FINAL TECHNICAL DESIGN MANUAL

JANUARY 2023

THE INFORMAL HOUSING THERMAL COMFORT PROJECT

CBALANCE
carbon • cost • community • climate

ACKNOWLEDGEMENTS

The 'Informal Housing Thermal Comfort' (cBalance) team would like to express their heartfelt gratitude to Mr. Surendra Shah, our lighthouse of hope-through-grass rooted-action in service of climate justice, who catalysed this endeavour in 2015 with spurring, illuminating insights about the systemic neglect of the extreme heat stress endured by residents of informal settlements in our cities, and a possible local contextual response to them – easily fabricated radiant barriers using readily available materials used in the built-space economy.

We are grateful to Kunda Ramgade and Maya Gaikwad - the women who shared their humbling stories of thermal discomfort in the informal structures they inhabit and for their willingness to participate in retrofitting experiments which involved installing an Alufoil barrier in their homes in the year 2017.

We are also grateful to Saath, Mahila Sewa Housing Trust, India Housing Federation, Micro Home Solutions, Shelter Associates, Homes in the City Network, Hunnarshala Foundation, Ghar Bachao Ghar Banao Andolan and Habitat & Livelihood Welfare Association who shared their experience of working with communities in Informal settlements, which supported us as we strategized our work on the 'Informal Housing Thermal Comfort' (Pilot) project.

We would like to express profound gratitude to our academic coordinator and design mentors (Yogesh Dandekar, Chetan Sahasrabuddhe, Gautami Renuse, and Nishant Rathod) and design interns (Shruti Srivastav, Manasi Jadhav, Zarina Partapurwala, Bhupesh Garg, Leelavathy, Dhananjay Andhale, Noel Prabhakar, Vaishnavi Deshpande and students from the Ananth National Fellowship cohort) who have made invaluable contributions to this endeavour. We are also humbled and encouraged by the contribution of professors from colleges affiliated with BNCA college, and Allana College of Architecture, who mentored us through the design process and encouraged their students to participate in this thermal comfort effort as part of their curriculum. We are immensely grateful to the fabricators; Riyaz, Martin, Nitin, Jeeralal, Shaukat, Subramani and their team for their mindful and skilled support during this endeavour.

We are grateful to the grassroots organisations 'Hasiru Dala', Maharashtra Social Housing and Action League (MASHAL) , Chintan and Habitat and Livelihood Association (HALWA) who anchored our engagement with the local communities. Their rapport with the local communities and their knowledge on how to navigate through different scenarios encountered on field, has helped us persevere mindfully on this journey.

This experimental endeavour would not have been possible without the love, support and participation of the community members inhabiting the settlements in our project cities. Words fall short for us to express the joy we have experienced while working with the communities in Shindevasti, Jyothipura, LalMitti, Rahulnagar and Bhalswa and we are truly indebted to them for their love towards our team and for the knowledge they have shared with us, ever since we started engaging with them.

We would like to express our heartfelt gratitude to the New Venture Fund and Ashden (Fair Cooling Fund) team for believing in this endeavour and for its empathetic engagement with us, throughout.

TABLE OF CONTENTS

I. About The Project..... 3

II. About The Manual..... 4

III. The Technical Design Process..... 5

1. Overview..... 5

2. Overarching Design Stages..... 6

Stage 1 – Material Finalisation..... 6

Stage 2 –Design..... 7

Stage 3 – Fabrication And Installation..... 18

Stage 4 – Performance Measurement..... 31

3. Solution Specific Information..... 32

A. Ecoboard..... 32

B. Alufoil..... 37

C. Roof Top Gardening..... 44

D. Dormer Window..... 50

E. Wood Wool Panel..... 53

F. Water Filled PET Bottle..... 55

I. ABOUT THE PROJECT

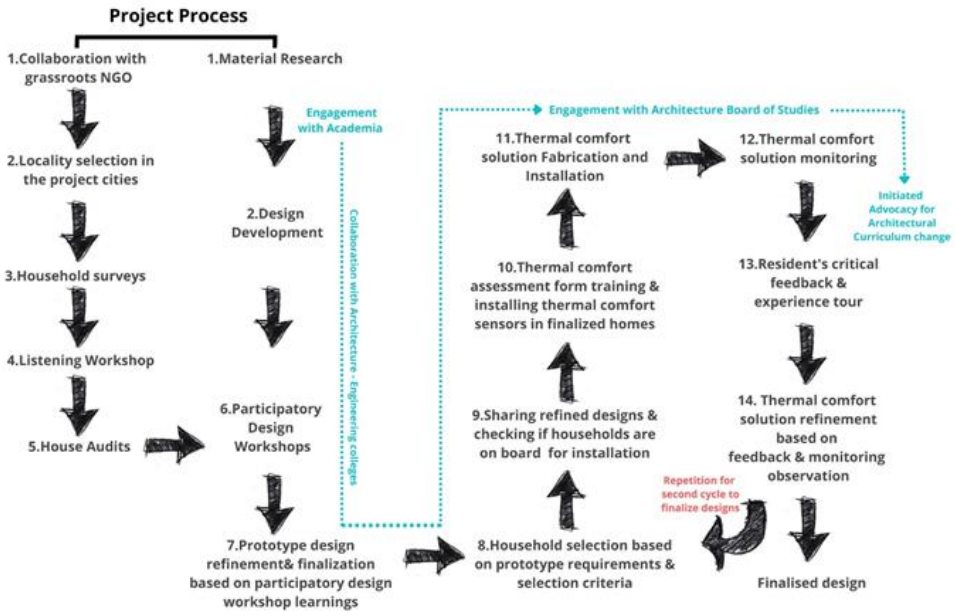
The Informal Housing Thermal Comfort Project (Pilot) is a multidisciplinary and multi-stakeholder experimental project aimed at co-creating thermal comfort solutions with informal housing communities with support from (formal and informal) built space professionals and academia.

The intervention was implemented in two cycles– the prototype design cycle and the design finalization cycle. The stakeholders that were a part of this multi-disciplinary project include NGO partners, community members, designers, architects, engineers, fabrication and installation persons, academicians and the board of studies of Architectural colleges.

The first cycle of the project comprised of listening, participatory design, critical feedback workshops, thermal comfort assessment form filling training and resident experience tours amidst other community engagement endeavours. The focus of the prototype design cycle was to contextualize the thermal comfort solutions 'with' community members and to test the effectiveness of materials and mechanisms from a list of shortlisted solutions such as Ecoboard, Alufoil, etc. At this stage, solutions were installed in a few houses in two cities respectively in homes of residents who agreed to work on experimenting with the co-created solutions which were monitored for a month. They were then revisited for the second iteration of designs. Students from architecture and engineering colleges contributed to the first cycle under as part of their internship program.

During the design finalization cycle, the aim was to refine the design of instillations that needed enhancements and install them in a few more houses respectively, in addition to reinstalling certain installations that needed refinement in the initial houses. There were houses that dropped off from the experiment and new houses that joined midway. The second cycle involved a few community engagement endeavours similar to the first stage which included a meeting to share refined designs and the list of selected households, thermal comfort assessment form filling training, critical feedback workshops and experience tours to harness resident feedback to support the process of finalizing the designs. Additionally, engagement with Architecture Board of Studies members to advocate for curriculum change to incorporate informal housing and sustainable architecture perspectives in university curriculum was also initiated during this cycle.

The flow chart provides an overview of the process flow of each cycle.



II. ABOUT THE MANUAL

This manual encapsulates details of the design, fabrication and installation processes of the thermal comfort solutions experimented with as part of the 'Informal Housing Thermal Comfort' project. It shares the rationale of and approach to the overarching steps that were undertaken to facilitate the design of thermal comfort retrofits experimented with in these settlements in collaboration with community members, fabricators, architecture college students among other stakeholders. The manual comprises questionnaires, checklists, contracts and other components, as applicable. These components are placed in boxes in the manual. The 'Solution Specific Information' section of the manual further describes each thermal comfort retrofit in detail and share guidelines on fabrication and installation for each retrofit solution.

It is vital to understand that while some of the thermal comfort interventions mentioned in this manual might work in certain contexts, they might not necessarily work in others. The weather conditions, spatial characteristics of a region and the receptiveness of a homeowner to a given solution are few crucial factors among a host of other factors that culminate to ensure that an intervention truly serves peoples thermal comfort needs.

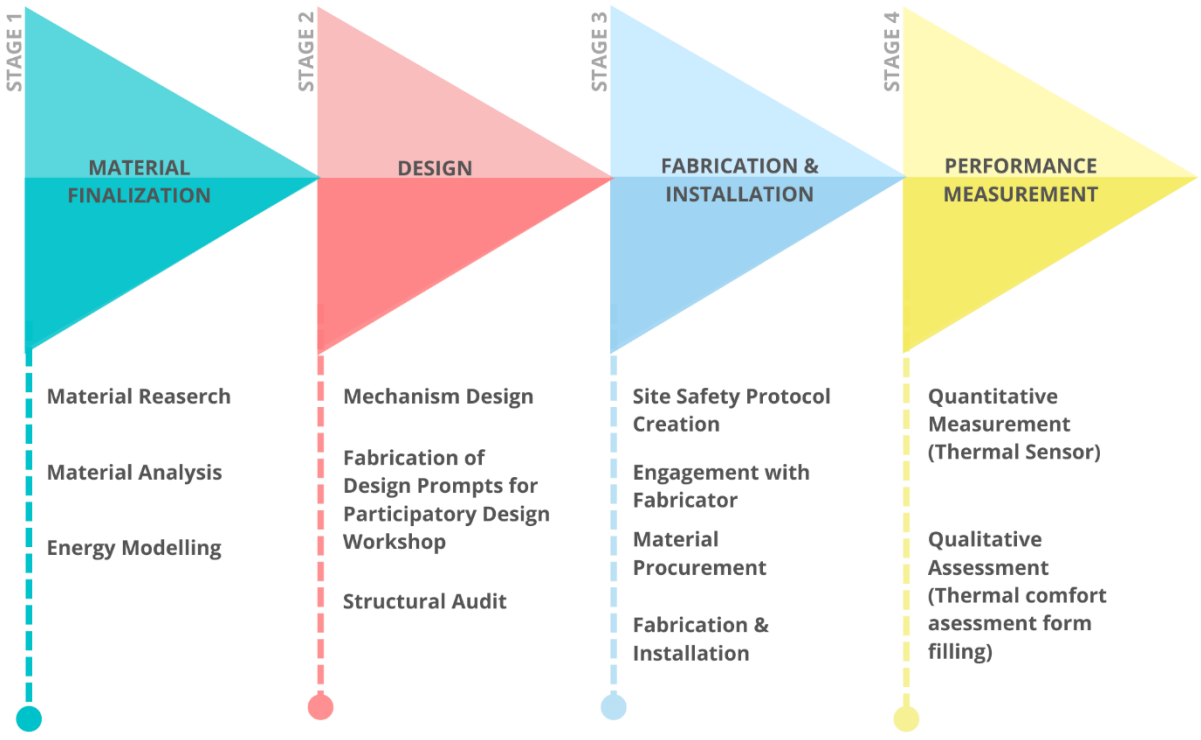
The dynamic nature of 'experimental' and 'community centric' interventions is a key characteristic that warrants attention.

Therefore, the intention is also to keep revising the content of this manual, as new learnings emerge on this journey of ensuring thermally comfortable living conditions by working 'with' inhabitants of marginalized urban settlements.

III. THE TECHNICAL DESIGN PROCESS

1. OVERVIEW

The design process occurred in 4 re-iterative stages which included material research and study, energy modelling, mechanism design, fabrication and installation. The material research focused on identifying materials that support combatting solar heat. During the material study phase, shortlisted materials were analysed against a scoring sheet. The materials were studied to understand certain physical properties like fire resistance, corrosion resistance, thermal conductivity, weight capacity, water absorption, etc. Thereafter, design mechanisms were worked on to support using the material to support with minimizing indoor temperatures in informal structures. The design process was facilitated by internal design team members with guidance from academic design mentors. After the tentative finalization of selected designs, working models were fabricated and shared with community residents at 'Participatory Design Workshops' as design prompts to support co-creating and contextualizing the designs before finalizing them for installation. Inputs from the participatory workshops led to iterations in the initial designs. A structural audit was conducted across homes to decipher which solution may be appropriate for each household. Once the designs were finalized and suitable house structures were identified and residents' consent was sought for the installation, fabricators were brought on-board before the final stage of design for an integrative design-build process, leading up to the installation stage. After installation, readings from sensors were recorded along with the feedback from residents regarding their thermal comfort through 'thermal comfort assessment forms' to understand the performance of the solutions both quantitatively and qualitatively. The stages and steps are illustrated in the diagram below.



2. OVERARCHING DESIGN STAGES

This subsection provides an overview of the overarching stages that were common for all the thermal comfort retrofits that were designed as part of the project. The stages described span material finalization, design, fabrication, installation and performance measurement.

STAGE 1 – MATERIAL FINALISATION

The material finalization processes happened parallel to the pre-installation community engagement process. This section primarily elaborates on 3 aspects: 'Material research and methodology', 'Detailed material study parameters and analysis process' and 'Energy Modelling of the materials.

1. MATERIAL RESEARCH

RATIONALE:

To have a list of materials that can be possibly used as retrofitting materials over the existing roofs of informal settlements to reduce the indoor temperature of informal structures.

APPROACH:

1. Prepare a list of heat combatting materials for detailed material study and analysis through online research.
2. Identify material dealers and manufacturers through online research.
3. Conduct a market study of streamlined materials by connecting with authorised dealers and manufacturers.
4. Gather applied knowledge and wisdom from allies who are working or have experience in the domain of structure cooling based on your networks or through online research.

2. MATERIAL STUDY

RATIONALE:

To study and analyse the selected materials in detail to support finalizing suitable materials for prototype design and installations.

APPROACH:

- Analyse each material identified during the material research stage based on the following criteria:
    - Scientific principles: Thermal conductivity, thermal mass, density, fire and corrosion resistance, water absorption and resistance and UV absorption.
    - Engineering aspects: Weight, load bearing capacity, thickness, sturdiness and wind resistance.
    - Environmental aspects: Embodied energy, water footprint, reusability, recyclability, energy footprint and local availability of the material.
    - Socio-economic aspects: Cost, lifespan, maintainability, local install ability.
    - Applicability (Architectural or Utilitarian): Spatial and structural application patterns, infrastructural requirement and roof application of the material or solution.
- Conduct a comparative analysis of the materials
- Rule out materials that are not suitable
- Conduct a secondary round of analysis for shortlisted materials

3. ENERGY MODELLING AND FULL-SCALE PROTOTYPE TESTING

RATIONALE:

To analyse the projected impact of reduction in temperatures of the selected materials

APPROACH:

Conduct building heat simulations of the shortlisted materials using Design Builder Software (or any other software) for building heat simulation for different type of houses in informal settlements i.e. Kutcha (tin roofed and walled), Semi-pucca (tin roofed and brick walled) and Pucca (brick walled and concrete slabbed) houses.

