HANDBOOK ON ACHIEVING THERMAL COMFORT WITHIN BUILT ENVIRONMENT

VOLUME II

TARU

Acknowledgment

We would like to thank The Rockefeller Foundation for supporting this action research project and members of Asian Cities Climate Change Resilience Network (ACCCRN) for giving specific inputs wherever necessary.

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TARU

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Edited by: Dr. Umamaheshwaran Rajasekar and Pankaj Khanna

Authors: Dr. Umamaheshwaran Rajasekar, Pankaj Khanna and Vishal Mehta

Contributors: Varsha Chouksey, Saumya Sahu, Shashank Mishra, G.K. Bhat, Piyush Shah, Anup Karanth and Ashish Mishra

Graphics and Design by: Vishal Mehta

Executive Summary

Indian cities have experienced unforeseen population growth over the last two decades and this trend is expected to continue over the next two decades. With increasing population, the housing stock will grow manifold and affordable housing will be the biggest challenge to meet. One of the greatest fallouts of rapid urbanization is seen in dilapidated and congested dwellings for the economically weaker segment of the urban population. Both private developers and government schemes which cater to this segment of housing need to ensure dignified and comfortable living for the urban poor.

At a parallel front, due to climate variability over the past few decades there has been evidences of increase in extreme events. According to the Intergovernmental Panel on Climate Change (IPCC), the land and ocean surface temperatures have undergone an increase of around one degree over the past century. In India, the mean maximum temperature has shown a rising trend across most geographies. The impact of increasing temperature combined with urban heat island effect is expected to be specially severe for economically weaker population, increasing vulnerability of its section of children and aged population.

Along with the growing aspiration amongst urban residents to own a house, people are willing to invest on technologies to modify their living environment and increase their comfort levels. The growing demand for air conditioning units and air coolers are best examples where people are willing to make both capital investments and operational expenses to suit their needs. Given this scenario of rapid urbanization, increase in built environment especially within urban areas and increase in an overall mean maximum temperature, indoor environmental comfort of dwellings becomes one of the most critical areas to address, both from the viewpoint of its intensive energy demand and its affordability for economically weaker segment of population.

In order to address the above challenge as a part of the Rockefeller funded Asian Cities Climate Change Resilience Network (ACCCRN) we have experimented 13 different cooling options demonstrated over 40,000 square feet of roof area in Surat and Indore, benefitting over 100 households. Cool roof options are passive means of achieving thermal comfort which don't rely on electrical means of space cooling. Some of these cool roofing options enhance thermal comfort by 2 to 4 degree centigrade and a few by more than 5 degree centigrade as compared to RCC roof slab.

These cool roof options with minimal operational cost (mostly onetime cost of implementation) will benefit residents in terms of increasing their thermal comfort without placing demands on their energy requirement for indoor environmental comfort. Monitoring results indicate that cool roofs can bring about appreciable reduction in indoor temperatures of up to 4 degrees more as compared to conventional RCC roofs during peak summer conditions when temperatures cross 40 ^{O}C. This is specially beneficial for low-income group population who don't have the means for energy intensive options such as air conditioning. The implementation of these options can be done at a fraction of cost if implemented during construction of the building. This document will act as a handbook for urban practitioners and managers highlighting some of the types of technology which can be implemented, how they can be implemented, indicative benefit of thermal comfort and the indicative cost for implementing cool roof options for increased comfort. This is intended to help users in choosing a cool roof option which best meets their purpose.

List of Abbreviations

ACCCRN - Asian Cities Climate Change Resilience Network
CRPV - Cool Roofing and Passive Ventilation
G.I. - Galvanized Iron
IDA - Indore Development Authority
IEC - Information-Education-Communication
IMC - Indore Municipal Corporation
IPS - Indian Patent Stone
IPCC - Intergovernmental Panel on Climate Change
MS - Mild Steel
PCC - Plain Cement Concrete
RCC - Reinforced Cement Concrete
SMC - Surat Municipal Corporation
SRI - Solar Reflective Index
XPS - Extruded Polystyrene Sheet

Units

Cu.ft - Cubic feet
Kg. - Kilogram
ft. - Feet
m - Meter
mm - Millimeter
Sq.ft - Square feet
Sq.m - Square meter

Contents

HOW TO READ THE DOCUMENT

For each technology demonstrations:

Page 1 shows the site location. It discusses the concept, construction detail and material specifications of the technology.

Page 2 explains the Application method for each technology, with photographs.

Page 3 represents the results of the study in form of Box plot.

Page 4 shows the cost calculations for each technology.

Surface Preparation and Waterproofing

Surface preparation and Water proofing were procedures on all demonstration
sites, as will also be required for any such roof treatment. As such they are indicated in the 'Application' sections of each technology profile. The procedure for the same, applicable to all technology options is given below.

Step 1 : Surface preparation

Ensure that the top surface of the roof slab is not uneven or blistered. Wash thoroughly with water for a clean, dirt-free surface to improve the bonding of the concrete slab and the waterproofing agent. Wherever cracks are observed in the roof slab, these will need to be repaired appropriately by chipping the concrete around the crack into a V-groove and filling with cement based grout. *Engineer's instructions to be followed for the same.*

Step 2 : Laying of Waterproofing

Apply the water-proofing treatment as per project specifications. Out of many options of waterproofing available in the market, in CRPV project acrylic based polymer modified cementitious flexible composite coating system was used.

Typically, this includes a base coat of water-proofing compound followed by a fibre glass fabric sheet and, finally 1 or 2 more layers of the water proofing compound.

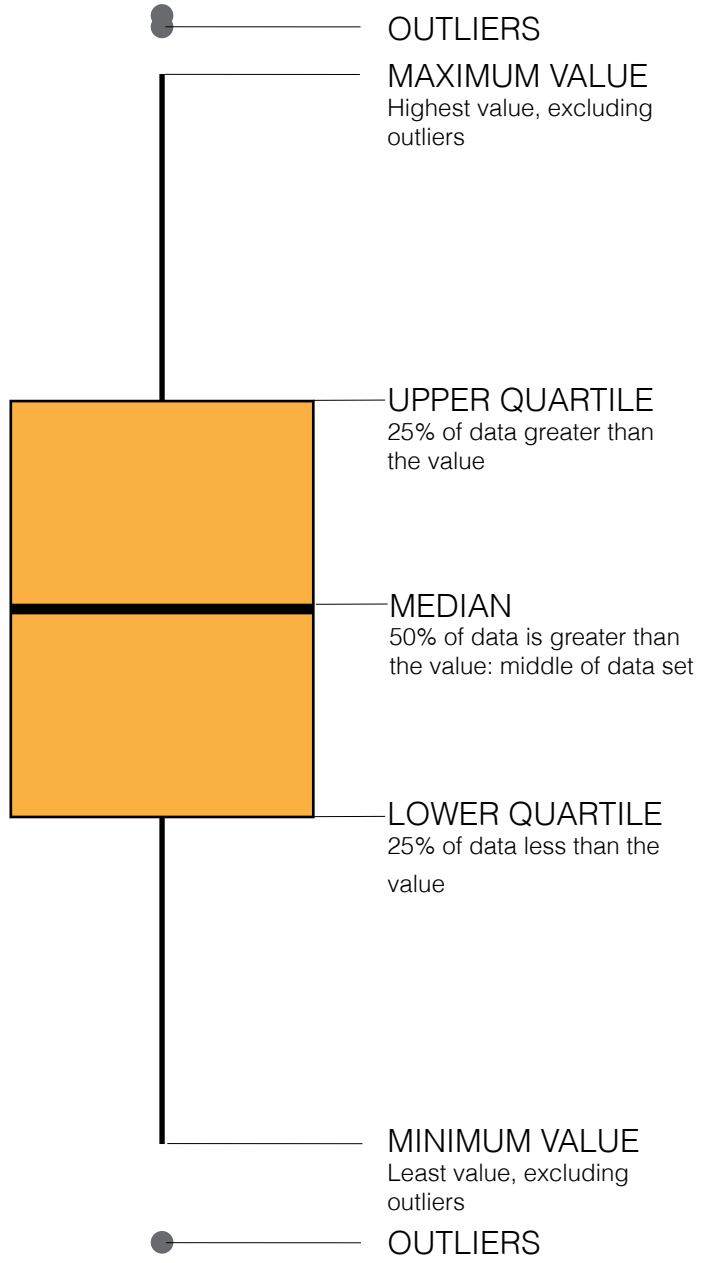
Step 1: Surface Cleaning

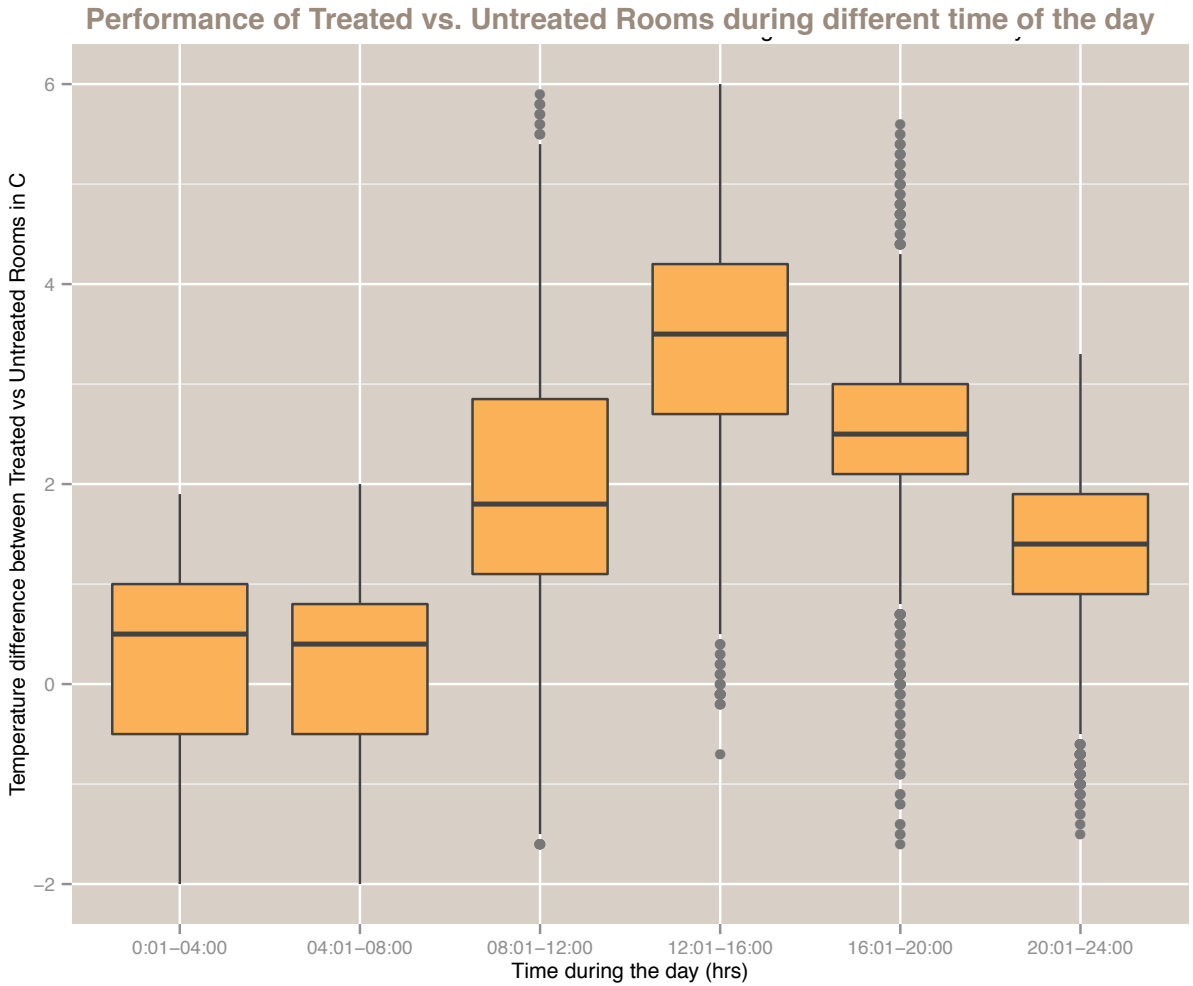
Step 2: Applying the base coat

Step 2: Laying of fibre glass fabric

Step 2: Applying 1st and 2nd coat over the fabric

Explanation of Box Plots





The box plot for each demonstrations represents the comparison of inside room temperature between the treated and untreated roofs during different times of the day. This data was collected using temperature and humidity data loggers, which were installed inside the rooms of treated and untreated roofs. The measurements were recorded at time intervals of 5 minutes during 24 hours period. The data was collected for period of 6 months (April - September, 2014).

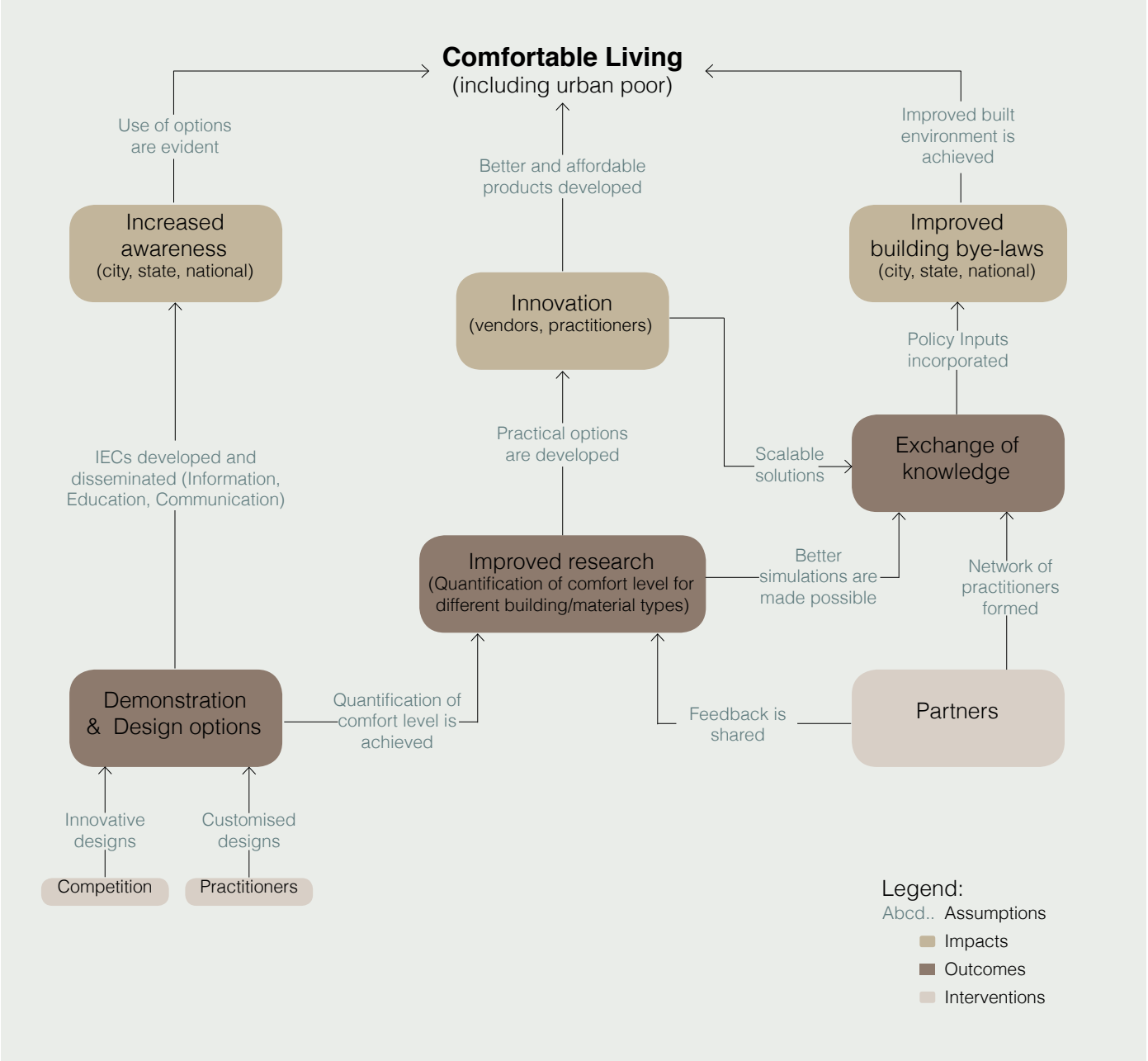
INTRODUCTION

Introduction

The goal of achieving thermal comfort in buildings through low-energy consuming means can be achieved through a series of actions which complement each other in making comfortable living a reality. The project approaches this goal by undertaking action on awareness building at state and national level, research on improved cool roof options, demonstration of cool roof technologies, monitoring efficacy of design options, capacity building of building professionals through dissemination of knowledge gained. This set of activities have been carried out in Gujarat and Madhya Pradesh with the bulk of work focussing on low-income housing and institutional buildings in Surat and Indore.

Research on Cool Roof options

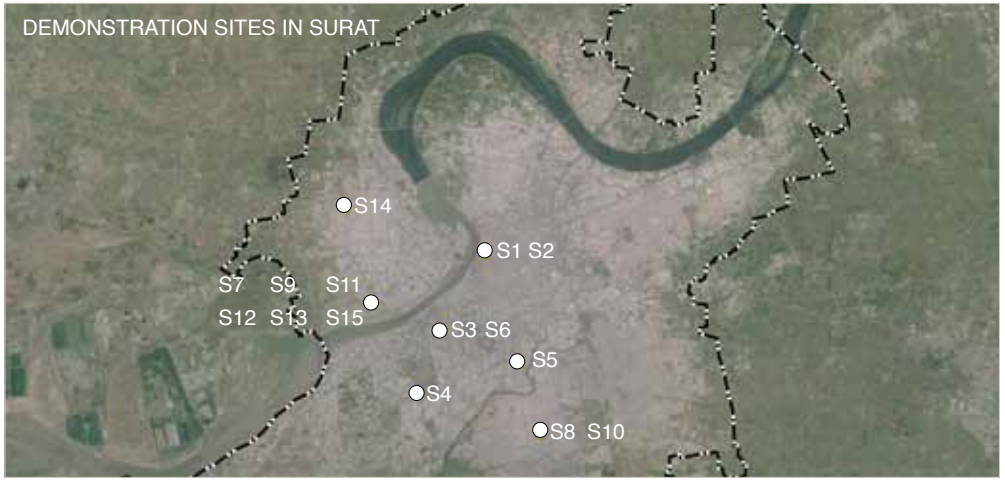
As a prelude to the demonstration of cool roof options on real buildings, research was undertaken on the possible range of options for increasing thermal comfort in buildings. These options represent both traditional and contemporary techniques to make buildings comfortable. These options were compiled into a handbook. This handbook will aid urban managers, engineers, architects and designers, who may consider using cool roofing and passive ventilation options for achieving thermal comfort at low energy costs.

