corporation Ltd (RSRDC)

Project snapshot

- Built-up area: 16,500 m^2
- Climate type: Composite

Charrette recommendations

- External wall insulation
- Efficient glazing
- Roof insulation
- High efficiency water-cooled chillers
- Natural ventilation and passive downdraft evaporative cooling in the common area
- Reduction in glazed area in the common core
- Integration of solar photovoltaic



Energy saving potential: 32%

CASE STUDY

Result of energy-efficiency measures adopted at Aranya Bhawan, Jaipur		
	Before Charrette	*After Charrette*
Roof	Un-insulated RCC slab: 150-mm	150-mm RCC slab + 40-mm polyurethane foam insulation
Wall	Un-insulated brick wall: 230-mm	115-mm brick wall + 50-mm extruded polystyrene insulation + 115-mm brick wall
Windows	Single glazing unit: 5-mm clear glass	Double glazing unit: 6-mm low – e glass + 12-mm air gap + 6-mm clear glass
HVAC System	Air-cooled variable refrigerant volume system with CoP*: 2.75	Centralized water cooled chiller system with CoP: 5.8
Building's EPI**	77 kWh/m^2/year	53 kWh/m^2/year
Construction cost	Rs 30 crore	Rs 30.6 crore

* Coefficient of performance

** Energy Performance Index : annual energy consumption per square metre of floor area

*** After one year Energy Performance Index (EPI) 43 kWh/m2/year

Case Studies – Buildings

Eicher HQ, Gurgaon

Sr. No.	No. of Stories Roof Area (Sqm) Wall Area (Sqm)	Architect	Green Consultant	Scope of Insulation	Project Status	Rating
1	7; 1300; 3600	Romi Khosla	Spectral (AECOM)	**Roof**– Overdeck PUF Spray 40mm thick & 40 kg/m3 density. **Wall –**External dry wall Insulation with Rockwool slab- 50 mm thick & 48 kg/m3 density	Operational 23% heat gain from envelope	Platinum Runnerup in system design category, Bry Air Awards ACREX 2015. ACRYCS .

Case Studies - Buildings

Bayer Eco Commercial Building Greater Noida

Sr. No.	No. of Stories; Roof Area (sq.m); Wall Area (sq.m)	Architect	Green Consultant	Scope of Insulation	Project Status	Rating
1	G+1 530.3	Sankalpan Architects Pvt. Ltd, Mumbai	Spectral (AECOM)	**Roof Insulation Material** – 75 mm Thick PIR Insulation **Exterior Wall Insulation (Type 1)** - 80 mm Thick PIR Insulation **Exterior Wall Insulation (Type 2)** - 150 mm Thick PIR insulation	Completed	Platinum – the highest LEED rated building @ 2011

Case Studies – Buildings

Indira Paryavaran Bhavan, Delhi
Net Zero Building

Sr. No.	No. of Stories Roof Area (Sqm) Wall Area (Sqm)	Architect	Green Consultant	Scope of Insulation	Project Status	Rating
1	7; 2640; 4685	Dipender Prasad Architect +CPWD	Kalpakrit, Spectral (AECOM)	**Roof**– Overdeck PUF Spray 40mm thick & 40 kg/m3 density cavity. **Wall –** Insulation with rockwool slab- 65 mm thick & 64 kg/m3 density	Operational	Platinum & GRIHA 5 Star

Barriers Affecting use of Building Insulation

* Awareness of benefits of insulation products among the building users.
* Building unique as per location of climate zone – limited technical knowledge on optimum selection.
* Lack of knowledge of durability, costs, energy saving, pay back and long term performance.
* Reluctance of contractors to widely accept insulation and knowledge of benefits or financial incentive of extra investment
* Being a finishing item finance dry up.
* Absence of case studies.
* Absence of proper Test Reports and testing equipments.
* No regulation in force.

Building Designers Strategy

* In-depth analysis of Building parameters
* High 'R' value & low 'U' value of insulation materials
* Consider insulation as overall design strategy
* Computerized Building Energy Simulation

  Selection-Application-Optimum Thickness
* Laboratory Test Reports of related properties
* Correct application techniques
* Consideration of insulation as Energy Conservation item

THANK YOU