STAGE 2 –DESIGN

This subsection gives an overview of the design process. The process was initiated after the material finalization stage. It was a re-iterative process which took multiple iterations to reach the final design. This section includes 2 other parts apart from the primary focus on 'Mechanism Design', namely 'Design Prompts' and 'Structural Audit' both of which informed the final design.

1. MECHANISM DESIGN

RATIONALE:

To design a range of simple, affordable and effective thermal comfort solutions comprising over and under the roof, static and dynamic solutions.

APPROACH:

1. Identify criteria that can support the mechanism design process. The criteria for this project included:
    - Simplicity
    - Affordability
    - Local availability materials
    - Experiment with certain sheet or panel-based solutions to test mechanisms based on the concepts of Radiant Barrier + night sky radiation
2. Inform design team members to conduct research about different mechanisms.
3. Ask team members to brainstorm each solution to come up with a design drawing.
4. Schedule weekly internal review sessions with team members to make space to share work progress and receive inputs from other team members.
5. Seek inputs from experienced design persons such as academic and product design mentors on bi-weekly basis.
6. Work on initial design prompts that can be presented to the community for their input.
7. Present the first cut of designs to the community at 'participatory design workshops' to facilitation the co-creation and contextualisation of designs based on their inputs.

2. DESIGN PROMPTS FOR PARTICIPATORY DESIGN WORKSHOPS

RATIONALE:

To fabricate working models that would serve as design prompts for the residents in the participatory design workshops. These were made to highlight some of the working mechanism ideas for the finalised solutions and to also prompt the residents to come up with more ideas

APPROACH:

1. Make a design drawing for each solution and explain it to the fabricator.
2. Evaluate options for locally available materials.
3. Work on identifying simple fabrication techniques for each solution with the fabricator.
4. Ask for the fabrication of 3 ft by 3 ft models for all the design ideas.

Design Prompt: Ecoboard Sliding

Design Prompt: Dormer Window

3. STRUCTURAL AUDIT

RATIONALE:

1. To understand the structure of the house to support refining the design.
2. To decide on which solution is best suited for a particular house structure.

APPROACH:

1. Create a structural audit questionnaire (can be found below)
2. Visit each house and fill the questionnaire with support from residents who are willing to support the audit process.

Questionnaire to Study Existing Structure for Prototype Designing

Team Member Name:

Date & Time:

House No. & Address:

House owner Name:

Note:

Attach photographs for reference.

Take all measurements in meters.

- **General:**

1. What are the dimensions of the structure?

Dimension	Value (in metres)	Comments/ Additional Remarks
Length		
Width		
Height		

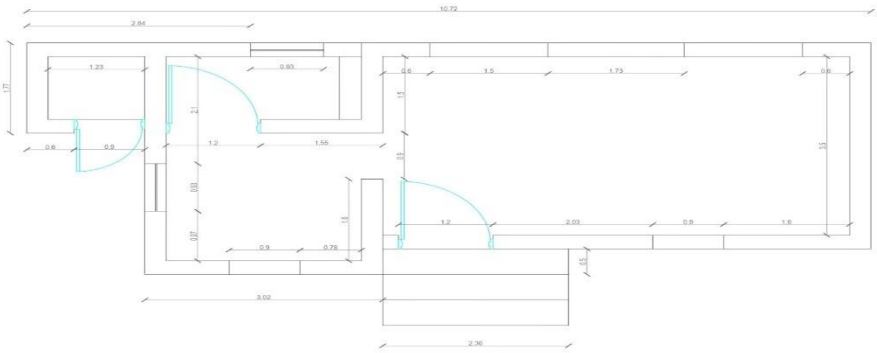
2. What is the temperature during the survey? (Average of 3 measurements/ readings)

- Surface temperature of the walls (℃)
- Surface temperature of the roof (℃)
- Surface temperature of the floor (℃)
- Inside Dry Bulb Temperature (℃)
- Inside Wet Bulb Temperature (℃)
- Outside Dry Bulb Temperature (℃)
- Outside Wet Bulb Temperature (℃)

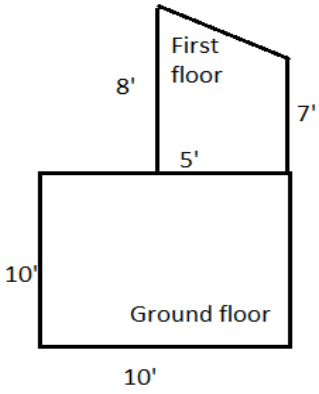
1. What is the layout and orientation of the house? (Direction towards north)

Note:

- *Carry hardcopy of the map of the area to be audited.*
- *Mark the house and its given number on with the help of Google Maps live location. The North will be fixed on the hardcopy.*



Plan



Section

- *To be more precise, in the box given below sketch SLD (single line diagram) PLAN and SECTION of the house with the rooms and other details.*
- *Check the North direction with the help of a compass and note is beside the plan.*
- *While sketching the Plan of the house/structure, label the existing doors (D1, D2), windows (W1, W2) and ventilators (V1, V2).*
- *Get the following details:*

1. *How many rooms are available in the house? (Example- 1 room, 1 toilet, backyard etc.)*
2. *Are there any adjoining structures around the house? If yes, how many and in which direction (N/S/E/W)?*
3. *Is there roof access for installation and maintenance? Ex. Staircase*
4. *Are there high-tension electric wires on the rooftop?*
5. *Do we have outdoor space access for the operation of dynamic mechanisms? (eg. Alufoil chain sprocket needs minimum. 3 feet gap on at least one side of the house)*

6. *How is water stored for use? (Ex : Overhead Tank, Sump, Hand Pump and Drums)*

- <u>Structural Details of Walls, Roof and Floor -</u>

1. Structure Assembly:

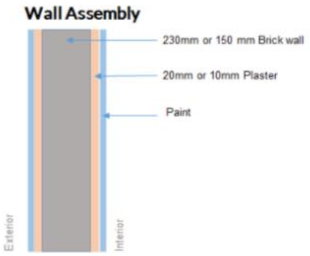
Structure Component (Composition - Assembly)		Type*	Layer 1	
			Material*	Thickness (in mm)
Roof	Flat, Gable, Shed			
Wall	Brick wall, Corrugated tin wall			
Parapet	No type available	NA		

**Notes:*
(i) Roof types; Wall types; Floor types (check reference images below)

Wall

Corrugated Tin wall

Brick wall



Roof

Roof shapes

Corrugated Tin roof

Concrete slab roof

(ii) If the roof is sloping, measure the angle (slope). (Below are the instructions to measure roof angle) (

Smaller Wall Height (m)	*Larger Wall Height (m)*	*Wall Width (m)*	*slope= tan-1(Larger Height - Smaller Height Wall Width)*

(iii) Enter NA if something is not applicable

- Other details of the Structural components:

*Note: *Ask Residents if the auditor can't see any leakage. **Attach pictures of damp surface*

Structural Component	Year of installation/ latest repair	Cracks	Leakage*	Corrosiveness*	Fire Resistance
		Good: approximately <5% area affected Average: 5-10% area affected Bad: >10% area affected	Good: approximately <5% area affected Average: 5-10% area affected Bad: >10% area affected*	Good: No corrosion Average: <5% area affected Bad: >5% area affected	Good: Fireproof Bad: Fire prone
Roof					
Wall					

Parapet					

- <u>Daylight and Ventilation</u>
- How is the Day lighting and Air ventilation in the structure?
  Note: Take this measurement in the center of the structure.
  Measure through Lux Light Meter by keeping it on the floor, switch off all lamps in the structure and measure only daylight

  What is illuminance? _____ lux
  (*Note: Illuminance is a measure of how much the incident light illuminates the surface*)

  a. Daylight - (rate on the scale)

- Very Poor
- Poor
- Sufficient
- Strong
- Very strong

  b. Ventilation - (rate on the scale)

- Still
- Slightly Still
- Just Right
- Slightly breezy
- Too breezy

- How many openings are available in the house?

a. Door-

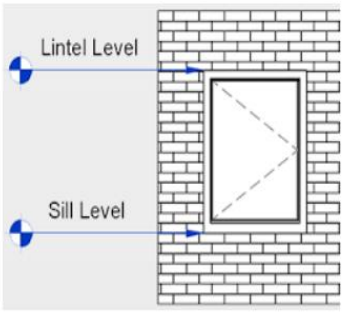
b. Window-

c. Ventilator-

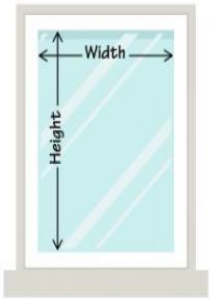
	Window Name	**Window Size**	**Door Name**	**Door Size**	**Ventilator**	**Ventilator Size**
	e.g.W1/W2	**(In metres)**	**e.g.D1/D2**	**(In metres)**	**e.g.V1/V2**	**(In metres)**

Height						
Width						
Sill Level						
Lintel Level						

**Note: Keep the labelling for the doors/windows/ventilators same as the sketch in the General Section. Reference images given below:*



Sill Level and Lintel Level of an opening

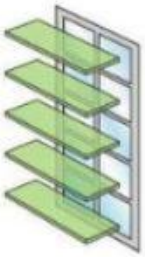


Height and width of an opening

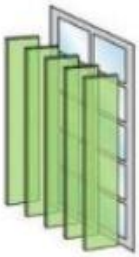
Shading Device

Chhajja

Awning



Horizontal shade



Vertical shade

Ventilator

Exhaust Fan

Jhali Window

Opening in the wall

Sr. No.	Opening name (eg. D1, W1)	Type of shading device used*	Size of shading device used (length x width x thickness)
1			
2			
3			

Note:

1.Keep the labeling for the doors/windows/ventilators same as the sketch in the General Section. Reference images given below:

2.Reference image of shading devices

3.Anything above Lintel level which helps in air and light exchange is a Ventilator.Ex: Exhaust fan, Jhali, Opening in the wall etc

- Additional Information

1. Roof (Supporting) Structure Material - on which the roof is resting or is set up (Example - GI sections/ wood/ bamboo)

2. Water supply system available in structure?(If yes How many tap connections) mention if any leakages found.

3. Rate the structure strength (out of 10)? Post scoring, Kindly describe and elaborate further.

   Note : Sturdy support, no structural enhancement : 7-10 , Medium support, need a few structural enhancements : 4-6, Poor/Damaged support, needs complete structural revamp : 0-3

4. Which day would be preferable to you for the participatory design workshop?

- Sunday
- Monday

- Tuesday
- Wednesday
- Thursday
- Friday
- Saturday

5. What time would be preferable to you for the participatory design workshop?

- Morning
- Afternoon
- Evening

- <u>Solution Specific Questionnaire:</u>

Sr. No.	Solution Name	Selection Criteria	Applicability on current structure	Reason
1	Alufoil (Static)	• Tin walls or brick walls (both are fine) • Sloping or flat roof both are fine • Should have a frame or brick wall to fix the ms sections	Yes / No	
	Alufoil (Dynamic)	• Wall type - Sturdy? • Roof strength - Adequate beam support? • Roof integrity - Any cracks/leakages present? • Roof Parapet - Can a MS Box section structural frame be fixed on the roof parapet?	Yes / No	

2	Modular Roofing Panels	• Sturdy, brick walls • Sloping or flat roof both are fine • Should have a frame or brick wall to fix the ms sections	Yes / No	
3	Fiberglass Insulation	• Flat or slight slope preferred • Structure should have high roof (9-10ft) • Waterproofing needs to be in place (Walls & roofs)	Yes / No	
4	Dormer Window	• Metal roof • Sturdy, brick walls • Sloping roof • Direction of Slope - Ideally facing North and North-East; but can also be installed in North-west, West and East directions	Yes / No	
5	Rooftop Urban Gardening	• Sturdy, brick walls • Sloping roof to drain out water • Accessible roof height (single storey) • 2 side access preferred • Should have own or nearby water source	Yes / No	
6	Water-filled PET-bottles	• Sturdy, brick walls • Flat or slight slope preferred • Accessible roof height (single storey)	Yes / No	

		• Should have own or nearby water source		
7	Wool Panels	• Clear height of the room • Stable walls (Brick / RCC). • The roof should be stable for bearing the load of the installation. • Space between existing roof structure and solution to devise the installation mechanism	Yes / No	
8	Ecoboard static	• Sturdy, brick walls • Flat or slight slope preferred • Structure should be rectangular or square in shape.	Yes / No	

STAGE 3 – FABRICATION AND INSTALLATION

The section provides an overview of 3 processes which were common for the fabrication and installation of all the prototypes. It elaborates on 'Site Safety Protocols', 'Engagement with Fabricators', 'Material Procurement' which supported the final 'Design and Installation Process'

1. SITE SAFETY PROTOCOLS

RATIONALE:

- To ensure safe and dignified working conditions for project workers
- To ensure the safety of inhabitants who open their homes to be part of the experimental endeavour

APPROACH:

1. Reflect on the processes involved in the fabrication and installation to determine possible spaces where caution is warranted to ensure safe and dignified living and working conditions during site work
2. Create a check list of factors that need to be taken care of before, during and after site work

The checklists below can be referred to for site safety procedures.

Safety Protocol Checklist

Date: ..... **Safety supervisor**: .....

Pre installation work:

- Have a handover call with the previous day's team to get updates on the following:
- Any safety measures to be mindful of in relation to today's work.
- Any eatables that need to be purchased.
- Any medical supplies that need to be purchased.
- Arrive at the material storage room 20 minutes prior to the scheduled installation time.
- Ensure the availability of the following items:
  - Water (not packaged)
  - Biscuits
  - Fruits (e.g., Bananas)
  - Torchlight
  - Grievance booklet
  - Log booklet
  - Pen
- Check that the first aid kit with the following material is available.
  - Gauze
  - Electral powder
  - Soframycin
  - Dettol
  - Band aid
  - Scissors
  - Cotton
  - Surgical tape
- Have a contact list of the following available to address unforeseen events:
  - Hospitals
  - Clinics

- Fire station
- Police station

- Carry the above-mentioned food items, booklets, and first aid kit to the installation site.
- After reaching the site, ensure that arrangements are made for residents (whenever applicable)
  - Food arrangements
  - Arrangements to move to a temporary safe space/location during installation
- Check that the installation supervisor is present on site.
- If child labour is present, follow steps mentioned in the 'Emergency Protocol' checklist.
- Check that the following are available at the site:
  - A sturdy ladder
  - A wooden stick
- Check that the project workers are wearing/have carried the following safety equipment:
  - Hand gloves (rubber gloves in case of electrical work)
  - Protective glasses (in case of welding and grinding)
  - Safety helmet
  - Safety shoes.
- Facilitate a safety protocol meeting with the installation supervisor and project workers before commencing installation work.

During installation work:

- Regular/Timely tasks during the installation process
- Remind project workers to wear protective gear as and when required.
- Remind project workers to drink water after every hour.
- Check that the water bottles are filled.
- Check that ladders have firm footholds and handholds before a project worker climbs.
- When a ladder is used, inform the installation supervisor to hold the ladder firmly from the lower side.
- Warn by-passers about possible dangers if they are near the installation work.
- Check that no harm is done to the inhabitants and their belongings
- Attempt to resolve any grievances by project workers and residents non-violently.

