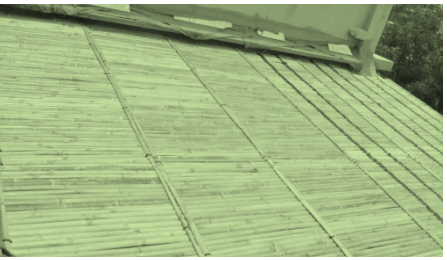



# Urban heat and options to mitigate

**Presented by: Dr. Mahesh Rajasekar**

TARU LEADING EDGE

ACCCRN Asian Cities Climate Change Resilience Network

What is this talk about?

# Quality of Life

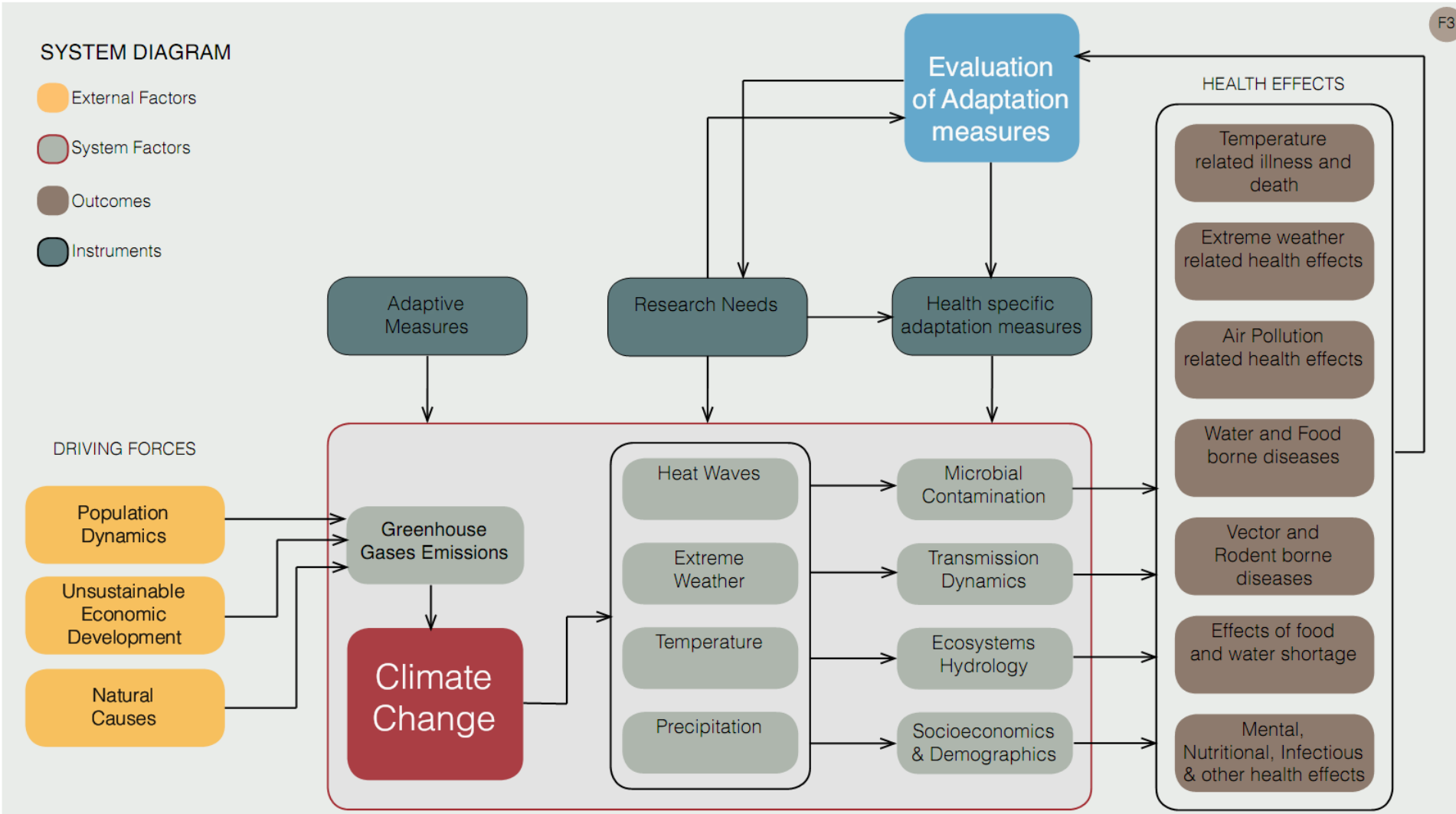
## ..and how our buildings can improve Quality of Life

# Structure of interaction

- **Context**
- **Thermal Comfort-** key concerns,
- **Cool roof technologies**- concepts, application

  Thermal Performance monitoring
- **Discussion**- promising solutions

# CLIMATE CHANGE AND POSSIBLE HEALTH IMPACTS

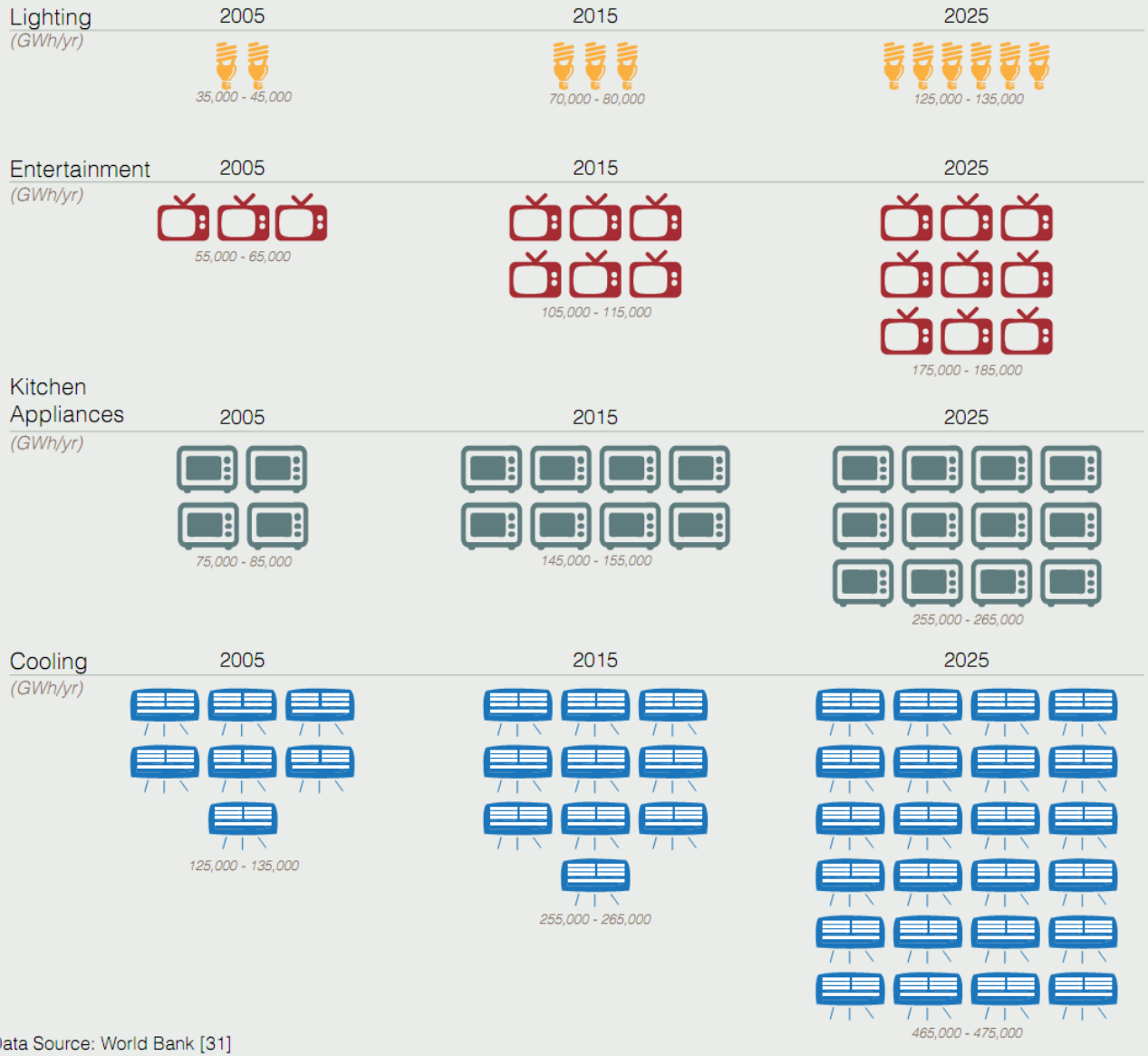



*Rapid urbanization and unsustainable growth are the major contributors to climate change.* ***Extreme weather conditions directly impact human health and also contribute to increased mortality.***

Adopted from WHO [31]