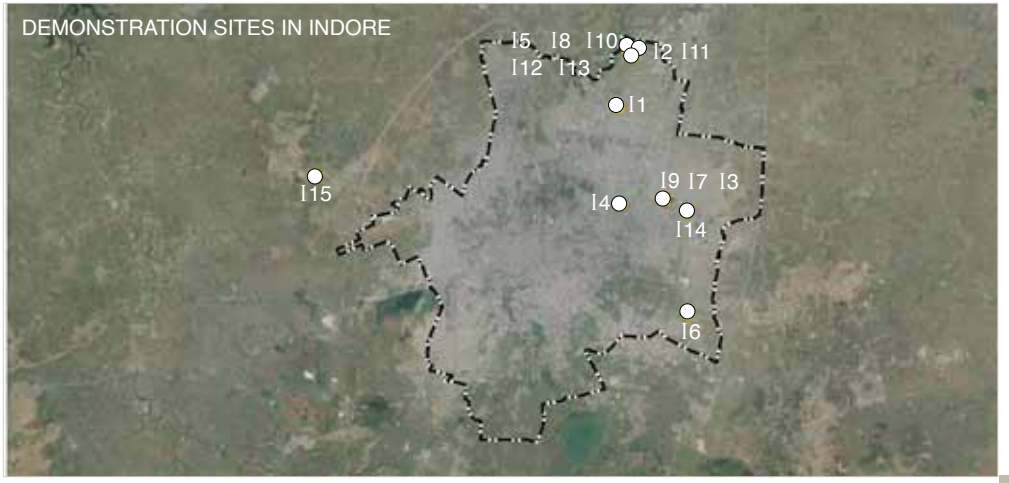


Demonstration Sites

Sr No.	Types of Demonstration	Site Location	Site Area sq. ft.
SURAT			
S1	Cool Roof Paint - Navpad Sales	Nanavat	400
S2	Cool Roof Paint - Navpad Sales	Panas	300
S3	Cool Roof Paint - Panache Greentech	Athwalines	855
S4	Cool Roof Paint - Panache Greentech	Adajan	929
S5	Thermocrete	Adajan	1,500
S6	Bamboo Screening	Athwalines	600
S7	XPS Sheet	Adajan	1,500
S8	Lime Concrete	Udhana	650
S9	Hollow Clay Tiles	Adajan	1,500
S10	Inverted Earthen Pots	Udhana	550
S11	China Mosaic Tiling	Adajan	1,500
S12	Insulmix: Insulated Mortar	Adajan	1,500
S13	Heat Resistant Tile - Thermatek	Adajan	1,500
S14	Shading Screen - Green Net	Palanpur Jakatnaka	600
S15	White Wash	Adajan	1,500

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
1I0	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





Demonstration of Design Options

A national level thermal comfort design competition was organized in order to encourage building professionals, technical experts and students to develop innovative and low-cost replicable design solutions. Apart from options selected through competition, vendors of cool roof products were also engaged to demonstrate their products. The design options thus collected were evaluated for their potential and competitive implementation costs to improve indoor thermal environments of EWS housing and reduce space cooling needs in middle to high income households. Around 40,000 square feet of area catering to more than 100 households in Surat and Indore were selected for demonstration of the identified options. The selected buildings cover major areas of the city and represent a good cross section of low and middle income households.

Performance monitoring

Monitoring of thermal comfort conditions has been carried out using temperature and humidity data loggers. Data loggers were installed inside the rooms of the buildings treated for cool roofing, outside the buildings and inside the rooms of neighbouring buildings without no cool roofing option to measure the relative gain in thermal comfort. The monitoring was carried out in two phases i.e. before implementing cool roof option and post implementation. This was done to identify baseline thermal comfort and quantify the improvement in thermal performance post cool roofing demonstration.

Each site was monitored for a period of 7 to 14 days during months starting from March to October 2014. Thermal characteristics were recorded at an interval of every 5 minutes. The data recorded by loggers has been linked to the CRPV website which enables this information to be accessed by various project stakeholders as well as well as general public. In addition, additional instruments such as infrared temperature profilers, thermal imager and anemometers were also used for preliminary on-the-spot assessments of surface temperatures of roofs.

A brief survey was conducted in a total of 200 buildings in Surat and Indore to scope the thermal comfort levels of the occupants within economically weaker section housings. Comparison was made to understand the effect of heat on people residing in different floors during different time of the day and different seasons in a year.

Training and Capacity Building

The project has worked in close association with the local governments in both cities. The project was encouraged and supported by the Indore Municipal Corporation (IMC), Indore Development Authority (IDA), Surat Municipal Corporation (SMC) and Surat Urban Development Authority (SUDA). Awareness workshops were conducted within both the cities to formally launch the CRPV project and in orienting the municipal and urban development agencies in the two states towards the need for collaborative action on enhancing thermal comfort in buildings against the backdrop of intensifying heat profiles of urban centres. The research outcomes and design options have been continuously shared with the city authorities for their feedback regarding options with the most potential for replication. Workshops were conducted both in Surat and Indore for sharing the design options and building capacity of engineers and architects who are involved in design and specifications of middle and low-income housing projects. In addition, private practitioners mainly architects – were also engaged for exposure to cool roof technologies.

Knowledge dissemination and Advocacy

Various knowledge exchange measures have been adopted by the project to reach out to a diversity of stakeholders. Through this project a website was launched – www.thermalcomfort.com – which provided constant updates of project activities to wider audience. Materials for Information-Education-Communication (IEC) were developed and shared with city stakeholders and state institutions for spearheading replication of some of some of the demonstrated options. A series of city workshops were conducted to disseminated learnings from this project to national, state and local government plan for providing safe and sustainable public housing.

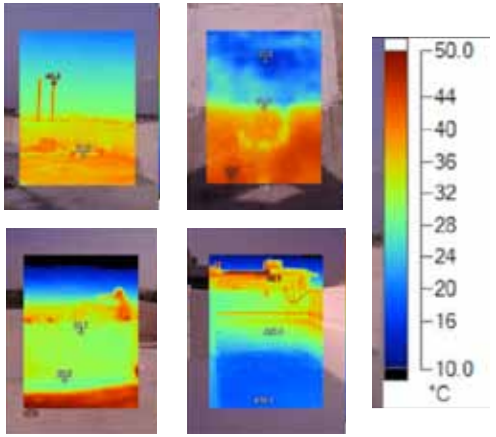
Performance Monitoring

MONITORING DEVICES

Temperature and Humidity data logger: Data logger was used to measure the humidity and temperature of indoor as well as the outdoor environment.

Thermal Imager : Thermal imager was used to measure the temperature variation or energy leak in the buildings.

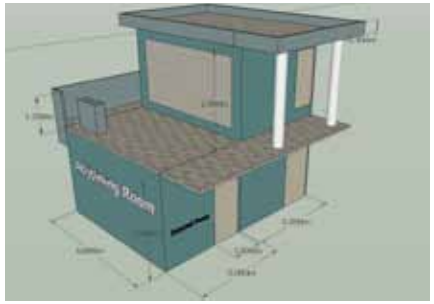
Infrared thermometer : A non contact IR thermometer measures the object's temperature by knowing the amount of infrared energy emitted by the object and its emissivity.

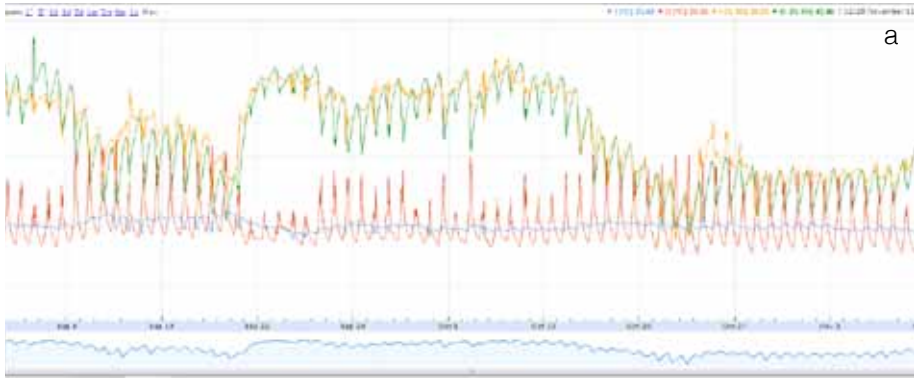


THERMAL IMAGES OF BUILDINGS

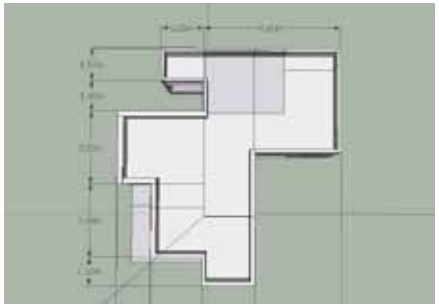
Data was collected using the monitoring devices like data logger, thermal imager and infrared thermometer. Above thermal images are examples of the data collected during the study. The images clearly represent the cooler surfaces (dark-light blue) in contrast with the hotter surfaces (yellow-orange-red). The thermal images give a clear indication of difference in surface temperature.

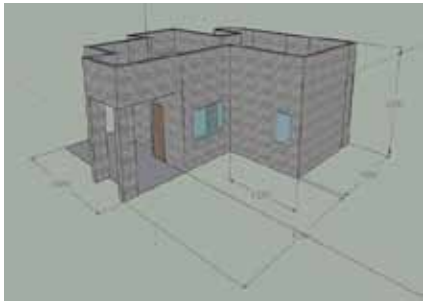
SITE: POLLUTION CONTROL BOARD, INDORE

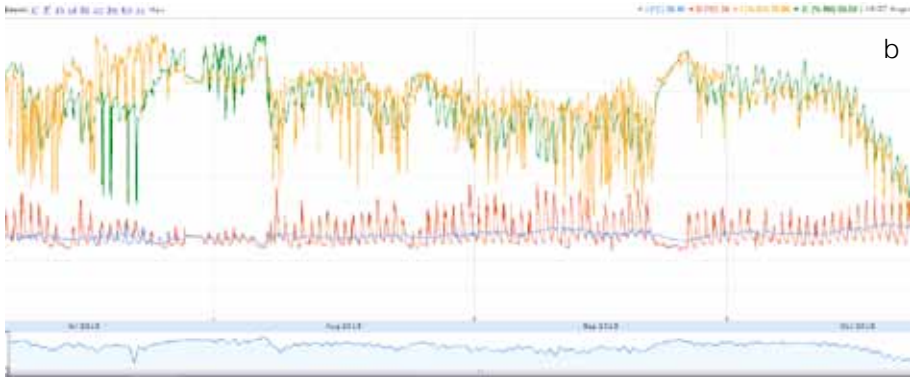




SITE: URBAN HEALTH CENTER, LAKHPATI, SURAT







MONITORING INSIDE AND OUTSIDE TEMPERATURE & RH [a: INDORE, b: SURAT]

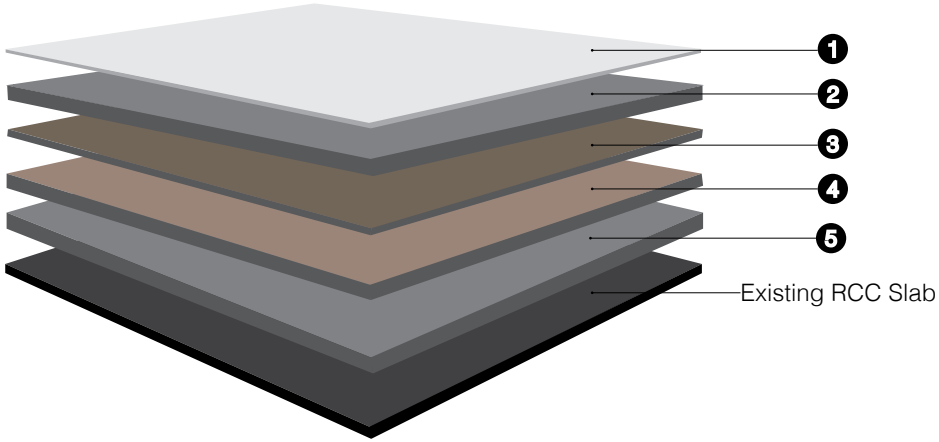
1. HOLLOW CLAY TILES

Site Location: INDORE

Concept

Hollow clay tiles have high thermal insulation and sound insulation property which is very effective in limiting heat flow. The air inside the cavities provides the insulation to heat ingress. The tiles should be aligned to ensured a continuous cavity which can allow passage of air and more efficient heat removal. Due to uniform multiple cavities, the tiles also have good load bearing capacity and are a good alternative to conventional bricks or clay tiles which are commonly used in terracing. The performance of hollow clay tiles can further be enhanced by a reflective finish over them. This can be a conventional ceramic tiles, heat resistant tiles or ceramic china mosaic.

Construction Detail



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)*

Material Specifications

• Hollow clay tiles with fluted edges. Tiles used in the project were of size 150 mm x 150 mm x 50 mm. Other sizes could also be used.

• Ceramic tiles - White or any light colour ceramic tile of 6-8 mm thickness. Ideally, they can be sourced as waste from tile makers or other building sites. If not, then they are locally available in 300 mm x 200 mm size. The ceramic tiles are broken in small pieces of 10 mm to 20 mm approximate size.

• Ordinary Portland Cement, Coarse sand and aggregate 10mm-20mm for Plain Cement Concrete (PCC) and cement-sand mortar

• White cement for joint filling with cement slurry

• Water proofing as per specifications (Cement Based Waterproofing Treatment)

Application

Step 1

Step 2

Step 3

Step 4

Step 1 : Surface Preparation and Laying of Cement Mortar Bedding

- Prepare cement mortar using cement and sand in 1:4 ratio.
- Make level markers in a square grid ensuring that the required slope is maintained to drain. Maintain 20mm average thickness of bedding mortar.

Step 2 : Application of Hollow Clay Tiles

- Lay hollow clay tiles over cement mortar - ensure continuity of cavity of hollow clay tiles. This continuous cavity can also be aligned on the terrace to allow air flow, which enhances thermal performance of tiles.
- In this case, the tiles are finished with china mosaic, so no gap has been left between tiles. In other cases, ensure a thin gap of 5-6mm between the tiles to be filled with cement mortar using fine sand.

Water proofing is done as per the specifications over hollow clay tiles.

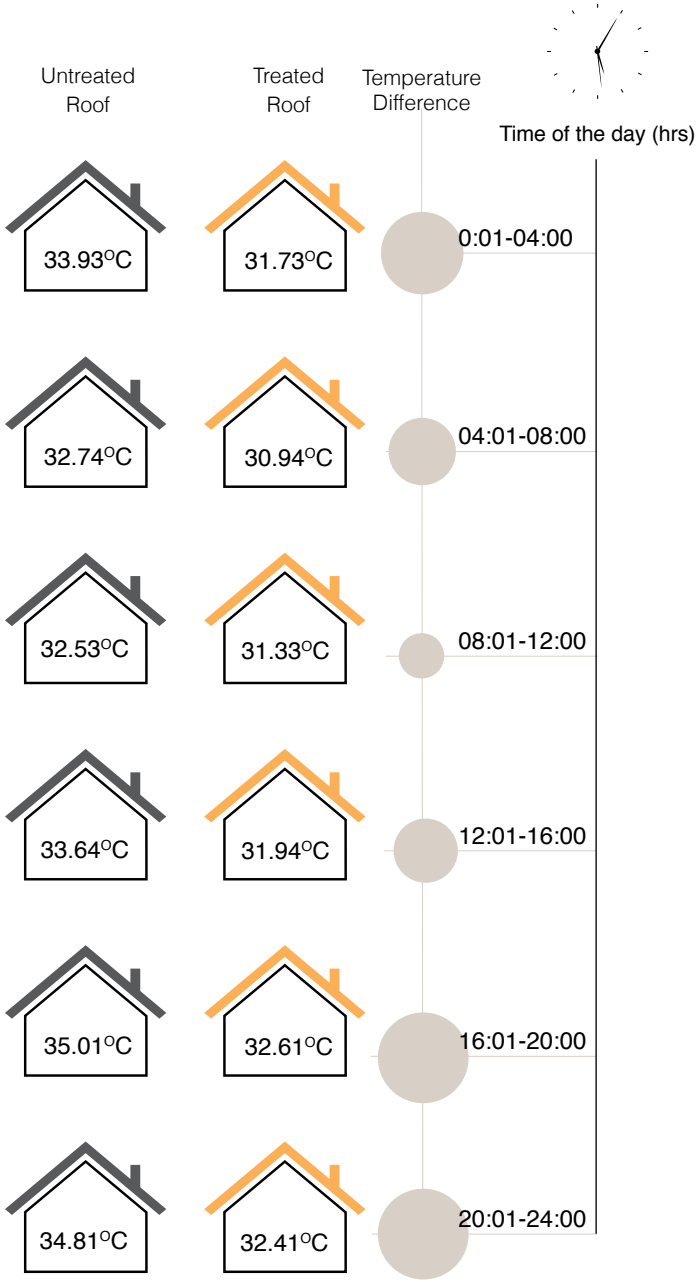
Step 3 : Breaking and Fixing of Ceramic Tiles

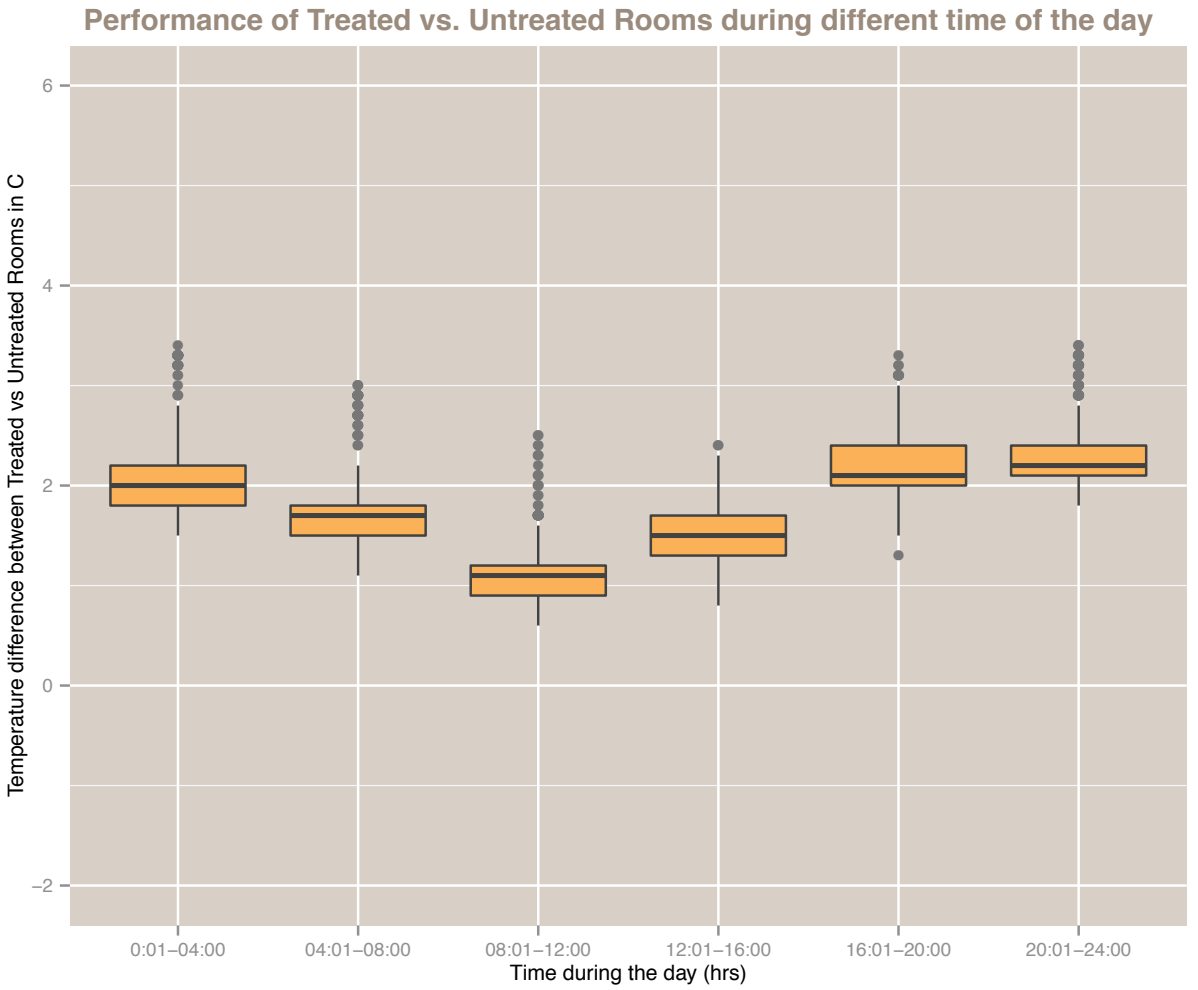
- Lay 50 mm thick bed of cement mortar over the waterproofing layer and smoothen surface using edger.
- Break the ceramic tiles into smaller pieces of random sizes of 20-30mm.
- Lay the broken ceramic tiles over cement slurry, leaving a gap of not more than 10mm for filling the joints with cement slurry.