- For minor injuries/ accidents, use the first aid kit.
- For major injuries/accidents take the injured person to the nearest clinic or hospital.
- For electrical hazards follow the steps mentioned in the 'Emergency Protocol' checklist.
- In case the installation work continues when it is dark, ensure that a torch is used.

Post installation work:

Daily tasks:

- Allocate 5-10 minutes post installation to:
- Update the logbook
- Make a note of any grievances by project workers and residents in the grievance book.
- Check the status of eatables and first aid kit supplies and make a note of anything that needs to be purchased the next day.
- Place the following in the material storage room:
- first aid kit
- Wooden stick
- Eatables
- Booklets and checklists.

Additional tasks on the last day of installation at a given household:

- Share numbers of project team members with household members after wrapping up installation and inform them to reach out immediately in case of installation related issues.
- Remind household members to fill the thermal comfort assessment forms for 7 days post-installation and inform them that they can reach out to project team members in case of any queries and concerns.

Emergency Protocol Checklist:

In case of Child Labor

- Halt the work
- Inform the fabricator that we do not support child labour and will make a call to 1098 (Childline India Foundation Helpline) if we learn that this practice will continue in the future.
- If the fabricator ensures you that child labour won't continue in the future, make him/her state the same in writing and sign his/her declaration.

- One the fabricator signs the declaration, ask him/her to make provisions for a legal-aged project worker to support the installation process.

If a person meets an electric current

- Disconnect the power supply (if possible) or use a wooden stick to separate the person from the electric current.
- Don't attempt to touch the person until you're certain the power supply is cut.
- As soon as the victim has been freed from the electrical source, call for an ambulance or medical help.
- While waiting for the ambulance, check whether the patient is conscious and breathing.
- If the person is unconscious and has stopped breathing, begin Cardiopulmonary Resuscitation (CPR).
- Keep doing CPR until medical help arrives.
- Place the patient in a recovery position if he or she is already breathing.
- You can prevent shock by laying the patient flat on the ground, with the head slightly lower than the body.
- If the person is conscious and breathing is normal, and if burns are present, cover with gauze, and do not apply ointment or lotion.

2. ENGAGEMENT WITH FABRICATOR

RATIONALE:

To engage with local fabricators humanely and equitably to support the thermal comfort retrofit fabrication process.

CRITERIA:

To identify:

- A fabricator who is ready to and has the capacity to undertake the work in the long-term
- A fabricator based in and around the locality.
- A fabricator who agrees to adhere to safety protocols during the fabrication process.

APPROACH:

1. Send a questionnaire to potential fabricators. (The template questionnaire is in the box below)
2. Analyse the fabricators response to the questionnaire and proceed with the next steps if the fabricators response to the questionnaire indicate potential.
3. Show the designs of the specific solutions to the fabricators to understand their capacity to fabricate the thermal comfort retrofit.
4. Visit their fabrication spaces to gauge their fabrication capacity
5. Select a fabricator who seems most suitable for the project work based on the above mentioned evaluation.
6. Sign a contract signed with the selected fabricator, (a template contract is in the box below the questionnaire under this section)

Interview Questionnaire for Fabricators

1. Name of the Fabricator
2. Location
3. You will provide fabrication for which solutions? (Select all that are applicable)
    a. Alufoil
    b. Wood Wool Panel
    c. Rooftop Urban Gardening
    d. Ecoboard
    e. Water-filled PET bottles
    f. Dormer Window
4. How many employees present?
    a. 0-5
    b. 6-10
    c. 11-15
    d. 16-20
    e. 21-25
    f. 25+
5. How many machines present in the workshop?
    a. 0-5
    b. 6-10
    c. 11-15
    d. 16-20
    e. 21-25
    f. 25+
6. Approx. annual turnover in Rs.
    a. 0-1 lakh
    b. 1-3 lakh
    c. 3-5 lakh

d. 5-7 lakh

e. 7-10 lakh

f. 10 lakh+

7. Child workers present?

   a. Yes

   b. No

8. What are some ways in which you will look to reduce wastage of materials?

9. What are some ways in which you will look to recycle materials?

10. Are you willing to provide warranty for your fabrication? If yes, how much?

11. What is the cost quotation for the selected design(s)? (If possible, provide cost break-up of solutions)

Fabricator Contract

cBalance Solutions Pvt. Ltd. is a knowledge-centric social enterprise rooted in sufficiency and social equity. We build tools to reduce carbon footprint and bridge the gap between climate-crisis knowledge and action by hand holding collectives into integrating the climate-emergency and climate-justice into their actions.

Someshwar Associates is a --- based company working in the field of construction, fabrication and installation.

This contract would lay down the guidelines on Safety, security and humane equity of all stakeholders involved on the fabrication site. Project Lead from Fabricator side, cBalance side and/or involved CSO side would require it to thoroughly go through it and ensure its implementation on the ground.

Safety and Security Guidelines:

- There is enough supply of basic personal protective equipments (*Safety glasses, Flame-resistant gloves, Ear plugs / earmuffs, Welding helmet, Oil-resistant shoes, protective clothing*) for all involved in work.
- All workers should always wear safety gloves and glasses without exception.
- Keep your fabrication shop/site organised, clean and free to clutters. All tools and equipments are kept in their places before and after use. Disorganized floors and messy areas can lead to falls and other injuries, so keep everything organized to ensure the highest safety precautions for you and your team members.
- Emergency contact numbers (Local Ambulance, Fire Station, Local Police station, local doctors, co-workers, important people, etc) be displayed at visible locations and be educated to all regular working people on the site.
- Fire Extinguishers be installed on the site and checked regularly for its proper functioning.

- Ensure a working ambient clean environment is maintained on the site. Enough natural sunlight, air ventilation, and fans are available.
- Basic Medical Kit box be available with all required items in it.
- Clean drinking water and appropriate basic sitting facilities are available.
- Communicate safety rules clearly and hold people accountable. Safety policies must be communicated clearly and effectively to all staff members, including visitors and new team members.
- All the waste generated (oils, metals, plastics, hazardous materials, etc) be appropriately segregated and disposed of which is not harming the environment in any sense.

Humane Social Equity Guidelines

- No child labour be involved during the work on the site.
- No exploitation of labour - labour laws to be followed, minimum wages as per the laws and market to be paid to the workers and helpers.
- Dignity of Labour to be maintained and followed at all levels, especially during conflicts.
- In case of any minor/major injuries or casualty, immediate nearby medical assistance be provided to the victim irrespective of his/her social or economic background.
- Maintain respectful, mindful & professional relationships with all team members and visitors, be it internal or external.

Since the project involves installation activities in the selected houses in the informal settlement, the work should be commenced keeping in consideration certain levels of safety, social equity by both installers and cBalance team coordinator, to ensure fairness and undisturbed environment by the retrofitting related processes and activities. Below are some of the checklists and protocols requested to be kindly followed:

<u>For Installers:</u>

- The installer needs to thoroughly check the installation after the prototype has been installed, in order that no gaps or loose ends are left, which could lead to a variety of happenings such as water leakages, rats, insects, etc. coming in from the gaps. It should be confirmed before the house is re-inhabited.
- Similarly, in case of prototypes which are to be opened/slided open or closed, the mechanical apparatus and functionality of it should be checked after the installation.
- In the installations with electrical work, safety measures to be followed so that no person in the house is harmed due to any carelessness.
- Safety gears and protective implements should be worn and used by all the workers.
- Lighting facilities such as flood lights, hand lights and area lighting should be placed in case of dark working conditions.

- A certain sense of organization and cleanliness be followed while working, the implements or tools should not be spread on the floor in the house. No garbage or leftovers, leave the place better than you found it.
- Child Labour is strictly prohibited. No child below 14 years of age shall be employed to work.
- Labour laws shall be followed, and minimum wages as per the laws and market shall be paid to the workers and helpers.
- No person/animal shall be harmed while the work and installation is being conducted and carried out.
- Medical assistance in case of any injuries be handy and available.
- The time and dignity of the families in whose house the work/installation is being commenced, be respected and the work schedule be adjusted according to their timings and comfort. This is primarily because, the community we are working in are a part of Informal economy i.e., daily wage earners. The time and livelihood conditions to be taken at the priority.
- Sufficiency of materials shall be followed, with minimal waste while at work.

For cBalance team:

- Thorough checking of the prototype installation before re-inhabitancy, so that no casualties or injury is incurred on the inhabitants of the house.
- Work shall be commenced with minimum interference to the surroundings so as not to create any pedestrian blockage or obstruction and prevention of injuries. The cBalance team member should be coordinating the timings and installation logistics with the family, before and after the installation.
- Make sure that the safety measures are followed on site, at work.
- Fair working hours and compensation shall be provided for all the project workers.
- Provide project workers with accessible means to raise workplace concerns. Discipline/ harassment and grievance procedures shall be made available for all.
- All accidents leading to personal injuries and/or property damage shall be reported immediately to the supervisor from cBalance Team.
- In case there are any injuries onsite, caused due to the installations/work fault at any stage of the work, the required medical assistance be provided by the team. First-aid kits including sterilized dressing, cotton wool and antiseptic cream shall be made available at readily accessible places.
- Materials provided by the cBalance team as listed below. Someshwar Associates will have to procure rest of the assembly materials except these given below.

Sr. No.	Material	Concerned Solution
1	Wood wool material sheet	Wood wool insulation

Fabricator Deliverables

Sr. No.	Installation
1	Wood wool panels in household 1
2	Wood wool panels in household 2
3	Pet bottle installation in household 3
4	Pet bottle installation in household 4

Payment Terms:

Sr. No.	Category	Percentage	Amount (INR)
1	Advance Payment	60%	30,000
2	Payment After Installation	40%	20,000
	Total	100%	50,000

Duration of partnership:

15th December 2021 to 24th December 2021 (Extendable subject to installation period)

Authorization:

_____	_____
Fabricator Name **Fabricators Shop name**	**Organisation Member Name** **Organisation Name**

3. MATERIAL PROCUREMENT

RATIONALE:

To procure materials for fabrication and installation.

CRITERIA:

1. To look for places where materials can be purchased at a reasonable cost
2. To look for places closest to the installation site

APPROACH:

1. Come up with the Bill of Material for each solution.
2. Conduct research of material selling places located near the installation site.
3. On identifying a suitable place, ask for the materials to be transported to the installation site.

4. FABRICATION AND INSTALLATION

RATIONALE:

To fabricate and install experimental thermal comfort retrofits.

CRITERIA:

- To use simple fabrication techniques.
- To ensure that the fabrication gets completed in a timely manner.
- To carry out installation with minimum disturbances to the residents and neighbours.

APPROACH:

The approach to fabrication and installation is described in the checklist below.

Fabrication and Installation Preparation Checklist

With external entities (fabricator, community members and NGO partner):

- Check if installation consent is sought from the households.
- Discuss the non-negotiables with the fabricator
  - Safety Protocol
  - Adherence to timelines
  - No child labour
- Discuss list of safety material needed during fabrication process
  - Hand gloves (rubber gloves in case of electrical work)
  - Protective glasses (in case of welding and grinding)
  - Safety helmet
  - Safety shoes
- Discuss prototype designs with the fabricator.
- Visit households to evaluate feasibility of installation with the fabricator.
- Strategize prototype design implementation based on house structure evaluation with fabricator.
- Discuss the types of installation material required based on implementation strategizing discussion with fabricator.

- Discuss the quantity of installation material required with the fabricator.
- Get a tentative daily schedule from the fabricator for material procurement and installation.
- Check if suggested installation day/time is suitable for households.
- Connect with households before installation to understand the need to make arrangements for food
- Connect with households before installation to check if there is a need for a place for family members to stay during installation.
- Arrange for a place in the community to store fabrication material with support from NGO partners.
- Arrange for a room for residents to stay during installation with support from NGO partners.
- Check for community members who can support food preparation with support from NGO partners.
- Find an electrician in the community with support from NGO partners.
- Get an electrical audit done by the electrician for each household to ensure safety.
- Check if the neighbours' walls or roofs are going to be affected due to the installation.
- Seek consent from the neighbours in case their walls and roofs are getting affected due to the installation.

Within the team:

- Orient team members to the purpose and use of the site supervision checklist.
- Conduct mock site-supervision 'role play' / situation-simulation session.
- Orient team members about the prototypes to be installed.
- Arrange for torches for workers and supervisors if working in the evening past sunset.
- Print site supervision checklist, logbook and grievance book.
- Purchase first aid kit material.
    - Gauze
    - Electral powder
    - Soframycin
    - Dettol
    - Band aid
    - Scissors
    - Cotton
    - Surgical tape

Fabrication and Installation Supervision Checklist

Date: ..... Installation supervisor: .....

Pre installation work:

- Have a handover call with the previous day's team to get updates on the following:
- Work done the previous day.
- Work to be done today.
- Any other specific installation suggestions.
- Checklist and logbook availability on site.
- Any property damages
- Charge your phone fully before you leave for the site.
- Arrive at the material storage room 20 minutes prior to the scheduled installation time.
- Check that installation material is available at the site before work begins.
- Check for the presence of the safety supervisor.

During installation work:

- Discuss installation details with the fabricator before the work begins.
- Don't let the installation work begin unless there are a minimum of 2 workers to support the process.
- Regular/timely tasks during the installation:
- Halt the work if a minimum of two workers are not present on site at any point in time.
- Check for minimum interference/ obstruction in the pedestrian pathway.
- Click photographs and videos after every hour.
- Provide project workers with a torch in case of dark working conditions.
- In cases of property damage note the cost of reimbursement in the logbook.
- Check that no loose ends or gaps remain at the end of the installation.

Post installation work:

Daily tasks:

- Update the logbook with the day's installation details.
- Discuss the work to be done the next day with the fabricator and enter details in the logbook.

- Decide on the reporting time for the next day and note it in the logbook.
- Check that installation material is cleared from the resident's house.
- Check that the waste is segregated and appropriately disposed of by the fabricator
- Update the residents about today's work and the work that will happen tomorrow.
- Inform residents about the installation team's reporting time for the next day (if applicable).
- Keep the checklist and logbook in the material storage room.
- Schedule a call with the next day's supervisor to share installation updates.
- Upload photographs to the pre-decided documentation database at the end of the day.
- Communicate property damage (if any) to the admin team the next day and commission reimbursement to the house owner thereafter

Additional tasks on the last day of overall installations:

- Ensure that the material storage space is cleared by the fabricator.
- Pay the room rent for the material storage space to the owner and collect a receipt for the same (as applicable).
- Inform the room owner that the work is complete and that the space has been cleared

STAGE 4 – PERFORMANCE MEASUREMENT

This subsection gives an overview of the thermal comfort performance measurement process. It consisted of two parts, the quantitative measurement and the qualitative measurement, the processes of both have been documented below.

1. QUANTITATIVE MEASUREMENT (PHYSICAL SENSORS)

RATIONALE:

To objectively measure the thermal comfort performance of the thermal comfort retrofits.

