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Experimental Investigation of false ceiling using bubble sheet for sustainable ventilation

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ABSTRACT

Ventilation with proper air change rate (ACR) is a crucial component in maintaining healthy indoor air quality, especially in buildings with poor air circulation. Traditional methods of ventilation, such as mechanical systems, will be costly and energy intensive. Specially in sheet metal roof top buildings the heat gain is more than concrete slab. The heat transferred in occupied space is not only by conduction. convection but radiation mode of heat transfer feels like burning sensation to the occupants. Bubble sheet installation as a false ceiling at predetermined distance will acts as radiation shield. The radiated heat energy is reflected back towards the ceiling, due heat transfer between ceiling and bubble sheet as a false ceiling the air between both is being heated. This heated air is replaced by either solar chimney or turbo ventilator. Controllable openings in the false ceiling provides predetermined air change through the occupied space. In heavily occupied buildings the ACR up to 10 is specified. Sustainable ventilation system with above features is installed in room number B-341, SSVPS B. S. Deore College of Engineering Dhule, (74o 45" N 20o 50" E, 259 m above MSL), about 150 km. NE of Nashik located in Maharashtra state of India. Through experimentation, the temperature at various locations in occupied space is observed. The results will provide valuable insights into the potential benefits and limitations of using natural ventilation processes for ventilation in buildings. Installation of bubble sheet as a false ceiling reduces the temperature of 6oC - 7oC in the occupied space.

KEYWORDS

Occupied space 1: Upper zone
Occupied space 2: Middle zone
Occupied space 3: Lower zone
Tavg: average of all occupied space temperatures
Tmin: mean value of average temperature
Tambient: ratio of Tavg:Tmin
ACR: Air Change Rate
POP: Plaster of Paris
VIPs: Vacuum Insulation Panels
RCC: Reinforced Concrete
Temperature: Degree Celsius (°C)
ACR: Air Changes Per Hour (ACH)

1. INTRODUCTION

This work explores the use of double side aluminum foiled bubble sheet as a false ceiling for ventilation in buildings. Ventilation is a crucial aspect of building design as it ensures a healthy and comfortable indoor air quality. Traditional ventilation systems are costly and energy-intensive, leading to increased operational costs for buildings.

Solar, wind energy and passive architecture for human comfort by S.D. Suryawanshi et.al.[1] concluded that
energy conservation in buildings is enhanced through innovative strategies such as venting hot air through ductwork and utilizing solar chimney. Solar chimney provides stack effect and the blacked outer surface heats the air column in the chimney gives thermosiphon effect, combination of both phenomena develops a natural draught for ventilation, resulting in improved human comfort and reduced electricity bills. Temperature inside the house is 4oC to 6oC less than non-ventilated house. Effect of building roof insulation measures on indoor cooling and energy saving in rural areas in Chongqing [16] Ran, Tang, Jiang, and Zheng conducted a study examining the effect of building roof insulation measures on indoor cooling and energy saving in rural areas, specifically in Chongqing. This research addresses the crucial role of roof insulation in enhancing energy efficiency and indoor comfort within rural settings. By analyzing the impact of different insulation strategies, the study provides valuable insights for sustainable building practices in Chongqing's rural communities. Impact on comfort when using rooftop ventilators for building ventilation with evaporative cooling [2], the work of A.B. Kulkarni et.al. states that, using evaporative cooling pad with water dripping from overhead tank being used for wetting the wood wool pads is an excellent option during load shading in the day time. Yiyun Zhu [3], Study in Qinba Mountains showed that aluminum foil bubble composites on underside of roofs reduced second-floor bedroom temperatures by 1.1°C, proving the effectiveness of radiant barrier roofs. Numerical simulation analysis found radiant heat transfer contributed 65% to insulation. Boixo et al. [17] investigate the effectiveness of cool roofs in Spain and Andalusia, particularly in reducing the need for indoor cooling during warmer seasons. Al-Obaidi et al. [18] propose a roofing system specifically designed for tropical climates, highlighting its success in managing heat and its ease of installation and maintenance. Tong and Hua [19] explore the practicality of passive cooling strategies in inclined roofs with natural ventilation, emphasizing the significance of utilizing natural airflow to regulate temperature. In contrast, Alam et al. [20] analyse the application of Vacuum Insulation Panels (VIPs) in non-domestic buildings, focusing on their convenience in providing excellent insulation while requiring minimal space, thus enhancing comfort and reducing energy consumption. Park, Choi, Lim, and Song [24] evaluated externally insulated systems with Vacuum Insulation Panels (VIPs) for high-rise buildings. Gonçalves, Simões, Serra, and Flores-Colen [25] reviewed the challenges of using vacuum panels in external insulation finishing systems, as discussed in Applied Energy.

