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Field Evaluation of Thermal Behavior of Aerogel-Infused Paint for Building Insulation

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ABSTRACT

Thermal coatings are highly sought after in both everyday living and industrial manufacturing. The utilization of aerogel in building insulation primarily relies on its low density, thermal insulating properties, flame retardancy, high light transmittance, and other distinctive features. This study investigates the thermal performance of an aerogel-based paint compared to conventional commercial paint for building envelope applications in hot climate conditions. Experimental tests were conducted under outdoor solar irradiation to assess surface temperature behavior, heat absorption characteristics, and effective thermal conductivity. A monitoring infrastructure was established to achieve this goal, allowing the on-site observation of temperature profile using a wireless sensor system called LoRa technology. According to the results, on average, aerogel coating showed a higher thermal reflectivity of 7% than conventional acrylic paint, around 2%. Besides that, the house applied with aerogel paint had a thermal conductivity of 0.019$\frac{W}{m^2 °C}$ while the conventional acrylic paint had a thermal conductivity of 0.131$\frac{W}{m^2 °C}$, representing an 85% improvement in thermal insulation performance. This enhanced performance is attributed to the aerogel's low thermal conductivity and high solar reflectivity, which together limit heat

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transfer through the wall. The findings highlight the potential of aerogel-enhanced paints as a passive thermal control strategy for improving indoor comfort and reducing energy demand in hot climate regions.

Keywords: Aerogel, heat transfer, thermal insulation coating

INTRODUCTION

Energy conservation and carbon reduction are two of the most pressing issues confronting human societies nowadays, and the future of humanity depends on how these issues are resolved. Several options have been engineered to address this issue. Thermal coatings are in high demand in domestic and industrial settings to tackle this issue due to excessive energy usage, especially during this post-pandemic era. As society evolves, demands for thermal coating performance in all industries grow. In recent years, thermal insulation has emerged as a popular research area (Ren et al., 2023; Shen et al., 2023; Sun et al., 2021). Thermal insulation materials have been widely applied in multiple sectors. It can be used on components of building construction, such as mortar (Becker et al., 2022), aggregate (L. Chen, 2011), and thermal insulation coating (X. X. Tao et al., 2010; Zhang et al., 2015). Besides that, aerogel has also been employed in aerospace applications (D. He et al., 2022; Pan et al., 2023; Vasile et al., 2020) in addition to the industrial equipment and pipeline usage (Mao et al., 2022). Moreover, the list of sectors or fields that employ the aerogel application has grown over the past decade and is still growing for the upcoming years. Therefore, on a more general note, aerogel has been applied to situations where temperature restrictions or overheating issues are a main concern. However, the insulation requirements vary depending on the application.

For example, buildings generate a lot of carbon dioxide yearly as part of the greenhouse gas emission plan. Though building energy demands increase, the demand for energy-saving materials and systems is rising due to concerns about greenhouse gas emissions (Berardi, 2017a, 2017b). According to the International Energy Agency's Global Buildings Tracker, building operations will account for 30% of global energy consumption in 2021, which is expected to keep rising, particularly in hot climate regions where solar heat gain significantly contributes to indoor thermal discomfort and increases cooling load. According to a study of building energy gain/loss paths, external walls and windows are significant sources of worry for building energy use. External walls gain/lose approximately 23-34% of energy, whereas windows gain/lose around 23-25% (Berardi, 2016; Powell et al., 2016; Raza et al., 2023). Even with the advancement achieved in the construction sector, these values are still worrying and must be reduced further. Due to that, among passive strategies, reflective coatings and thermal insulation paint have a crucial and distinct role in energy-efficient, low-carbon buildings by minimizing heat loss or gain in buildings (Nie et al., 2020; Z. Chen et al., 2023). Conventional paint, however, often lacks significant thermal resistance, limiting its ability to reduce heat transfer through building walls effectively. Therefore, insulation materials are increasingly being developed with high comfort levels to enhance the longevity of buildings and meet energy-saving requirements (Thapliyal & Singh, 2014).

The thermal properties of buildings depend on the thermal conductivity of the walls and roofs. Specifically, thermal insulation coatings may restrict heat transfer between an object and its environment, preserving a pleasant indoor temperature and less energy wastage. Most coatings employ thermal insulation or reflecting filler to improve thermal insulation capabilities. Thermal insulation coatings typically consist primarily of polymers and fillers (Miao et al., 2023; Wei et al., 2022). The primary role of the polymer is to disperse and secure the filler within the substrate. In contrast, filler is crucial for achieving low thermal conductivity and is indispensable for the thermal insulation coating. Therefore, it is essential to choose a suitable filler while carefully preparing the thermal insulation coating. Aerogel, a material currently being researched, is a strong candidate crucial for reducing building emissions by serving as an effective insulating material (Ganobjak et al., 2020).