APPROACH:

1. Install a memory card in the thermal sensor to capture readings
2. Tag the name of the person who's house the sensor will be installed in on the sensor
3. Install sensors in each house 7 days prior to the installation
4. Install one sensor in a house in the neighbourhood where no installation has/will be undertaken
5. Install one sensor outdoors to capture outdoor measurements
6. Remove the sensor eight days after the installation
7. Analyse the data to estimate the thermal comfort performance of each household in comparison to the surroundings and neighbouring house temperature

2. QUALITATIVE MEASUREMENT (THERMAL COMFORT ASSESSMENT FORM FILLING)

RATIONALE:

To subjectively estimate the thermal comfort performance of the households

APPROACH:

1. Prepare a thermal comfort assessment form (refer to the 'Thermal Comfort Assessment Form Training' sub-section under the 'Community Engagement' section of the manual for the form template)
2. Train residents to fill the form
3. Ask residents to fill the form continuously 7 days prior to the installation and 8 days after installation
4. Collect the form from residents 8 days after the installation.
5. Analyse the data to understand the subjective thermal comfort performance of each solution.

3. SOLUTION SPECIFIC INFORMATION

This section provides a detailed description of each thermal comfort retrofit experimented with as part of this project. Each subsection provides a basic description of a given retrofit followed by describing its working mechanism. It shares its material requirements and describes the fabrication and installation process followed by maintenance guidelines, as applicable. This information is supported by the working drawing and installation image for each retrofit.

A. ECOBOARD

DESCRIPTION

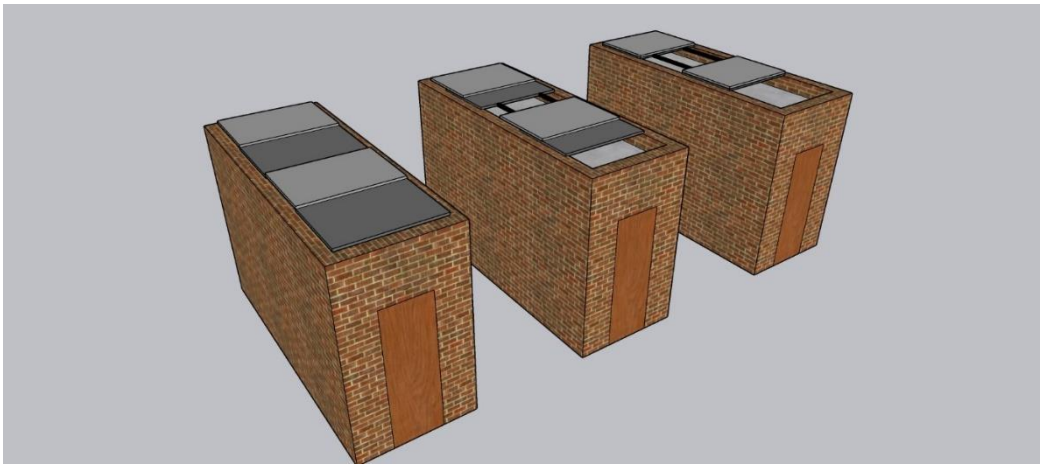
These boards are made from multi-layer plastic which are hard to recycle and end up in landfills usually. Tetra packs and other plastic objects are compressed under high temperature to create a consolidated board that can later be used to make furniture, as doors and other objects.

MECHANISM 1 – SLIDING

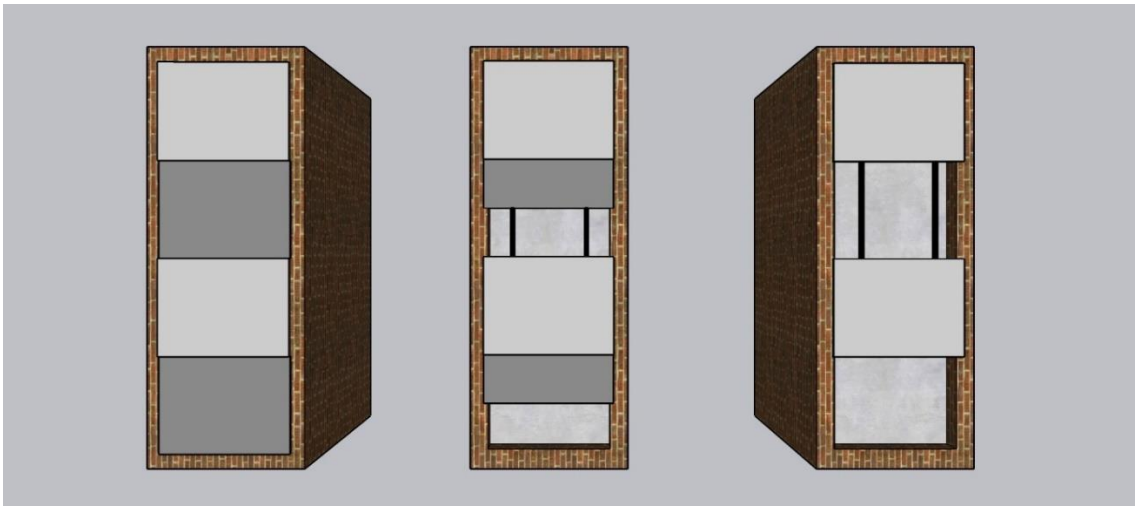
1. MECHANISM DESCRIPTION

The sliding mechanism operates like sliding drawers, wherein channels and rollers help slide the boards to one end of the house to allow night sky radiation to facilitate cooling within the house at night. A pulley mechanism is incorporated within the system to handle the sliding movement.

2. WORKING DRAWINGS



Sliding mechanism (upper view): (left to right) closed, opening, open



Sliding mechanism (upper view): (left to right) closed, opening, open

3. MATERIAL REQUIREMENTS

Eco board, metal pipe with square cross-section, metal-based c-type channels, metal strips, nuts, bolts, long bolt, metal pipes

4. FABRICATION AND INSTALLATION

1. Make fractal design of 12 ft x 8 ft.
2. Calculate the fractals required for the roof.
3. Work out the geometry of the fractals on the roof.
4. Build a metal framework base on the roof.
5. Bolt the framework base to the roof with bolts.
6. Make the static frames on top of the framework by welding the strips.
7. Fix the material on this frame.
8. Beneath the static frame, make another frame through welding the metal strips to house the material.
9. Provide c-channels on the sides for the bottom frame to slide in them.
10. Weld the connecting pipes on the frame.
11. Weld the other side of connecting pipes to the other similar frame.
12. Fix the material on these frames.
13. Weld the nut beneath the base frame.
14. Weld long bolt beneath the bottom frame and ass it through the nut. This is called the half-nut mechanism.
15. Provide a long handle on the nut and bring it down to human height.

5. INSTALLATION IMAGE

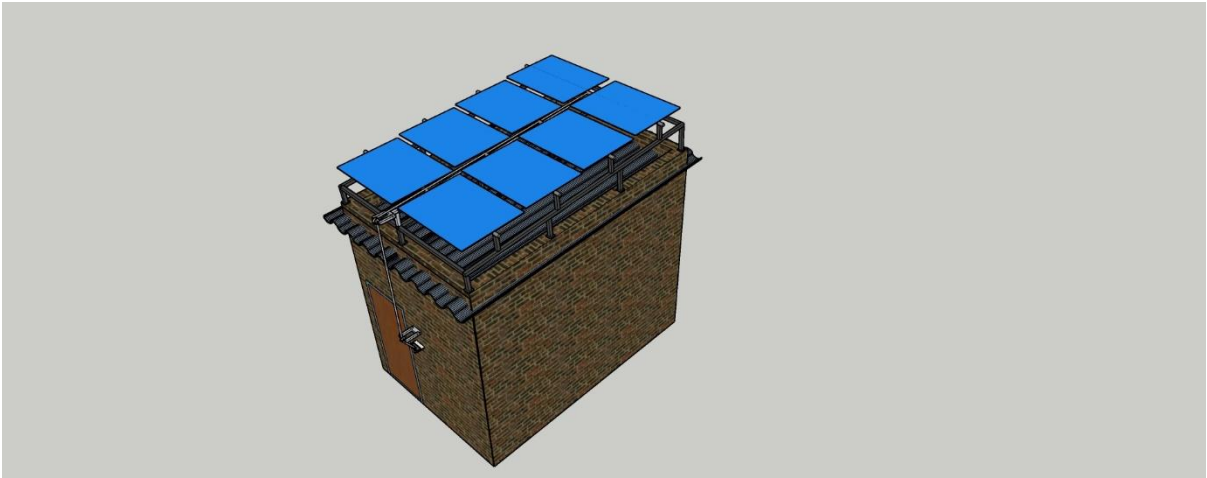
Ecoboard Sliding (Closed)

MECHANISM 2 – CHAIN AND SPROCKET

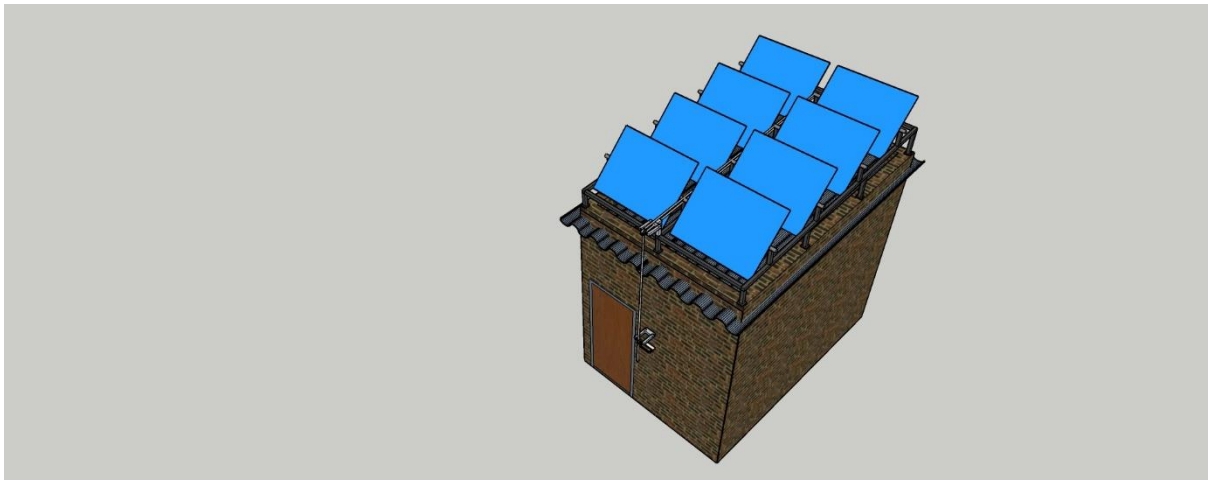
1. MECHANISM DESCRIPTION

The chain-sprocket mechanism works on the principle of louvres, wherein all the panels of the louvres can be opened and closed at the same time to allow radiant barrier and night-sky radiation as required. The movement is enabled with the help of chain and sprockets. It is operated with the help of a bicycle pedal which can move the chain in both the directions to a certain extent to enable the dynamic motion.

2. WORKING DRAWING



Chain-sprocket upper View- Closed Panels



Chain Sprocket Upper view: Open Panels

Chain Sprocket Operation

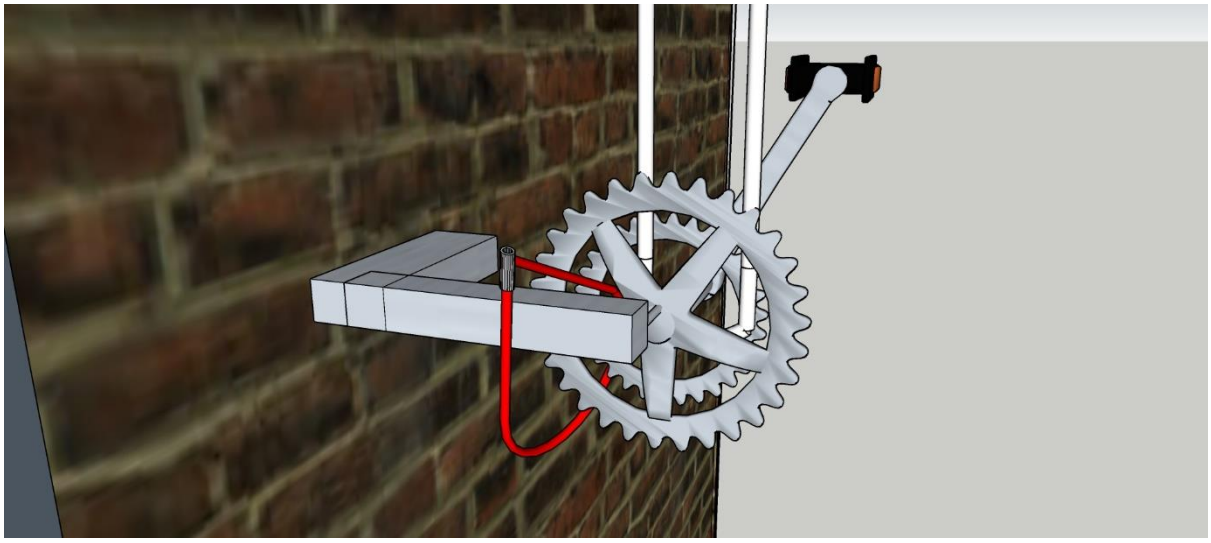
3. MATERIAL REQUIREMENTS

Ecoboard (Conduct aerodynamic analysis of the panels on a software (eg. Ansys fluent) to determine the optimum panel size), metal pipe with square cross section, metal pipe with circular cross section, metal strips, PPGI/GI sheet, bearings (the inside diameter of bearing should match the outside diameter of round pipe), chains, sprockets, self-screws, pulley.

4. FABRICATION AND INSTALLATION

1. Make a fractal design of 12 ft x 8 ft.
2. Calculate the fractals required for the roof.
3. Work out the geometry of the fractals on the roof.
4. Make base frame using square pipes.
5. Weld the support on the base frame using square pipes.
6. Fix base frame on the roof.
7. Weld bearing support pillars using flat metal strips.
8. Weld bearing collars on the metal strips.

9. Fix bearings inside the collars.
10. Insert sprockets inside the round pipe and weld them.
11. The sprockets need to be aligned and welded perfectly in a straight line for smooth functioning of the chains.
12. Synchronize the chains and fix them.
13. Insert the pipes inside the bearing.
14. Make frames using metal strips.
15. Fix the Ecoboard on the frames.
16. Place the framed ecoboard on the round pipe and ensure that there is no sagging.
17. Proceed to weld frames on the round pipe.
18. Fix the pulley in front of the first frame.
19. Fix another pulley down in line with the last pulley so that it is accessible to the human hand
20. Fix chains between the last two pulleys
21. Fix a pedal on the last pulley.
22. Provide a pedal lock on the pedal for locking the mechanism in one position.