Step 4 : Finishing and Washing the top surface

- As the tile laying progresses, keep filling the joints with white cement slurry and finishing the joints flush with the tile surface.
- Wash the finished surface with water.
- Cure the china mosaic for at least 24 hours.

Thermal Performance





Performance as compared to RCC slab

The treated space remains around 2 °C cooler as compared to untreated space. The higher heat retention capacity due to air void within the tiles extends thermal performance till late evening.

Cost Calculations

Cost calculation is based on technology demonstration on a terrace of area 100 Sq.m (1,076 Sq.ft.). All rates are market rates or as per Schedule of Rates 2014

Materials and Specifications	Rate (Rs.)	Amount (Rs.)
Material		
Epoxy based Water proofing with Fibre Glass Reinforcement – 1,076 Sq.ft	33 per Sq.ft	35,508
Bedding Mortar cement:sand 1:4, 50mm thick – 177 Cu.ft (for both hollow clay tile and china mosaic)	91 per Cu.ft.	16,000
Hollow Clay Tiles + Transport- 1,076 Sq.ft	11 per Unit	47,344
China Mosaic Tiles - 1,076 Sq.ft	25 per Sq.ft	26,900
Material Wastage @ 5%	-	7,700
Labour		
Epoxy based Water proofing with Fibre Glass Reinforcement – 1,076 Sq.ft	12 per Sq.ft	12,912
Laying Bedding mortar – 1:4 (2 layers - for hollow clay tiles and china mosaic finish) Skilled – 6 mandays Unskilled – 18 mandays	 750 per manday 350 per manday	 3,000 6,000
Laying Hollow Clay Tiles Skilled - 4 mandays Unskilled - 8 mandays	 750 per manday 350 per manday	 3,000 2,800
Breaking ceramic tiles for china mosaic Unskilled – 3 mandays	 350 per manday	 1,050
Laying china mosaic – Fixing on Mortar Skilled – 4 mandays Unskilled – 12 mandays	 750 per manday 350 per manday	 3,000 4,200
Labour cost for lifting of material from GF to Terrace	350 per manday	5,250
Joint filling with white cement slurry (material and labour) – 1,076 Sq.ft	10 per Sq.ft	10,760
Total (Material & Labour) = Rs. 1,84,309 **Cost/Sq.ft Rs. 172**		

2. LIME CONCRETE

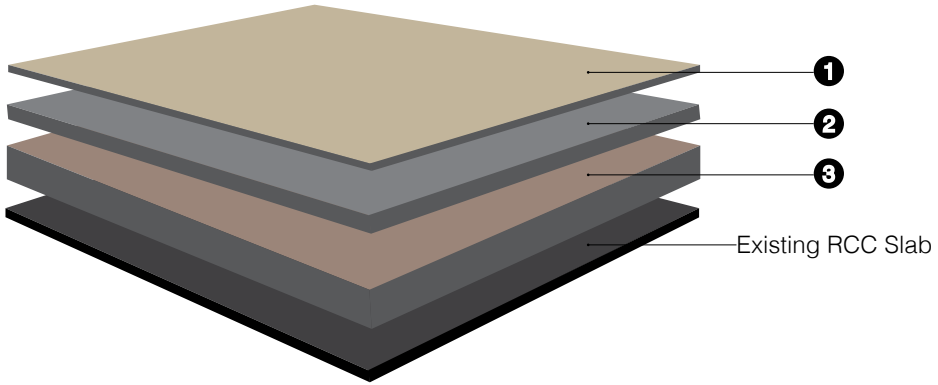
WITH NATURAL WATER PROOFING

Site Location: INDORE

Concept

Brick jelly-lime concrete has traditionally been used as a weathering layer over roofs, most notably in buildings constructed more than 50 years ago. These roofs would often use materials like alum and soap to be added to water used for making concrete – this would enhance the water proofing capacity of the lime concrete. The principle is to install a layer of concrete made with lime-surkhi mortar with broken brick as coarse aggregate. Surkhi, which is crushed brick powder would replace sand in lime concrete. The same concept has been enhanced with traditionally known natural water-proofing agents such as jaggery, gallnut and bael fruit. The lime concrete can then be covered with terracing material such as tiles.

Construction Detail



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)*

Material Specifications

- Bael Fruit (wood apple or trefoil), The fruits are broken in small pieces.
- Jaggery – old discarded jaggery (ripe jaggery) also known as ‘kala gud’.
- Gallnut fruit – broken in small pieces of up to 15mm.
- Quicklime (>70% purity)
- Broken Brick Chips
- Clean coarse sand for lime concrete and mortar bedding mortar
- Cement for cement slurry
- Mangalore Tiles (Clay Tiles)
- Red Cement for joint filling

Application

Step 1

Step 2

Step 3

Step 4

Step 1 : Preparing Fermented Water

• Mix broken bael (also known as wood apple or trefoil), gallnut and jaggery in water – (10 bael dry ripe fruit + 4 kg gallnut (both in small broken pieces) + 8 kg jaggery in 100 litres of water). As a thumb rule – 100 litres of fermented water for 250 sq.ft. area.
• Stir the mixture adequately. This fermented water is stirred twice a day for 5 days.

Step 2 : Slaking of Lime

• Bunds of sand and brick chips were prepared.
• Place the quicklime on top of it (in small batches).
• Add water to quicklime and cover the quicklime with sand and allow overnight slaking.
• The next day add water to the mixture, to make a mortar of workable consistency.

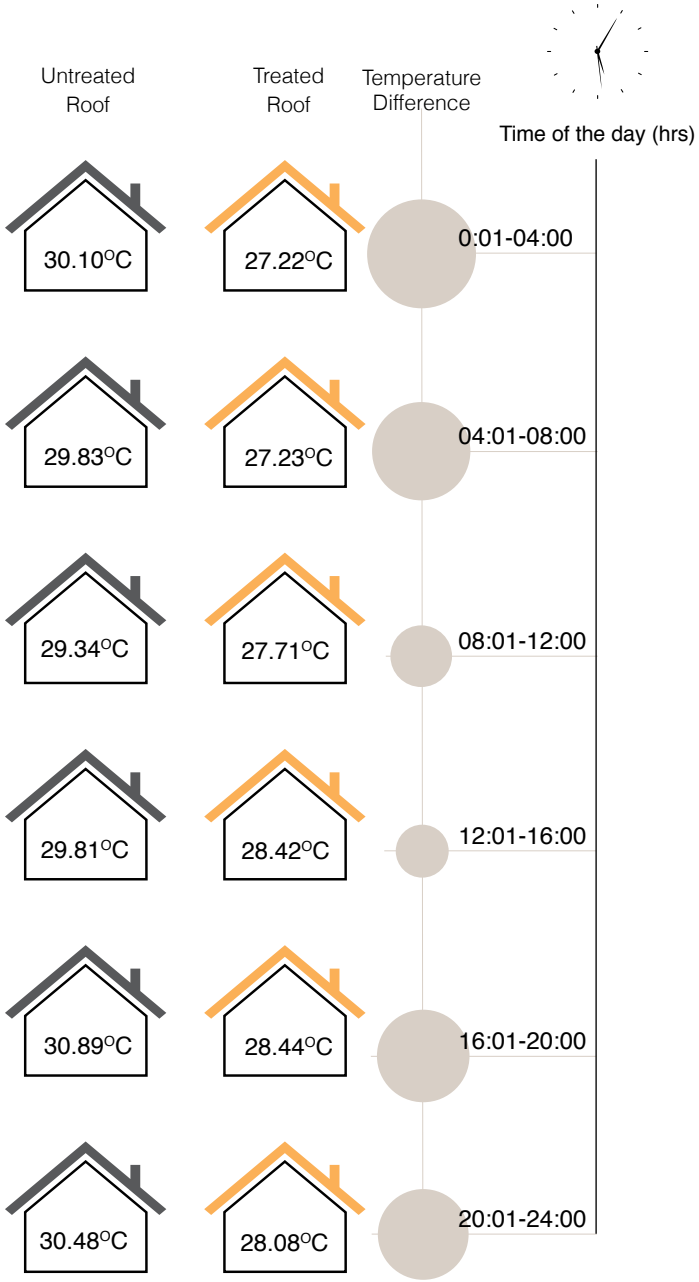
Step 3 : Application of Lime Concrete with natural proofing

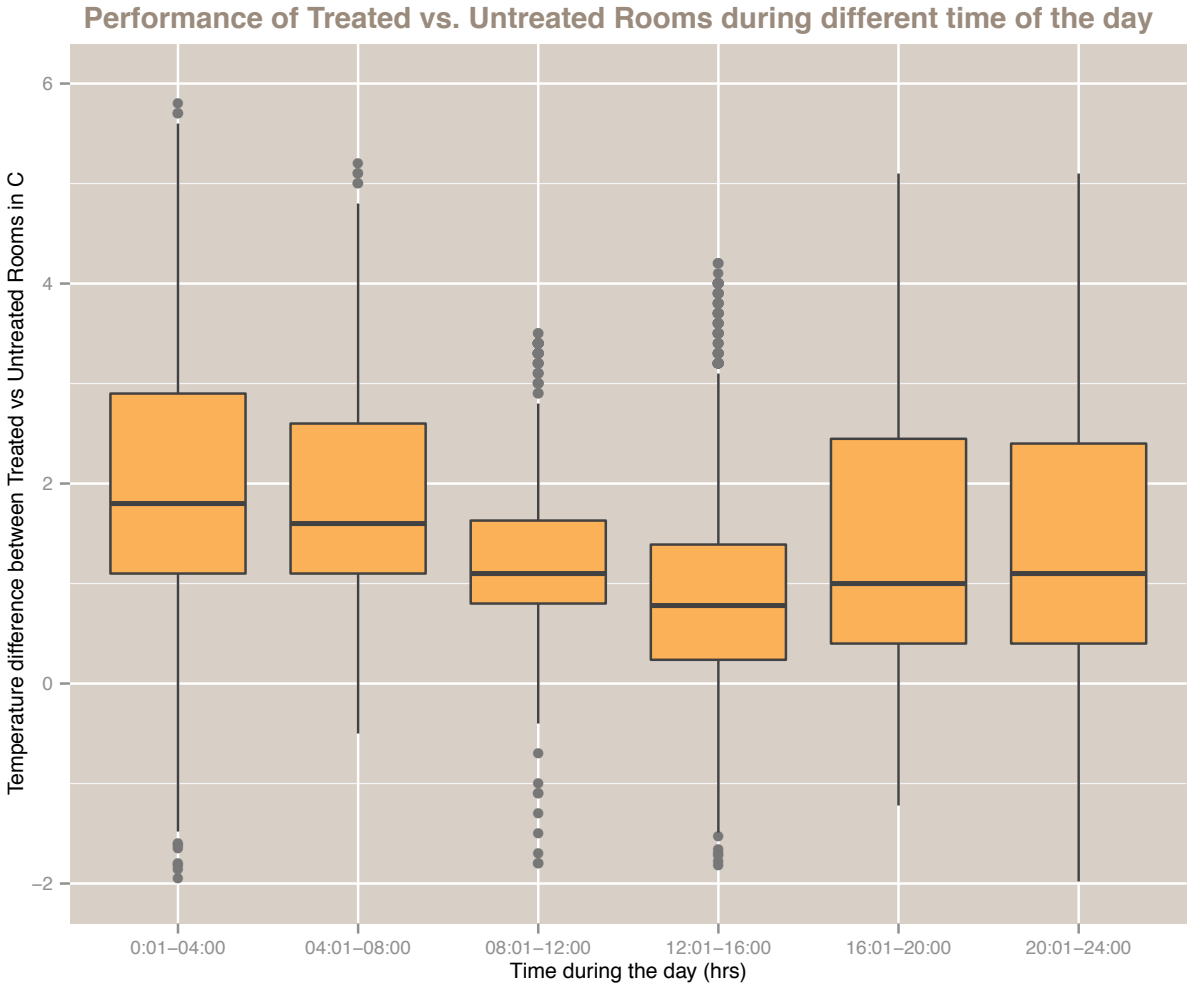
• Lay 100 mm thick base layer of lime concrete and smoothen surface using edger.
• Allow the base layer to dry for 24 hours.
• Cure the lime concrete using fermented water prepared earlier with bael, jaggery and gallnut by spreading it over the lime concrete layer for 4 to 5 days.

Step 4 : Finishing with Mangalore Tiles

• Lay 50 mm thick layer of cement mortar over lime concrete.
• Lay Mangalore tiles over a bed of cement slurry and cure using water for 24 hours.
• Lay red cement slurry over broken Mangalore Tiles for filling joints and gaps if any. Wash the finished surface using water.

Thermal Performance





Performance as compared to RCC slab

The treated space remains around 2-3 °C cooler as compared to untreated space, with the performance being slightly better in the evening and early morning hours

Cost Calculations

Cost calculation is based on technology demonstration on a terrace of area 100 Sq.m (1,076 Sq.ft.). All rates are market rates or as per Schedule of Rates 2014.

Materials and Specifications	Rate (Rs.)	Amount (Rs.)
Material		
Quicklime, 124 Cu.ft	170 per Cu.ft	21,000
Coarse Sand, 177 Cu.ft	37 per Cu.ft	6,500
Burnt Brick Aggregate - Surkhi, 424 Cu.ft	42 per Cu.ft	18,000
Bael (wood apple) Fruit, 60 fruits	55 per fruit	3,300
Gallnut, 24 Kgs.	65 per Kg.	1,560
Jaggery, 48 Kgs.	45 per Kg.	2,160
Bedding Mortar, Cement : Sand - 1:4, 25mm thick, 177 Cu.ft	91 per Cu.ft	8,000
Mangalore Tiles, 1975 tiles	22 per tile	43,456
Material wastage @ 5%	-	6,678
Labour		
Preparing bael, gallnut and jaggery fermented water Unskilled - 6 mandays	 350 per manday	2,100
Preparing and laying Lime Concrete Skilled - 4 mandays Unskilled - 18 mandays	 750 per manday 350 per manday	 3,000 6,300
Finishing with Mangalore tiles Skilled - 2 mandays Unskilled - 6 mandays	 750 per manday 350 per manday	 1,500 2,100
Labour cost for lifting of material from GF to Terrace	350 each Nos.	2,800
Total (Material & Labour) = Rs. 1,28,454 **Cost/Sq.ft Rs. 120**		

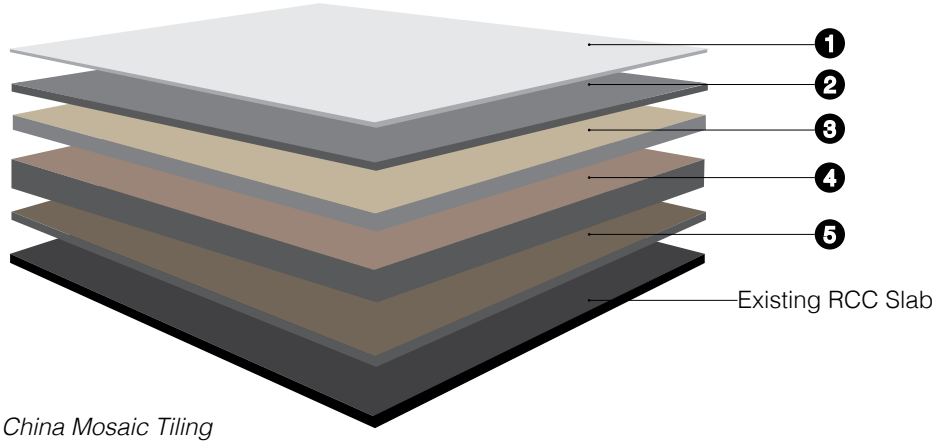
3. INVERTED EARTHEN POTS

Site Location: SURAT

Concept

Using earthen pots to keep roofs cool has been traditionally practiced in hot and dry areas, such as Rajasthan and Gujarat. Earthen pots are commonly available almost throughout the country and can also be made to specific sizes by potters. They are an affordable material to insulate roofs by forming air pockets which limit heat flow through the roof. Locally available earthen clay pot exhibits high thermal insulation property. In this technique, a layer of inverted pots is laid on the roof and the spaces formed in between are filled up with plain cement concrete or lime concrete. A lightweight filler like cinder or building waste can also be used in concrete to fill the spaces and then with an impervious layer like ceramic tiles.

Construction Detail



1. *China Mosaic Tiling*
2. *20-25mm Cement Mortar bedding (Cement : Sand = 1 : 4)*
3. *50mm IPS (Indian Patent Stone) (Cement : Sand : Aggregate = 1 : 2 : 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)*

Material Specifications

• Earthen pots of 175mm diameter and 75mm height - these are commonly available and can be made to order by a potter.

• Ceramic tiles - White or any light colour ceramic tile of 6-8 mm thickness. Ideally, they can be sourced was waste from tile makers or other building sites. If not, then they are locally available in 300 mm x 200 mm size. The ceramic tiles are broken in small pieces of 10 mm to 20 mm approximate size. China mosaic has been done at the project site for a reflective finish.

• Ordinary Portland Cement, Coarse sand and aggregate 10mm-20mm for Plain Cement Concrete (PCC) and cement-sand mortar.

• White cement for joint filling with cement slurry

• Water proofing as per specifications (Cement Based Waterproofing Treatment)

Application

Step 1

Step 2

Step 3

Step 4

Note: Surface preparation and Water proofing were done before implementation of this technology.

Step 1 : Laying of Earthen Pots

- Lay cement slurry over waterproofing layer.
- Put inverted earthen pots over wet cement slurry. Before placing the pots ensure they are not cracked, not over burnt and are soaked in water.
- Place the pots with their rim touching so that the spaces to be in-filled are minimized.

Step 2 : Fixing of Earthen Pots

- Prepare cement mortar using cement and sand in 1:4 ratio.
- Fix the pots using the cement mortar by in-filling the spaces between the pots, having the thickness of about 50mm.