Aditya, Mahlia, Rismanchi, Ng, Hasan, Metselaar, Muraza, and Aditiya [26] provided insights into insulation materials for energy conservation in buildings in Renewable and Sustainable Energy Reviews. Ciampi, Leccese, and Tuoni [21],[22] investigated the energy performance of ventilated and micro ventilated roofs, another study examined ventilated facades in summer cooling. Adamczyk and Dylewski [23] explored the sustainability impact of thermal insulation investments in construction.

Air movement in naturally ventilated buildings by H.B. Awbi [6] conducted study in office room and the atrium in summer. A review and winter update on rooftop ventilator [7] design of rooftop turbine ventilator which is not only ventilate well even in low wind speed region, but also could be a simple yet effective multifunction device. Indoor Air Quality Measurement with the Installation of a Rooftop Turbine Ventilator by Jason Lien et.al. [8] presents a numerical analysis of the difference in comfort level inside a room of a residential building when roof top turbine ventilator is installed. By Haihua Zhang, Yao Tao and Long Shi [9] A solar chimney is a renewable energy system used to enhance the natural ventilation in a building based on solar and wind energy. This solar-assisted passive ventilation system attached to the building envelope is a top choice for improving natural ventilation and thermal comfort in specific climate conditions. Performance of solar chimney by K.S. Ong and C.C. Chow, [10] conducted a detailed study on air flow and air temperature of solar chimney and purposed a mathematical model of a solar chimney to predict the performance. Performance characteristics of turbo ventilator [11] the author aims to advance rooftop ventilator performance through experimental and analytical investigation. Utilizing computational fluid dynamics software offers cost effective improvements for future designs. Effect of ventilation of space between roof and false ceiling on air-conditioning load [13], flowing outside air between the roof and false ceiling reduces roof load by up to 22%, with peak savings around 11am. Optimal parameters include 2m/s air velocity, 20m roof length and a 30o roof inclination angle, resulting in an average 17.4% load reduction. This technique holds potential for energy conservation in airconditioned building, but further research is required. Applications of Roof Thermal Insulation in Tropical Climate Ar. Dr. Lim Chin Haw, Senior Research Fellow [14] Reflective foil's high reflectivity and low emissivity properties help to decrease radiative heat gain and lower cooling energy consumption. Mass insulation is highly beneficial for countries that experience cold winter with extreme low ambient temperature. Kwok [15] highlights that occupant in naturally ventilated schools find comfort. This suggests potential energy savings in well-designed, naturally ventilated environments, offering schools a cost-effective solution for long-term energy conservation. Li, Min, Wu, Zhishen, and Tan, Jinmiao [27] investigated the heat storage properties of cement mortar incorporated with composite phase change material, as detailed in Applied Energy.

The use of double side aluminum foiled bubble sheets offers a cost-effective and energy-efficient solution for ventilation and air quality. These sheets are lightweight, easy to install, and provide excellent thermal insulation which acts as a radiation shield.

The parameters of building ventilation design are height from ground, orientation, ceiling material, windows and door location, source of heat, feasibility of solar chimney or turbo ventilators etc.

Based on above mentioned research background present experimental study purposes a false ceiling structure, which consists of an available sheet metal roof, application of aluminum foil bubble sheet as a radiation shield, turbo ventilator, GI wire grid to support the bubble sheet and predefined controllable vents for air circulation. This false ceiling is expected to perform a crucial role in the thermal comfort and ventilation of the sheet metal roof top houses. Overall, this research aims to contribute to the development of more sustainable and environmentally friendly ventilation strategies that can be incorporated into future building designs. This study provides new ventilation ideas and effectiveness of bubble sheet material to reduce heat gain through the roof.