Pedal System : Zoomed view

5. INSTALLATION IMAGE

Ecoboard Chain Sprocket (Closed and Open)

B. ALUFOIL

DESCRIPTION

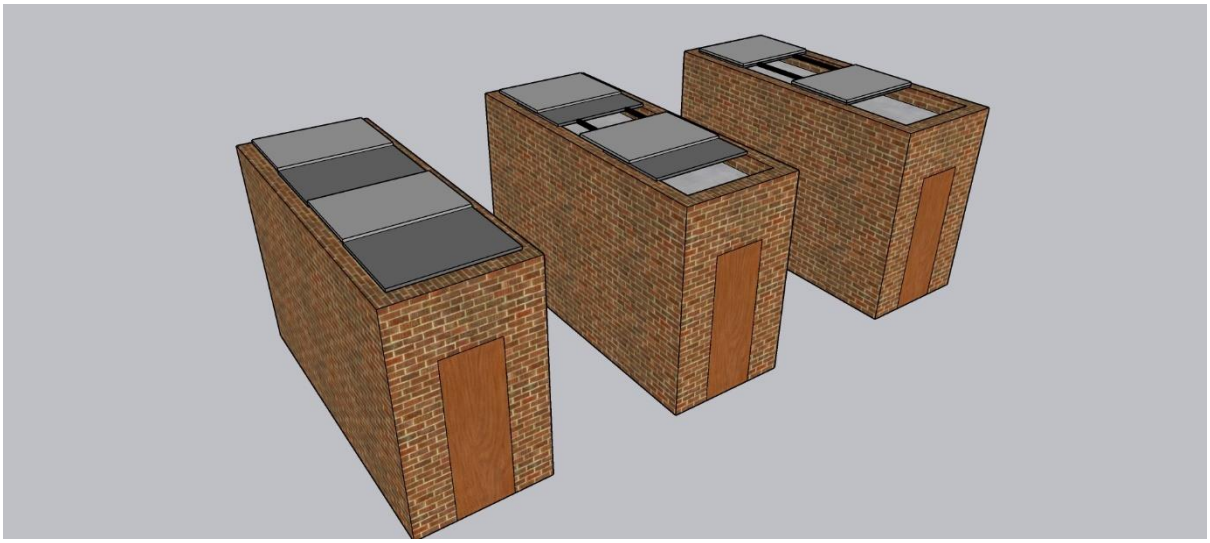
Cross-linked polyethylene foam (also known as XLPE) is a closed-cell foam characterised by a compact feel and resistance to water. It is covered with a low-emissivity and high reflectivity aluminium coating on one side which ensures no heat is emitted inside the space.

MECHANISM 1 – SLIDING

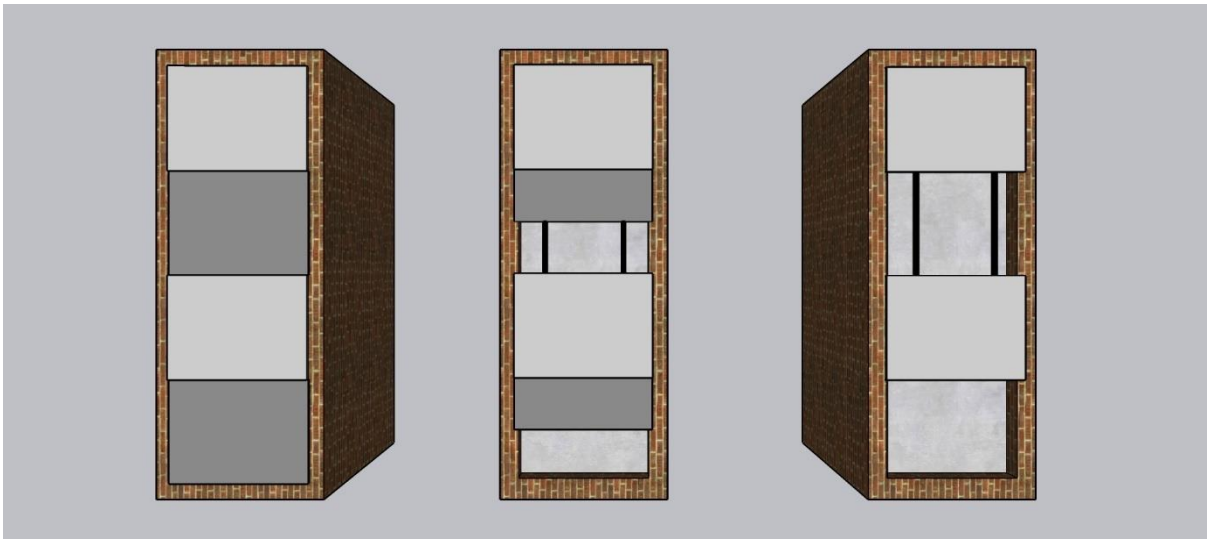
1. MECHANISM DESCRIPTION

The sliding mechanism operates on the principles of sliding drawers, wherein channels and rollers help slide the boards to one end of the house to allow radiant barrier and night sky radiation principles at play. A pulley mechanism is incorporated within the system to handle the sliding movement for the resident.

2. WORKING DRAWINGS



Sliding mechanism (upper view): (left to right) closed, opening, open



Sliding mechanism (upper view): (left to right) closed, opening, open

3. MATERIAL REQUIREMENTS

Alufoil, metal pipe with square cross-section, metal-based c-type channels, metal strips, sliding roller bearings, nuts, bolts, pulley, rope

4. FABRICATION AND INSTALLATION

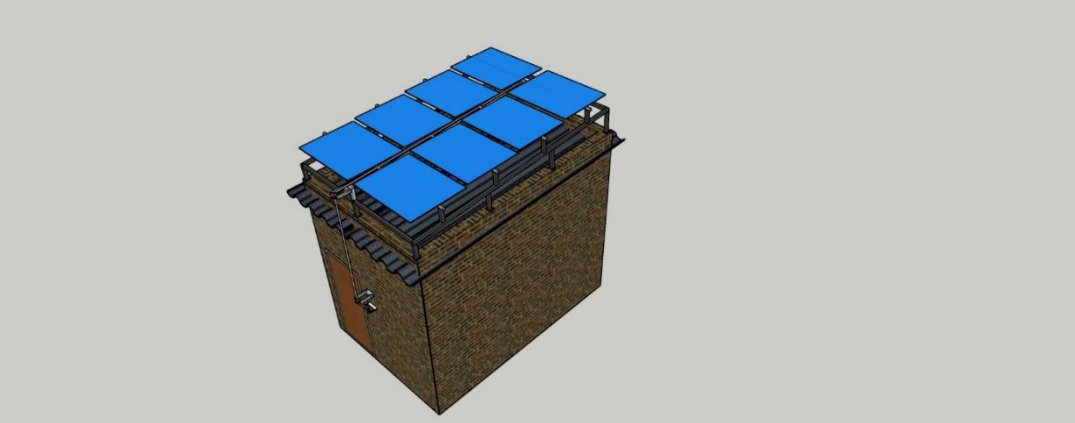
2. Make fractal design of 12 ft x 8 ft.
3. Calculate the fractals required for the roof.
4. Work out the geometry of the fractals on the roof.
5. Build a metal framework base on the roof.
6. Bolt the framework base to the roof with bolts.
7. Make the static frames on top of the framework by welding the strips.
8. Fix the material on this frame such that the shiny side is facing down.
9. Attach GI sheets on top of the material.
10. Beneath the static frame, make another frame through welding the metal strips to house the material.
11. Fix the material on this frame such that the shiny side is facing down.
12. Attach GI sheets on top of the material.
13. Provide c-channels on the sides for the bottom frame to slide in them.
14. Weld the connecting pipes on the frame.
15. Weld the other side of connecting pipes to the other similar frame.
16. Weld the nut beneath the base frame.
17. Weld long bolt beneath the bottom frame and ass it through the nut. This is called the half-nut mechanism.
18. Provide a long handle on the nut and bring it down to human height.

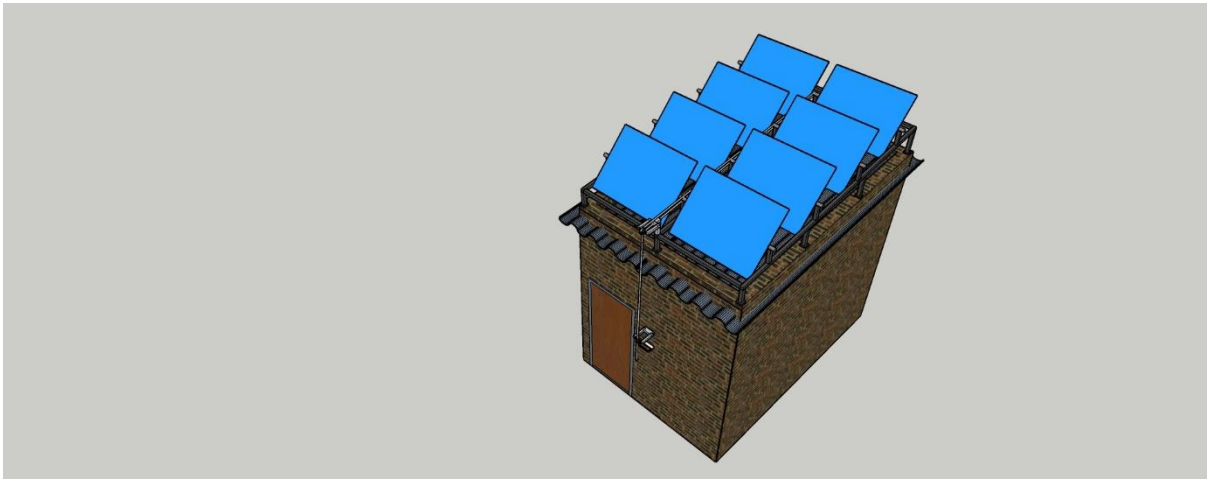
MECHANISM 2 – CHAIN AND SPROCKET

1. MECHANISM DESCRIPTION

The chain-sprocket mechanism works on the principle of louvres, wherein all the panels of the louvres get opened and closed at the same time to allow radiant barrier and night-sky radiation as required. The movement is enabled with the help of chain and sprockets. It is operated with the help of a bicycle pedal which can move the chain in both the directions to a certain extent to enable the dynamic motion.

19. WORKING DRAWING





Chain sprocket upper view: Open panels

Chain sprocket: Operation

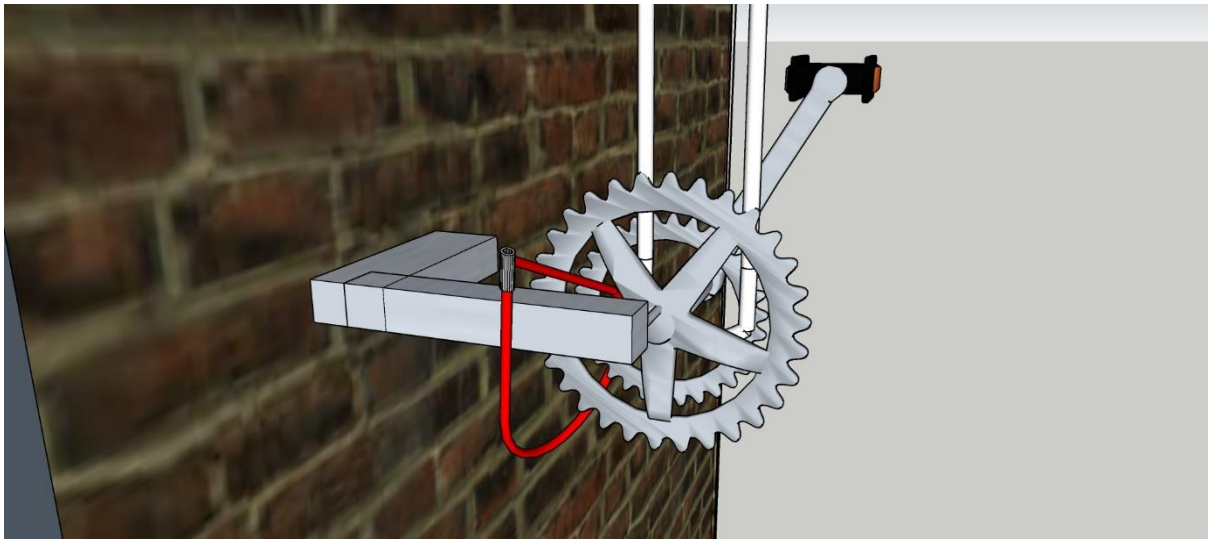
20. MATERIAL REQUIREMENTS

Alufoil, metal pipe with square cross section, metal pipe with circular cross section, bearings (The inside diameter of bearing should match the outside diameter of round pipe), chains, sprockets, self-screws, pulley, rope

21. FABRICATION AND INSTALLATION

1. Make a fractal design of 12 ft x 8 ft.
2. Calculate the fractals required for the roof.
3. Work out the geometry of the fractals on the roof.
4. Make base frame using square pipes.
5. Weld the support on the base frame using square pipes.
6. Fix the base frame on the roof.
7. Weld bearing support pillars using flat metal strips.
8. Weld bearing collars on the metal strips.
9. Fix bearings inside the collars.

10. Insert sprockets inside the round pipe and weld them. The sprockets need to be aligned and welded perfectly in a straight line for smooth functioning of the chains.
11. Insert the pipes inside the bearing.
12. Make frames using metal strips.
13. Fix the GI sheet on Alufoil using self-screws. The non-shiny side of the alufoil should be facing the GI sheet.
14. Fix the GI sheet with alufoil on the frames with the alufoil facing the roof i.e., the GI sheet should be facing the sky.
15. Weld frames on the round pipe.
16. There should be no sagging in the round pipe
17. Synchronize the chains and fix them.
18. Fix the pulley in front of the first frame.
19. Fix another pulley down in line with the last pulley so that it is accessible to the human hand
20. Fix chains between the last two pulleys
21. Fix a pedal on the last pulley.
22. Provide a pedal lock on the pedal for locking the mechanism in one position.



