Assessment of PI/PU Insulation for Thermal Comfort and Energy Efficiency

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Objectives

- Comparative assessment of PUR insulation boards with vermiculite, and brickbat coba as roof insulation to achieve energy efficiency & thermal comfort.
- To perform the sensitivity analysis of different physical parameters (e.g., insulation thickness, insulation types, wall or roof insulation, room aspect ratio, etc.) on thermal comfort using a conjugate heat transfer computational model.

Experimental Setup

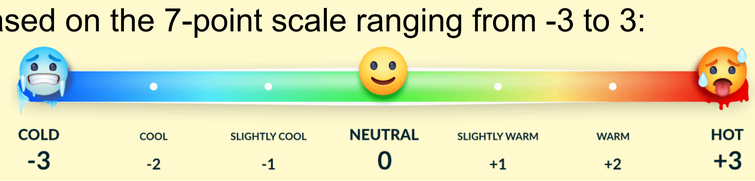
- Six rooms (4.35 × 3.15 × 3.3 m^3) constructed in Gurugram, India.
- Two categories of rooms:

Category A: Without HVAC	
R_1	No insulation *(baseline model)*
R_2	With *Kingspan Jindal (KJ) PUR* insulation board on the roof
R_3	With *brickbat Coba* insulation on the roof
R_4	With *vermiculite* insulation on the roof
Category B: With HVAC (Room temp: 24°C)	
R_5	No insulation *(baseline model)*
R_6	With *KJ PUR* insulation board on the roof

- The data recorded by different sensors has been analyzed for one complete year duration (February 2023 to January 2024).
- Sensors: Air temperature and humidity, energy logger, flux meter, indoor and outdoor air velocity, Lux meter.

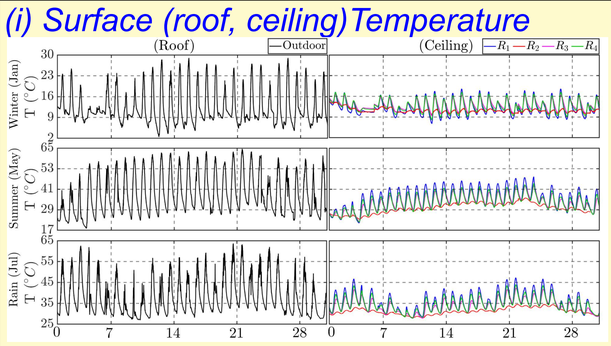
ANSI/ASHRAE Standard 55-2017

- ASHRAE Standard 55 [1] specifies conditions for acceptable thermal environments and is intended for use in the design, operation, and commissioning of buildings and other occupied spaces.
- *The Predicted Mean Vote (PMV)* is the most widely adopted standard for thermal comfort studies across the world. PMV is used to describe thermal comfort based on the 7-point scale ranging from -3 to 3:

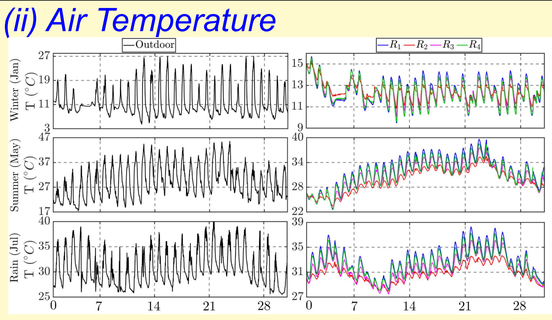


Experimental Results: Category A

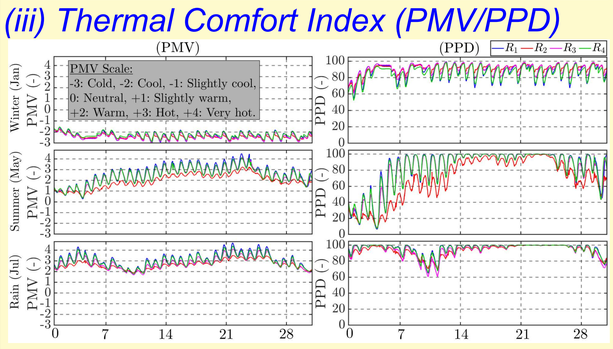
(i) Surface (roof, ceiling)Temperature



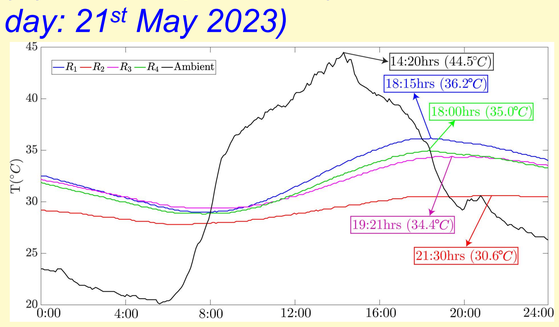
(ii) Air Temperature



(iii) Thermal Comfort Index (PMV/PPD)



