Summary of Research Progress from May 2022- May 2023

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Investigating the role of vernacular and conventional building materials in passively regulating indoor-humidity for occupant wellness

The way buildings are constructed (material, geometry, form, etc.) determines indoor comfort, which has a direct bearing on occupants' wellness depending upon their personal attributes like clothing, physiology, and other preferences. Indoor temperature and humidity are key determinants of comfort (a key physiological indicator of wellness). Wellness in the context of study incorporates thermal, skin-related and respiratory comfort.Temperature variations in response to external climates for different building typologies have been extensively studied. While humidity remains acknowledged in the scientific community as a determinant of comfort and health, studies examining humidity explicitly, surprisingly, are very few.

The present work examines the role of humidity on occupant wellness, comparing naturally ventilated dwellings constructed using natural(Adobe/Earth Plaster) and modern(Brick and RCC, Cement plaster) building materials.

Objectives

1. **To develop and test a framework to examine a building's ability to passively regulate indoor moisture**
2. **To examine the role of indoor moisture on occupant comfort and well-being/wellness.**

Key research outcomes presented in the last Annual Review (May 2022)

A case study was conducted in Jamgoria village, Jharkhand. In-situ indoor measurements of Temperature and Relative humidity for one year in buildings constructed of natural (Adobe, Earth plaster) and modern (Brick /RCC, cement plaster) materials were done. Concurrently external environmental parameters were monitored. It was found that the indoor diurnal humidity variations are lower in buildings constructed with earth-based materials when compared to the latter for the same external environment[3]. Hygroscopic building material exhibit moisture buffering properties which help to regulate indoor moisture. A novel, compact in-situ surface interaction monitoring sensor assembly was instrumented to investigate the surface interactions in buildings causing variation in indoor RH in different buildings.

On-field Aggregate comfort survey (Thermal, Skin, and Respiratory) for the community was conducted for 50 occupants living in both the building typologies. An inconsistency was observed in the on-field observed comfort votes and computed values using existing models [3,8].

Research progress from May 2022-May 2023

Objective 1 Work Packages

1. Surface Level: In-situ Moisture Buffering Study

A study was conducted into surface-level moisture interactions in conjunction with indoor temperature, relative humidity, air velocity, and mean radiant temperature. A novel, compact, low-cost sensor assembly was developed to monitor in-situ surface moisture interactions. In-situ measurements for both building typologies were completed. Data analysis is complete, and manuscript preparation is in progress.

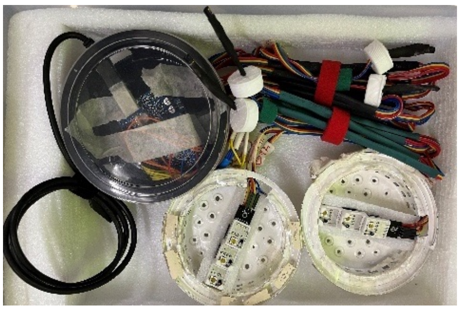

Figure 1 Low Cost Sensor Assembly

2. Material level: Hygrothermal Characterization of materials and Moisture Buffering capacity testing

Earth-based building material (Plaster and core) samples were collected from the field. Part of the hygrothermal characterization of the collected samples (density, Vapor sorption curve, pore surface area) was conducted at University of Bath, UK. For further tests, instrumentation of the doubly-guarded hotbox has been completed, and the testing is in progress. This apparatus is envisaged to assess the diurnal/seasonal, climate-based variability in hygroscopic performance.