# HOUSEHOLD ELECTRICITY CONSUMPTION IN INDIA

F4



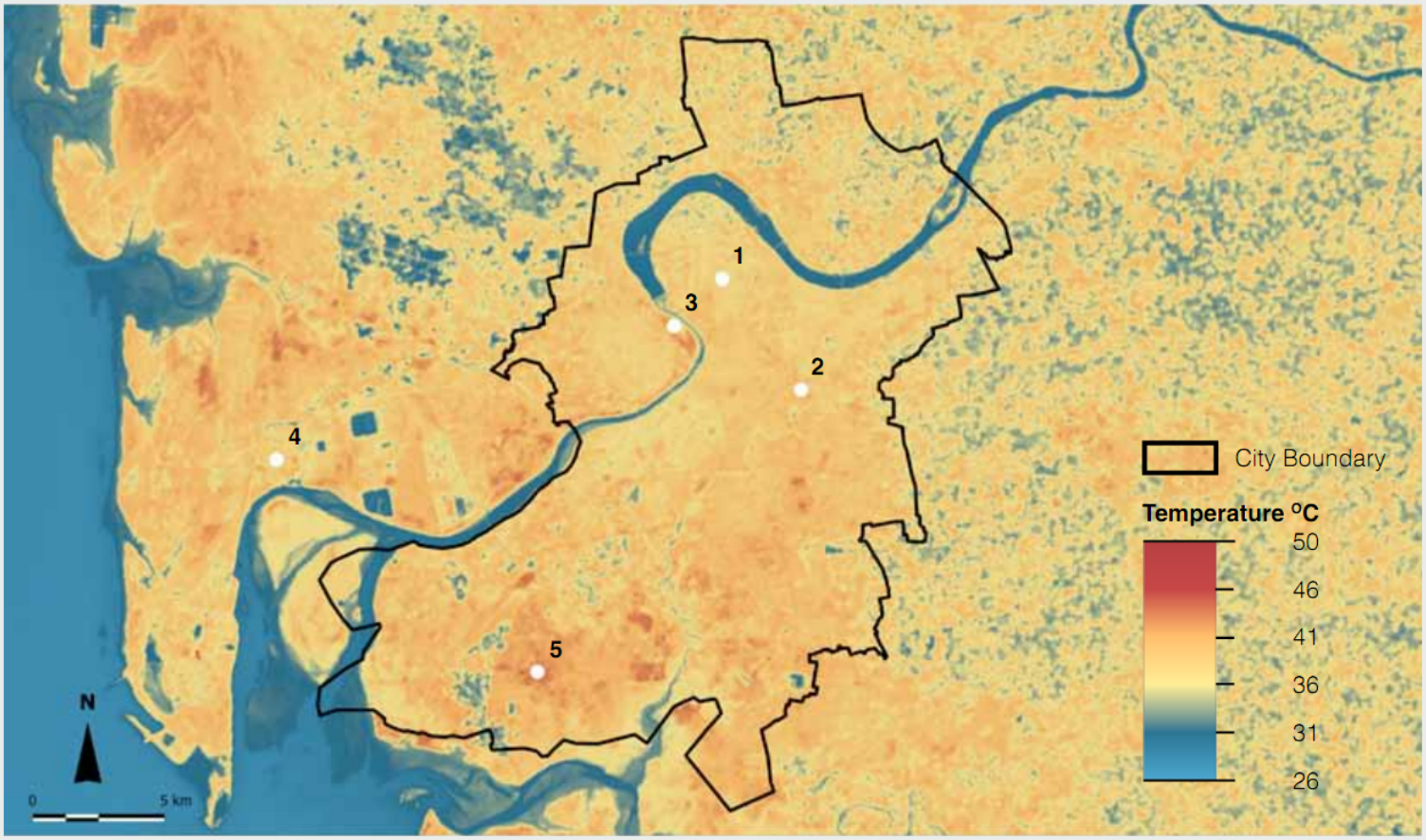

Data Source: World Bank [31]

***Demand of Air conditioners** in India will rise from 4.7 million in 2011 to 48 million by 2031.*

***Air coolers and fans** will see an increase of 130 million and 735 million respectively between 2011 and 2031.*

# Land surface Temperature Surat

F13

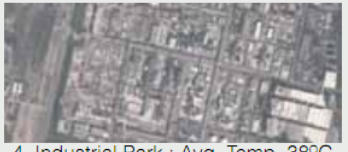



The image shows the land surface temperature of Surat city captured in April 2013.