2. COMPARATIVE STUDY

2.1 Plaster of Paris:

Plaster of Paris provides a smooth and visually appealing finish, enhancing the aesthetic appeal of the room. But POP is not breathable, hindering ventilation and potentially leading to issues such as poor air quality, moisture buildup, and microbial growth. Prone to cracking and crumbling over time, especially in areas with temperature and humidity fluctuations, compromising the integrity of the false ceiling and affecting ventilation systems

2.2 Paint:

Paint is easily applied and comes in various colors, offering flexibility in design and decor. But it lacks structural integrity and ventilation properties, incapable of supporting ventilation systems such as air ducts or fans. Inadequate airflow through the paint can hinder proper circulation and ventilation in the room, leading to potential discomfort and air quality issues.

to potential discomfort and air quality issues.

2.3 Thermocol

Thermocol sheets are Lightweight and cost-effective, making it a popular choice for false ceiling applications. One of the main reasons for not using thermocol sheet as a false ceiling for ventilation is that thermocol is a poor insulator and can actually hinder proper ventilation. Thermocol has a low resistance to heat and does not allow air to flow freely, which can lead to poor air circulation and trapped heat in the room. This can result in discomfort for occupants and can also increase energy consumption as the air conditioning system will have to work harder to maintain a comfortable temperature. Structural rigidity is another limitation.

2.4 Wooden Board

Wooden Boards offer a natural and warm aesthetic, adding character and charm to the room. One reason not to use wooden boards as a false ceiling for ventilation is that wood is a combustible material, which could pose a fire hazard in the event of a fire breaking out in the building. Additionally, wood can absorb moisture over time and become prone to mold and mildew growth, which could negatively impact indoor air quality and pose health risks to occupants.

2.5 Asbestos

Asbestos is a highly toxic material that can cause serious health risks when it is disturbed or deteriorates. The fibers released from asbestos can become airborne and easily inhaled, leading to respiratory issues such as lung cancer, asbestosis, and mesothelioma. Therefore, using asbestos sheets as a false ceiling for ventilation can pose a significant health hazard to the occupants of the space. It is important to avoid using asbestos in any form in construction or renovation projects and instead opt for safer, asbestos-free materials.

2.6 Grass

Grass can attract insects, pests, and allergens, which can be a nuisance and a health hazard for occupants in the space. It may also harbor mold or mildew if not properly cared for. Grass is flammable and could pose a fire hazard if exposed to heat sources or electrical wiring in the ceiling.

2.7 Comparison of cited materials with Aluminum foil bubble sheet.

The aluminum foil bubble sheet false ceiling presents a compelling solution for enhancing indoor comfort and ventilation in buildings. Acting as a versatile barrier, it serves as both a radiation shield and insulating material, effectively reducing heat gain from the rooftop or ceiling. Its use as a radiation shield cut down the burning sensation in occupied space below the sheet metal roof top. What sets the bubble sheet apart is its ability to maintain thermal comfort while facilitating controlled airflow through predefined openings. This ensures proper ventilation, mitigating issues such as stale air accumulation and discomfort. Unlike other materials like plaster of Paris or thermocol, the bubble sheet offers a balanced approach and provides hazard free indoor environment without the maintenance challenges of grass or wood, combining insulation with safe and healthy ventilation benefits unlike highly toxic asbestos material. Its versatility allows for application in various building types, making it a cost-effective and practical choice for improving indoor air quality and ensuring occupant comfort.

3. EXPERIMENTATION

To investigate the effectiveness of using aluminum foil bubble sheet as a false ceiling to reduce heat gain, an experimental setup is prepared in a room B-341 having dimensions of 5.5m x 9m. The room was equipped with temperature sensors to measure the temperature, solar radiation and air velocity. The temperature difference between the room with the false ceiling and a room without the false ceiling was monitored over a period of time.

The thermocouples installed for measuring the temperature at 3 different levels each thermocouple is placed at distance of 3 feet vertically from each other in occupied space and fourth one is above the bubble sheet to measure the hot air temperature which is being ventilated. At same time solar radiations and wind velocity is measured. For data collection of the temperature, wind velocity and solar radiations datalogger is used.

Fig 1 Inside view of installation in room No. B-341.