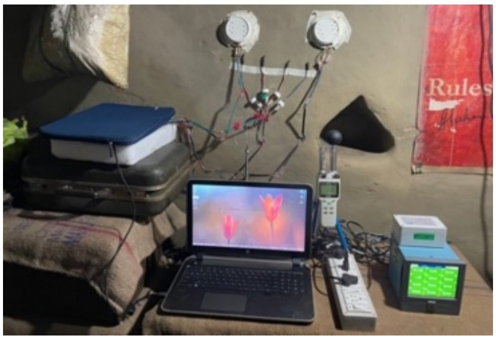

Figure 2 On-field Surface Level Measurements

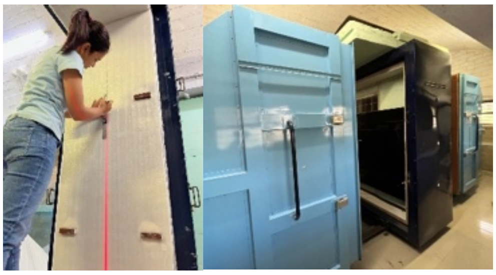

Figure 3 Hotbox Setup for moisture buffering testing

3. Application of observed experimental properties

The impact of experimentally observed properties on buildings in different climatic zones and indoor parameters is being studied using computational simulations. Also, to demonstrate the use of the framework, the viability of using waste End-of-life (E-o-L) photovoltaic panels (PV) as building materials and their implications thermal performance of buildings was conducted [2,7]. Implementing strategies to improve hygrothermal performance of such buildings with a calibrated model of E-o-L PV building constructed in IISc is being examined. Part of this work has been accepted to be published and presented at EUPVSEC 2023[5].

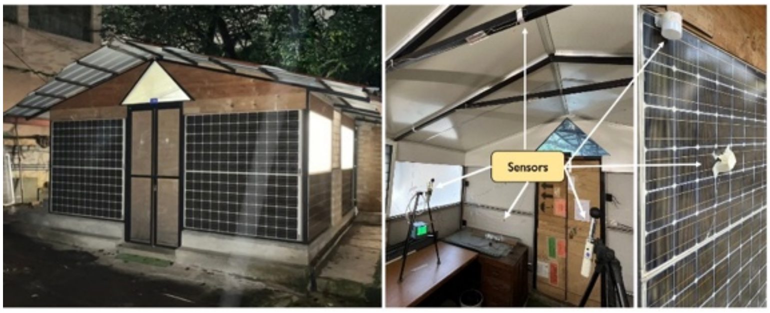

Figure 4 Setup for data collection for calibrating simulation model of E-O-L BIPV at IISc

Objective 2 Work Packages

4. Computational Examination of Thermal and Skin Comfort

An energy balance-based computational approach has been adopted to understand skin-related thermo-physiological variation with varying indoor environmental parameters. This model was validated with extensive on-field experimental survey data (physiology and health parameters, comfort votes, thermal imagery). Part of this work [6] was presented at BSA-2022 Conference in Italy, where it was awarded the "*Best Student Competition award for technical merit and methodology*". An extended Invited Journal article for this work has also received preliminary acceptance [1].

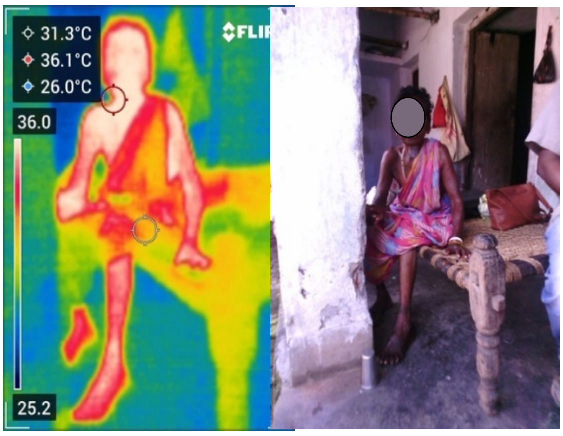

Figure 5 On-field Occupant comfort data ; Thermal Image (Left), corresponding to regular camera image (Right)

1. Examining respiratory comfort

A preliminary investigation of respiratory comfort attributed to indoor humidity variation was reported in [8]. An energy-balance-based computational approach has been adopted for respiratory comfort examination. Part of this work has received preliminary acceptance to be published and presented at CISBAT 2023[4].