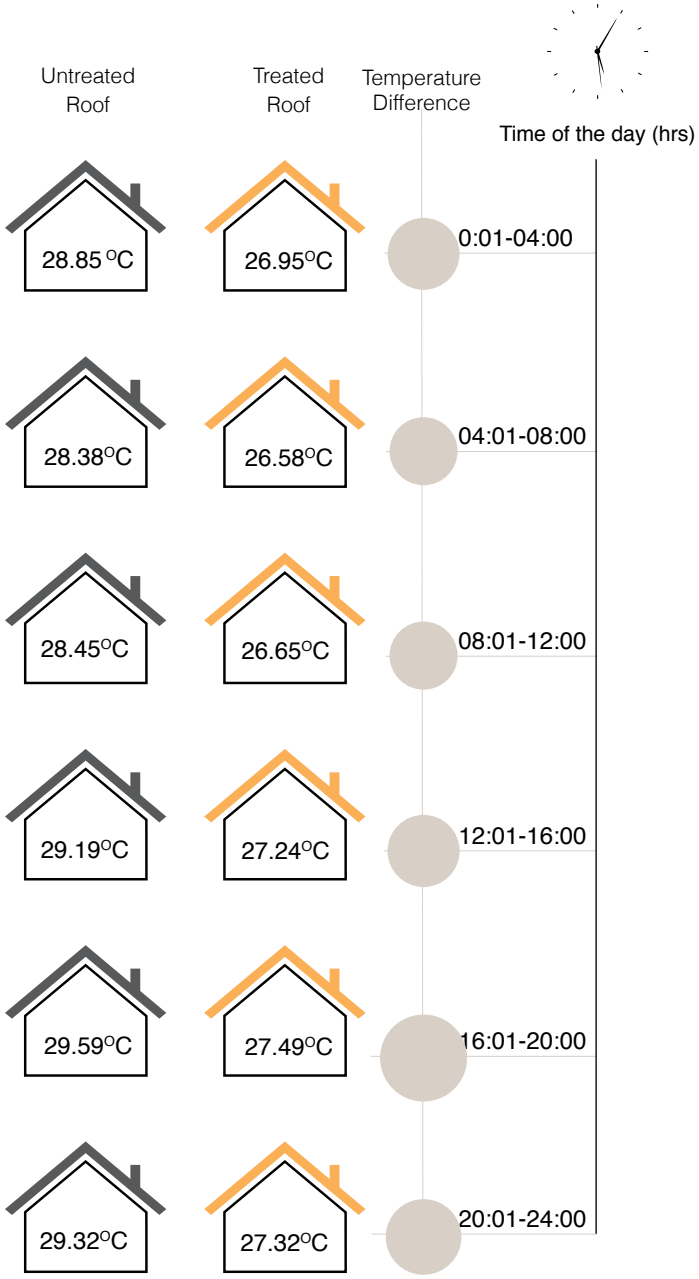
Step 3 : Laying of IPS

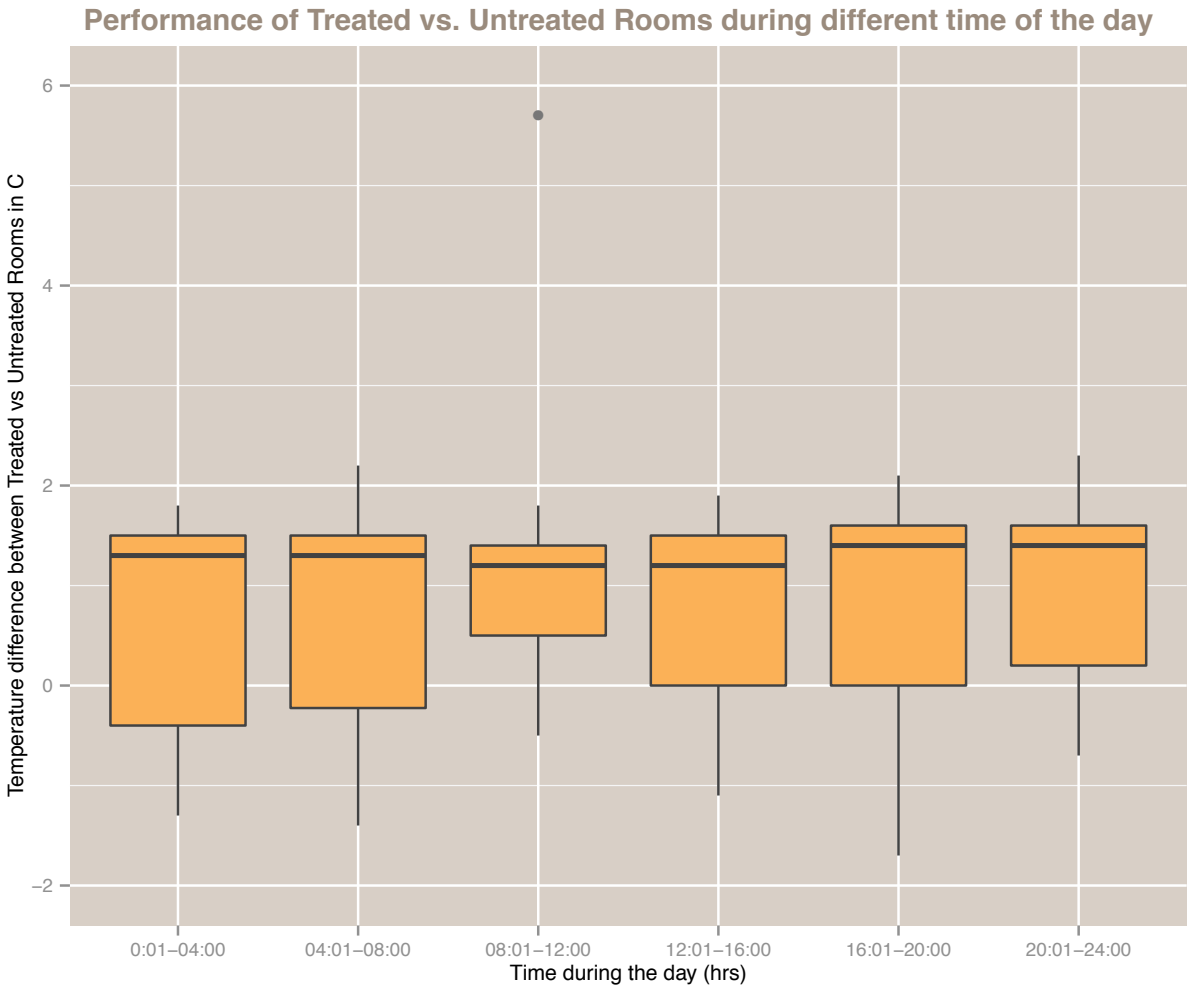
- Cure the cement mortar and let it harden for a day before laying PCC.
- Lay 50 mm thick layer of PCC (Cement : Sand : Aggregate = 1 : 2: 4) over inverted earthen pots and smoothen the surface using edger.

Step 4 : Finishing the roof with China Mosaic reflective surface

- Break ceramic tiles into small pieces for laying.
- Apply cement slurry over IPS and lay broken ceramic tile pieces (china mosaic) on it.
- Cure using water after 24 hours.
- Fill joints in tiles with white cement slurry and finish it flush with the tile surface. Wash the finished surface clean with water.

Thermal Performance





Performance as compared to RCC slab

The treated space remains around 1.5-2 °C cooler as compared to untreated space, with the performance being consistent throughout the day.

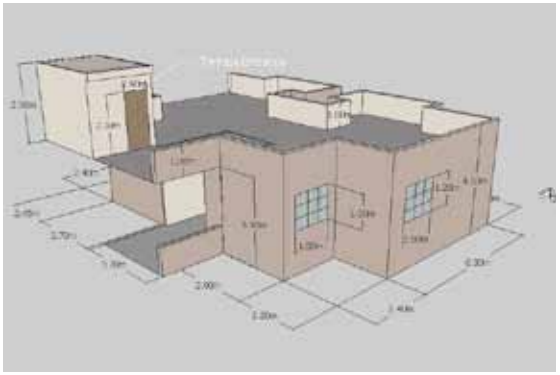
Cost Calculations

Cost calculation is based on technology demonstration on a terrace of area 100 Sq.m (1,076 Sq.ft.). All rates are market rates or as per Schedule of Rates 2014.

Materials and Specifications	Rate (Rs.)	Amount (Rs.)
Material		
Epoxy based Water proofing with Fibre Glass Reinforcement – 1,076 Sq.ft	33 per Sq.ft	35,508
Plain Cement Concrete 1:2:4, 50mm thick – 177 Cu.ft	99 per Cu.ft	17,500
Bedding Mortar cement:sand 1:4, 25mm thick – 88 Cu.ft	91 per Cu.ft	8,000
Earthen Pots	5 per Nos.	24,210
Ceramic tiles – 1,076 Sq.ft	25 per Sq.ft	26,900
Material Wastage @ 5%	-	6,215
Labour		
Epoxy based Water proofing with Fibre Glass Reinforcement – 1,076 Sq.ft	12 per Sq.ft	12,912
Laying Plain Cement Concrete – 1:2:4 Skilled – 6 mandays Unskilled – 18 mandays	 750 per manday 350 per manday	 4,500 6,300
Laying Bedding mortar – 1:4 Skilled – 4 mandays Unskilled – 12 mandays	 750 per manday 350 per manday	 3,000 4,200
Placing Earthen Pots Unskilled - 2 mandays	 350 per manday	700
Breaking ceramic tiles for china mosaic Skilled – 2 mandays Unskilled – 4 mandays	 750 per manday 350 per manday	 1,500 1,400
Laying china mosaic – Fixing on Mortar Skilled – 4 mandays Unskilled – 12 mandays	 750 per manday 350 per manday	 3,000 4,200
Labour cost for lifting of material from GF to Terrace	350 per manday	1,750
Joint filling with white cement slurry (material and labour) – 1,076 Sq.ft	10 per Sq.ft	10,760
Total (Material & Labour) = Rs. 1,71,945 **Cost/Sq.ft Rs. 160**		

4. HEAT RESISTANT TILES

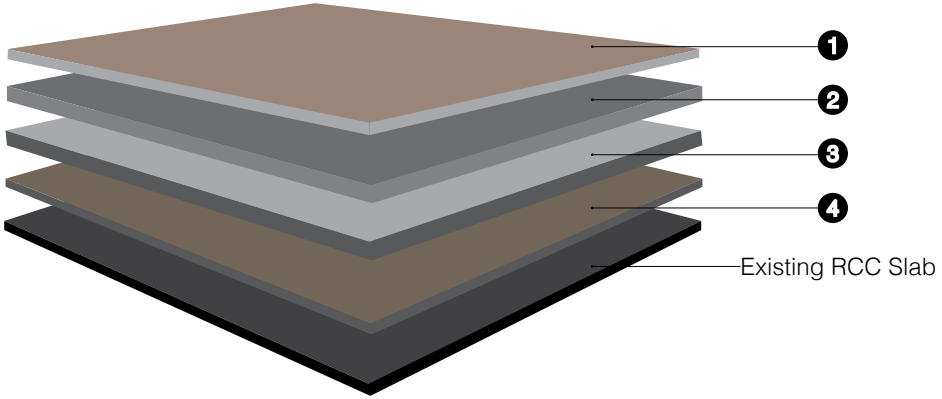
Site Location: INDORE



Concept

The heat resistant tile 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. Alternatively, the Solar Reflectance Index(SRI) is a measure of the coolness of a roof. For low-sloped roofs, the minimum solar reflectance and emittance for a 3 year old weathered surface are generally 0.7 and 0.75 respectively. By comparison, reflectance of a conventional gray coloured concrete roof is in the 0.2-0.4 range. Although, white surfaces are generally the coolest surfaces, coloured surfaces can also be made into cool roofs through reflective coatings.

Construction Detail



1. *Ceramic based Thermatek tiles (300mm x 300mm x 6mm)*
2. *20-25mm Cement Mortar bedding (Cement : Sand = 1: 4)*
3. *50mm Level course of PCC (Cement : Sand : Aggregate = 1 : 2: 4)*
4. *4 to 5mm Water Proofing (as specified)*

Material Specifications

• White coloured ceramic based impervious heat resistant tiles meant for over-deck application. Other light colours of high solar reflectance can also be used.
Specifications of Thermatek tiles -
Solar reflectance 0.73, emittance 0.93 and SRI 91

• Size of tile 300 mm X 300 mm X 20 mm

• Weight approximately 4 kg/ tile

• Ordinary Portland Cement, Coarse sand and aggregate 10mm-20mm for Plain Cement Concrete (PCC) and cement-sand mortar

• White cement for joint filling with cement slurry

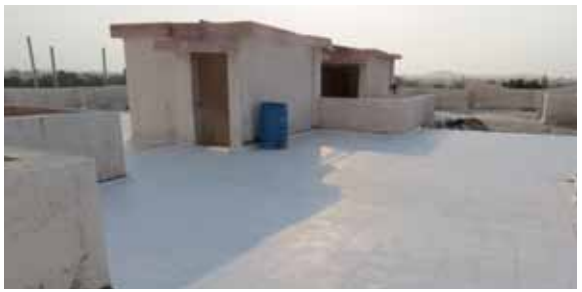
• Water proofing as per specifications (Cement Based Waterproofing Treatment)

Application

Step 1

Step 2

Step 3



Step 4

Note: Surface preparation and Water proofing were done before implementation of this technology.

Step 1 : Laying of Plain Cement Concrete

- Lay 50 mm thick layer of Plain Concrete Cement (PCC) over waterproofing layer.
- Allow PCC layer to dry for 24 hours

Step 2 : Laying of Cement Mortar Bedding

- Make level markers in a square grid ensuring that the required slope is maintained to drain. Maintain 20mm average thickness of bedding mortar.
- Lay the bedding mortar over the PCC layer and maintain proper level with edger.

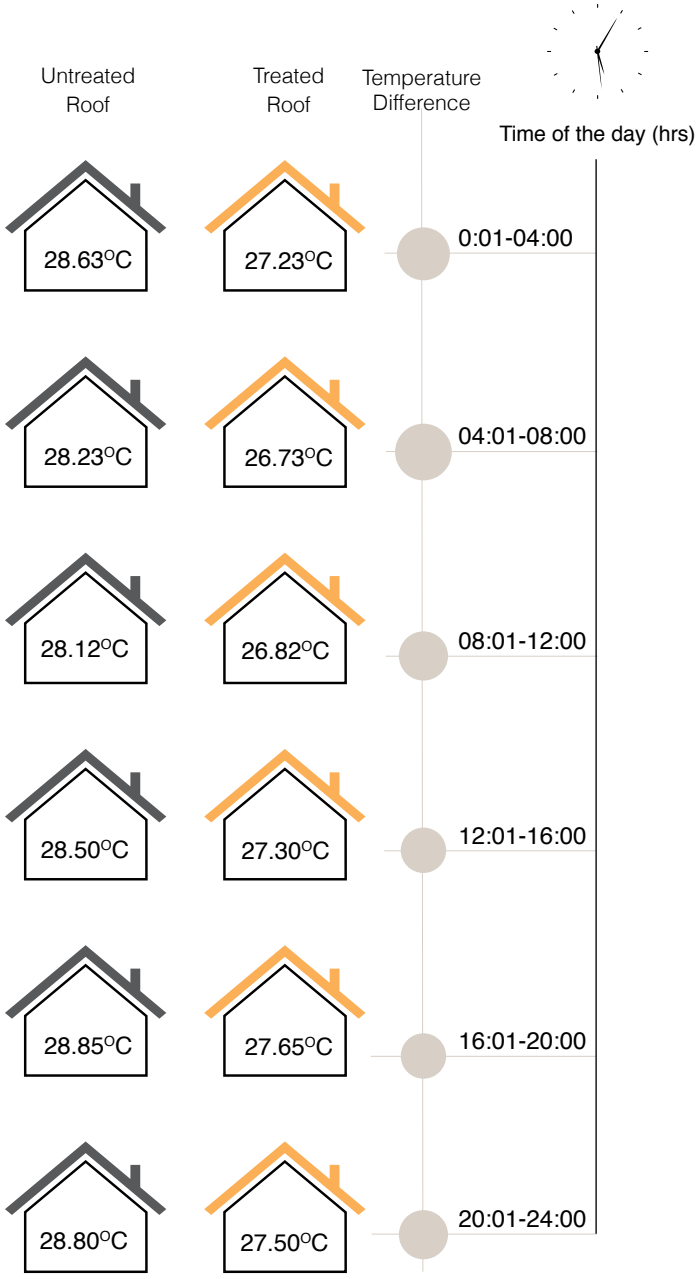
Step 3 : Lay Heat Resistant Tiles

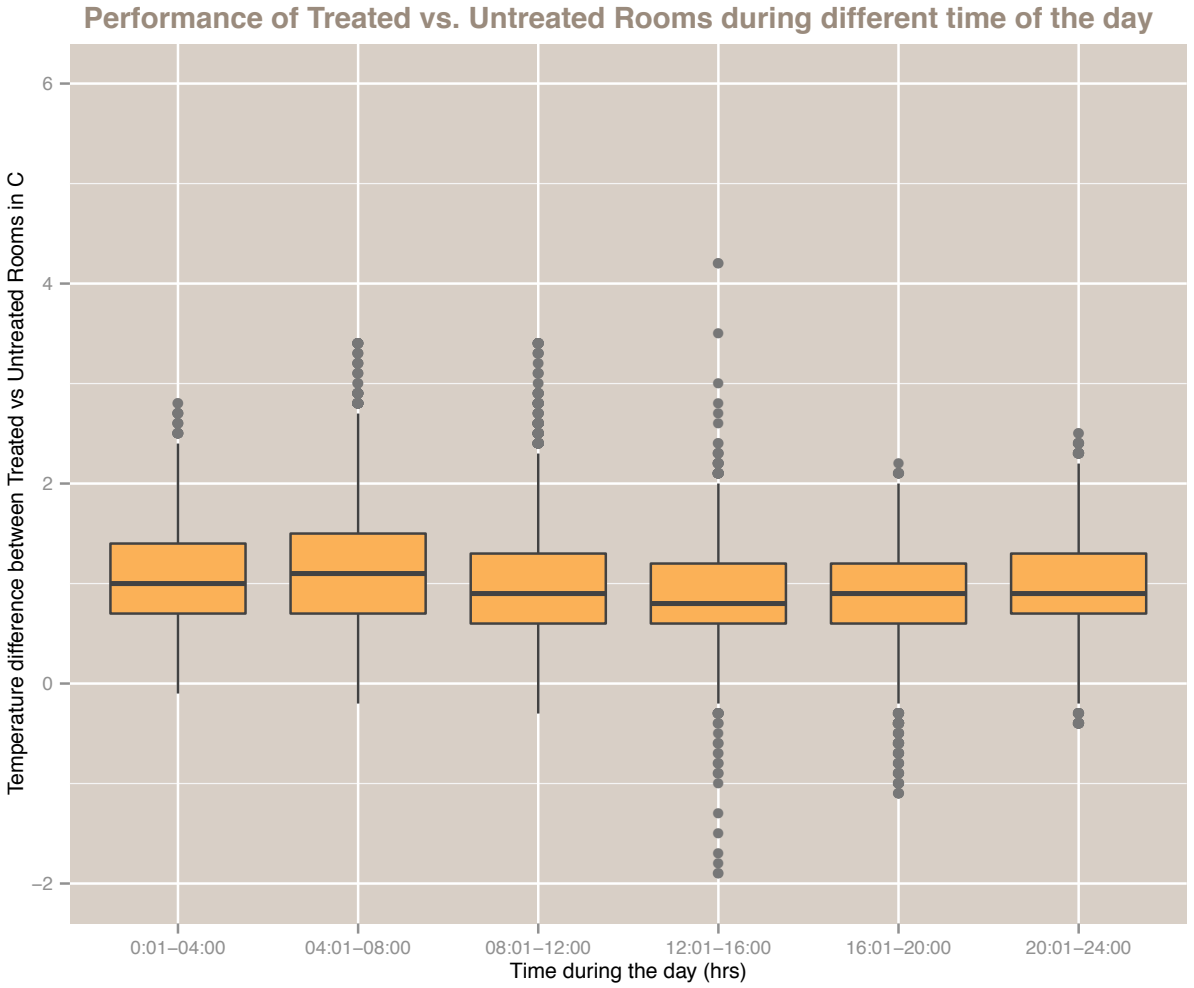
- Lay cement slurry over cement mortar.
- Lay thermatek tiles on top of cement slurry and let it dry for 24 hours.
- Ensure a gap of 2mm between tiles which will later be grouted with cement slurry.

Step 4 : Finishing and Washing the top surface

- After 24 hours curing, fill joints between tiles with white cement slurry
- Wash the finished surface with phosphoric acid (diluted with water as per specification) and scrub the surface with a wet mop/sponge.

Thermal Performance





Performance as compared to RCC slab

The treated space remains around 1.5 °C cooler as compared to untreated space and the performance remains more or less consistent throughout the day.