1. Residential : Avg. Temp. 37°C

2. Commercial : Avg. Temp. 39°C

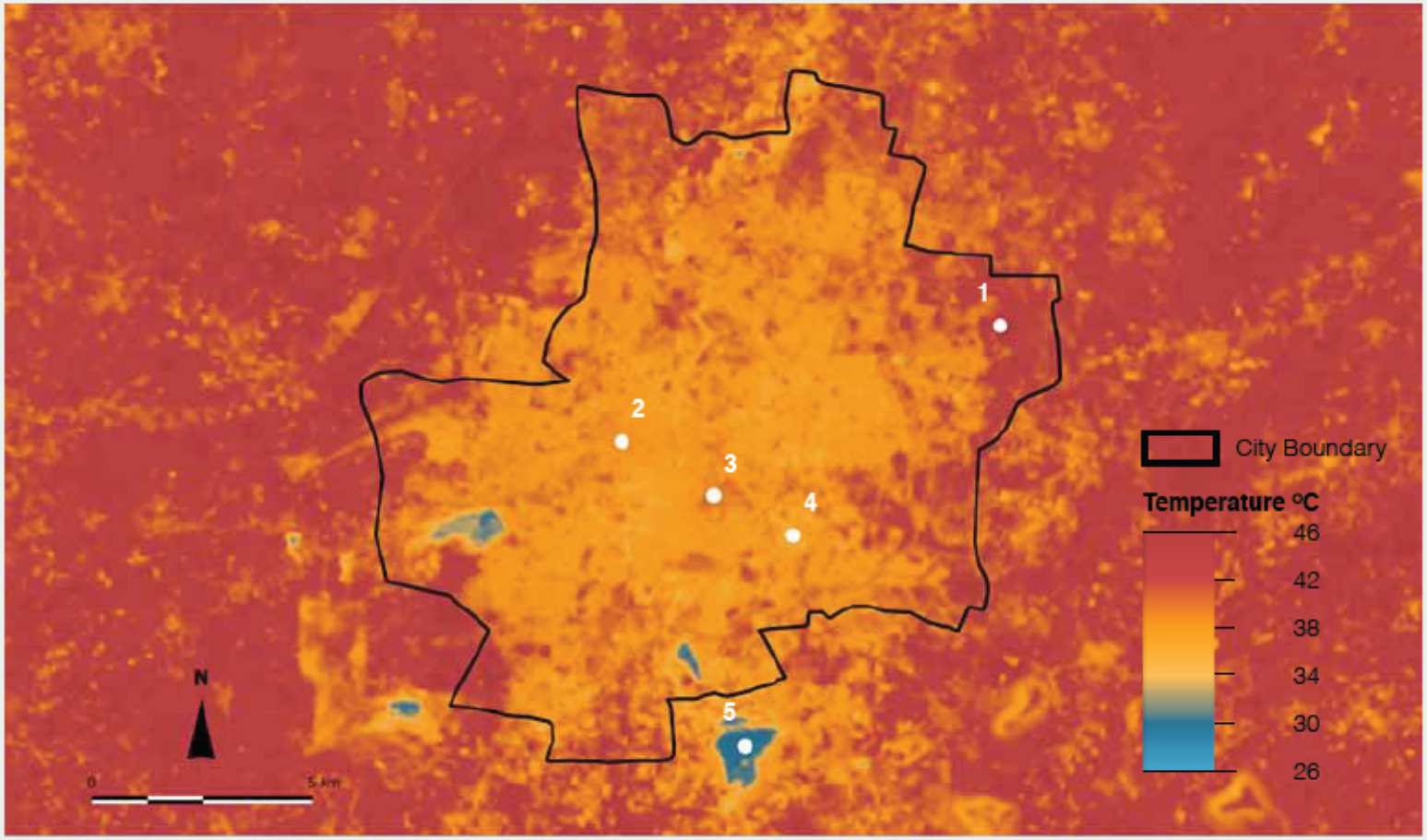
3. River Bank : Avg. Temp. 39°C



4. Industrial Park : Avg. Temp. 38°C

5. Non Agricultural Land : Avg. Temp. 42°C

# Land surface Temperature Indore





1. Open Land : Avg. Temp. 42°C


2. Residential : Avg. Temp. 41°C

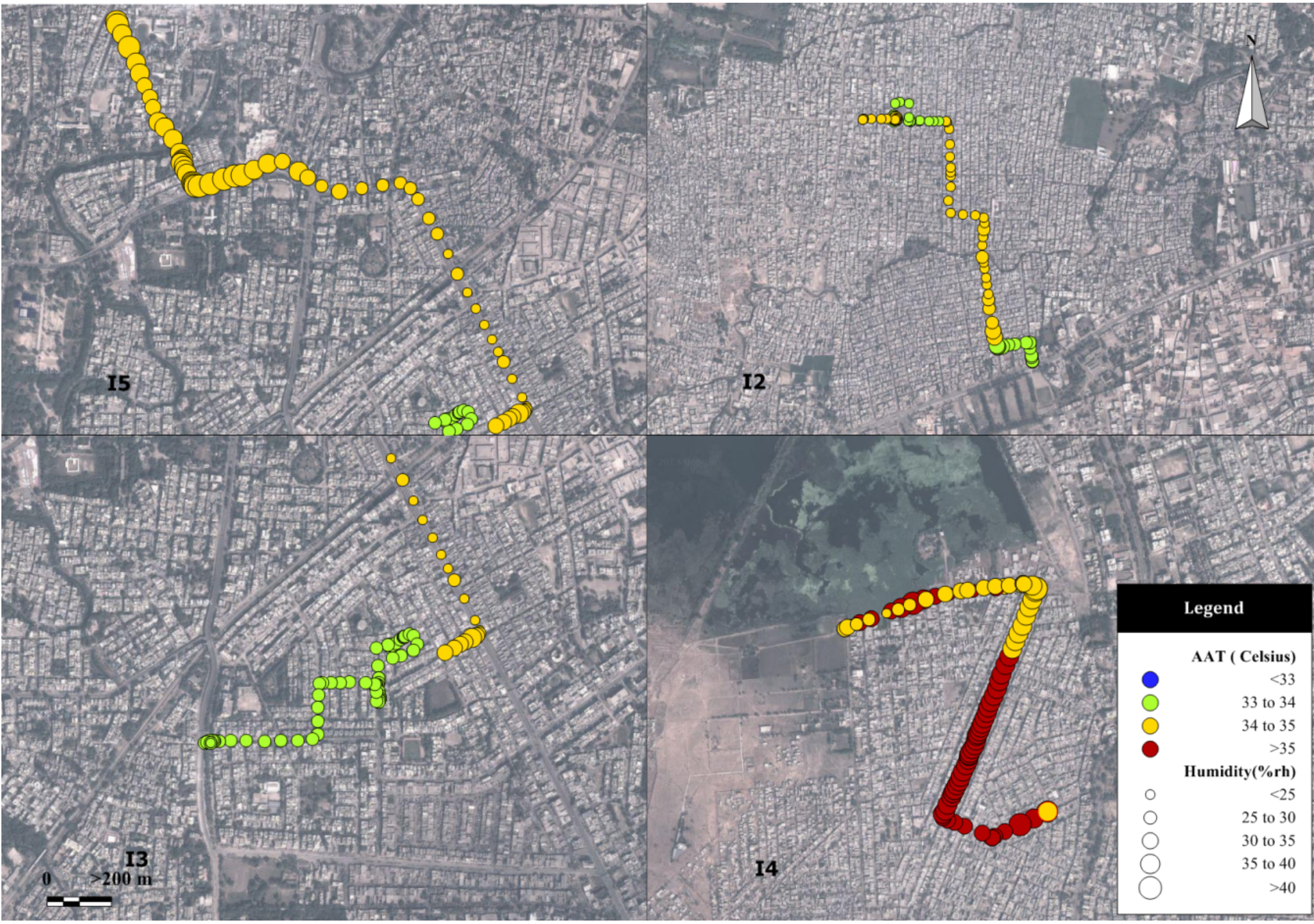

3. Commeroial : Avg. Temp. 43°C

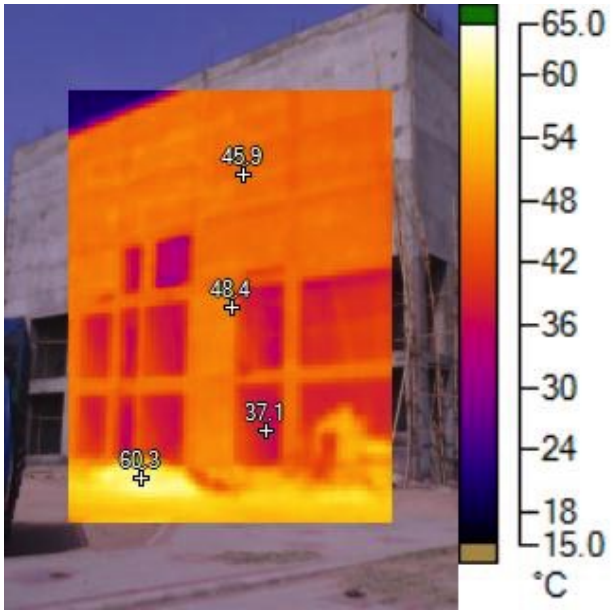

4. Green Spaoe : Avg. Temp. 39°C


5. Water Body : Avg. Temp. 39°C

The image shows the land surface temperature of Indore city captured in May 2013.

In the above image every pixel (cell) represents relative surface temperature of the city and its surrondings. Due to lack of vegetation (bare soil) in the month of May, the rural areas tend to radiate/exhibit more heat. One can also notice the considerably cooler water bodies.


I5
I2
I3
I4
N
0
>200 m
Legend
AAT ( Celsius)
<33
33 to 34
34 to 35
>35
Humidity(%rh)
<25
25 to 30
30 to 35
35 to 40
>40




**Thermal Infrared Image**
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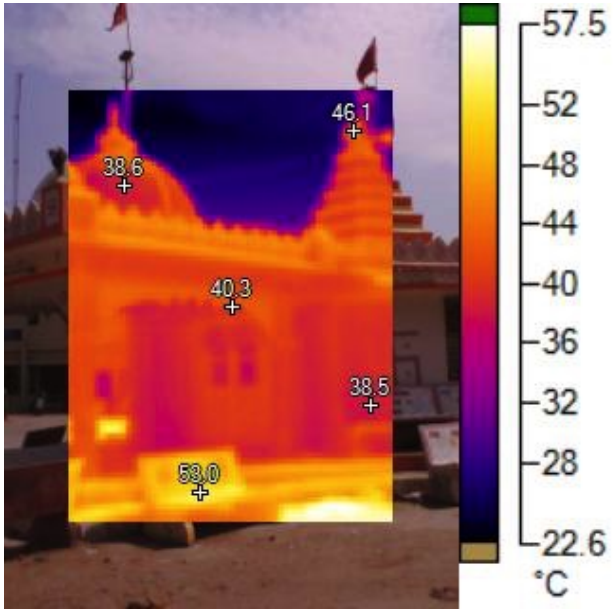


**Thermal Infrared Image**
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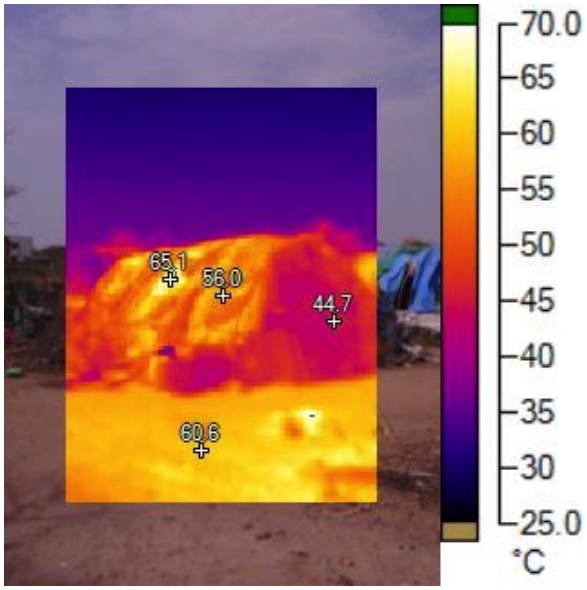


**Thermal Infrared Image**
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**Visible Light Image**
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**Visible Light Image**
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**Visible Light Image**
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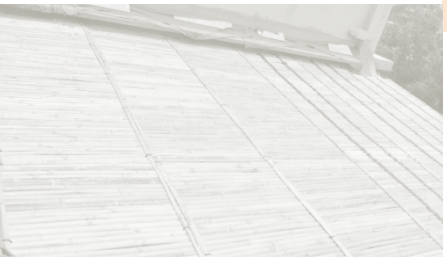
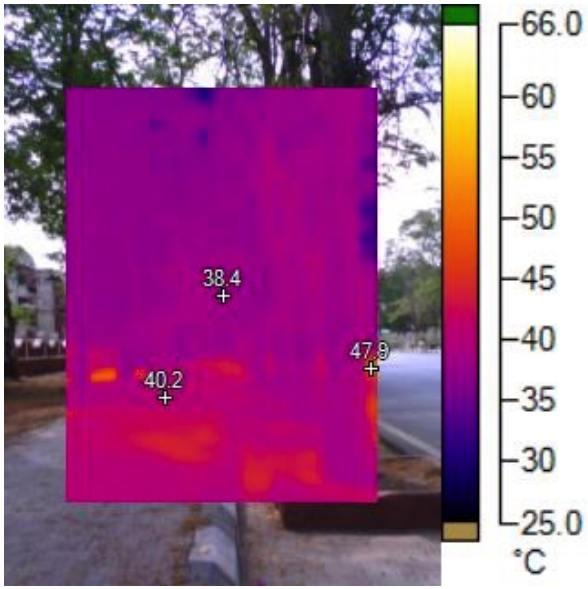