Fig. 2 Outside view of turbo ventilators on sheet metal roof top of the building.

Fig.3 Inside view of installation in room No. B-341.

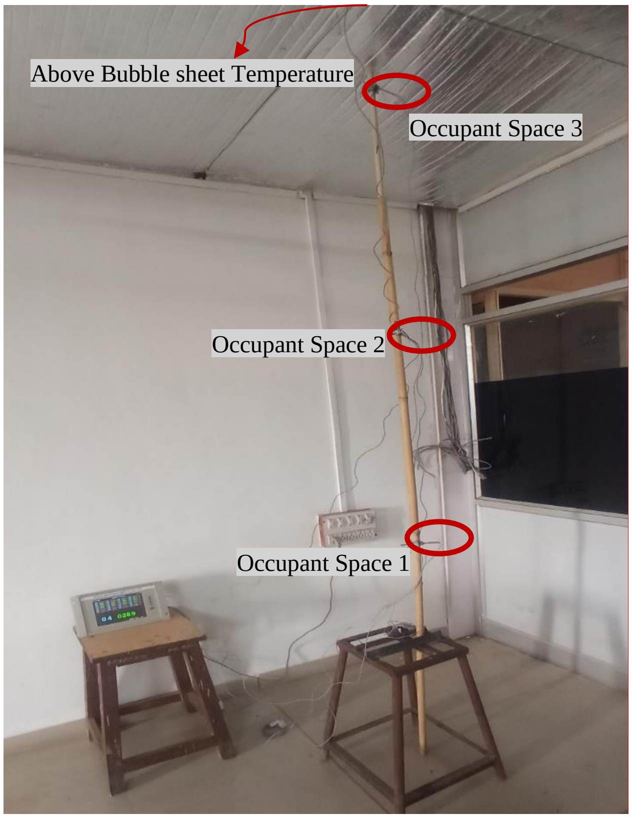

Fig. 4 Experimental setup in room No. B-341.

4. RESULTS

The outcomes of this meticulous experimentation unveil a robust confirmation of the aluminum foil bubble sheet false ceiling's capacity to effectively manage indoor temperatures, thereby amplifying thermal comfort within the enclosed environment. Building upon previous research endeavors which initially showcased promising reductions in heat gain within spaces adorned with this innovative ceiling solution, our latest findings serve to deepen and affirm its efficacy. Noteworthy among our observations is the consistent temperature disparity recorded between the region above the bubble sheet false ceiling and the occupied space beneath it, indicating a noticeable temperature drop of 7°C.

The application of the aluminum foil bubble sheet false ceiling extends beyond managing temperatures in hot climates; it also demonstrates notable effectiveness in winter conditions. Our observations reveal that this innovative solution contributes to a reduction in heat loss from the room, particularly during colder months. As evidenced by our data analysis, the graph illustrates a compelling trend: after midnight, the environmental temperature experiences a more pronounced decrease compared to the room temperature. This phenomenon suggests that the false ceiling serves as a barrier against heat dissipation, thereby helping to maintain warmer indoor temperatures during winter nights. Such findings not only underscore the versatility of the aluminum foil bubble sheet false ceiling but also highlight its potential to enhance thermal comfort and energy efficiency year-round, making it a valuable asset in diverse climatic contexts.

Moreover, this examination has shed light on the inherent durability and resilience of the bubble sheet material itself. Demonstrating commendable resistance to wear and tear, the bubble sheet exhibits a longevity that promises sustained performance even under prolonged usage. While the passage of time may manifest in minor sagging of the bubble sheet, a concern swiftly mitigated by the straightforward act of tightening the GI wire infrastructure, its overarching durability and wear resistance ensure continued functionality and effectiveness. This resilience, coupled with the system's adeptness at maintaining optimal indoor temperatures even during nocturnal hours, amplifies its appeal as a versatile and indispensable solution for indoor thermal management.

In summary, our comprehensive investigation underscores the aluminum foil bubble sheet false ceiling's remarkable potential to substantially elevate indoor thermal comfort and energy efficiency across a spectrum of settings. Through meticulous experimentation and analysis, we have not only validated its efficacy but also affirmed its durability and adaptability, positioning it as a compelling solution for sustainable and comfortable indoor living environments.