Objectives	Work Packages (Highlighted-Accomplished in the last year)	Status	
1. To develop and test a framework to examine a building's ability to passively regulate indoor moisture	1a. Conducting a case study on naturally ventilated buildings (Adobe/Earth Plaster) and modern buildings (Brick and RCC, Cement plaster) to understand indoor moisture regulation.	Complete	
	1b. Investigation of hygrothermal properties of earth-based materials through field and laboratory measurements.		
	1b.1 On-field Surface Measurements	Complete	
	1b.2 Lab Scale Hygrothermal Investigations (Vapor Sorption, Pore size, particle size, pore volume)	Complete	
	1b.3 Thermal Conductivity, Moisture Buffering Investigations	Ongoing	**Nov 2023**
	1c. Performing whole building hygrothermal simulations to study the role of relevant parameters (climate zone, building geometry, volume, surface area, and air changes) on indoor humidity regulation.	Ongoing	**Sept 2023**
	1d. Testing the framework to propose interventions for enhanced hygrothermal performance of EoL PV as an emerging building material.		
2. To examine the role of indoor moisture on occupant comfort and well-being/wellness.	2a. Identification of humidity-related comfort indicators through a multidisciplinary literature review	Complete	
	2b. Examining On-field Aggregate comfort vote for thermal, skin, and respiratory comfort of occupants in these buildings in the light of indoor air parameters with existing computational models	Complete	
	2c. Development and validation of a 2-core human thermophysiological model for Indian Occupants to evaluate humidity-related thermal and skin comfort	Complete	
	2d. Examining humidity-related respiratory using a mathematical model of human respiratory airways	Complete	

Research Publications (Highlighted -Accomplished in the last year)

Peer-Reviewed, Indexed Journal Articles:

1. **Priyadarshani, S.**, Mani, M., Maskell, "A novel approach examining comfort accounting for indoor humidity: A rural Indian case-study" (Preliminary Acceptance Received)
2. Rao, Roshan R., **Priyadarshani, S.**, and M. Mani, M., "Examining the use of End-of-Life (EoL) PV panels in housing and sustainability," *Sol. Energy*, vol. 257, no. June 2023, pp. 210–220, 2023, doi: 10.1016/j.solener.2023.04.033
3. **Priyadarshani, S.**, Mani, M., Maskell, D.,"Influence of building typology on Indoor humidity regulation", *REHVA J.*, vol. 6, no. December, pp. 48–52, 2021, Available: https://www.rehva.eu/rehva-journal/chapter/influence-of-building-typology-on-indoor-humidity-regulation, ISSN 1307-3729.

Peer-Reviewed Conference Articles:

4. **Priyadarshani, S.**, Mani, M., Maskell, D., "Examining respiratory comfort in vernacular and conventional buildings",17th CISBAT 2023, 13-15 September, Lausanne, Switzerland (Preliminary Acceptance Received)
5. **Priyadarshani, S.**, Rao, Roshan.R., Mani, M., "Studying Interventions to Regulate Indoor Hygrothermal Comfort in Building Integrated with End-of-Life (EoL) PV Panels",40th European Photovoltaic Solar Energy Conference and Exhibition 2023, 18-22 September, Lisbon, Portugal (Acceptance Received)
6. **Priyadarshani, S.**, Rao, Roshan.R., Mani, M., Maskell, D.,"Investigating the role of humidity on indoor wellness in vernacular and conventional building typologies", In Proceedings of Building Simulation Applications 2022: 5th IBPSA Italy Conference – Bolzano (Italy), doi: 10.13124/9788860461919
7. Rao, Roshan.R., **Priyadarshani, S.**, Mani, M.,"An Investigation into thermal performance of buildings built using upcycled End-of-life Photovoltaic Panels", In Proceedings of Building Simulation Applications 2022: 5th IBPSA Italy Conference – Bolzano (Italy), doi: 10.13124/9788860461919
8. **Priyadarshani, S.**, Mani, M., Maskell, D., "Discerning relative humidity trends in vernacular and conventional building typologies for occupant health," in *Proceedings of the 17th International Healthy Buildings Conference, 21-23 June, 2021*, pp. 587–598, [Online]. Available: https://www.sintefbok.no/papers/index/38/sintef_proceedings. ISBN: 978-82-536-1728-2