# Addressing Heat in urban areas




**Thermal Infrared Image**
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**Visible Light Image**
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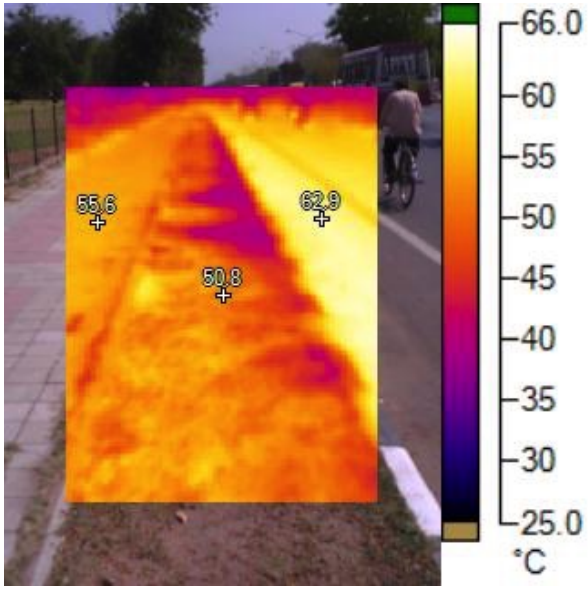


**Thermal Infrared Image**
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**Visible Light Image**
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# SCHEMATIC DIAGRAM OF URBAN HEAT ISLAND MITIGATION STRATEGIES IN BUILDINGS

**Building**

## Protect from solar radiation

### Planting of Vegetation

Green Roofs

Green Walls

Vegetation around buildings

### Shading Devices

Movable

Fixed

## Minimize heat infiltration

### Building Envelope

Optimum insulation

Air tightness

Reflective materials

Thermal inertia

## Reduce anthropogenic heat

### Energy Efficiency

Energy Efficient lighting

Energy efficient household appliances

Energy efficient office equipments

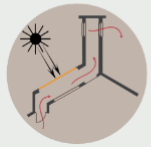
## Maintain comfortable thermal environment

### Alternatives to air conditioning

Ground coupled heat exchanger

Natural and controlled mechanical ventilation

Radiant cooling system



Solar cooling

Adopted from Melissa Giguere [32]


Cool Roofs
Green Roofs
Passive Ventilation
Insulation
Health
Energy saving
Building cooling
City cooling
Global cooling
Low maintenance
Compatibility

# The Cool Roof Project

- Implemented as part of ACCCRN initiative to build climate change resilience in cities
- Focuses on mainstreaming options for passive thermal comfort options for Low-Rise-High-Density urban development, focusing on EWS
- Objectives-
  - Develop a suite of technology options to improve thermal comfort
  - Monitored the performance of the thermal comfort options
  - Increase awareness about cool roof options
  - Identity scalable cool roof options





# Thermal comfort and its importance in buildings

# Comfort in buildings today

- **Design and construction of buildings mostly does not consider the climate and its effect on indoor thermal comfort**
  - Roofs receive strongest intensity of solar radiation and conduct it inside the building
  - Inadequate ventilation – heat build-up inside rooms
  - Inadequate shading of glazed areas
- **There is over dependence on "active" or mechanical cooling to maintain comfortable indoor environment – primarily air conditioning in hot climate of India**
- **Urban Heat Island effect – creation of "extra hot" conditions in the urban environment**
  - Density of buildings and restricted air movement
  - Heat absorbed by materials and radiated back – pavements and walls,
  - Lack of green spaces
  - Exhaust of air conditioners

# Low-income housing

EWS housing Madhya Pradesh

- More than 90% of the shortfall in the housing for the urban poor is in the EWS and LIG segment – LIH housing in Indore is now growing very rapidly
- 1 BHK are the dominant product in the market, customers prefer smaller house with more rooms than larger house with fewer rooms
- Maintaining comfortable indoor conditions in compact and tight spaces is only possible with improved design and a more efficient building envelope
- The valuable efforts of govt. of MP should not create a housing stock which is uncomfortable to live in and affects the health of occupants

# Air conditioned houses

## Challenge –

- If building envelope is poor, there is a heavier cost of air conditioning because of greater heat gain and greater loss of cool from conditioned rooms
- Glazed areas become critical – conventional 6mm float glass lets in more than 90% of heat inside the room – shoots up the peak load
- Poor quality of building can create heavy dependence on air conditioning – adverse health effects.

# Areas for improvement

**Challenge – to avoid uncomfortable build-up of heat and to ensure adequate flushing out of heat by air flow**

- **Roofs**

  RCC finished with cement plaster has very little resistance to heat transmission – results in large heat gain

- **Windows**

  Shading of windows such that direct heat gain is avoided for large part of the year

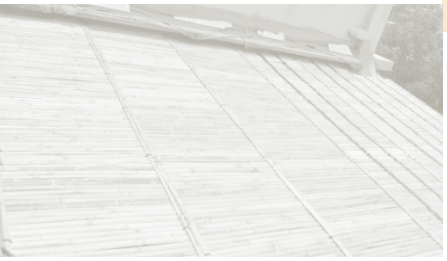
- **Air Flow**

  Positioning of windows to create cross ventilation, providing mechanical ventilation devices near the ceiling, using courtyards to increase air flow

- **Green Spaces**

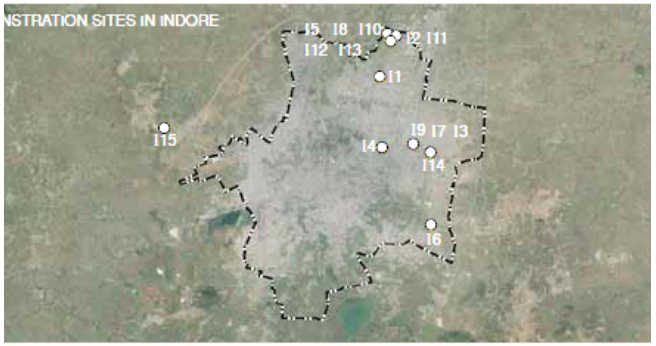
  Improving air quality of the housing complex, localized cooling through evapo-transpiration




# Options for Cool Roof

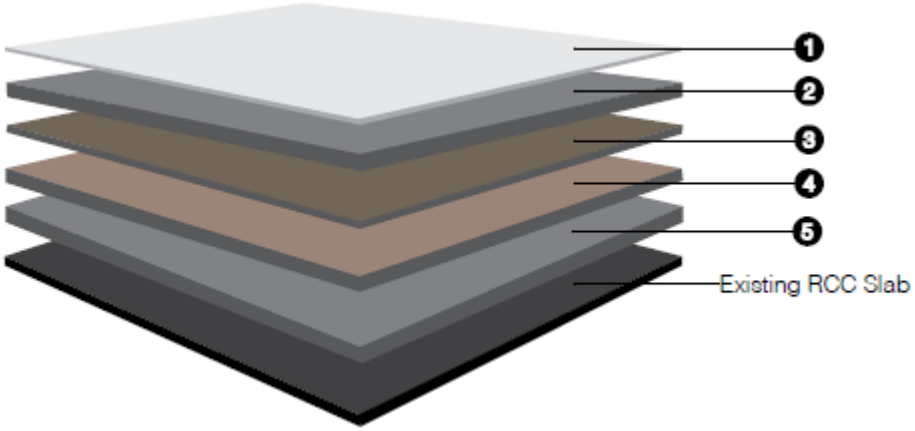
## As demonstrated in Indore




| Sr No. | Types of Demonstration | Site Location | Site Area Sq. ft. |
|---|---|---|---|
| **INDORE** | | | |
| I1 | Cool Roof Paint - Panache Greentech | Khajrana Road | 840 |
| I2 | Cool Roof Paint - Panache Greentech | Niranjanpur | 506 |
| I3 | Cool Roof Paint - Pidilite | Juni Chawl | 540 |
| I4 | Cool Roof Paint - Pidilite | Scheme No. 78 | 350 |
| I5 | Thermocrete | Niranjanpur | 1,000 |
| I6 | Bamboo Screening | Bhil Paltan | 400 |
| I7 | Cellulose Fibre | Khajrana Road | 600 |
| I8 | XPS Sheet | Niranjanpur | 1,000 |
| I9 | Lime Concrete | Khajrana Road | 600 |
| 110 | Hollow Clay Tiles | Nainod | 2,000 |
| I11 | Inverted Earthen Pots | Niranjanpur | 300 |
| I12 | China Mosaic Tiling | Niranjanpur | 1,400 |
| I13 | Heat Resistant Tile - Thermatek | Niranjanpur | 1,400 |
| I14 | Shading Screen - Green Net | Goyal Vihar Colony | 400 |
| I15 | White Wash | Nainod | 1,500 |

# Hollow Clay tiles

- High thermal insulation and sound insulation property which is very effective in limiting heat flow. Air cavities block heat flow.
- Due to uniform multiple cavities, the tiles also have good load bearing capacity.
- Good alternative to conventional bricks or clay tiles
- Tile size 150 mm x 150 mm x 50 mm. Hollow clay tiles with fluted edges. Other sizes could also be used.