Cost Calculations

Cost calculation is based on technology demonstration on a terrace of area 100 Sq.m (1,076 Sq.ft.). All rates are market rates or as per Schedule of Rates 2014,

Materials and Specifications	Rate (Rs.)	Amount (Rs.)
Material		
Epoxy based Water proofing with Fibre Glass Reinforcement – 1,076 Sq.ft	33 per Sq.ft	35,508
Plain Cement Concrete 1:2:4, 50mm thick – 177 Cu.ft	99 per Cu.ft	17,500
Bedding Mortar cement:sand 1:4, 25mm thick – 88 Cu.ft	91 per Cu.ft	8,000
Thermatek Tiles - Material + Transport - 1,076 Sq.ft	45 per Sq.ft	48,420
Material wastage @ 5%	-	6,140
Labour		
Epoxy based Water proofing with Fibre Glass Reinforcement – 1,076 Sq.ft	12 per Sq.ft	12,912
Laying Plain Cement Concrete – 1:2:4 Skilled – 6 mandays Unskilled – 18 mandays	 750 per manday 350 per manday	 4,500 6,300
Laying Bedding mortar – 1:4 Skilled – 4 mandays Unskilled – 12 mandays	 750 per manday 350 per manday	 3,000 4,200
Laying thermatek Tiles - Fixing on mortar Skilled – 4 mandays Unskilled – 12 mandays	 750 per manday 350 per manday	 3,000 2,100
Labour cost for lifting of material from GF to Terrace	350 per manday	5,250
Joint filling with white cement slurry (material and labour) – 1,076 Sq.ft	5 per Sq.ft	5,380
Total (Material & Labour) = Rs. 1.61,540 **Cost/Sq.ft Rs. 150**		

5. COOL ROOF PAINT

Site Location: INDORE

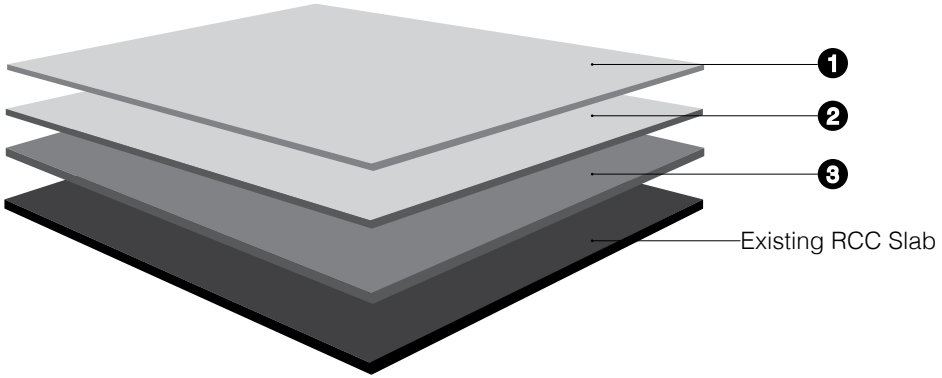
Concept

A simple and effective means to reduce the indoor temperature of rooms, especially at the top floor is to reduce the amount of heat gain through the roof. Roof is the primary source of heat gain for spaces, exposed to directly to sunlight. This amount of heat gain can be reduced substantially if the incident sunlight is reflected back to the atmosphere. Doing so will reduce the amount of heat gained by the roof surface.

This can be achieved by using simple techniques like applying high SRI value Reflective paints, also known as Cool Roof Paints. The application of these types of reflective paints is very simple and time effective, although the procedure may vary between different manufacturers.

This technique is a contemporary advanced alternative to the traditional white wash technique. Although, cool roof paints are still to gain popularity within the residential market however, they are gaining traction within commercial and industrial usage within India.

Construction Detail



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

Material Specifications

Cool Roof treatment has been done with the following products of Panache Greentech Solutions Pvt. Ltd

- MX Cool Guard - base coat
- MX Cool Top - Second coat of reflective paint
- Transeal - final coat of water repellent film

Application

Step 1

Step 2

Step 3

Step 4

Step 1 : Surface Preparation

- Ensure that the top surface of the roof slab is not uneven or blistered. Lightly chip away any unevenness to get a level surface.
- Wash thoroughly with water for a clean, dirt-free surface.

Step 2 : Application of Base Coat

- Prepare the base coat by mixing the coating powder with a measured quantity of water.
- Stir the mixture to make a viscous paste for base coating.
- Apply the base coat evenly on the prepared surface using a paint brush and allow to dry for minimum 2 hours.

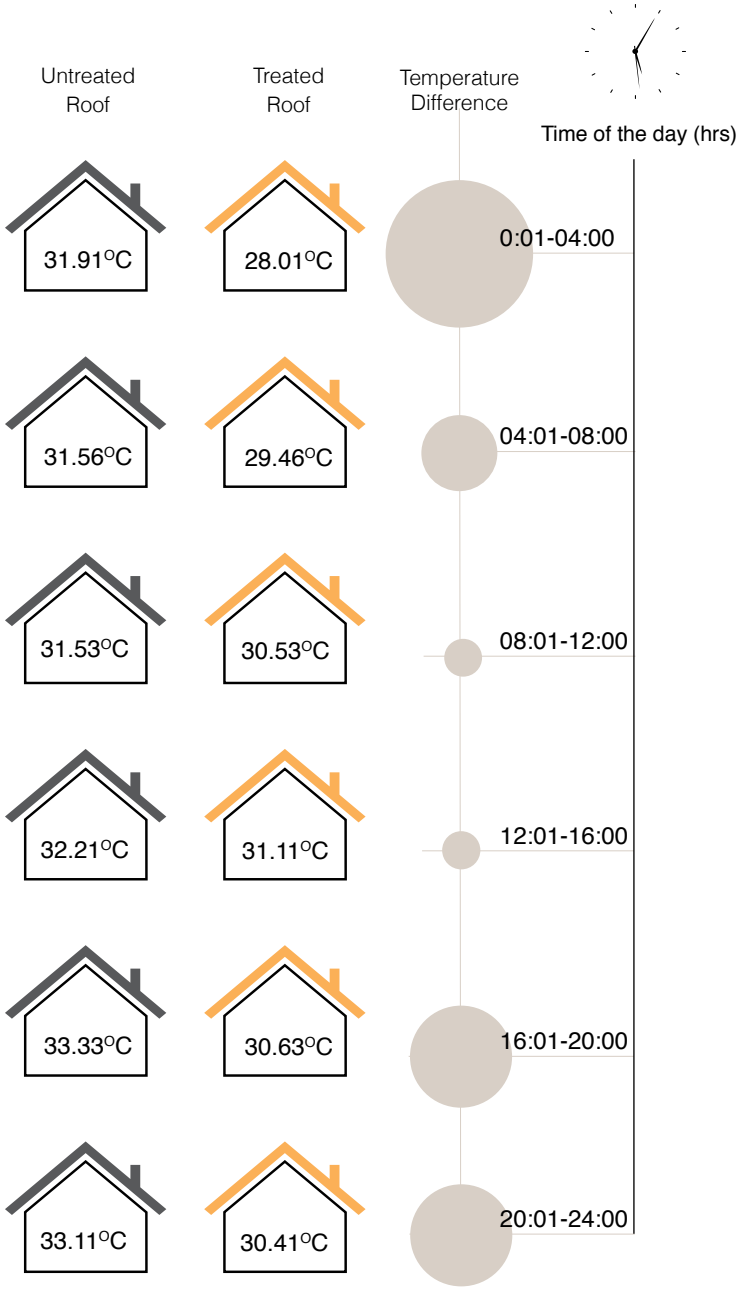
Step 3 : Application of Reflective Paint

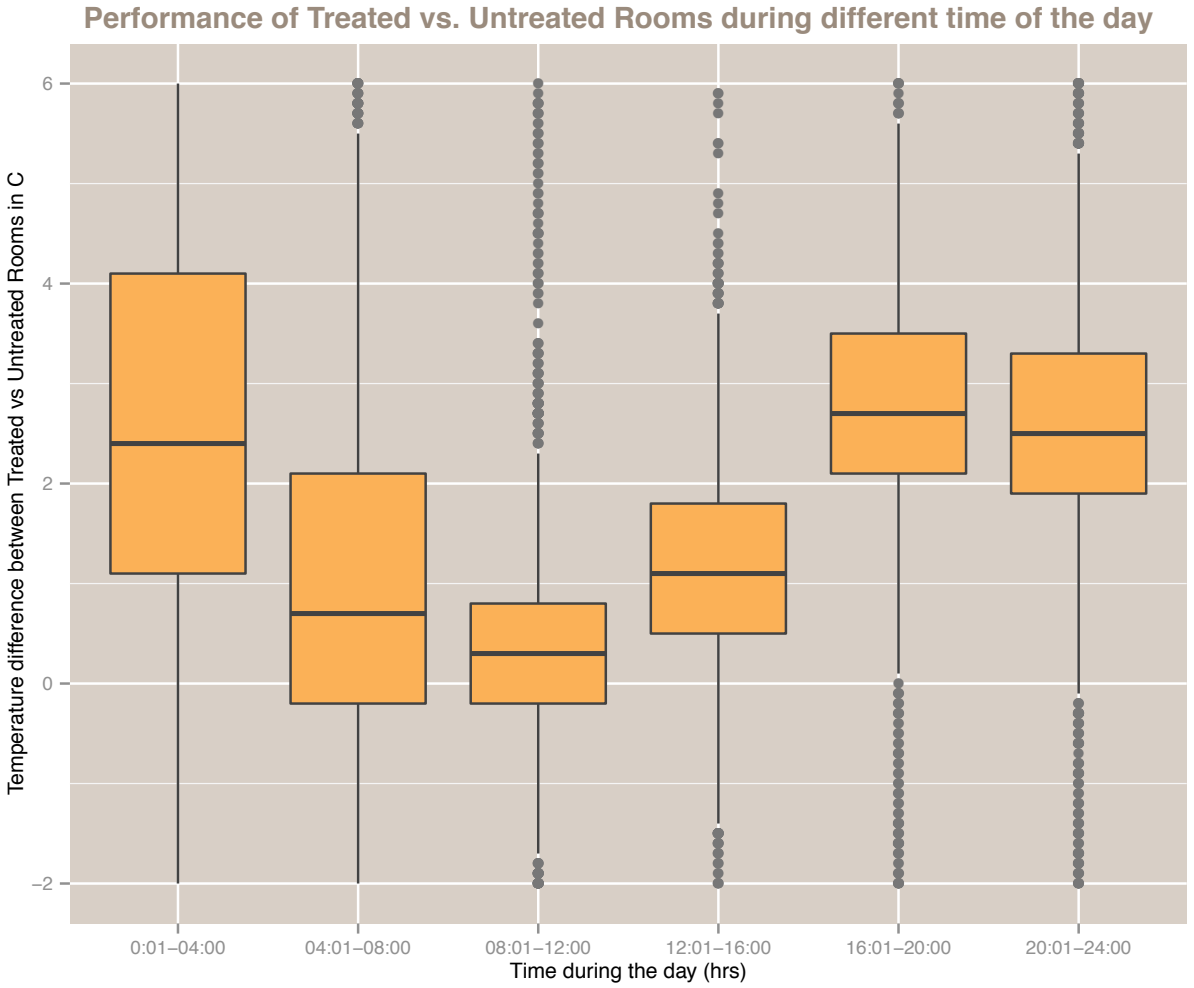
- Open the ready to use reflective paint and check the viscosity of the paint. If required, then add thinner and make the paint more workable.
- Apply two coats of reflective paint over the base coat.
- Allow sufficient drying time after application of each coating. Usually it is 2-3 hours on a bright, sunny day.

Step 4 : Application of Final Reflective Coat

- Once the reflective paint coating has dried the surface is ready to be sealed with a final coat of reflective coating.
- This is usually a thin polymer-silicon based water repellent transparent film, which increases the reflective properties of the surface by making it shinier.
- Also, these transeal coatings provide additional benefit of waterproofing by creating a thin and hence reducing the porosity, which prevents the water molecules from penetrating.
- Leave the coatings to dry for minimum two hours.

Thermal Performance





Performance as compared to RCC slab

The treated space remains around 2-4 °C cooler as compared to untreated space. The 3-stages reflective paint treatment significantly reduces heat ingress into the slab and results in a greater reduction of indoor comfort during the evening and night hours

Cost Calculations

Cost calculation is based on technology demonstration on a terrace of area 100 Sq.m (1,076 Sq.ft.). All rates are market rates or as per Schedule of Rates 2014.

Materials and Specifications	Rate (Rs.)	Amount (Rs.)
Material		
Epoxy based Cool Roof Paint– 1,076 Sq.ft	20 per Sq.ft	21,250
Labour		
Cleaning and Painting	5 per Sq.ft.	5,380
Total (Material & Labour) = Rs. 26,630 **Cost/Sq.ft Rs. 25**		

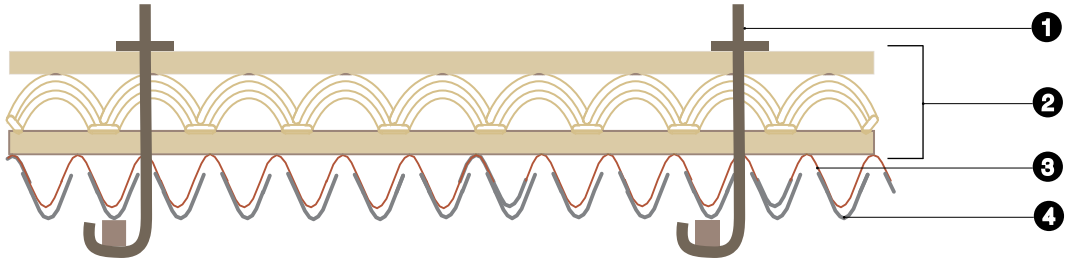
6. BAMBOO SHADING SCREEN

Site Location: SURAT

Concept

Shading an exposed surface is an effective means of reducing the heat transfer through the surface, as is commonly seen in various kinds of shading devices used for windows. The similar concept also works on the roof which receives the maximum solar radiation in tropical climate. In this technique, the shading screen for the roof is made with panels which are made using split bamboo and placed on a basic support structure which enables an air gap between the panel and roof surface. Therefore bamboo is used both in making the shading device and in creating an air cavity between the panels. Wherever available, well seasoned bamboo is an efficient material which can be used as a light-weight shading device. Although it can be applied over flat RCC roofs, this technique is particularly relevant for sloping roofs which are made using corrugated Tin sheets or Asbestos sheets

Construction Detail



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

Material Specifications

- Bamboo of diameter 2.5”-3” - hollow bamboo with a wall thickness of 1/2”-3/4”, distance between nodes 1’-1’6”. the bamboo should be at least 1 month old
- G.I. Nails of 20 mm length
- G.I. Wires of 20 gauge length
- J-bolt and nut - GI/ stainless steel - length around 170mm long, diameter 6mm.
- Nylon Strips
- Wood primer and oil paint for Bamboo Frame
- Tools for working with bamboo – carpentry drill machine, sickle, hacksaw, hammer and other working tools (screw driver, spanners, plier, etc.)

Application

Step 1

Step 2

Step 3

Step 4

Step 1 : Fabrication of Bamboo Frames

- Ensure the bamboo is clean and of a uniform cross section by cutting off the tapering ends of bamboo.
- Scrape the nodes from the bamboo, using a sickle.
- Split bamboo into four thinner strips
- Fabricate a rectangular bamboo frame of size 11 feet x 5 feet – this is the structural frame for the shading screen.

Step 2 : Fabrication of Bamboo Screens

- Place bamboo strips laterally (touching each other) and fix to the frame using nails.

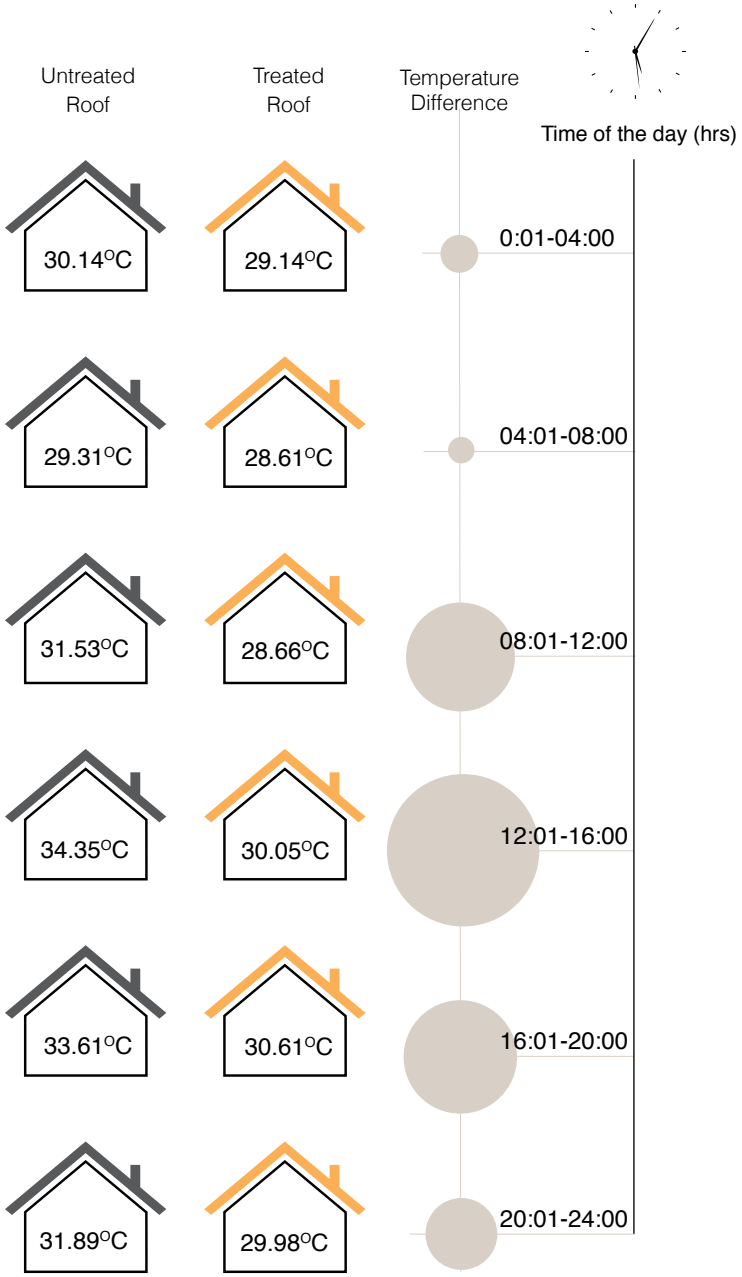
Step 3 : Application of Anti Corrosive Paint

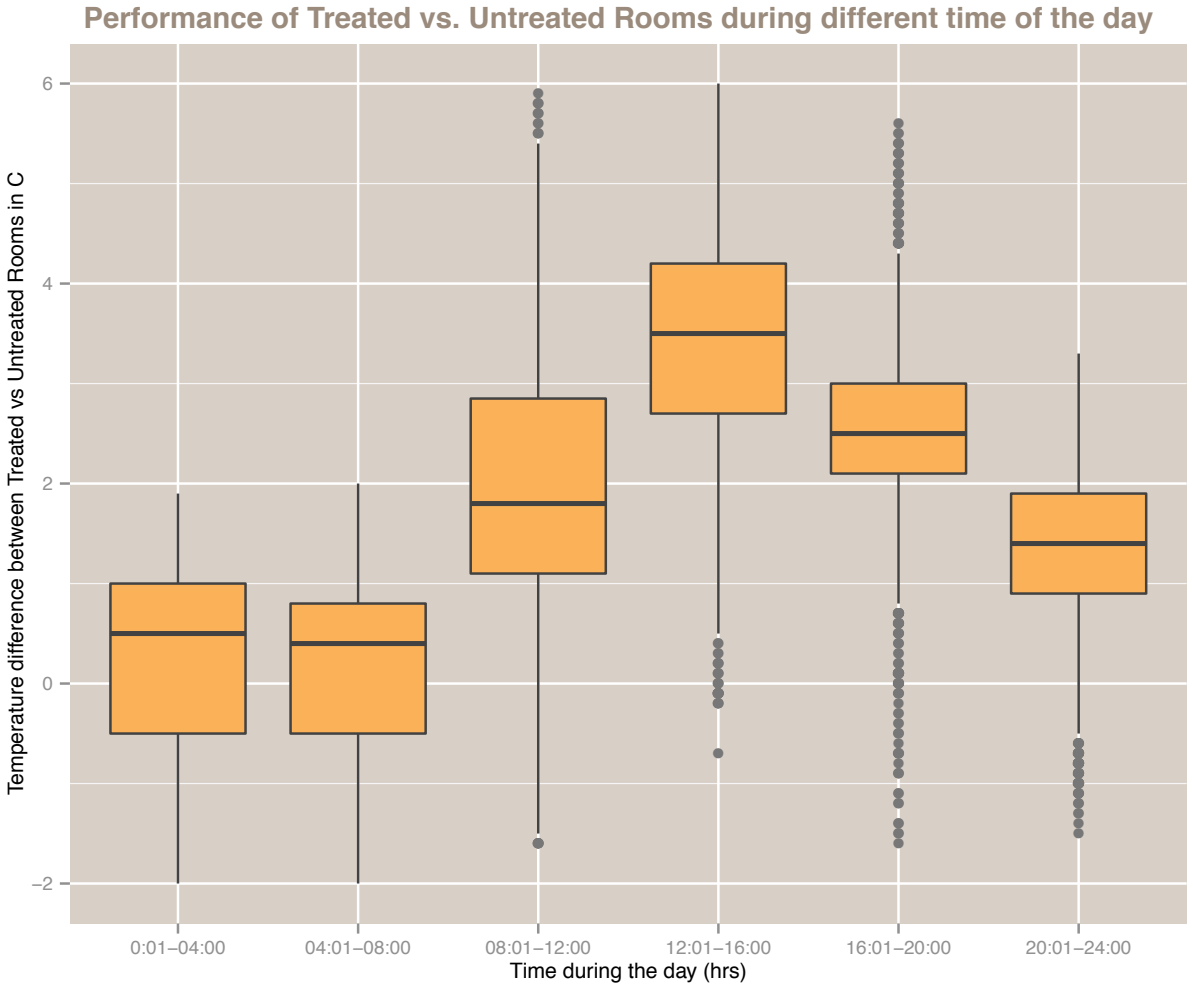
- Apply corrosion-resistant paint along the joints of nails and bolts ensuring all the exposed nails and bolts are coated. 'Black Japan' which is an anti-corrosion black bituminous paint commonly available in the market, can be used for this purpose.