Date: 28/10/2023

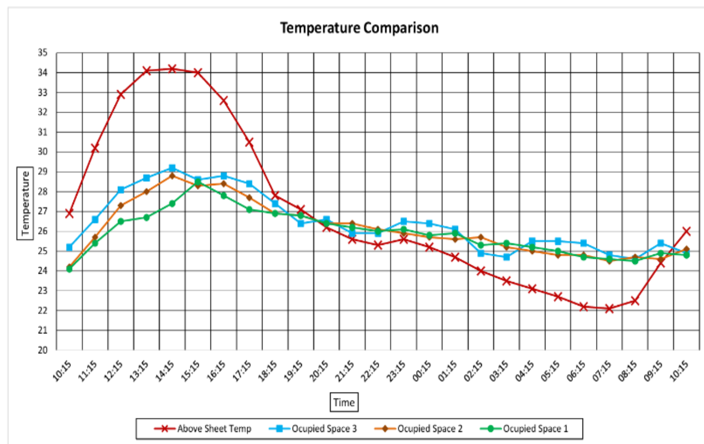

Fig. 5 Time Vs Temperature

Date: 02/02/2024

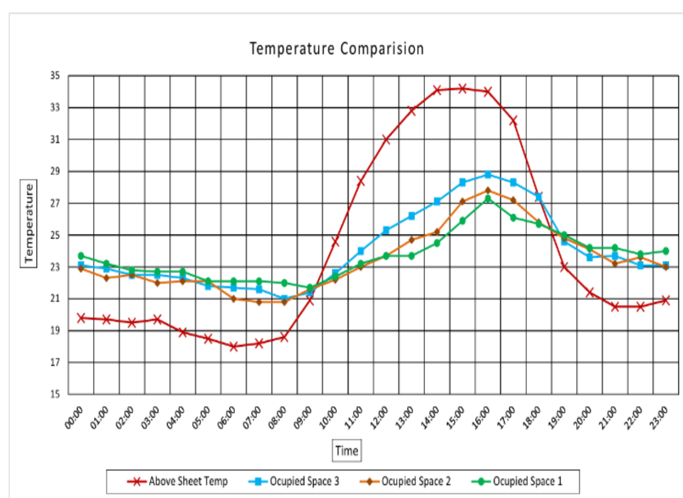

Fig. 6 Time Vs Temperature

Date: 14/02/2024

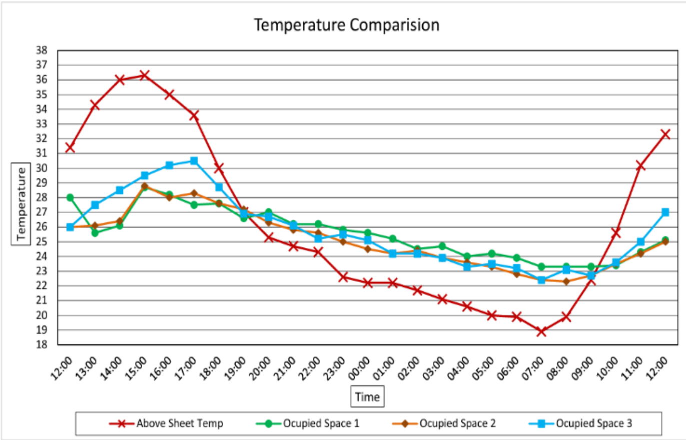

Fig.7 Time Vs Temperature

5. VALIDATION

The researchers validated their readings by referencing a research paper authored by Yiyun Zhu and Xianling Wang, which focused on the Qinba Mountains. They compared temperature data from various occupied spaces (OS) over time. The original readings were conducted on July 27-28, 2019, while their own readings were taken on October 28-29, 2023.