1. *Broken China Mosaic tiles fixed with white cement*
2. *20-25mm Cement Mortar bedding (Cement : Sand = 1: 4)*
3. *4 to 5mm Water Proofing (as specified)*
4. *Hollow Clay Tiles (150mm x 150mm x 50mm)*
5. *50mm Cement Mortar bedding (Cement : Sand = 1: 4)*

# Hollow Clay tiles

Step 1

Step 2

Step 3

Step 4

## Steps

a. Lay mortar bed
b. Lay tiles with aligned continuity of cavity
c. Water proofing
d. Apply reflective finish with china mosaic

## Cost

**Tile cost Rs.11 per tile**

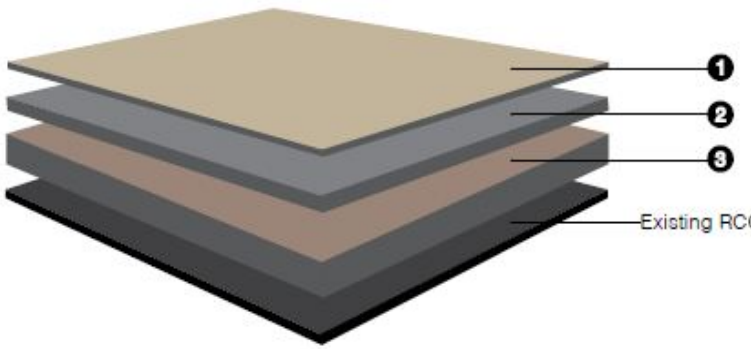
Material: rs.124/sq.ft

Labour: Rs.48/ sq.ft

Total Rs.172/sq.ft

# Lime Concrete

- Brick jelly-lime concrete has traditionally been used as a weathering layer over roofs
- Fermented water (gallnut, jaggery, bael fruit) used to enhance the water proofing capacity of the lime concrete.
- Surkhi, which is crushed brick powder would replace sand in lime concrete
- The lime concrete can then be covered with terracing material




1. *Mangalore Tiles (150mm x 150mm x 10mm)*
2. *20-25mm thick Cement Mortar bedding (Cement : Sand = 1 : 4)*
3. *100mm layer of Lime Concrete (Hydrated lime : Sand : Broken brick chips = 1 : 1 : 2)*

# Lime Concrete

Step 1

Step 2

Step 3

Step 4

## Steps

a. **Preparing Fermented Water**
   10 bael fruit+4kg gallnut+8 kg jaggery in 100 litres water

b. **Slaking of Lime**

a. Bunds of sand and brick chips, covered with quicklime and slaked

c. **Application of Lime Concrete , curing with fermented water**

d. **Finishing with Mangalore Tiles**

## Cost

**Bael, gallnut, jaggery – 7000 Rs. Per 1000 sq.ft**

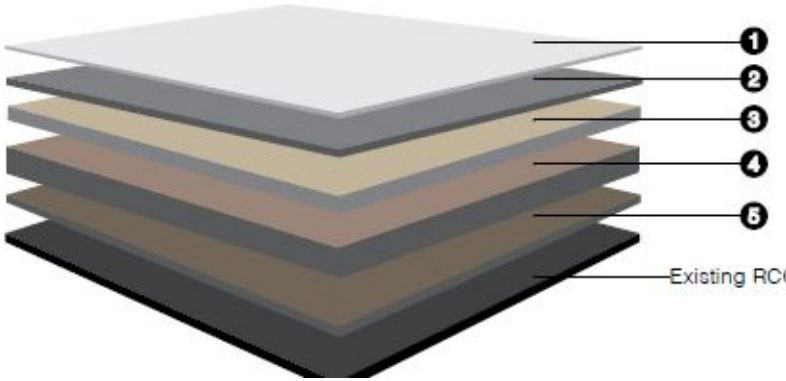
**Material: rs.102/sq.ft**

**Labour: Rs.18/ sq.ft**

**Total Rs.120/sq.ft**

# Inverted Earthen Pots

- Earthen pots are an affordable material to insulate roofs by forming air pockets which limit heat flow through the roof.
- Locally available earthen pots exhibit high thermal insulation property.
- Earthen pots inverted and space between pots filled with cement concrete/ lime concrete. Lightweight filler like cinder or building waste can also be used




1. *China Mosaic Tiling*
2. *50mm IPS (Indian Patent Stone) (Cement : Sand : Aggregate = 1 : 2 : 4)*
3. *20-25mm Cement Mortar bedding (Cement : Sand = 1 : 4)*
4. *Inverted Earthen Pots (diameter -175mm & depth - 75mm) fixed with cement mortar (Cement : Sand = 1 : 4)*
5. *4 to 5mm Water Proofing (as specified)*

# Inverted Earthen Pots

Step 1

Step 2

Step 3

Step 4

**Steps**

a. Laying of Earthen Pots with rims touching
b. Fixing of Earthen Pots with cement mortar
c. Laying of PCC over pots
d. Finishing the roof with China Mosaic reflective surface

**Cost**

**Earthen Pot cost Rs.5 per pot**

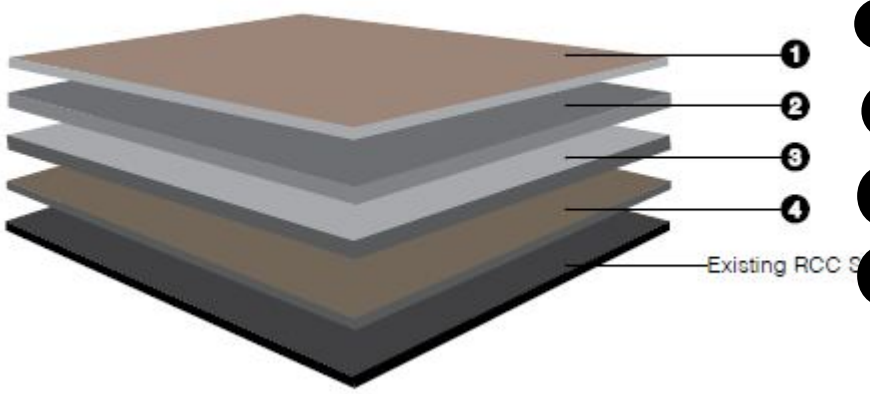
Material: rs.110/sq.ft

Labour: Rs.50/ sq.ft

Total Rs.160/sq.ft

# Heat Resistant Tiles

- It works on the concept of radiant barrier which obstructs the transmission of solar radiation inside the house through the roof.
- High solar reflectance and high thermal emittance are the two requirements of a cool roof
- Reflectance of cool material – min.0.7, reflectance of gray coloured concrete 0.2-0.3




- *Ceramic based Thermatek tiles (300mm x 300mm x 6mm)*
- *20-25mm Cement Mortar bedding (Cement : Sand = 1: 4)*
- *50mm Level course of PCC (Cement : Sand : Aggregate = 1 : 2: 4)*
- *4 to 5mm Water Proofing (as specified)*

# Heat Resistant Tiles

Step 1

Step 2

Step 3

Step 4

**Steps**

a. Laying of Plain Cement Concrete
b. Laying of Cement Mortar Bedding
c. Lay Heat Resistant Tiles with a gap for filling by cement slurry
d. Finishing and Washing the top surface

**Cost**

**Tile + transport cost Rs.45 per tile**

Material: rs.108/sq.ft

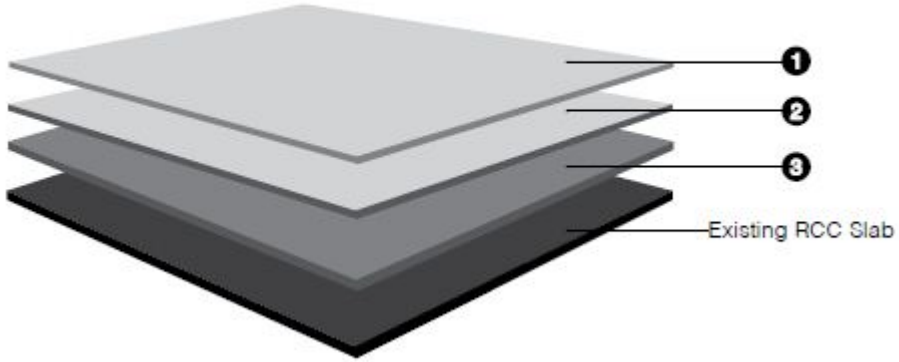
Labour: Rs.42/ sq.ft

Total Rs.150/sq.ft

# Cool Roof Paints

- Reduce the amount of heat gain through the roof
- Cool Roof paints have high solar reflectance
- A simple and effective means to reduce the indoor temperature
- This technique is a contemporary alternative to the traditional white wash technique.