Step 4 : Installation of Bamboo Screens

- Drill on top of roofing sheets and fix "J" bolts to roofing sheets.
- Install bamboo panels by fixing them using "J" bolts.
- Bamboo panels are then bound at joints using G.I wires and nylon wires to provide additional strengthening

Thermal Performance





Performance as compared to Galvanized Iron Sheet

The treated space remains around 3-4 °C cooler as compared to untreated space during afternoon and evenings and around 2 degrees at other times of the day.

Cost Calculations

Cost calculation is based on technology demonstration on a terrace of area 35 Sq.m (377 Sq.ft.). All rates are market rates or as per Schedule of Rates 2014.

Materials and Specifications	Rate (Rs.)	Amount (Rs.)
Material		
Bamboo, 160 Nos.	70 per bamboo	11,200
Nails, GI Wires, Tools etc.	-	4,500
Wood Primer & Oil Paint	-	2,500
Material wastage @ 5%	-	802
Labour		
Making bamboo panels and installation Skilled artisan - 18 mandays Unskilled - 8 mandays	 750 per manday 350 per manday	 13,500 2,800
Total (Material & Labour) = Rs. 35,302 **Cost/Sq.ft Rs. 94**		

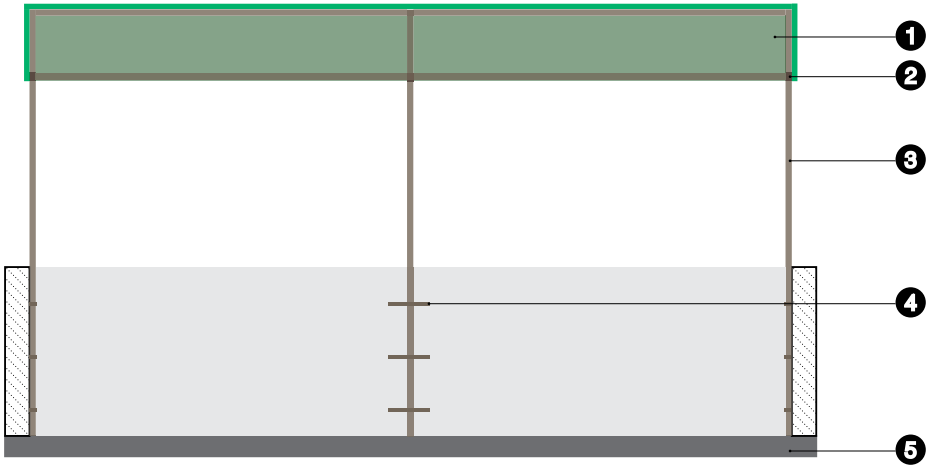
7. GREEN MAT SHADING

Site Location: INDORE

Concept

Shading of building elements is the most basic strategy to achieve thermal comfort. Depending on the design of shading device and its positioning which influences the interception of solar radiation, varied degree of thermal comfort can be achieved. Green Mats are available as a covering for greenhouses to grow plants. Depending on their openings, they can provide shading of varied degrees, generally up to 70%. Even though they are not as effective as insulating materials, their simple and low-cost application makes them an attractive option to increase thermal comfort by reducing the roof surface temperature and in also making terraces more usable during hot season.

Construction Detail



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

Material Specifications

• Mild Steel Hollow Box steel Section of size 50 mm x 50 mm x 5 mm for structural frame, welding equipment to install the frame.

• Green Mat – 250 GSM woven cloth synthesised by polyethylene. The cloth is available from 15% - 90% shading percentage. The cloth is available in a width of 1.0 metre.

• G.I. wires of 20 Gauge to tie the green mat to steel frame.

Application

Step 1

Step 2

Step 3

Step 1 : Fabrication of Steel Structure

• Prepare a framing plan for the green mat. Ensure that unanchored span of green mat does not exceed 5-6 feet to prevent it from experiencing major uplift forces.
• Procure Mild Steel Square Hollow Sections of 50 mm x 50 mm x 5 mm. This is an efficient section for erecting a frame to cover a terrace area, generally up to 1000 sq.ft. The height of the frame can range from 8 feet to 10 feet for more efficient shading.
• MS Strips are welded at bottom of MS sections to clamp it with wall.

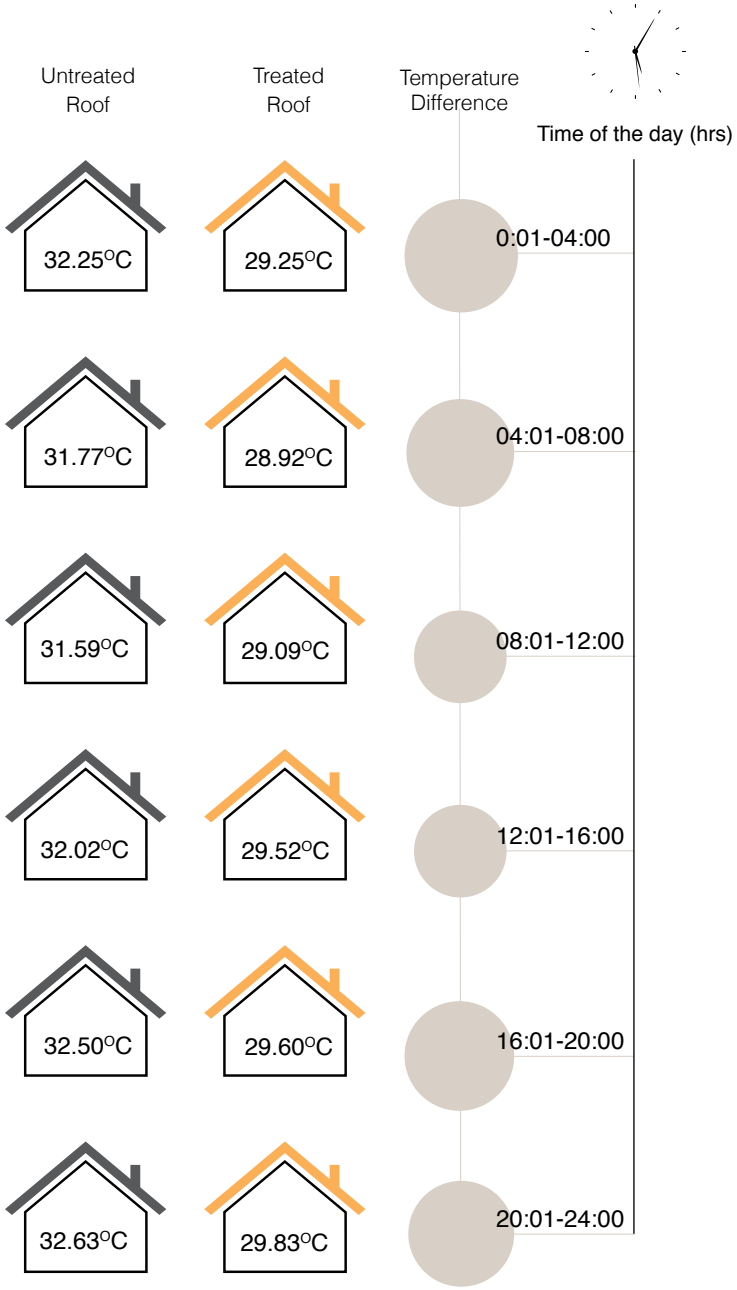
Step 2 : Erection of Steel Structure

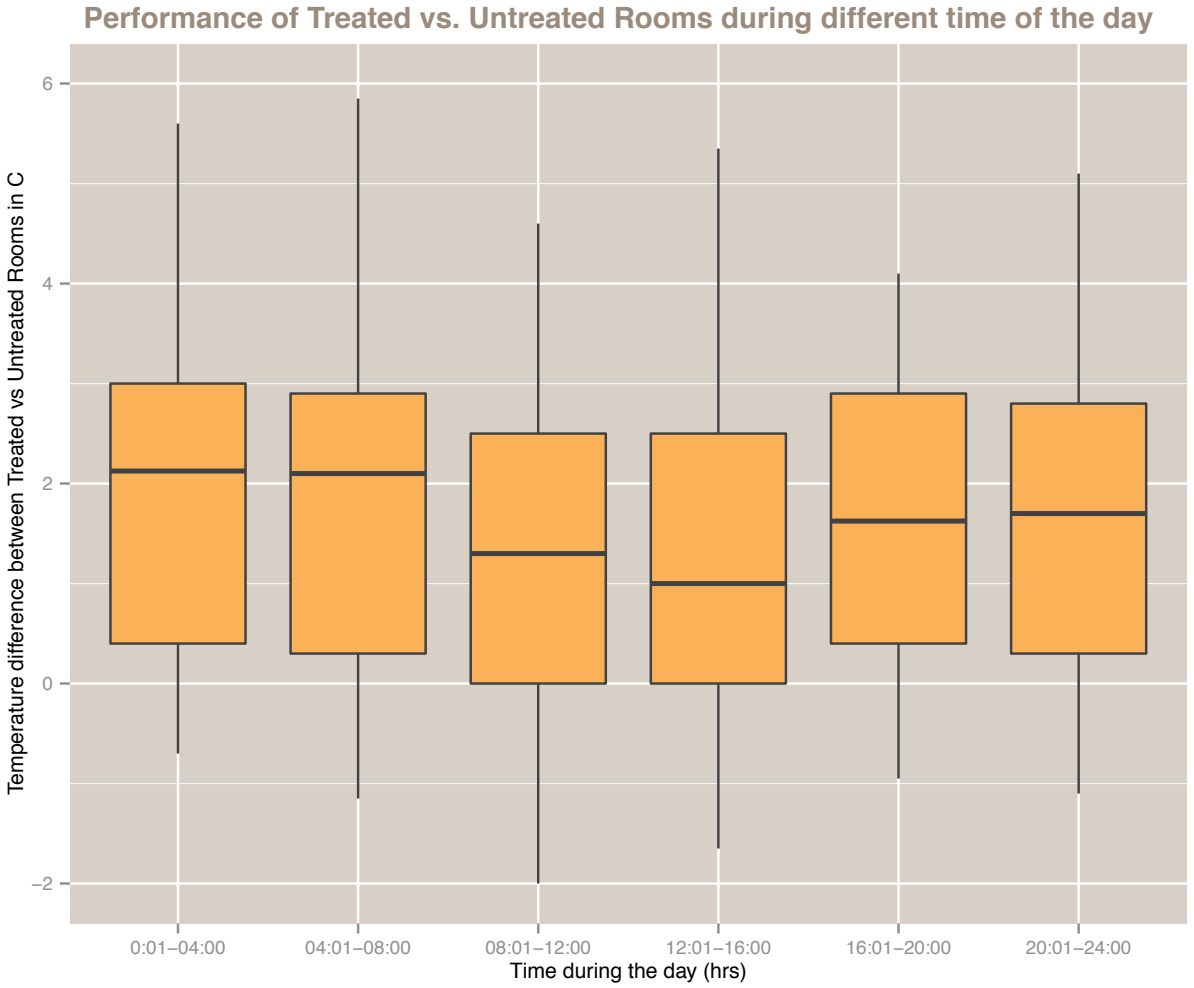
• Construct the MS frame by welding at necessary points.
• Apply Black Japan Paint or an equivalent coating to make the mild steel hollow section resistant to corrosion.

Step 3 : Installation of Green Mat

• The green net cloth is available in a width of 1000 mm.
• The edges of the cloth are folded/taped along the length in order to avoid fraying.
• In practice, people also tend to stitch the cloth along the length so as to withstand high tension during after erection of the frame.
• The cloth is tied to the MS frame using 20 Gauge G.I. wires.

Thermal Performance





Performance as compared to RCC slab

This technology provide a constant indoor comfort in the range of 2.5 to 3 °C throughout the day. The intensity of direct solar radiation decreases from direct to diffuse, which is responsible for the roof's performance

Cost Calculations

Cost calculation is based on technology demonstration on a terrace of area 37 Sq.m (400 Sq.ft.). All rates are market rates or as per Schedule of Rates 2014.

Materials and Specifications	Rate (Rs.)	Amount (Rs.)
Material		
Square Hollow Sections - Poles ,100 ft.	60 per Kg.	11,000
Square Hollow Sections - Grids (horizontal bracing), 180 ft.	60 per Kg.	19,750
Square Hollow Sections – Tie members 40 ft.	60 per Kg.	4,400
Black Japan Paint	-	1,000
Green Mat (Double Layer)	15 per Sq.ft	15,000
Labour		
Labour Cost of Fabrication @ 25 Rs/Kg.	25 per Kg.	15,000
Green Mat - Labour Cost with Binding Wires	4 per Sq.ft	4,000
Total (Material & Labour) = Rs. 70,150 **Cost/Sq.ft Rs. 175**		

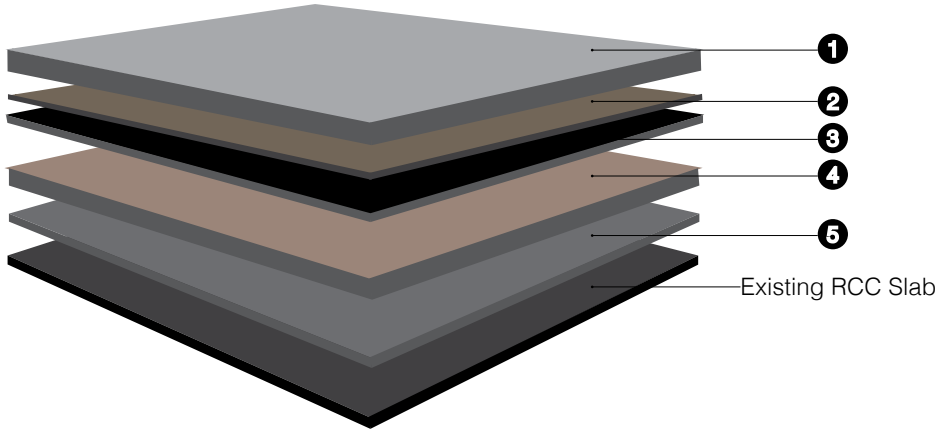
8. EXTRUDED POLY-STYRENE (XPS) SHEET

Site Location: INDORE

Concept

Polystyrene foam has a good resistance to flow of heat and sound and is a commonly used raw material for insulation boards in construction industry. It is commonly available in two forms – Expanded Polystyrene Foam (EPS) formed by expanding beads containing gas and Extruded Polystyrene foam (XPS), formed by adding gas during extrusion. 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, with a good moisture barrier which can severely damage the foam and increase conductivity.

Construction Detail



1. *50mm Average IPS (Cement : Sand : Aggregate = 1 : 2 : 4)*
2. *4 to 5mm Water Proofing (as specified)*
3. *1.5mm thick Membrane over XPS (Extruded Polystyrene) Sheet*
4. *50mm thick XPS (Extruded Polystyrene) Sheet*
5. *20-25mm Cement Mortar Bedding (Cement : Sand = 1 : 4)*

Material Specifications

• Extruded Polystyrene (XPS) sheets - 50-75mm thickness - available as rigid foam boards with a closed cell structure, thermal conductivity at 25 ^{O}C is 0.028 W/m.K, density 32kg/m^{3}.

• Masking/Cello Tape to stick XPS sheet.

• Vapour barrier - in the form of a plastic film of 100-120 gsm

• Ordinary Portland Cement, Coarse sand and aggregate 10mm-20mm for Plain Cement Concrete (PCC), mortar bunds, cement-sand mortar and IPS for finishing.

• Water proofing as per specifications ((Cement Based Waterproofing Treatment).

Application

Step 1

Step 2

Step 2

Step 3

Step 1 : Laying of Cement Mortar Bedding

• Make level markers in a square grid ensuring that the required slope is maintained to drain. Maintain 20mm average thickness of bedding mortar.

Step 2 : Application of XPS Sheet

• Lay XPS sheets over the bedding mortar, connecting the ship laps provided on the edges of the sheet. Ensure that the joints between the rows of XPS sheets are staggered.

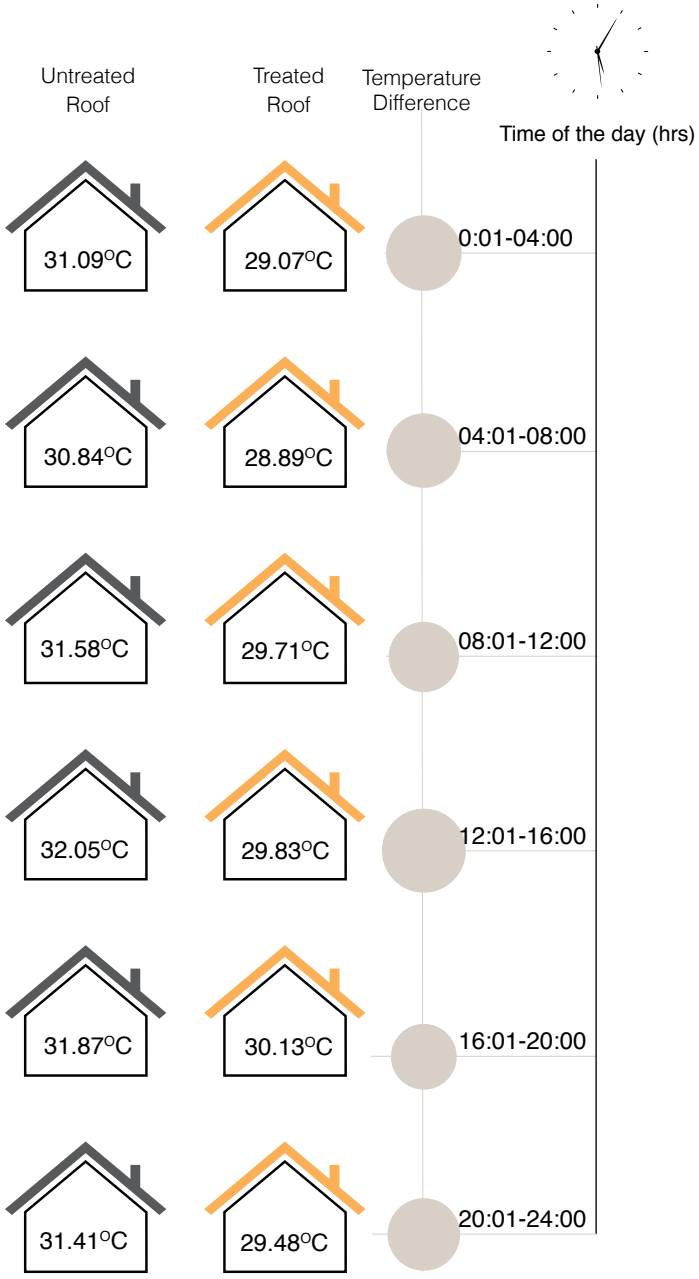
• Place the vapour barrier plastic membrane over the XPS sheets. Provide a 75mm overlap at the edges. Stick the membrane using masking tape.