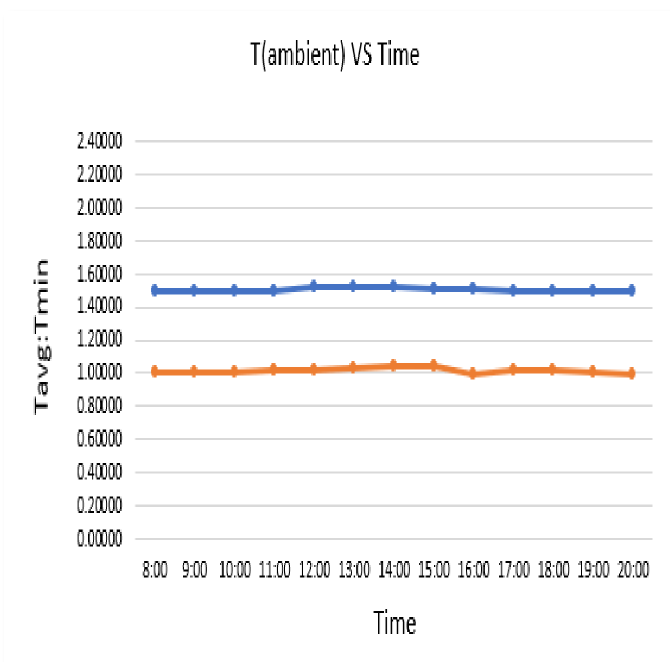

Fig. 8 Tambient VS Time

Yiyun Zhu and Xianling Wang

Present work

6. FUTURE SCOPE

The project aims to design and develop a sustainable ventilation system tailored to the unique challenges posed by various building structures, including those with sheet metal or reinforced concrete (RCC) roofs. Through meticulous geometry generation and experimental setup, detailed simulations will be conducted to analyse airflow dynamics within these structures. Factors such as window and door openings, building location, and exposure to solar radiation and wind velocity will be incorporated to ensure accurate representation of real-world conditions. The installation of ventilation mechanisms, including turbo ventilators and/or solar chimneys, will be strategically planned to achieve proper air change rates and create suction effects, enhancing thermal comfort while minimizing energy consumption.

Simulations will also encompass duct connectivity to evaluate airflow patterns within the entire ventilation system, ensuring efficient distribution of air throughout the building. Comparative study of windows glass panel with and without application Reflective film to assess its impact on reducing heat gain, while various attachment methods for bubble sheets under roofs or false ceilings will be explored to enhance thermal insulation.

Cost-effectiveness and sustainability will be key considerations throughout the project, with rigorous cost-benefit analyses and assessments of energy efficiency and environmental impact guiding decision- making. Validation of simulation results through real- world installations will be conducted, with continuous optimization to refine the design and improve performance under different conditions.

Ultimately, the project aims to demonstrate the practical feasibility and effectiveness of the developed ventilation system in real-world building projects, gathering feedback to inform further refinements and future research directions. Through collaboration with industry partners and research institutions, the project seeks to drive innovation in building ventilation technology and contribute to sustainable and comfortable indoor environments.

7. CONCLUSION

The investigation into the thermal insulation performance of radiant barrier roofs employing aluminium foil bubble sheets yielded significant insights. The presence of thermal resistance within the aluminium foil bubble composites, which addresses the three modes of heat transfer (radiation, conduction, and convection), underscores their positive insulating effect. Consequently, radiant barrier roofs demonstrate promising potential for widespread adoption, particularly in regions characterized by hot-summer/cold-winter climates. This project was conducted in room B-341, where notable reductions in room temperature by 4°C were observed compared to spaces lacking false ceilings. The installation of turbo ventilators along the ridge of sheet metal roofs effectively maintains positive air change, with exceptional performance observed during hot and humid conditions, such as in July 2023. The lightweight nature of bubble sheets facilitates straightforward installation using 2mm G.I wire grills measuring approximately 4X3.5 feet. Securing the wire to the wall involves the use of 7mm fasteners with clamps crafted from 40mm pieces of M.S. angle. The inclusion of eight controllable openings sized at 150X100mm allows for adaptable air exchange, accommodating seasonal climatic variations with ease. Moreover, this project underscores the cost-effectiveness and feasibility of adopting radiant barrier roofs with aluminium foil bubble sheets, particularly in low-income urban areas and slums. By providing a viable solution for improving thermal comfort and energy efficiency in housing for low-income populations, this study not only addresses pressing socio-economic challenges but also contributes to the advancement of sustainable and equitable development practices. The application of innovative materials and techniques in this context highlights the potential to uplift marginalized communities and foster inclusive growth in urban environments.

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