Construction Detail




- *Final Reflective Coat : Thin polymer-silicon based water repellent transparent film*
- *First Reflective coat over the base coat*
- *Base coat of white paint*

# Cool Roof Paints

Step 1

Step 2

Step 3

Step 4

## Steps

a. Surface Preparation
b. Application of Base Coat – paste of coating powder
c. Application of Reflective Paint- 2 coats with sufficient drying time
d. Application of Final Reflective Coat – silicon based water repelling film

## Cost

Material: rs.20/sq.ft

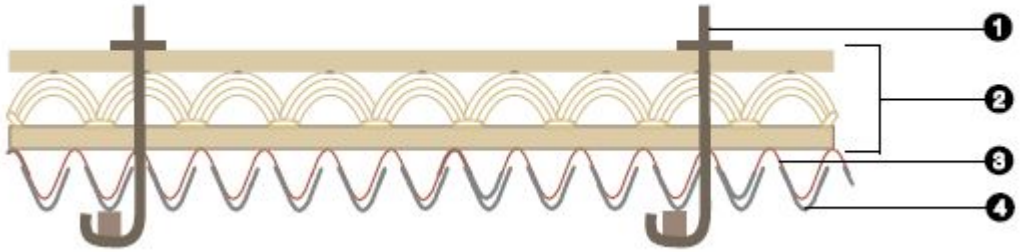
Labour: Rs.5/ sq.ft

Total Rs.25/sq.ft

# Bamboo Shading Screen

- Shading an exposed surface is an effective means of reducing the heat transfer through the surface
- Bamboo panel placed on a basic support structure which enables an air gap between the panel and roof surface
- Well seasoned bamboo is an efficient material which can be used as a lightweight shading device.
- Shading device can be used over RCC roof as well as sloping roofs which are made using corrugated Tin sheets or Asbestos sheets

Construction Detail




- *J Bolts*
- *Bamboo Panel (3300mm x 1,500mm)*
- *Red oxide Paint on existing roof*
- *Existing Galvanized Iron Sheet roof*

# Bamboo Shading Screen

Step 1

Step 2

Step 3

Step 4

**Steps**

a. **Fabrication of Bamboo Frames of 11'x5' size -** bamboo of uniform cross section, scrape the nodes, split into thinner strips
b. **Fabrication of Bamboo Screens**
c. **Application of Anti Corrosive Paint on GI sheets and nails**
d. **Installation of Bamboo Screens on GI sheets with J bolts**

**Cost**

**Bamboo cost Rs.70 per bamboo**

**Material: rs.50/sq.ft**

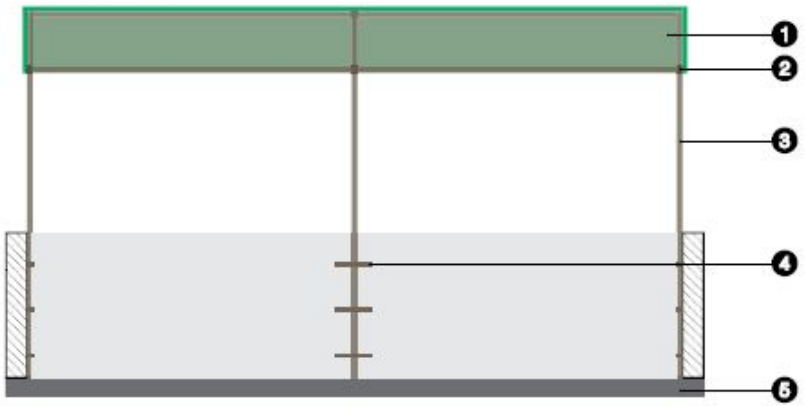
**Labour: Rs.44/ sq.ft**

**Total Rs.94/sq.ft**

# Green Mat Shading

- Shading of building elements is the most basic strategy to achieve thermal comfort.
- Green Mats are available as a covering for greenhouses to grow plants - they can provide shading upto to 70%.
- Simple and low cost application reduces the roof surface temp and makes terrace more usable during hot season.

Construction Detail




1. *Green mat*
2. *MS hollow box section - Poles and Grids*
3. *Hollow box section - Tie member*
4. *MS clamps*
5. *Existing terrace slab*

# Green Mat Shading

Step 1

Step 2

Step 3

**Steps**

a. **Fabrication of Steel Structure**

b. Prepare a framing plan, limit unsupported spans of mat, mild steel square hollow sections 50mmx50mm, height of frame 8-10 feet

c. **Erection of Steel Structure,**
Coat steel section with anti corrosive agent

d. **Installation of Green Mat**

**Cost**

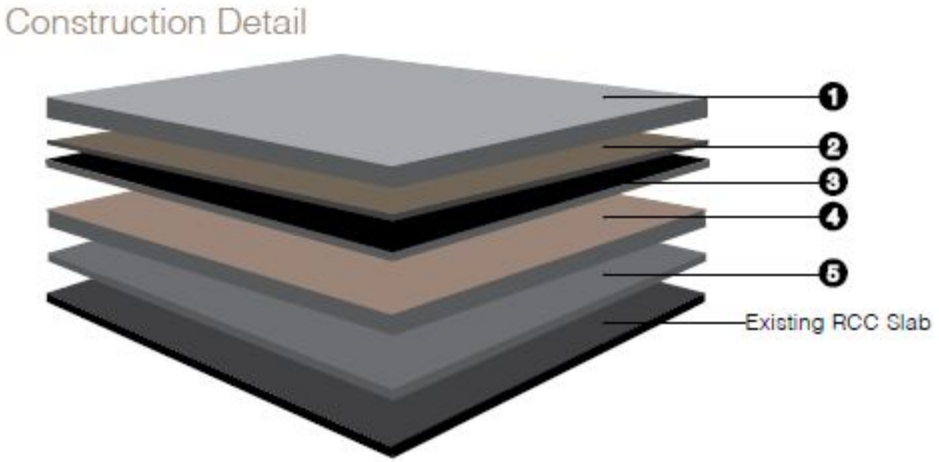
**Material: rs.128/sq.ft**

**Labour: Rs.47/ sq.ft**

**Total Rs.175/sq.ft**

# Extruded Polystyrene (XPS)Sheet

- High thermal insulation and sound insulation property
- XPS sheets/ boards are lightweight in the density range of 28-45 kg/m3, with conductivity of 0.029-0.04 W/m.K
- They are most effective when used as above-deck insulation for roof slabs
- Good Moisture Barrier is critical for efectiveness




- *50mm Average IPS (Cement : Sand : Aggregate = 1 : 2 : 4)*
- *4 to 5mm Water Proofing (as specified)*
- *1.5mm thick Membrane over XPS (Extruded Polystyrene) Sheet*
- *50mm thick XPS (Extruded Polystyrene) Sheet*
- *20-25mm Cement Mortar Bedding (Cement : Sand = 1 : 4)*

# Extruded Polystyrene (XPS) Sheet

Step 1

Step 2

Step 2

Step 3

**Steps**

a. **Laying of Cement Mortar Bedding**

b. **Application of XPS Sheet**

Connect the ship laps at edges of sheets,

stagger rows of sheets

Place vapour barrier membrane with overlaps

c. **Finishing with IPS**

**Cost**

**XPS Sheet cost Rs.50/sq. ft.**

**XPS Sheet vapour barrier Rs.10/ sq.ft**

**Material: rs.123/sq.ft**

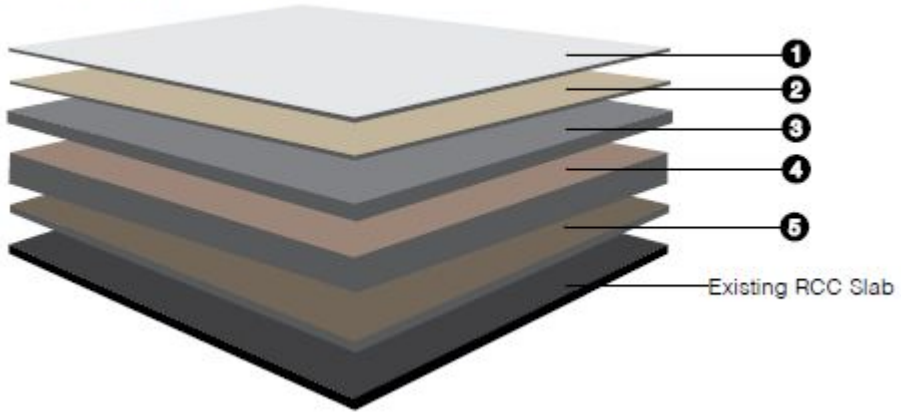
**Labour: Rs.37/ sq.ft**

**Total Rs.160/sq.ft**

# Cellulose Fibre

- Cellulose is one of the most environment-friendly raw materials for insulation sourced from recycled paper and processed into a fibrous state, has a U-value ranging from 0.03-0.04 W/m.K,
- Cellulose fibre is mixed cement-sand mortar to form a kind of paper-crete
- This is topped with an IPS layer which can be coated with a surface hardener