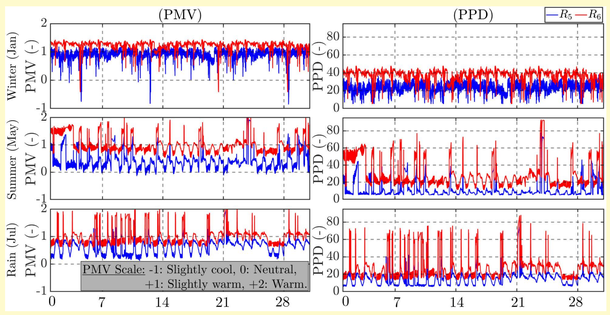
(iv) Air Temperature (hot summer day: 21st May 2023)



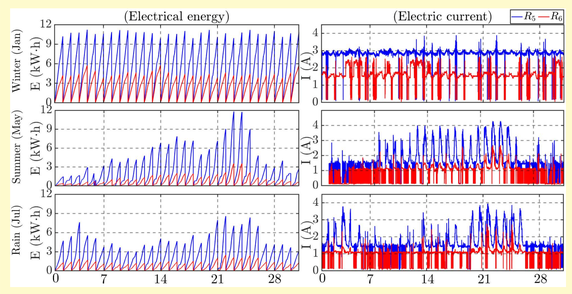
Type of insulation on the roof		Without any insulation	PUR insulation board	Brickbat Coba	Vermiculite in cement
Overall Heat Transfer Coefficient (W/m^2.K)		**3.74**	**0.37**	**3.42**	**1.50**
Difference between max outdoor temp & max indoor air temp on the hottest day	Max outdoor temp: 44.5°C				
	Max indoor air temp	36.2°C	30.6°C	34.4°C	35°C
	Difference	**8.3°C**	**13.9°C**	**10.1°C**	**9.5°C**
Peak-to-peak indoor air temperature variation on the hottest day	Max indoor air temp	36.2°C	30.6°C	34.4°C	35°C
	Min indoor air temp	29°C	27.8°C	29.4°C	28.8°C
	Variation	**7.2°C**	**2.8°C**	**5.0°C**	**6.2°C**
Time to reach max indoor air temp after outdoor has reached max temp on the hottest day	Time at max. outdoor temp: 14:19				
	Time at max. indoor air temp	18:25	20:25	18:35	18:19
	Delay	**3.9 hours**	**7.2 hours**	**5 hours**	**4 hours**

Experimental Results: Category B

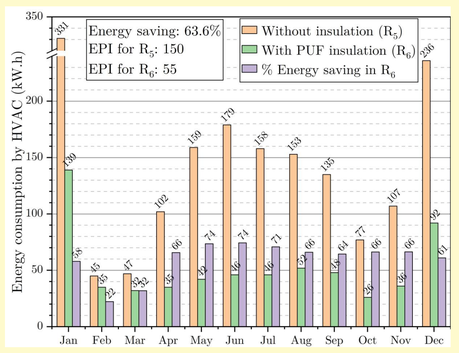
(i) Thermal Comfort Index (PMV/PPD)