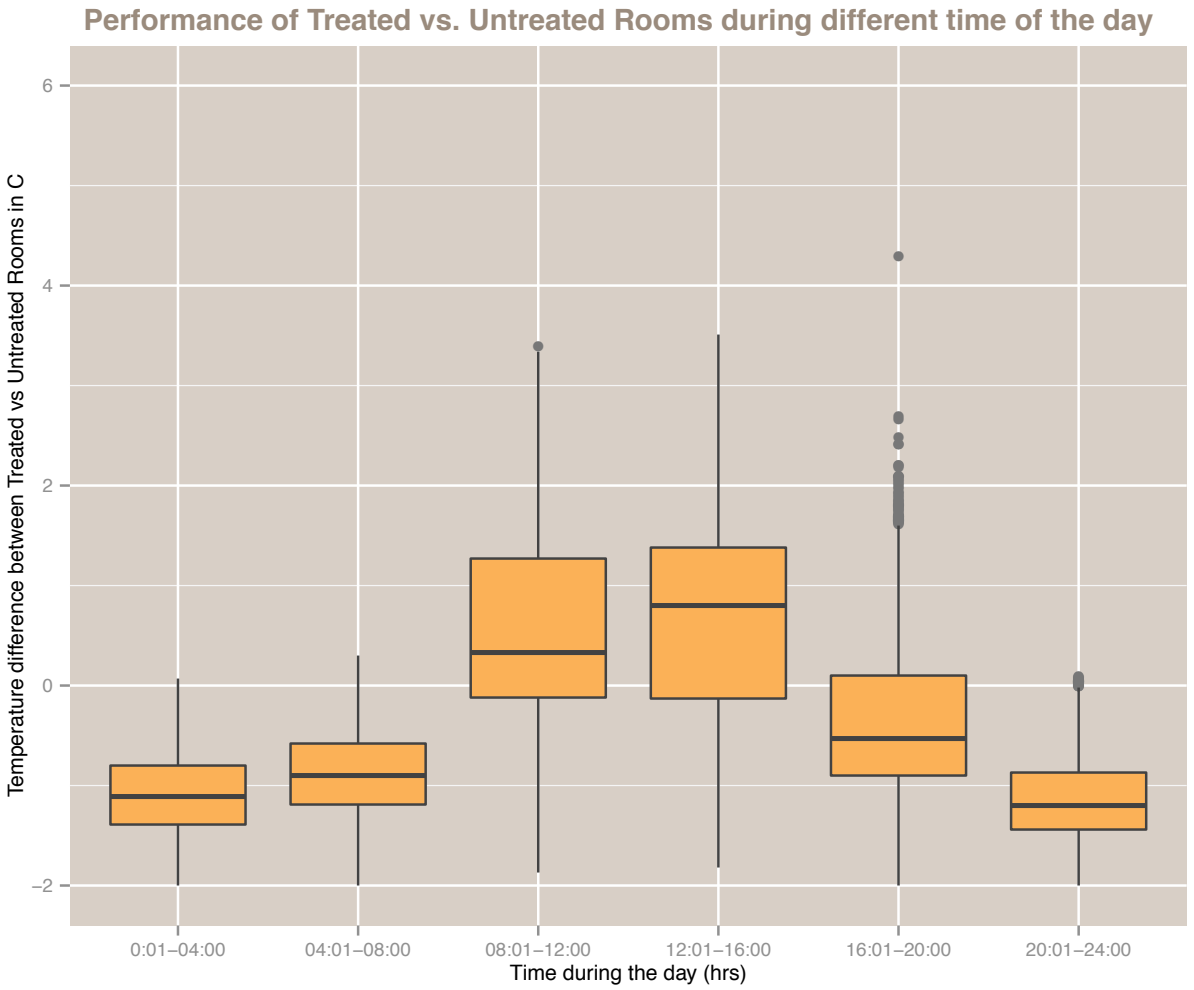
Water proofing is done as per the specifications over vapour barrier.

Step 3 : Finishing with IPS

• Lay 50 mm thick of IPS (Indian Patent Stone) over XPS sheet and smoothen surface using edger.

Thermal Performance





Performance as compared to RCC slab

The treated space remains around 1-2 °C cooler as compared to untreated space, with the performance being better in the afternoon hours.

Cost Calculations

Cost calculation is based on technology demonstration on a terrace of area 100 Sq.m (1,076 Sq.ft.). All rates are market rates or as per Schedule of Rates 2014

Materials and Specifications	Rate (Rs.)	Amount (Rs.)
Material		
Epoxy based Water proofing with Fibre Glass Reinforcement – 1,076 Sq.ft	33 per Sq.ft	35,508
IPS Floor, 1:2:4, 50mm thick - 177 Cu.ft	99 per Cu.ft	17,500
Bedding Mortar cement:sand 1:4, 25mm thick – 88 Cu.ft	91 per Cu.ft	8,000
XPS Sheet (Material + Transport) – 1,076 Sq.ft	50 per Sq.ft	53,800
XPS Sheet Vapour barrier (Material + Transport) – 1,076 Sq.ft	10 per Sq.ft	1,0760
Material wastage @ 5%	-	6,678
Labour		
Epoxy based Water proofing with Fibre Glass Reinforcement – 1,076 Sq.ft	12 per Sq.ft	12,912
Laying IPS – 1:2:4 Skilled – 6 mandays Unskilled – 18 mandays	 750 per manday 350 per manday	 4,500 6,300
Laying Bedding mortar – 1:4 Skilled – 2 mandays Unskilled – 6 mandays	 750 per manday 350 per manday	 1,500 2,100
Laying XPS Sheet – Fixing on mortar Skilled – 4 mandays Unskilled – 12 mandays	 750 per manday 350 per manday	 3,000 4,200
Labour cost for lifting of material from GF to Terrace	350 each Nos.	5,250
Total (Material & Labour) = Rs. 1,71,608 **Cost/Sq.ft Rs. 160**		

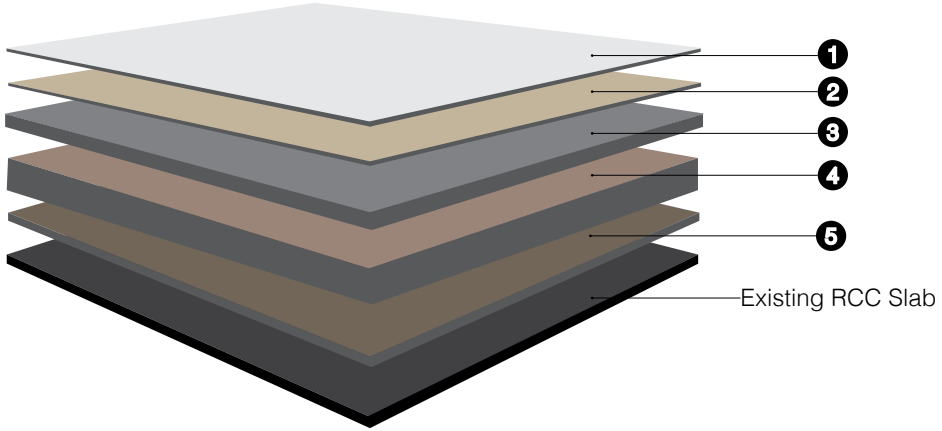
9. CELLULOSE FIBRE

Site Location: INDORE

Concept

Cellulose is one of the most environment-friendly raw materials for insulation sourced from recycled paper and cardboards and processed into a fibrous state. It has a U-value ranging from 0.03-0.04 W/m.K, which is comparable to other conventional insulation options like XPS sheets and is also one of the most fire resistant forms of insulation. In this concept, cellulose fibre is mixed cement-sand mortar. This forms a type of paper-crete in which the fibres get coated with cement sand mortar such that on drying, many air pockets are left inside, giving the dried material an insulating property.
This is topped with an IPS layer which is coated with a paste of ceramic powder to increase surface hardness.

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)*

Material Specifications

• Cellulose fibre - this is fibre based insulation, preferably paper based insulation. The size of fibres should be such that it should be possible to mix it with cement paste

• Ordinary Portland Cement, Coarse sand and aggregate 10mm-20mm for Plain Cement Concrete (PCC) and cement-sand mortar

• Ceramic powder - available as a mineral powder, used as a hardening agent from ceramic industry. This material has been used in an experimental sense and its use is optional

• Hydrated lime for reflective surface

• Water proofing as per specifications (Cement Based Waterproofing Treatment)

Application

Step 1

Step 2

Step 3

Step 4

Note: Surface preparation and Water proofing were done before implementation of this technology.

Step 1 : Application of Cellulose Fibre

• Prepare a mix of cellulose fibre and cement sand mortar. Mix Cement and sand in the ratio of 1:4. Moisten the cellulose fibre so that it can mix easily. Add it to the cement-sand mix, add water to the mix and mix thoroughly till the fibres are properly coated with mortar.
• Cellulose fibre can be added in the ratio of 5-8% by weight of the total fibre-mortar mix.
• Lay the fibre-mortar in 75mm thickness over the water-proofed roof surface.

Step 2 : Laying of Indian Patent Stone

• Lay 50 mm thick of IPS (Indian Patent Stone) over base layer and smoothen surface using edger.

Step 3 : Laying of Ceramic Powder Slurry

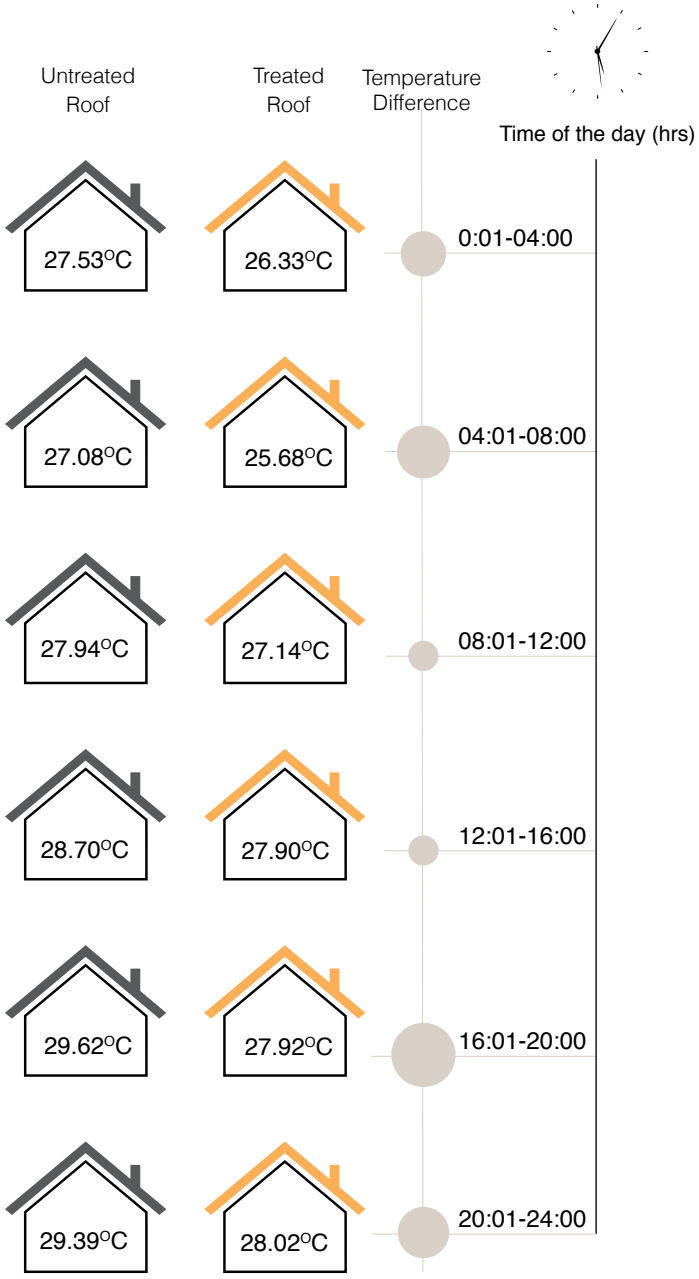
(Note: This is an optional step for additional hardness. A well finished and cured IPS of 50-60mm thickness is also sufficient.)

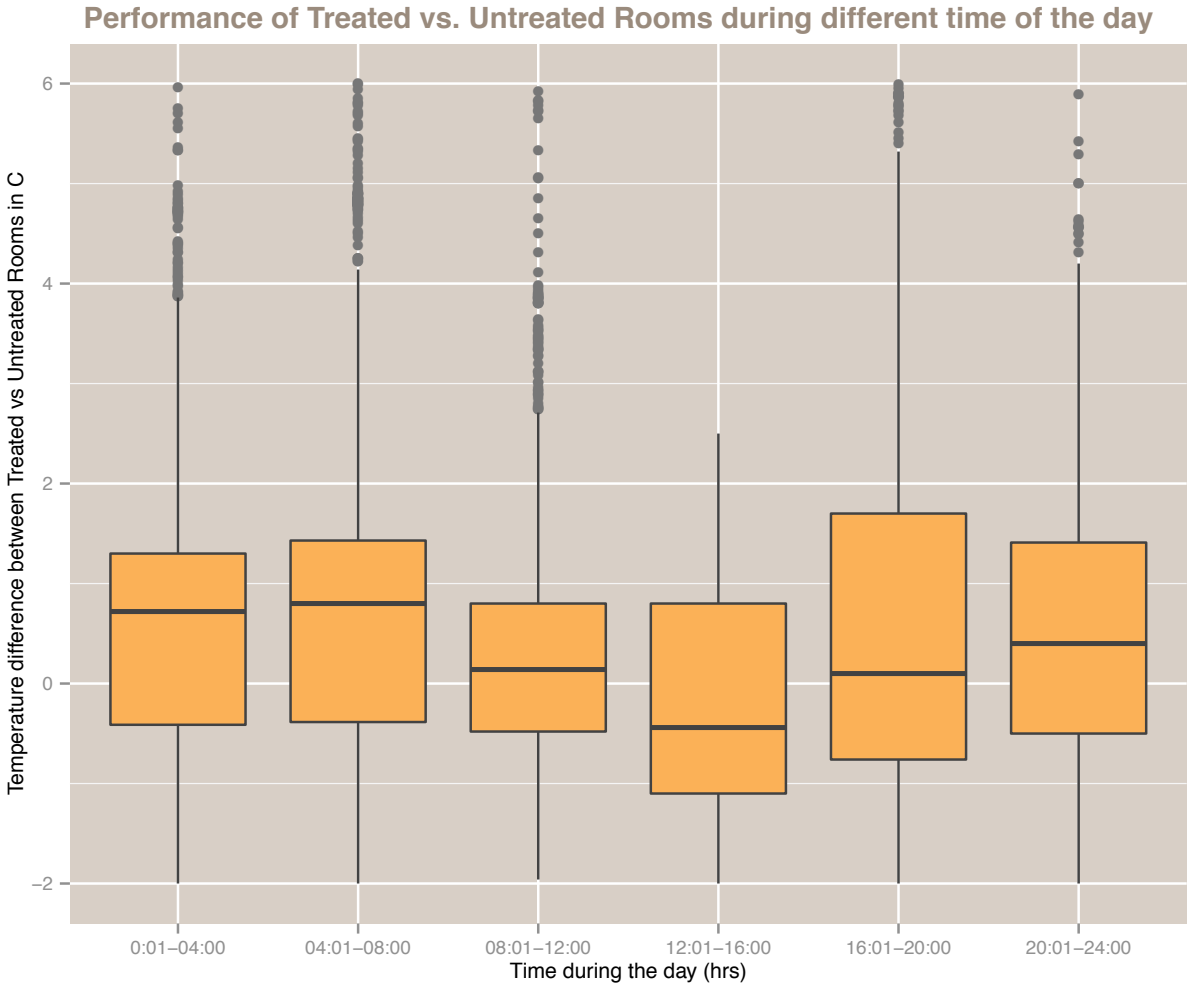
• Square shape markings are done over semi dry IPS surface using thread.
• Mix ceramic powder with water.
• Lay ceramic powder slurry over the semi dry IPS surface to provide hardness to the surface.

Step 4 : Finishing with hydrated Lime

• Mix hydrated lime with water.
• Apply 2 coats of hydrated lime mix over the top surface to make reflective surface.

Thermal Performance





Performance as compared to RCC slab

The treated space remains around 1 °C cooler as compared to untreated space during afternoon and evenings . The sub-optimal performance is possibly because the distribution of cellulose fibre in cement mortar does not sufficiently increase its insulative capacity.

Cost Calculations

Cost calculation is based on technology demonstration on a terrace of area 100 Sq.m (1,076 Sq.ft.). All rates are market rates or as per Schedule of Rates 2014

Materials and Specifications	Rate (Rs.)	Amount (Rs.)
Material		
Epoxy based Water proofing with Fibre Glass Reinforcement – 1,076 Sq.ft	33 per Sq.ft	35,508
Cement Sand Mortar Layer 1:4, 75mm thick - 265 Cu.ft	91 per Cu.ft	24,500
Cellulose Fibre (including transport) - 200 kgs. - 16 bags	250 per Kg.	47,500
IPS floor of 1:2:4, 25mm thick - 88 Cu.ft	99 per Cu.ft	8,750
Ceramic Slurry (Material + Labour) – 1,076 Sq.ft	10 per Sq.ft	1,0760
Material wastage @ 5%	-	6,500
Labour		
Epoxy based Water proofing with Fibre Glass Reinforcement – 1,076 Sq.ft	12 per Sq.ft	12,912
Laying IPS floor – 1:2:4 Skilled – 6 mandays Unskilled – 18 mandays	 750 per manday 350 per manday	 4,500 6,300
Laying Fibre Mortar Layer, 75mm thick Skilled – 4 mandays Unskilled – 12 mandays	 750 per manday 350 per manday	 3,000 4,200
Labour cost for lifting of material from GF to Terrace	350 per manday	3,500
Total (Material & Labour) = Rs. 1,67,780 **Cost/Sq.ft Rs. 156**		

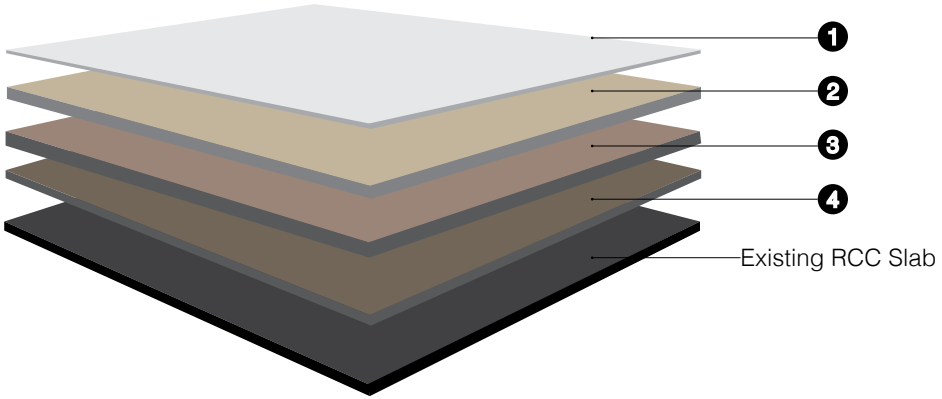
10. CHINA MOSAIC TILING

Site Location: SURAT

Concept

The purpose of china mosaic terrace is to provide a reflective layer to the roof which reflects a considerable amount of solar radiation falling on the roof and subsequently 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, laid on a cement mortar bed, with joints between tiles sealed with white cement.

Construction Detail



1. *Broken China Mosaic tiles fixed with white cement*
2. *20-25mm Cement Mortar bedding (Cement : Sand = 1: 4)*
3. *50mm Level course of PCC (Cement : Sand : Aggregate = 1 : 2: 4)*
4. *4 to 5mm Water Proofing (as specified)*

Material Specifications

• White cement for joint filling with cement slurry. In some cases, colour stainer may need to be added to cement to achieve the required colour of grout with respect to the china mosaic colour. (The ceramic tiles are broken in small pieces of 10 mm to 20 mm approximate size)

• Ordinary Portland Cement, Coarse sand and aggregate 10mm-20mm for Plain Cement Concrete (PCC) and cement-sand mortar

• White cement for joint filling with cement slurry. In some cases, colour stainer may need to be added to cement to achieve the required colour of grout with respect to the china mosaic colour.