Construction Detail




1. *Two coats of Hydrated Lime Slurry*
2. *Ceramic Powder Slurry*
3. *50 mm IPS (Indian Patent Stone) (Cement : Sand : Aggregate = 1 : 2 : 4)*
4. *75 mm layer of Cellulose Fibre blended with cement mortar (Cellulose fibre : Cement : Sand = 1 : 2: 4)*
5. *4 to 5mm Water Proofing (as specified)*

# Cellulose Fibre

Step 1

Step 2

Step 3

Step 4

**Steps**

a. **Application of Cellulose Fibre**

   Moisten cellulose fibre, add to cement-sand mix and mix thoroughly

   Fibre ratio 6%-8% by weight

b. **Application of Indian Patent Stone**

c. **Laying of Ceramic Powder Slurry**

d. **Finishing with hydrated Lime**

**Cost**

**Cellulose Fibre cost Rs.250 per Kg**

**Material: rs.125/sq.ft**

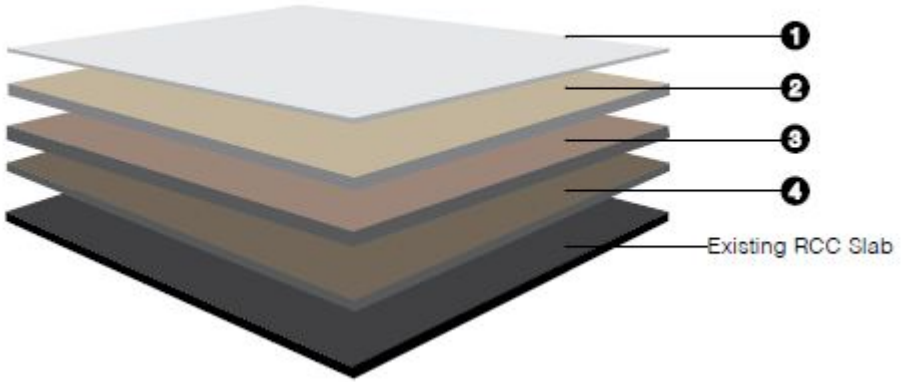
**Labour: Rs.31/ sq.ft**

**Total Rs.156/sq.ft**

# China Mosaic Tiling

- The purpose of china mosaic terrace is to provide a reflective layer to the roof
- Also re-emits the absorbed portion of solar energy
- The reflective layer is formed by broken and randomly sized pieces of light coloured ceramic tiles
- Joints between tiles sealed with white cement

Construction Detail




- *Broken China Mosaic tiles fixed with white cement*
- *20-25mm Cement Mortar bedding (Cement : Sand = 1: 4)*
- *50mm Level course of PCC (Cement : Sand : Aggregate = 1 : 2: 4)*
- *4 to 5mm Water Proofing (as specified)*

# China Mosaic Tiling

Step 1

Step 2

Step 3

Step 4

## Steps

a. **Laying of Plain Cement Concrete**
   Finish in slope, allow to dry
b. **Laying of Cement Mortar Bedding**
c. **Breaking and Fixing of Ceramic Tiles**
   Fix with light hammering, Leave gap for cement slurry
d. **Finishing and Washing the top surface**

## Cost

**Tile cost Rs.25 / sq.ft**

**Material: rs.70/sq.ft**

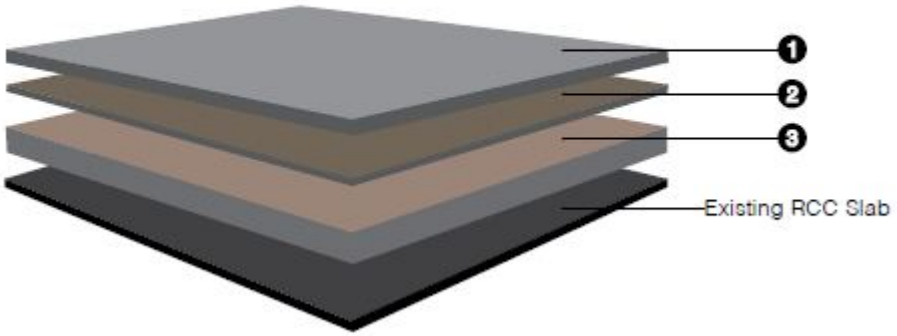
**Labour: Rs.67/ sq.ft**

**Total Rs.137/sq.ft**

# Thermocrete

- **Air cavities inside a material increases its ability to obstruct transfer of heat or cold through it –** EPS, styrofoam cups, AAC blocks
- **Thermocrete uses the same principle in a low-tech way by mixing Thermocol (extruded polystyrene) balls/ beads in a concrete mix.**
- **Thermocol or EPS (Extruded Polystyrene) balls size: 10-20mm diameter**

Construction Detail




- *50mm Average IPS (Cement : Sand : Aggregate = 1 : 2 : 4)*
- *4 to 5mm Water Proofing (as specified)*
- *75mm thick layer of Thermocrete (Cement : Sand : EPS balls = 1 : 1 : 4)*

# Thermocrete

Step 1

Step 2

Step 3

Step 4

**Steps**

a. **Preparing the Cement Mortar Bunds**

2mx2m size bunds 75mm thick

b. **Application of Thermocrete**

For 2mx2m area, 60-70kg cement, 60-70 kg sand, 1 kg EPS balls

c. **Laying of Cement Mortar and Water proofing**

d. **Finishing with IPS**

**Cost**

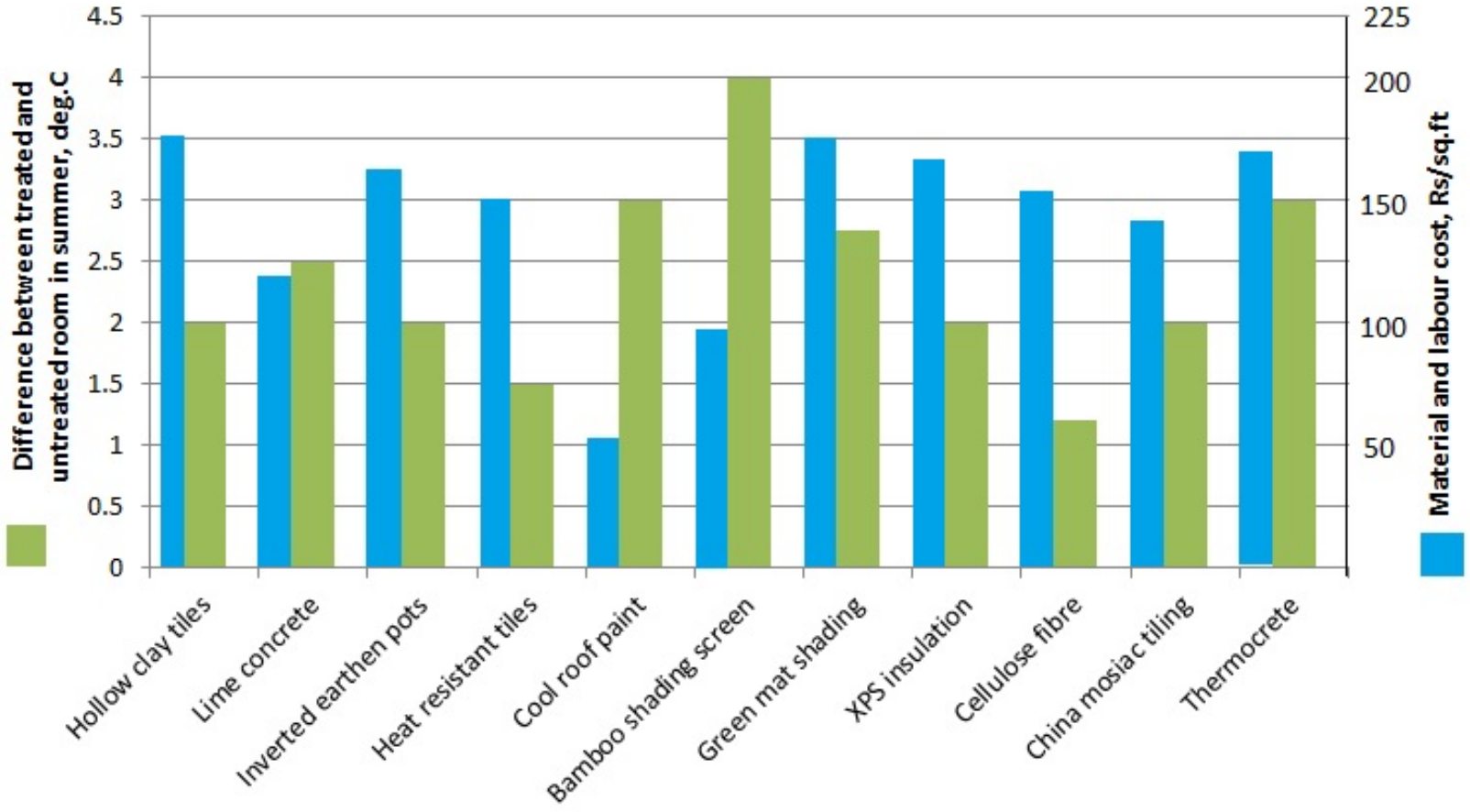
**Thermocrete balls cost Rs.340 per kg**