Pedal System: Zoomed view

22. INSTALLATION IMAGE

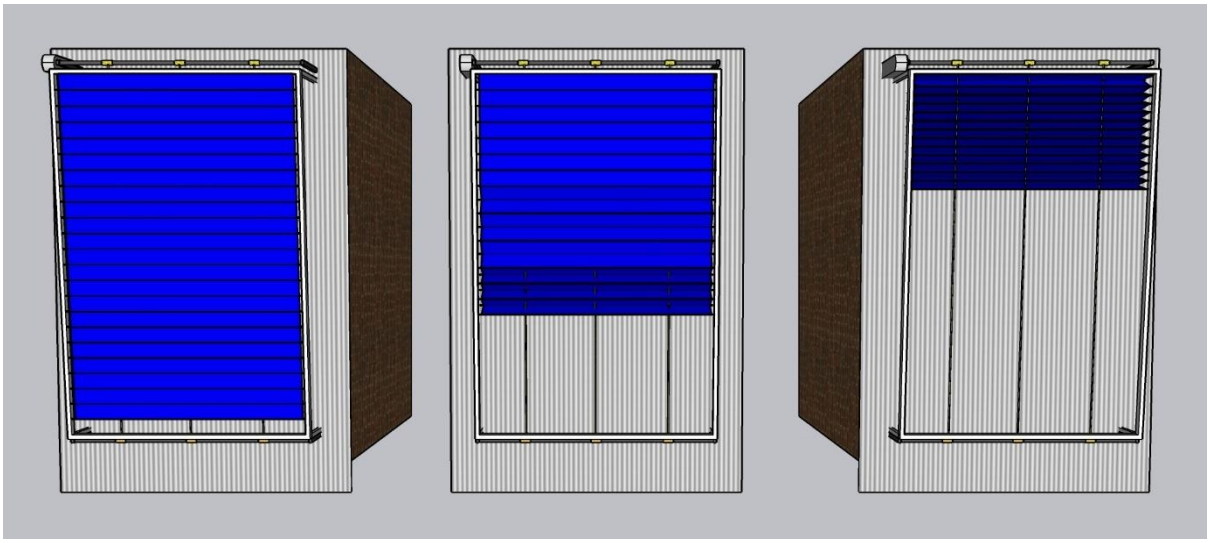
Alufoil Chain Sprocket Installation

MECHANISM 3- PIPE MOTOR

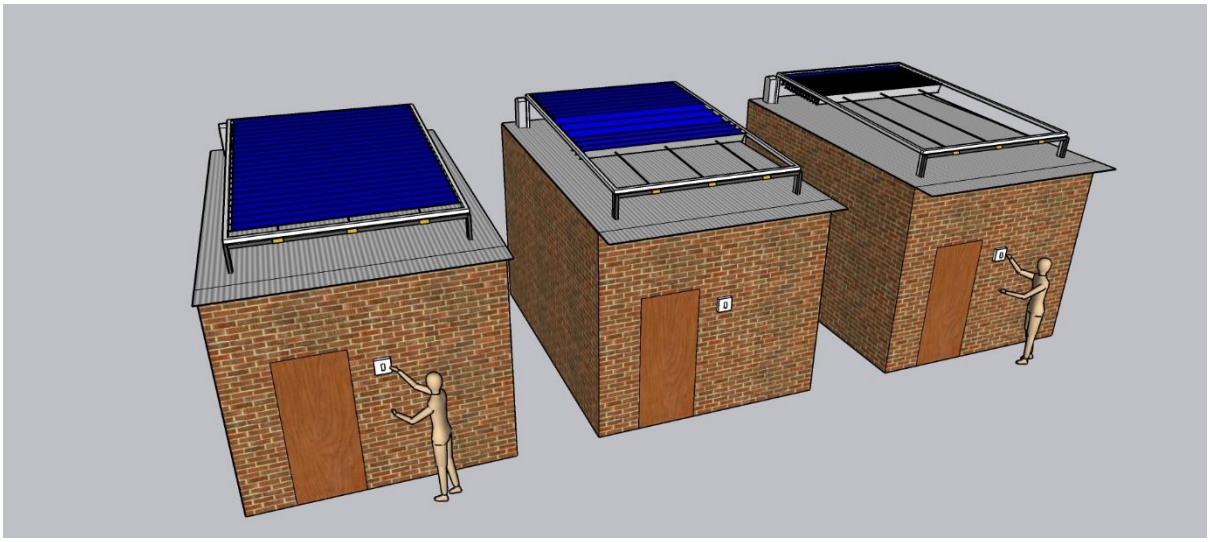
1. MECHANISM DESCRIPTION

The pipe motor mechanism is like an automated curtain mechanism where the Alufoil sheet can be folded and unfolded as required to work as a radiant barrier during the day and facilitate night sky radiation at night. The Alufoil is supported on a rope which winds and unwinds to enable opening and closing the alufoil that is resting on it. The rope is wound on the pipe which is controlled by a motor. There is a switch to enable the opening and closing of the mechanism.

2. WORKING DRAWINGS



Pipe motor mechanism (uper view): (left to right) closed , opening, open



Pipe motor mechanism operation: (left to right) closed , opening, open

3. MATERIAL REQUIREMENTS

Alufoil (The thickness of the alufoil should not be more than 8 mm) , metal pipe with square cross section, metal pipe with circular cross section, bearings (The internal diameter of bearing should match the outside diameter of round pipe) , chains, sprockets, self-screws, steel wire rope with pvc coating, silpaulin (The

silpaulin needs to be at least 120 gsm to ensure long life), nylon rope, thread and needle for sewing alufoil, motor, motor coupling, motor housing, motor cover, hole buttons, silpaulin sewing thread and needle.

4. FABRICATION AND INSTALLATION

1. Make a fractal design of 12 ft x 8 ft.
2. Calculate the fractals required for the roof.
3. Work out the geometry of the fractals on the roof.
4. Make base frame using square pipes.
5. Weld the support on the base frame using square pipes.
6. Weld inverted u-channels on the sides.
7. Put runners inside these channels.
8. Fix the base frame on the roof.
9. Weld bearing support pillars using flat metal strips.
10. Fix bearings inside the collars.
11. Fix pipe inside the bearings such that pipe goes through the bearing and extends on one side.
12. Fix the motor housing.
13. Fix the motor inside the housing.
14. Fix the motor cover on top of the motor
15. Connect the extended pipe and motor with the help of a coupling.
16. Divide the silpaulin into equal number of parts such that each part doesn't exceed 2 feet.
17. Make creases at every division.
18. Put a hollow steel pipe and sew it at every division to make the crease more visible.
19. Install hooks on the sides of these pipes.
20. Connect the hooks to the runners installed inside the side channels.
21. The hooks need to be exactly beneath the runners to avoid it being dragged behind them.
22. Towards the top side of each division of the creased silpaulin, make holes from which the rope will pass.
23. Fix the hole buttons in these holes.
24. Cut the Alufoil strips of the size of each panel.
25. Sew the Alufoil on the underside of the silpaulin such that shiny side is facing downward using Speb 7 or Fevicol SR 996.
26. Wind the steel wire ropes on the round pipe in one direction.
27. Pass the ropes from the hole buttons.
28. Pass the ropes over the pipe on the other end and bring it back to the initial position.
29. The mechanism should not experience sagging. For this tension in the rope is critical.
30. Wind the ropes on the pipe in the opposite direction.
31. Attach flip switch to the motor with the help of an electrician which rotates in the opposite direction when flipped.
32. The pipe which is connected to motor needs to be in one line with no sagging.

5. INSTALLATION IMAGE

Next page

Alufoil Pipe Motor (Closed)

MECHANISM 4 – STATIC

1. MECHANISM DESCRIPTION

This is a fixed/static installation and does not involve moving parts.

2. MATERIAL REQUIREMENTS

Alufoil, Fevicol SR 996/Speb 7 adhesive, metal pipe with square cross-section, metal strips, GI sheets, self-screw, paint

3. FABRICATION AND INSTALLATION

APPROACH 1 (under the roof installation):

1. Apply adhesive on the underside of the roof.
2. Apply adhesive on the non-shiny side of the alufoil.
3. Paste the alufoil onto the roof. Ensure the shiny side faces down.
4. Stick from one direction to ensure that no air gaps get created.

2. APPROACH 2 (over the roof installation):
    1. Cut GI sheets according to the roof measurements.
    2. Cut Alufoil sheet according to the size of the GI sheets.
    3. Stick the alufoil sheet to the GI sheet. The adhesive must be applied on the non-shiny side of the alufoil.
    4. Cut square cross-section metal pipes according to make a frame.
    5. Place this frame at 0.5 ft height from the roof to ensure there is provision for little airflow beneath it.
    6. Paint the frame.

7. Fix the alufoil with GI sheet on the metal frame using self-drilling screw. Ensure the shiny side is facing down.

4. INSTALLATION IMAGE:

C. ROOF TOP GARDENING

DESCRIPTION

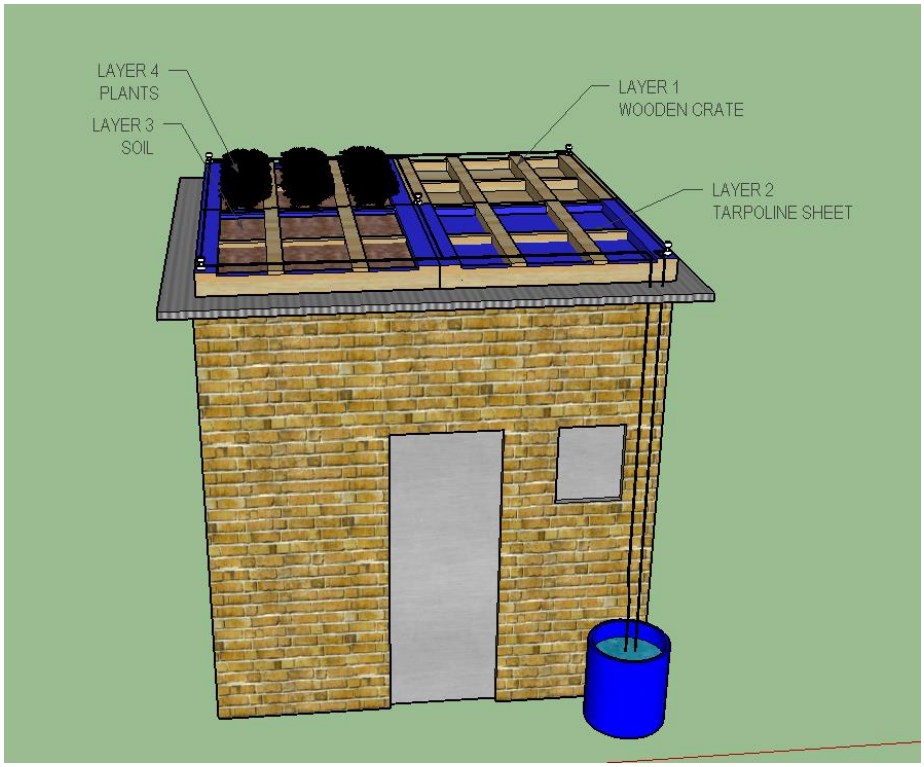
A layer of vegetation cultivated in diverse ways on the roof eg. In pots, brick beds, wooden crates, grow bags, etc.

MECHANISM 1 – WOODEN FRAME

1. MECHANISM DESCRIPTION

A rectangular or square structure with wooden planks installed on the roof serves as a growing space for vegetables and fruits which facilitate shading and cooling through the thermal mass of the soil, in addition to serving as a source of food for the homeowner.

2. WORKING DRAWING



3. MATERIAL REQUIREMENTS

Wooden planks, soil, compost, manure, cocopeat, native seeds (avoid seeds of plants like pumpkin, gourd, etc to avoid heavy load on the roof.), native seedlings (avoid plants like pumpkin, gourd, etc to avoid heavy load on the roof.), red-oxide paint, tarpaulin sheet, green net, bamboo sticks or wooden planks, zip locks, irrigation system (motor pump, PVC pipes, driplines, valves)

4. FABRICATION AND INSTALLATION

1. Ensure that roof is strong enough to bear the load of the soil, water and people who walk on the roof.
2. Vertical support beams of the house structure on which roof is laid should be grounded at least 1 foot deep.
3. Once it is ensured that structure has the capacity to bear the load of the installation the installation work can be commenced by cleaning the rooftop.
4. Apply red oxide paint on the roof and allow it to dry for 30 mins.
5. Spread a tarpaulin sheet over the roof.
6. Prepare a wooden frame according to the shape of the roof. It should be placed over the tarpaulin sheet.
7. The frame should be situated along the slope of the roof.
8. Ensure that a walking space of at least 1 foot is available at all edges of the roof.
9. Keep a holding rope along the pathway to support homeowners walk along the pathway.
10. Make holes on frame towards the lower side of the roof slope to support water drainage.
11. Fix chicken wire mesh (1.6 mm gauge) at the opening of the hole from outside the structure.
12. Prepare potting mix with soil, cocopeat, compost, neem cake/bonemeal powder. Suggested composition is soil (30%), cocopeat (45%), compost (20%), Neem cake/bone meal (5%). It is recommended that the amount of soil be added and more biomass along with Biochar/charcoal be added to the potting mix.

13. Put the potting mix on the tarpaulin and spread it equally on all sides of the structure.
14. Ensure that the soil depth is at least 4-6 inches (Note: 15 bags of potting mix with 25 kgs in each bag is sufficient for a 40 square feet structure of 8 inches' depth.)
15. Sprinkle water so that the entire soil layer is wet.
16. Check for any cracks or bending under the roof.
17. If a bend is observed, immediately stop the work and provide extra beam support to the roof structure, so it can bear extra load.
18. Implement a drip irrigation system on the structure. For this:
    - Lay the drip lines on the soil
    - Fix the valves for every drip line and connect all drip lines with a common pipe
    - Connect this pipe to a water motor (1/2 hp capacity) kept in the house near water tank.
    - Connect the water motor to an electricity source.
    - Check that the water drops fall inside the bag and not outside
    - Fix any issues of water leakage on the path of pipes or on the roof.
    - Depending on the height of the roof and pressure of water, adjust time of watering so soil gets irrigated well.
19. After installing the irrigation system, raise 4 bamboo sticks on the roof.
20. Using zip-locks tie the green net to the bamboo sticks at a height of at least 3 feet from the roof.
21. Give an extra support stick from the centre of the green net. It should look like a cone-shaped elevated green shade net structure.
22. Place trellis sticks at the edge of the structure.
23. Separate sowing lines for each plant type to be made in the soil with fingers.
24. Ensure plant lines are at least 2 inches away from water drip line.
25. Put seeds of vegetables and plants (as appropriate for the season) at maximum depth of 2 inches in the soil.
26. Cover the seeds gently with soil.
27. Apply a light layer of dry grass on the soil as mulch.

5. MAINTENANCE GUIDELINES

1. Ensure that a staircase is available to access the roof whenever needed.
2. Limit frequent walking on the roof.
3. Check the soil moisture and overall health of plants periodically (at least once a week).
4. Regular checks to be made for rats, cats, dogs and other small animals who might build their homes or sleep in the soil.
5. Evaluate for any water leakage or cracks in pipes of drip irrigations system (at least once a week).
6. Evaluate for any water leakage or cracks in pipes of drip irrigations system once a week.
7. The roof should be checked regularly for any bending due to the weight.
8. If bending is observed the strength of the structure should be enhanced or the weight of the intervention will need to be reduced.
9. Ensure water availability in the water tank daily.
10. In case of failing of automated watering or no electricity, water the plants manually.
11. In case green net structure falls due to heavy winds or any other reason, reconstruct it back quickly.
12. Follow seasonal multi cropping of seeds.
13. After each season (3-4 months), rehash entire soil and mix more compost, cocopeat or manure to it and layer the soil again. Keep remnants of previous plants as biomass.
14. Keep irrigating the soil at least twice a day in summer season.
15. Clean the chicken mesh at drainage holes at least once in 3 months.
16. During monsoon, if water logging in the soil is found then manually remove the water.