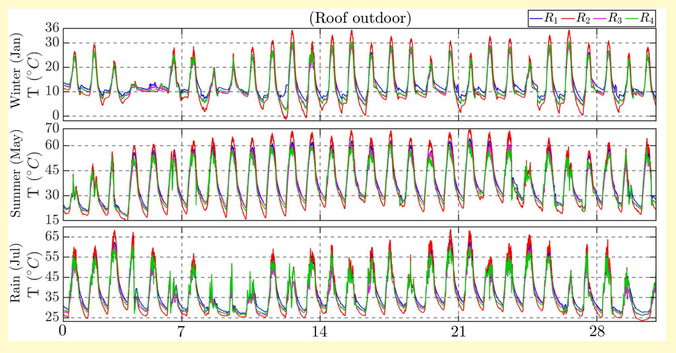
(ii) Electrical Energy consumption



(iii) Energy Savings



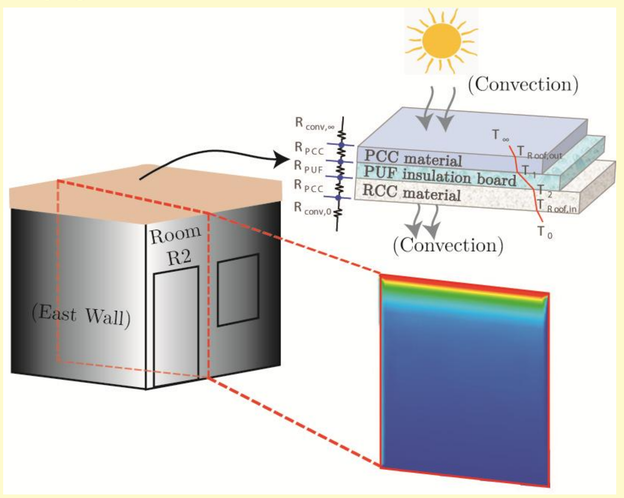
(iv) Outside Roof Temperature

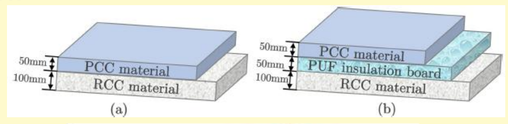


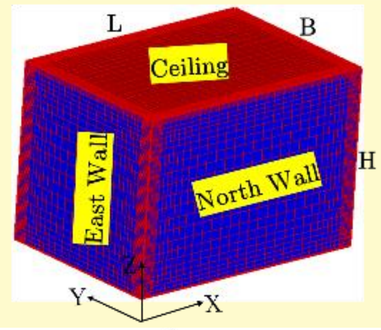
Type of insulation on the roof		Without any insulation	With PUR insulation board	Remarks
Monthly (May 2023) energy consumption in a room (24°C)	Energy consumed	157.3 kW.Hr	43 kW.Hr	**72.7%** energy saving with insulation board. Peak power is lesser by **51%.** Lesser tonnage AC is needed.
	Peak power attained	918 W	453 W	
Early-averaged energy consumption for a month	Energy consumed	144.1 kW.Hr	52.4 kW.Hr	**63.6%** energy saving with insulation board. Peak power is lesser by 37%. Lesser tonnage AC is needed.
	Peak power	918 W	583 W	

Sensitivity Analysis

Conjugate Heat Transfer Computational Model:



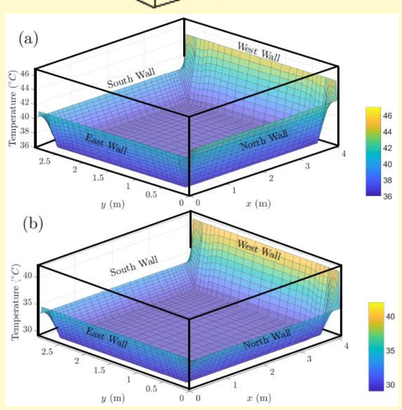




Sensitivity of Physical Parameters:

Physical properties	Effect on thermal comfort#
Insulation Thickness	★★
Wall Insulation	★★★★★
Roof Thickness	★
Wall Material	★★★★★
Ceiling Height	★★★★
Room Aspect Ratio	★

#★: least effective, ★★★★★: highly effective



Summary

- It is observed that the PUR insulation is the most effective material for improving thermal comfort and energy efficiency among all the insulating materials (vermiculite in cement and brickbat coba) tested in the present study.
- The effectiveness of the PUR insulation is highest during hot weather; the use of the PUR insulation in the roof delayed the peak temperature.
- Peak-to-peak indoor air temperature variation is reduced with PUR insulation compared to other insulation materials.
- To maintain the indoor temperature with HVAC system, the energy saving was highest (74%) during the Summer months (May & June) and it was lowest (22%) during the winter/spring months (February).
- The indoor thermal comfort is highly dependent on the wall materials, wall insulation, and ceiling height.

REFERENCES

[1] ASHRAE, Thermal Environmental Conditions for Human Occupancy: ANSI/ASHRAE Standard 55-2017,