**Material: rs.135/sq.ft**

**Labour: Rs.35/ sq.ft**

**Total Rs.170/sq.ft**

# Performance of cool roof options



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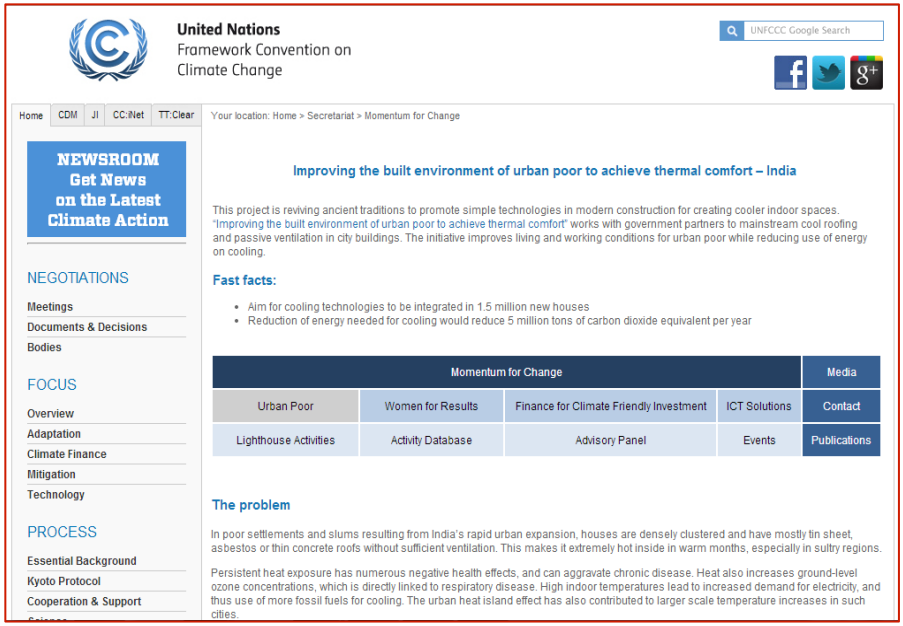
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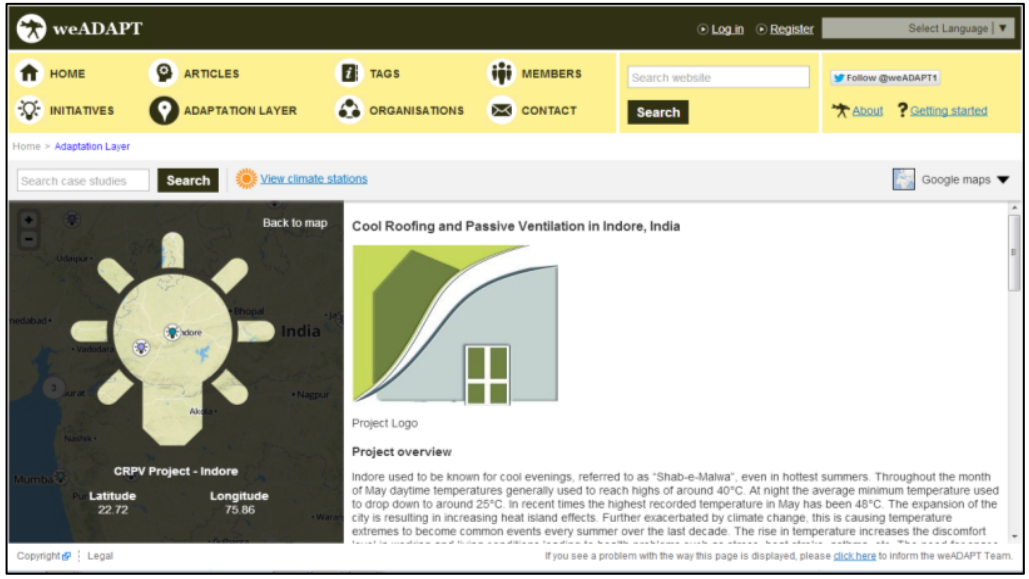
Improving the built environment of urban poor to achieve thermal comfort – India
This project is reviving ancient traditions to promote simple technologies in modern construction for creating cooler indoor spaces. "Improving the built environment of urban poor to achieve thermal comfort" works with government partners to mainstream cool roofing and passive ventilation in city buildings. The initiative improves living and working conditions for urban poor while reducing use of energy on cooling.
Fast facts:
Aim for cooling technologies to be integrated in 1.5 million new houses
Reduction of energy needed for cooling would reduce 5 million tons of carbon dioxide equivalent per year
Momentum for Change
Media
Urban Poor
Women for Results
Finance for Climate Friendly Investment
ICT Solutions
Contact
Lighthouse Activities
Activity Database
Advisory Panel
Events
Publications
The problem
In poor settlements and slums resulting from India's rapid urban expansion, houses are densely clustered and have mostly tin sheet, asbestos or thin concrete roofs without sufficient ventilation. This makes it extremely hot inside in warm months, especially in sultry regions.
Persistent heat exposure has numerous negative health effects, and can aggravate chronic disease. Heat also increases ground-level ozone concentrations, which is directly linked to respiratory disease. High indoor temperatures lead to increased demand for electricity, and thus use of more fossil fuels for cooling. The urban heat island effect has also contributed to larger scale temperature increases in such cities.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CRPV Project - Indore
Latitude 22.72
Longitude 75.86
Cool Roofing and Passive Ventilation in Indore, India
Project Logo
Project overview
Indore used to be known for cool evenings, referred to as "Shab-e-Malwa", even in hottest summers. Throughout the month of May daytime temperatures generally used to reach highs of around 40°C. At night the average minimum temperature used to drop down to around 25°C. In recent times the highest recorded temperature in May has been 48°C. The expansion of the city is resulting in increasing heat island effects. Further exacerbated by climate change, this is causing temperature extremes to become common events every summer over the last decade. The rise in temperature increases the discomfort
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# Web Site


Thermal Comfort
Exploring cool-roof and passive ventilation techniques to achieve thermal comfort
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GALLERY
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SEARCH
Project Details
About TARU
About ACCCRN
Partners
Download E-Brochure
Download Poster
Competition deadline
0 Days
0 Hours
0 Minutes
Register for Competition
ACCCRN
Asian Cities Climate Change Resilience Network
Promoting cool roof and passive ventilation concepts for indoor temperature comfort
The need for space cooling has increased and growing incomes and aspirations have resulted in air-conditioners replacing fans in most of the middle class houses. This trend is likely to grow over coming years that can potentially increase the peak electricity demand at city level. While green housing is being promoted, Indian cities already have a significant proportion of houses built over last three decades or older, which have minimal provisions for passive space cooling. The paradigm of Low rise – High density (LRHD) growth that was followed by urban planners until recently has excluded possibility of using centralised space cooling systems. This pattern also takes high heat input from the sun due to higher ratio of exposed roof area to floor areas. The cost of retrofitting existing building stock to make them energy efficient is a very costly affair and therefore other simpler cost effective options need to be explored to minimise energy consumption.
Poor settlements and slums are very dense and have low ventilation facilities and the poor cannot afford electricity bills for space cooling, especially under rapidly growing tariff regime. The poor live mostly in houses with either tin sheet or asbestos roofs or thin concrete roofs often without sufficient ventilation also. The rooms heat up fast and the indoor atmosphere is quite hot and humid. Even good ventilation can significantly reduce the temperatures in these houses. Simpler and cost effective options like roof ventilators need to be explored for those settlements depending on passive cooling principles in addition to cool roofs. Ready-made affordable technologies or modules are either not readily available or popular in India.
Cool roofing is one such technology that is becoming popular in developed countries. India had a tradition of whitewashing/ white tiled flooring of the roofs and walls, especially in desert regions. A variety of cost effective options are available in the market ranging from simple lime wash with adhesives to polyurethane based insulation materials. This low tech options combined with the improved ventilation can improve indoor comfort for all sections of the society.
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Transformation of Heat Islands in a Cooling Exercise: Indore
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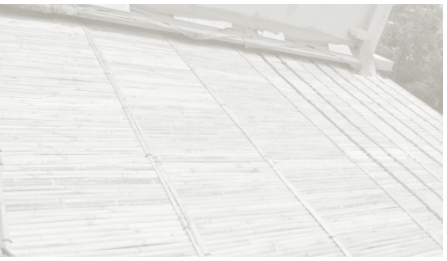
Beating Heat Under Cool Roof: Surat
Times of India Surat edition of 01 July 2014 reportedly covered the Cool ..
Demonstrations Completed!
The second phase of Thermal Comfort Design Competition ended on 25 June 2014. ..
Second phase of Demonstration begins




# Thank you.