17. Replenish with soil if too much of erosion is observed.

6. INSTALLATION IMAGE

At the end of the next section (with growbags)

MECHANISM 2– GROW BAGS

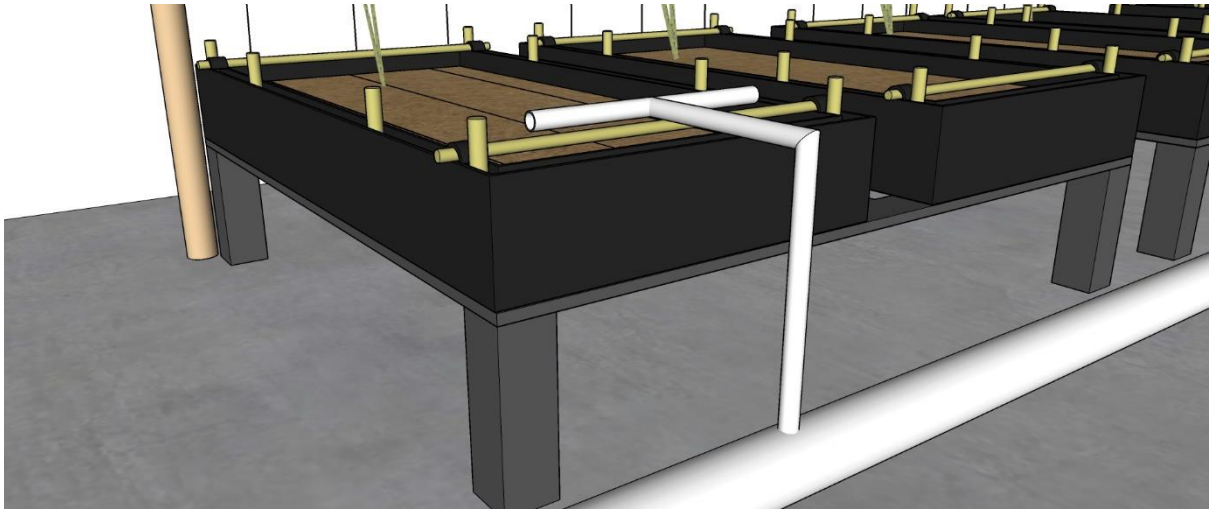
1. MECHANISM DESCRIPTION

Vegetables and fruits are grown over the roof in growbags. Growbags are made up bio fibre material. This installation supports cooling through shading and thermal mass of the soil, in addition to serving as a source of food for the homeowner.

2. WORKING DRAWING

Rooftop garden: zoomed out view.

Rooftop Garden: zoomed in roof view.



Rooftop Garden: Watering System

3. MATERIAL REQUIREMENTS

Growbags (4*2 square feet), bricks, soil, compost, manure, cocopeat, native seeds (avoid seeds of plants like pumpkin, gourd, etc to avoid heavy load on the roof.), native seedlings (avoid seeds of plants like pumpkin, gourd, etc to avoid heavy load on the roof.), green net, bamboo sticks or wooden planks, zip locks, irrigation system (motor pump, PVC pipes, driplines, valves)

4. FABRICATION AND INSTALLATION

1. Ensure that roof is strong enough to support the load of the soil, water and people who walk on the roof.
2. Vertical support beams of the house structure on which roof is laid should be grounded at least 1 foot deep.
3. Once it is ensured that structure is ready to bear the load of the installation the installation work can be commenced by cleaning the rooftop.
4. Make stands for grow bags with a height by welding square pipes.
5. Place growbags on the stands such that the longer side of the bag is along the slope
6. Ensure walking space of 1 foot at least is left from all edges of the roof.
7. Keep at least 2 feet between 2 growbags as walking space.
8. Prepare potting mix with soil, cocopeat, compost, neem cake/bonemeal powder. Suggested composition is soil (30%), cocopeat (45%), compost (20%), Neem cake/bone meal (5%).
9. Put the potting mix in the bags and spread it equally on all sides of the bag.
10. Ensure soil depth is at least 4-6 inches (Note: One growbag can have 100 kgs potting mix with soil height of 3 inches.)
11. Fix bamboo sticks (of 1 foot each) at all the 4 corners, so a proper rectangular shape of bag is maintained.
12. Tie ropes in a mesh form to make guideways for creepers to grow.
13. Sprinkle water over the entire soil layer.
14. Implement a drip irrigation system on the structure. For this:
    - Lay the drip lines on the soil
    - Fix the valves for every drip line and connect all drip lines with a common pipe
    - Connect this pipe to a water motor (1/2 hp capacity) kept inside the house near water tank.
    - Connect the water motor to an electricity source.
    - Check that the water drops fall inside the bag and not outside
    - Fix any issues of water leakage on the path of pipes or on the roof.

- Depending on the height of the roof and pressure of water, adjust time of watering so soil gets irrigated well.

15. After installing the irrigation system, raise 4 bamboo sticks on the roof.
16. Use zip-locks to tie green net to the bamboo sticks at a height of at least 3 feet from the roof.
17. Give an extra support stick from the centre of the green net. It should look like a cone-shaped elevated green shade net structure.
18. Place trellis sticks at the edge of the structure.
19. Separate sowing lines for each plant type to be made in the soil with fingers.
20. Ensure plant lines are at least 2 inches away from water drip line.
21. Put seeds of vegetables and plants (as appropriate for the season) at maximum depth of 2 inches in the soil.
22. Cover the seeds gently with soil.
23. Apply light layer of dry grass on the soil as mulch.

5. MAINTENANCE GUIDELINES

1. Ensure that a staircase is available to access the roof whenever needed.
2. Limit frequent walking on the roof.
3. Check the soil moisture and overall health of plants periodically (at least once a week).
4. Regular checks to be made for rats, cats, dogs and other small animals who might build their homes or sleep in the soil.
5. Evaluate for any water leakage or cracks in pipes of drip irrigations system (at least once a week).
6. The roof should be checked regularly for any bending due to the weight.
7. If bending is observed the strength of the structure should be enhanced or the weight of the intervention will need to be reduced.
8. Ensure water availability in the water tank on a daily basis.
9. In case of failing of automated watering or no electricity, water the plants manually.
10. In case green net structure falls due to heavy winds or any other reason, reconstruct it quickly.
11. Follow seasonal multi cropping of seeds.
12. After each season (3-4 months), rehash entire soil and mix more compost, cocopeat or manure to it and layer the soil again. Keep remnants of previous plants as biomass.
13. Keep irrigating the soil at least twice a day in summer season.
14. During monsoon, if water logging in the soil is found then manually remove the water.
15. Replenish with soil if too much of erosion is observed.

6. INSTALLATION IMAGE

Next page

Rooftop Garden: Grow Bag (left), Wooden Frame (right)

Rooftop Garden Irrigation System

D. DORMER WINDOW

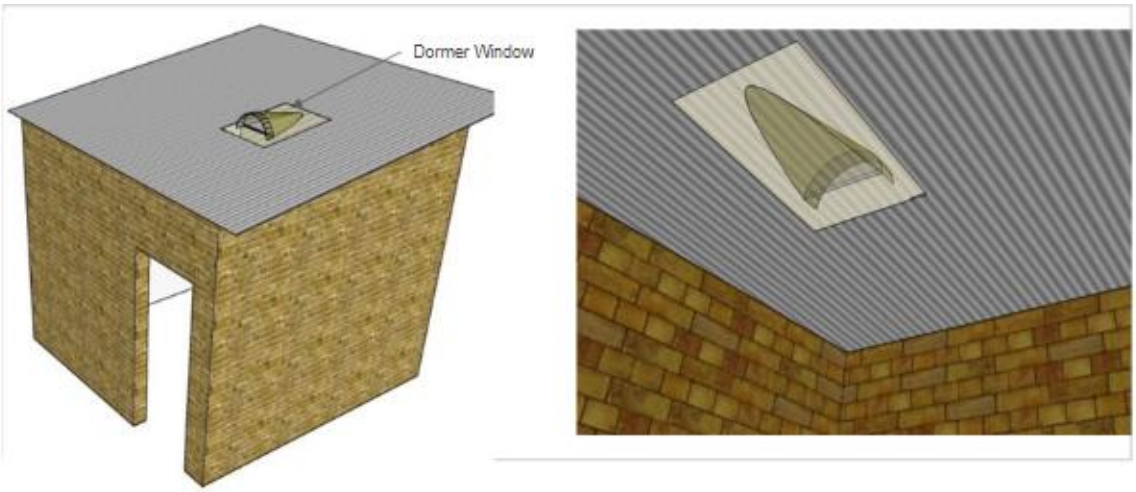
DESCRIPTION

Dormer window is a hump shaped window that is designed to be retrofitted onto existing corrugated steel/tin/cement roofs. It is made of fibreglass moulded into a hump to be retrofitted. The pane is made of translucent plastic to diffuse light and avoid glare.

1. MECHANISM DESCRIPTION

The mechanism works on the principle of convective ventilation where warm air rises up and vents out of the Dormer window. The window ideally needs to be fit on the highest available height for the principle to function. The fibre reinforced plastic is moulded into a hump with an opening at the bottom towards interior of the house to allow warm air to circulate and vent. The gap is covered with a metal net to prevent insects and other animals from getting in the house.

2. WORKING DRAWINGS



Over the Roof View | Under the Roof View

3. MATERIAL REQUIREMENTS

Hump shaped male and female mould made up of wood, fibre reinforced plastic (FRP) sheet (3 mm), roofing sheet cutter, nuts and bolts, cement, waterproofing solution, metal net.

4. FABRICATION AND INSTALLATION

1. Fabricate and prepare the hump shaped mould with the curved part at a height of at least 15 cm (this is the height up to which water splashes after hitting the roof during rains, hence this height will avoid the water to enter through the window's opening) that can be used to fabricate every dormer window structure in one piece.
2. Fabricate the base of the dormer window as per exact measurements of crest and trough of the roofing sheet of the structure where the dormer window will be installed.
3. Manufacture and cast the dormer window in one piece using the mould technique so that no cracks or openings are left for water inlet or leakage, based on the following steps:
    - Lay the FRP sheet over the male part of the mould.
    - Heat the FRP sheet
    - Put the female mould on the sheet and press it
    - Mould the plastic sheet in such a way that the semi-circular opening is covered with a small overhang of around 4-5" to prevent the rains from coming in the house.

4. Cover the semi-circular opening that will be facing outward above the roof with a metal net for preventing insects, animals and birds from entering the house through the dormer window.
5. Identify a suitable location on the roof to install the dormer window using the guidelines below:
    - The highest part in the room.
    - Opposite the existing window or the door for the stack ventilation principle to work in the house, where the door/window becomes an inlet and dormer acts as an outlet.
    - Maintain at least a 4 feet distance of the opening from the fan, so it does not create counter air pressures that can pull and circulate the warm air that collects at the top
6. Cut the portion of the roof identified through the above analysis based on the dormer window dimensions.
7. Install the front part i.e., the opening of the dormer window towards the slope of the roof to prevent the rainwater coming in the house.
8. Install the opening of the window facing the leeward side.
9. Fix the dormer window with the help of self-tapping screws as well as adhesive in between the sheet of dormer window and the roof with the horizontal holds resting on the existing roof.
10. Apply a coat of silicon along the joint between the window and existing roof to prevent water leakage and strengthen the joints.
11. Provide u-channels from the periphery of the dormer window from the inside and extend them outside the house to make guideways for water that might enter the house.
12. Include sliding mechanism to open and close the window from the inside by using aluminium sliding mechanism.

5. INSTALLATION IMAGE

Dormer Window: Indoor view

E. WOOD WOOL PANEL

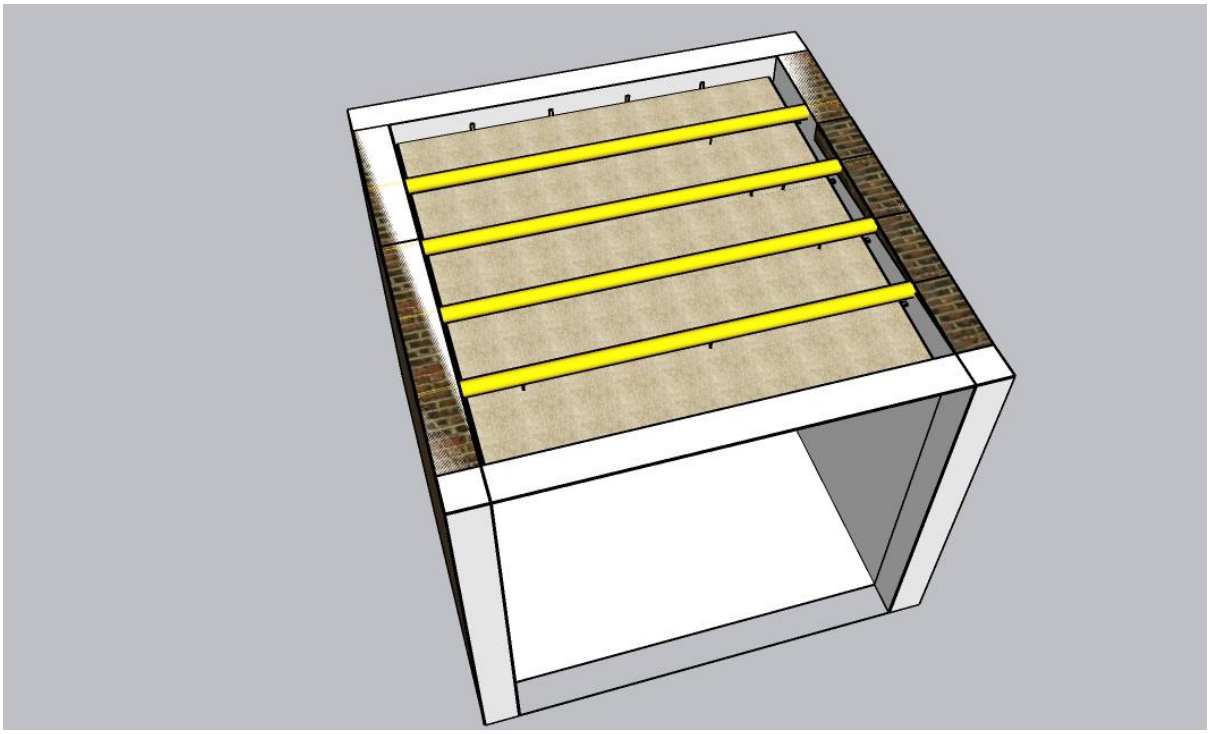
DESCRIPTION

Wood Wool Panel is an environment-friendly, recyclable material made from wood wool, cement and water. It is installed under the roof.