• Water proofing as per specifications (Cement Based Waterproofing Treatment)

Application

Step 1

Step 2

Step 3

Step 4

Note: Surface preparation and Water proofing were done before implementation of this technology.

Step 1 : Laying of Plain Cement Concrete

- Lay a layer of Plain Concrete Cement (PCC) of average thickness 50 mm over the dried waterproofing layer.
- Finish the PCC in adequate slope of minimum 1 in 25 as per down take points of the roof.
- Allow the PCC layer to dry for 24 hours.

Step 2 : Laying of Cement Mortar Bedding

- Make level markers in a square grid ensuring that the required slope is maintained to drain. Maintain 20mm average thickness of bedding mortar.
- Lay the bedding mortar over the PCC layer and maintain proper level with edger.

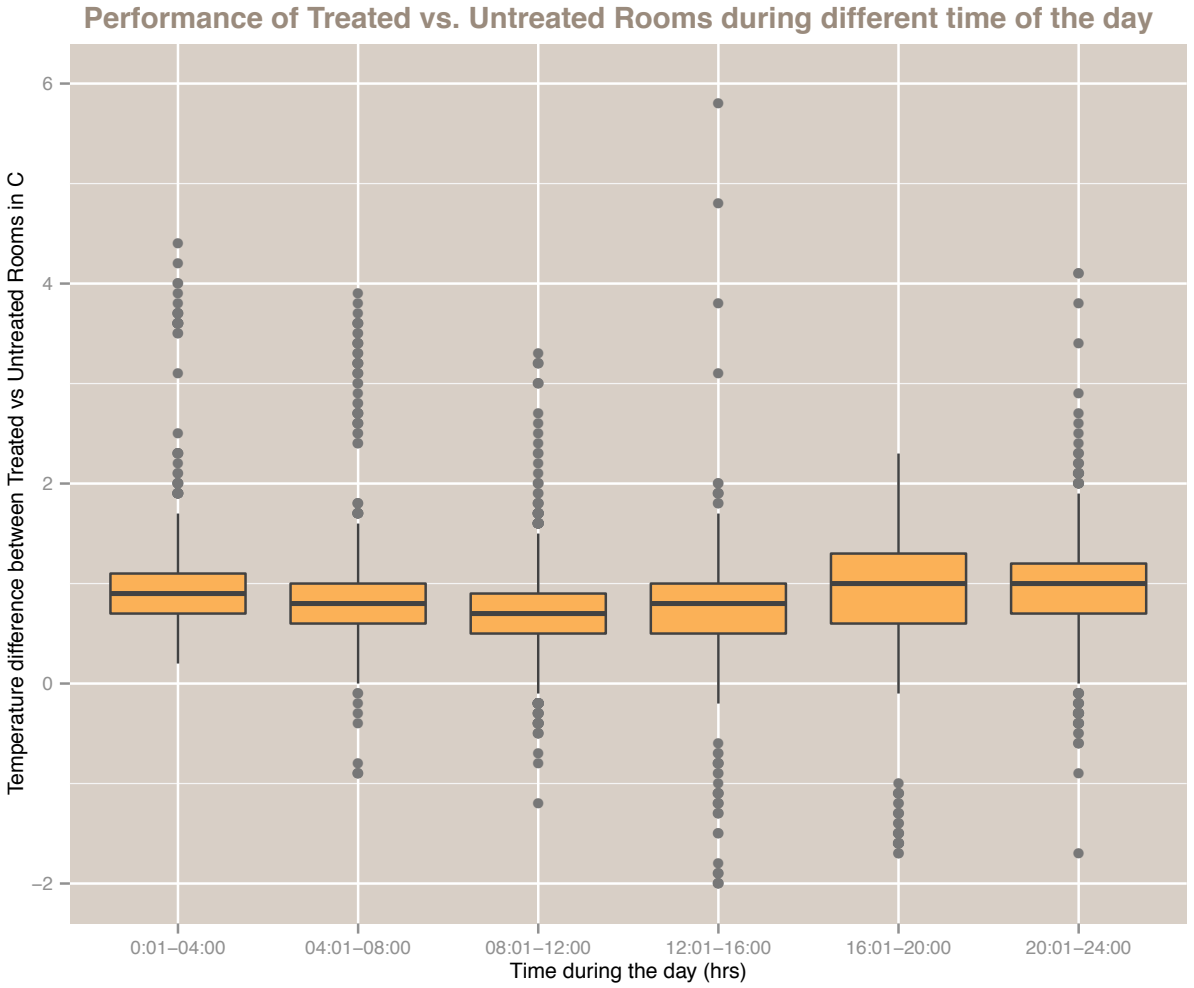
Step 3 : Breaking and Fixing of Ceramic Tiles

- Break the ceramic tiles into smaller pieces of random sizes of 20-30mm.
- Lay cement slurry over bedding mortar.
- Lay the broken ceramic tiles over cement slurry, leaving a gap of not more than 10mm for filling the joints with cement slurry. Fix the tiles tightly be light hammering. Remove grey cement from the joints by scrapping before final set of cement. Depending on the case, the tiles can also be arranged in a mosaic of desired visual representation to create a design.

Step 4 : Finishing and Washing the top surface

- As the tile laying progresses, keep filling the joints with white cement slurry and finishing the joints flush with the tile surface.
- Wash the finished surface with water.
- Cure the china mosaic for at least 24 hours.

Thermal Performance



Performance as compared to RCC slab

The treated space remains around 1 °C cooler as compared to untreated space and the performance remains more or less consistent throughout the day. This average performance can be improved by a addition of a heat resistant layer such as hollow clay tile.

Cost Calculations

Cost calculation is based on technology demonstration on a terrace of area 100 Sq.m (1,076 Sq.ft.). All rates are market rates or as per Schedule of Rates 2014

Materials and Specifications	Rate (Rs.)	Amount (Rs.)
Material		
Epoxy based Water proofing with Fibre Glass Reinforcement – 1,076 Sq.ft	33 per Sq.ft	35,508
Plain Cement Concrete 1:2:4, 50mm thick – 177 Cu.ft	99 per Cu.ft	17,500
Bedding Mortar cement:sand 1:4, 25mm thick – 88 Cu.ft	91 per Cu.ft	8,000
China Mosaic Tiles – 1,076 Sq.ft	25 per Sq.ft	26,900
Material wastage @ 5%	-	5,333
Labour		
Epoxy based Water proofing with Fibre Glass Reinforcement – 1,076 Sq.ft	12 per Sq.ft	12,912
Laying Plain Cement Concrete – 1:2:4 Skilled – 6 mandays Unskilled – 18 mandays	 750 per manday 350 per manday	 4,500 6,300
Laying Bedding mortar – 1:4 Skilled – 4 mandays Unskilled – 12 mandays	 750 per manday 350 per manday	 3,000 4,200
Breaking ceramic tiles for china mosaic Unskilled – 3 mandays	 350 per manday	 1,050
Laying china mosaic – Fixing on Mortar Skilled – 4 mandays Unskilled – 12 mandays	 750 per manday 350 per manday	 3,000 4,200
Labour cost for lifting of material from GF to Terrace	350 per manday	5,250
Joint filling with white cement slurry (material and labour) – 1,076 Sq.ft	10.00 per Sq.ft	1,0760
Total (Material & Labour) = Rs. 1,47,475 **Cost/Sq.ft Rs. 137**		

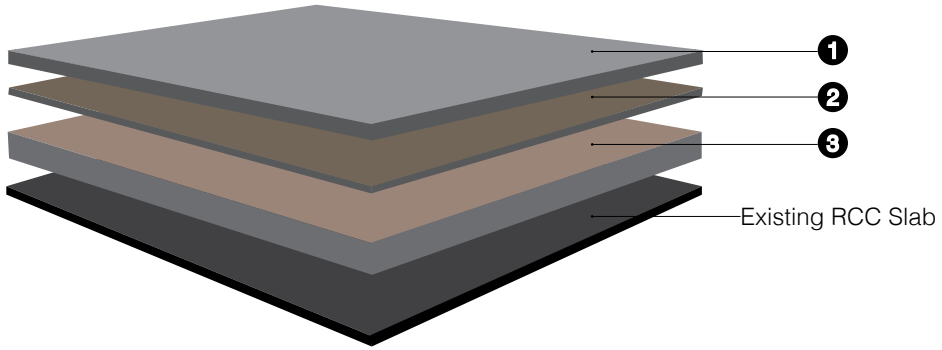
11. THERMOCRETE

Site Location: INDORE

Concept

Air cavities inside a material increases its ability to obstruct transfer of heat or cold through it. This concept is used in a variety of heat and sound insulation techniques such as in EPS insulation, Styrofoam cups, and also in Autoclaved Aerated Concrete (AAC) blocks. Thermocrete uses the same principle in a low-tech way by mixing thermocol (extruded polystyrene) balls/ beads in a concrete mix. Cement concrete finish which is conventionally used in terraces is improved for thermal performance by introducing a layer of thermocrete prepared and poured in-situ at site. The thermocol balls can be conveniently sourced from packaging industries or manufacturers of bean-bags.

Construction Detail



1. *50mm Average IPS (Cement : Sand : Aggregate = 1 : 2 : 4)*
2. *4 to 5mm Water Proofing (as specified)*
3. *75mm thick layer of Thermocrete (Cement : Sand : EPS balls = 1 : 1 : 4)*

Material Specifications

• Thermocol or EPS (Extruded Polystyrene) balls of 10-20mm diameter - these are normally available with suppliers of EPS/ thermocol packaging

• Ordinary Portland Cement, Coarse sand and aggregate 10mm-20mm for Plain Cement Concrete (PCC), mortar bunds and IPS for finishing.

• Water proofing as per specifications (Cement Based Waterproofing Treatment).

• Fibre glass reinforcement sheet for waterproofing (Available in roll of size 1 m x 50 m).

Application

Step 1

Step 2

Step 3

Step 4

Step 1 : Preparing the Cement Mortar Bunds

• Divide the terrace into 2m x 2m compartments of 75mm thickness - this can either be made with bricks or cement mortar. Divide the terrace into 2m x 2m compartments of 75mm thickness - this can either be made with bricks or cement mortar.

Step 2 : Application of Thermocrete

• Prepare thermocrete mixture using cement, sand and EPS (Extruded Polystyrene balls) in 1:1:4 ratio. For 75mm thick thermocrete in a 2m x 2m bund - material quantities are approximately 60-70 kg cement, 60-70 kg sand and 0.8-1 kg EPS balls .

• Fill the bunds with 75mm thick thermocrete. First, mix the ingredients in a dry state, then add some water and mix for 2-3 minutes. Continue to mix till the EPS balls are completely coated in cement mortar.
It is better to prepare the mix in a container instead of a heap which, helps in containment of the lightweight EPS balls during mixing.

• Lightly compact the thermocrete mix using a trowel. Cure the mix for 1 day.

Step 3 : Laying of Cement Mortar and Water proofing

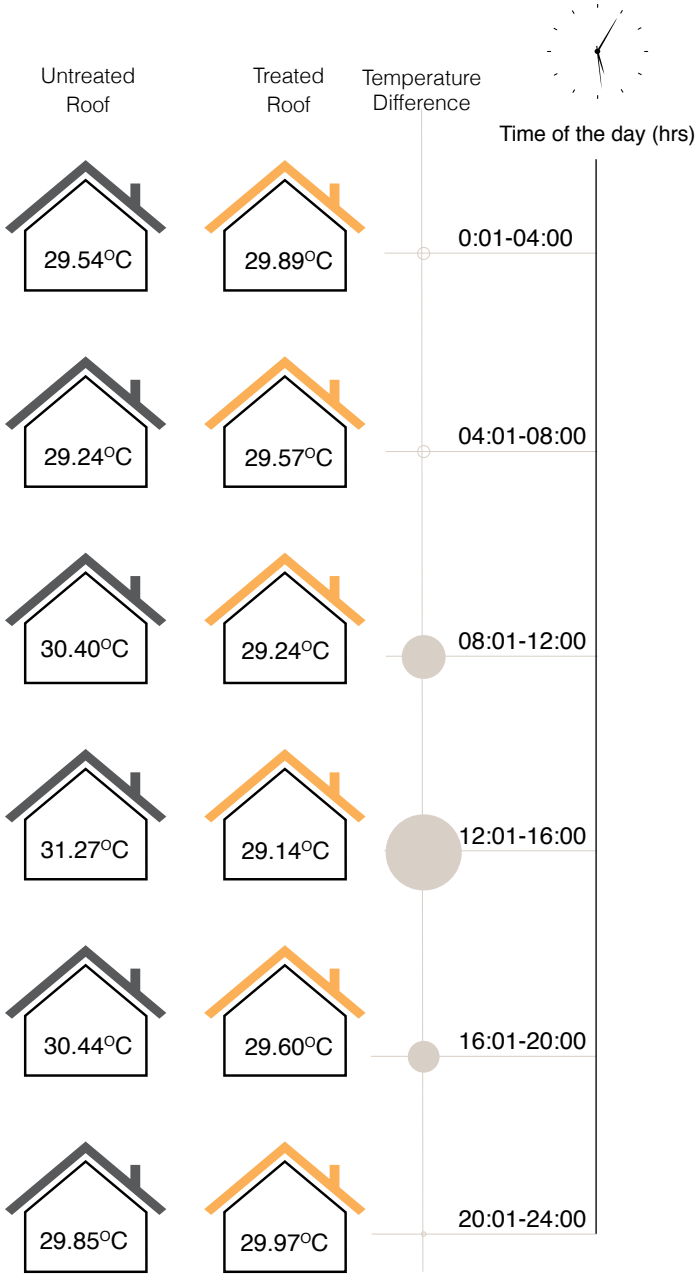
• Lay a cement mortar bed of average 20mm thickness to desired slope. Smoothen the surface using trowel. Cure the mix for one day.

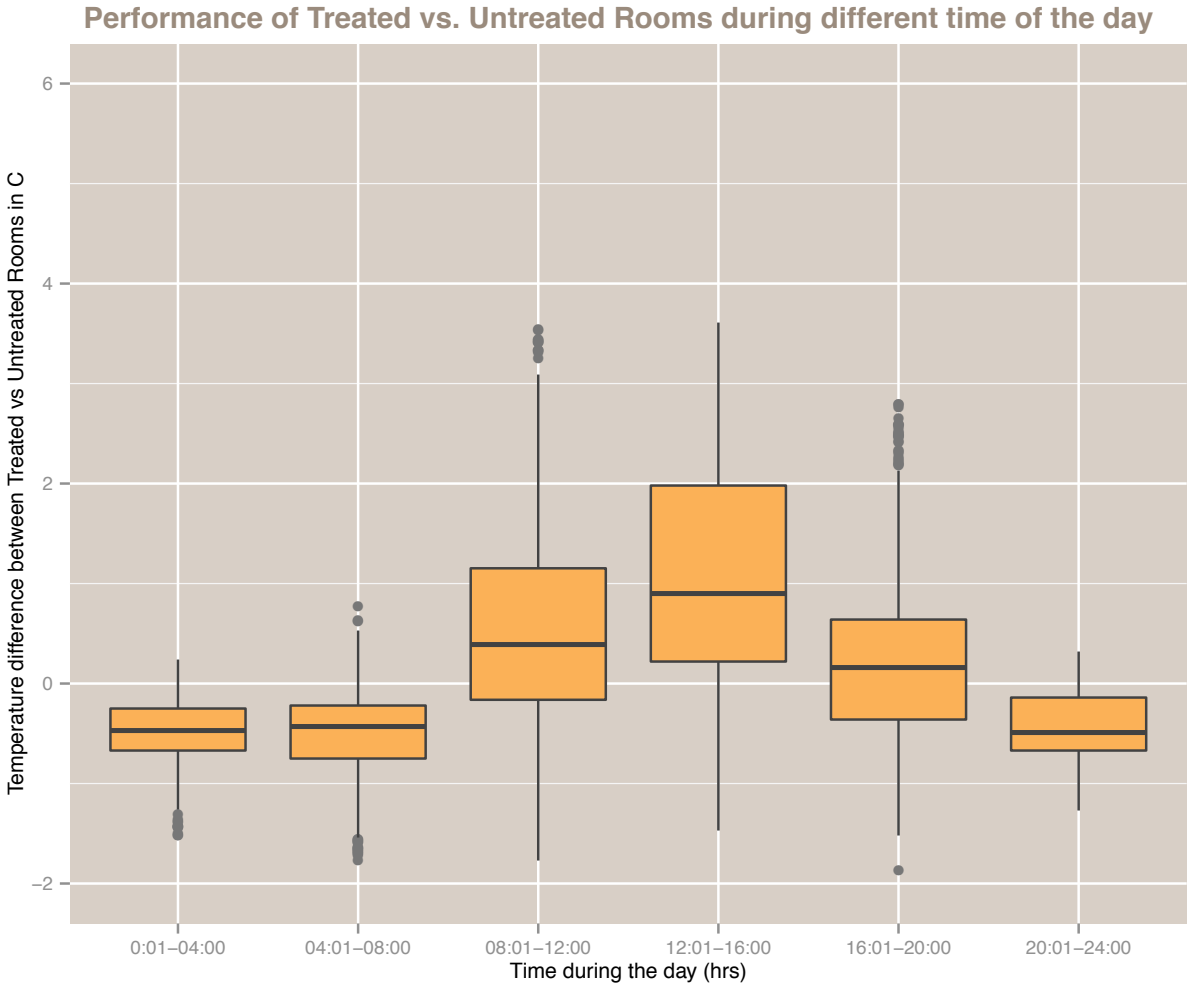
Water proofing is done as per the specifications on Thermocrete

Step 4 : Finishing with IPS

• Lay 50 mm thick of IPS (Indian Patent Stone) over water proofing and smoothen surface using edger.

Thermal Performance





Performance as compared to RCC slab

The treated space remains around 2-3 °C cooler as compared to untreated space, with the performance being better in the afternoon hours.

Cost Calculations

Cost calculation is based on technology demonstration on a terrace of area 100 Sq.m (1,076 Sq.ft.). All rates are market rates or as per Schedule of Rates 2014.

Materials and Specifications	Rate (Rs.)	Amount (Rs.)
Material		
Epoxy based Water proofing with Fibre Glass Reinforcement – 1,076 Sq.ft	33 per Sq.ft	35,508
Cement mortar for making bunds - mix 1:5 - 35 Cu.ft	85 per Cu.ft	3,000
IPS 1:2:4, 50mm thick – 177 Cu.ft	99 per Cu.ft	17,500
Thermocrete, 75mm thick - 1:2 - 177 Cu.ft	71 Cu.ft	18,750
Thermocol Balls (Material + Transport)	340 per Kg.	64,600
5% Wastage on Material Cost	-	6,817
Labour		
Epoxy based Water proofing with Fibre Glass Reinforcement – 1,076 Sq.ft	12 per Sq.ft	12,912
Making mortar bunds Skilled – 1 mandays Unskilled – 1 mandays	 750 per manday 350 per manday	 750 350
Laying IPS – 1:2:4 Skilled – 6 mandays Unskilled – 18 mandays	 750 per manday 350 per manday	 4,500 6,300
Laying Thermocrete, 75mm thick Skilled – 4 mandays Unskilled – 12 mandays	 750 per manday 350 per manday	 3,000 4,200
Labour cost for lifting of material from GF to Terrace	350 each Nos.	5,250
Total (Material & Labour) = Rs. 1,83,590 **Cost/Sq.ft Rs. 170**		

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Prepared by:

TARU

TARU Leading Edge Pvt. Ltd.
M-6, 2nd Floor, Aurobindo Marg, Hauz Khas, New Delhi-110016, India
Phone +91 11 26518271,26518272
Fax +91 11 41580116