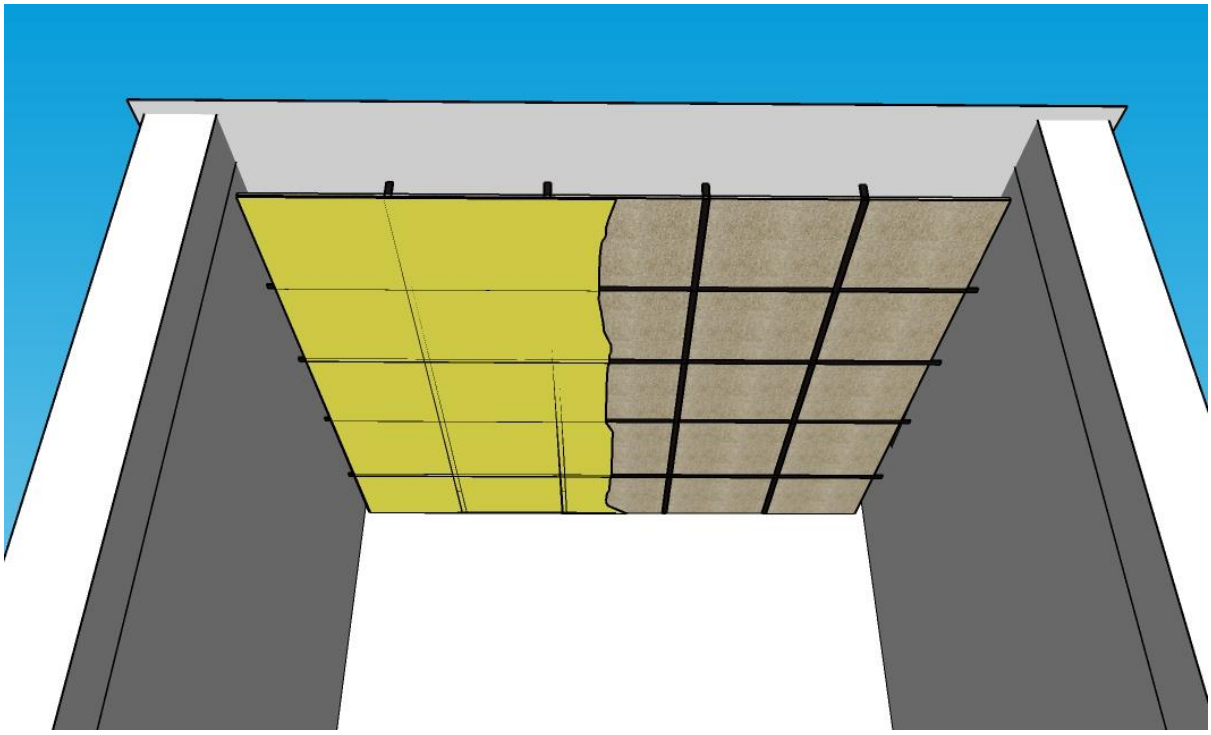
1. MECHANISM DESCRIPTION

This is a fixed/static installation and does not involve moving parts.

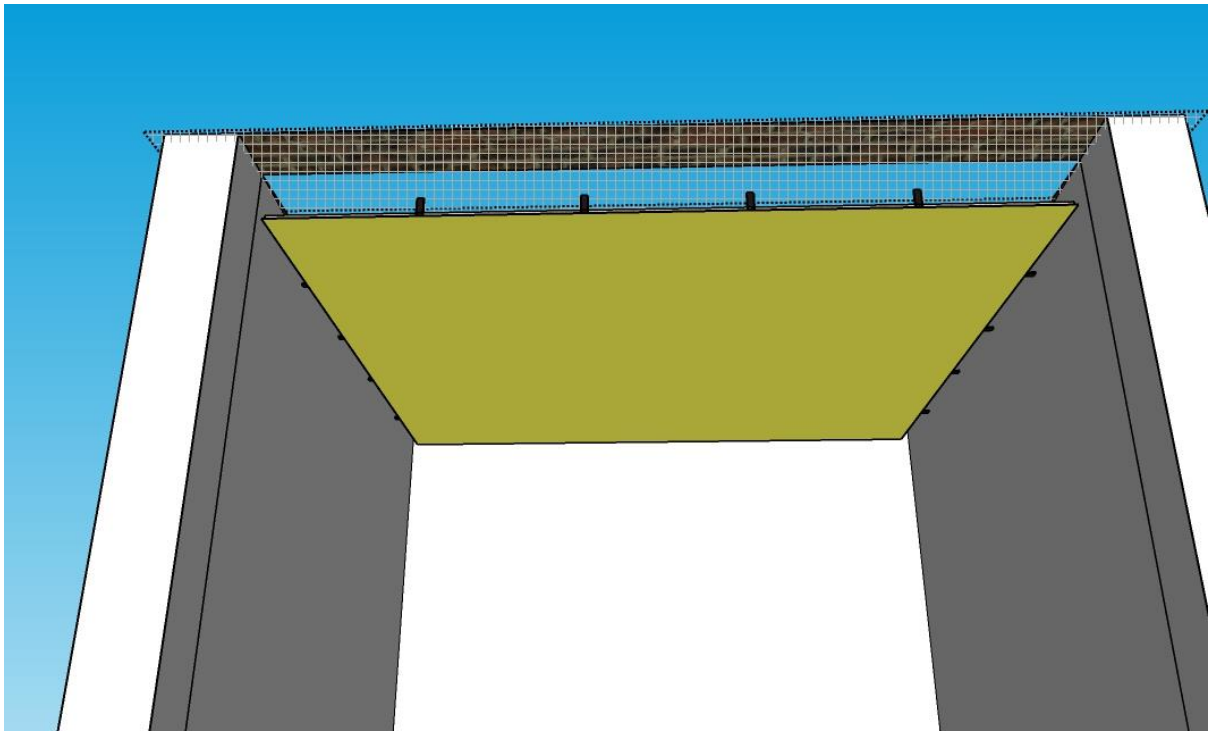
2. WORKING DRAWING



Wood Wool: Upper view (minus roof)



Wood Wool: Under the roof view (panels and silpaulin both visible)



Wood Wool: Under the roof view (silpaulin visible)

3. MATERIAL REQUIREMENTS

Wood wool panels, L-angle metal plates, Small metal pieces for support, GI wire

4. FABRICATION AND INSTALLATION

1. If there are cracks on the roof close/seal the cracks by using adhesives, stick tar sheet. Place a tarpaulin sheet or extra roofing sheet over the cracks if none of the other sealing solutions are available.
2. Cut 4 L-angles each being of the size of the edge of the wood wool panel.
3. Paint them
4. Weld one L-angle on one end of the house beneath the roof
5. Weld the second L-angle at a distance equal to the width of the panel
6. Weld the third L-angle connecting one end of the above two sides
7. Fix the panel inside these three-support frames
8. Weld the fourth L-angle
9. Repeat the process for the other panels
10. Stick a tarpaulin sheet from beneath to prevent any particles falling from the board

5. INSTALLATION IMAGE

F) WATER FILLED PET BOTTLE

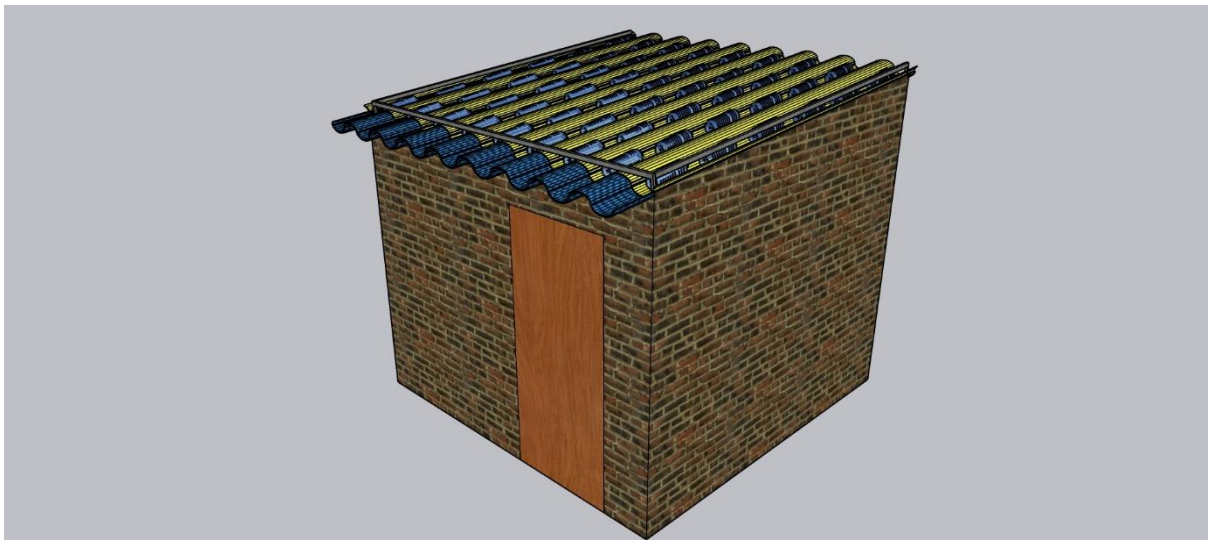
DESCRIPTION

Plastic PET Bottles which are generally used for packaging water or beverages are filled with water and placed above the roof.

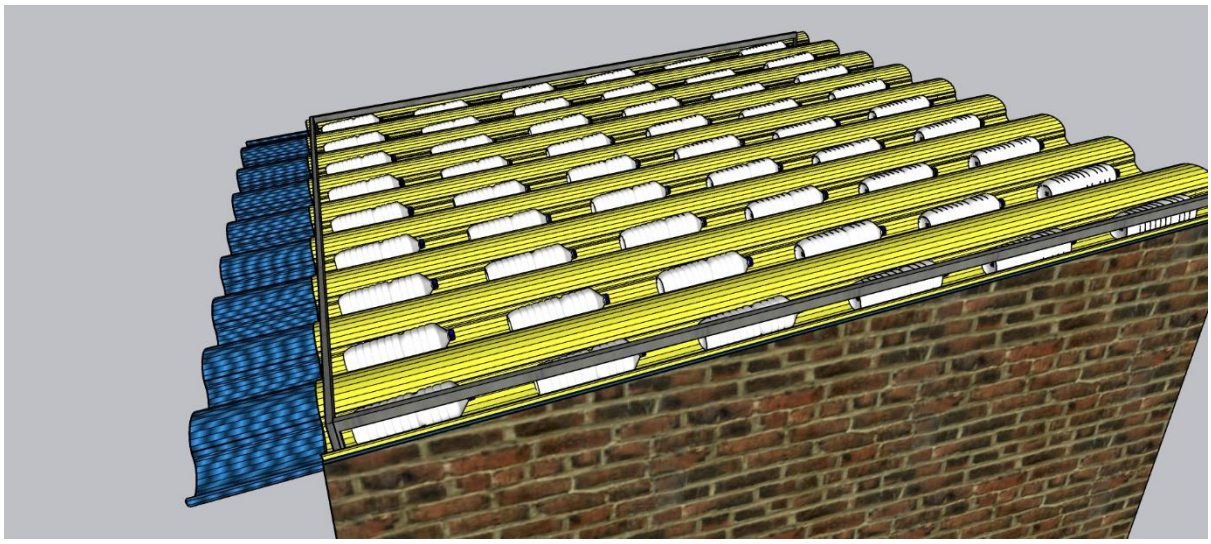
1. MECHANISM DESCRIPTION

Water has the highest specific heat capacity than any liquid. Specific heat is defined as the amount of heat one gram of a substance must absorb or lose to change its temperature by one degree Celsius. For water, this amount is one calorie, or 4.184 joules. Thus, it can absorb a lot of heat before its temperature rises. This trait helps it to stabilize temperature in its surroundings. To benefit from this heat resisting property of water, discarded PET bottles are filled with water and stuck on the roof. This low cost, zero energy passive thermal comfort solution increases the thermal mass of the roof i.e., its ability to store heat, for a longer duration before letting it seep into the house through the day and reversing the heat transfer process of the water during the night, since the warmed water during the day gets cooled during the night due to the drop in ambient temperature, which in turn keeps the roof cool the next morning even when the sun starts to heat up.

2. WORKING DRAWING



Water filled PET bottles: Zoomed out view



Water Filled PET bottles: Zoomed-in view

3. MATERIAL REQUIREMENTS

Old or new plastic bottles without any cracks, water to fill bottles, HDPE material tarpaulin sheet, good quality adhesives - Fevicol SR 996 & Speb 7 adhesive.

4. FABRICATION AND INSTALLATION

I. Bottle Preparation :

A. METHOD 1: The bottles are stuck without any coating and with an estimation of 1 bottle/sq. ft.
B. METHOD 2: The bottles are painted with white reflective paint. An average thermal comfort improvement of 1 deg C as compared to the base case has been observed through this method by experimentation.
C. METHOD 3: The bottles are coated with low-emissivity plaster. An average thermal comfort improvement of 1 deg C as compared to the base case has been observed through this method by experimentation.

D. METHOD 4: The intensity of bottles is increased to 2 bottles/sq. ft. to increase the thermal mass on the roof through higher volume of water. An average thermal comfort improvement of 2 deg C as compared to the base case has been observed through this method by experimentation.

II. Bottle Installation

1. Remove dust or any obstacles from the roof.
2. Apply adhesive on the roof and place a double layer of tarpaulin over it. (Single layer of tarpaulin is also sufficient; however double layering gives an extra protection from monsoon.)
3. Wait for minimum 15 minutes for the tarpaulin to stick to the roof.
4. Check at random points, if tarpaulin is glued adequately to the roof or not. Come down from the roof post this activity.
5. Remove all labels from the bottles.
6. Fill all bottles with normal temperature water and fix the caps tightly. Ensure there is no water leakage from any side of the bottle.
7. Gently carry the bottles on the roof and place them at a regular interval from each other.
8. The points below share guidance on how to place the bottles:
    - If roof has trough and crest (like a wave) then place bottles in trough gaps. This will ensure that water does not get stagnant on the roof due to the bottles.
    - Point the cap of the bottle in the opposite of the slope of the roof.
    - Good spacing would be 4-6 inches between two bottles.
    - Leave half foot space on all the edges of the roof for walking.
    - If the structure has very high strength (e.g., Very strong roof sheet, good supports), no. of bottles = 2 x roof area in sq. ft.
    - If the structure has high strength (e.g., Adequately strong roof sheet, adequate supports), no. of bottles = 1.5 x roof area in sq. ft.
    - If the structure has average strength, no. of bottles = roof area in sq. ft.
    - If the structure has weak strength (e.g., cracked sheets, weak support), no. of bottles = 0.75 x roof area in sq. ft.
    - Ensure that bottles are not fixed on broken or bent parts of the roof.
9. Apply Fevicol or SR 996 adhesive to one side of PET bottle and to tarpaulin sheet.
10. Place each PET bottle over the glue and apply some pressure, so that it sticks firmly.
11. Perform a random check to see if the bottles are glued well to the tarpaulin.
12. Install a pipe frame on the periphery of the roof at low height (lower than the width of bottle) on three sides (lower end and on the sides) to prevent the bottles from falling down in case it comes off.

I. MAINTENANCE GUIDELINES

1. Check the roof once a month for any cracks or misplaced bottles.
2. Replace bottles as applicable.

6.INSTALLATION IMAGE

Email: vivek@cbalance.in

Ph.:
8530887227/ 9987061676

Address:
cBalance Solutions Pvt. Ltd.
H2-7, Brahma Paradise, Nathan Road,
Sangamwadi, Pune 411001

Website:
https://cbalance.in/