Aerogel is a solid material with a definite shape and a complex structure of tiny, linked particles arranged in a three-dimensional network (Adhikary et al., 2021; Mazrouei-Sebdani et al., 2022). Aerogel has some remarkable characteristics because of its distinctive composition, such as a high specific surface area (500–1000 m^2/g), low density (0.003–0.2 g/cm^3), extremely low thermal conductivity (0.013–0.14 W/mK), and a high acoustic impedance (~1.05 MRayl). Aerogel possesses features that make it very suitable for various applications, such as thermal and acoustic barriers and other prospective uses (Hu et al., 2024; J. Tao et al., 2023; Wang et al., 2021).

Aerogel technologies are currently of significant importance in the worldwide insulation market. They are used in the building industry for various applications such as façade systems, plasters, boards, translucent panels, and aerogel panels for ventilation systems (Wakili et al., 2015). The utilization of aerogel in building insulation primarily relies on its low density, thermal insulating properties, flame retardancy, high light transmittance, and other distinctive features. Currently, the application form comprises aerogel glass, aerogel insulating coating, aerogel fiber composite material, and aerogel concrete and mortar. A building envelope insulation system utilizing aerogel material will be designed to achieve this objective, considering its advantages, as illustrated in Figure 1. The wall constitutes the most extensive surface area within the building envelope and contributes to approximately 30% of the building's energy consumption. Therefore, prioritizing insulation for the external wall is crucial for building energy conservation (Yu & Liang, 2016). Silica aerogel panels are also produced using other matrices, such as melamine foam and diverse fiber varieties. Table 1 displays the recorded thermal conductivity of the aerogel panel for several matrix materials and their corresponding densities (Joly et al., 2017; Shanmugam et al., 2020).

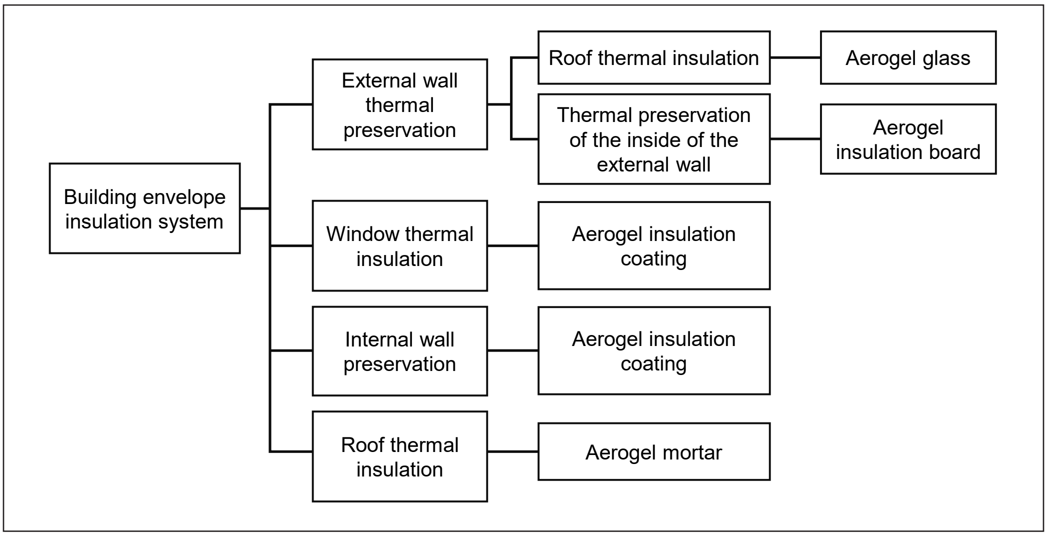


Figure 1. Building envelope insulation system utilizing aerogel material
Note. Reproduced from Yu and Liang (2016)

Table 1
Thermal conductivity of the aerogel matrix materials and their corresponding densities

Reference	Aerogel material	Density, ρ (kg/m³)	Thermal conductivity, k [W/(m.K)]
Joly et al. (2017)	Aerogel panel with melamine (10 mm)	98.7 - 101.0	0.0137 - 0.0136
	Aerogel panel with PET fiber (13 mm)	118.2 - 116.6	0.0148 - 0.155
	Aerogel panel with glass fiber (30 mm)	98.0 - 106.1	0.0148 - 0.0151
	Aerogel panel with needle glass fiber (7 mm)	182.5 - 194.9	0.0142 - 0.0156
S. He et al. (2025)	Aerogel blanket		0.028
Cuce et al. (2014)	Solid aerogel		0.012 - 0.020
Lu et al. (2018)	Aerogel from fly ash and bottom ash		0.0385
Karim et al. (2023)	Aerogel-based mortar coating	180.0	0.04
Y. X. Chen et al. (2022)	Geopolymer foam aerogel render (GFAR)	715.2	0.133
Zhu et al. (2018)	Aerogel using industrial solid wastes and dislodged sludges		0.03-0.032
Ibrahim et al. (2018)	Aerogel-based plaster	120	0.027

Note. Reproduced from Joly et al. (2017) and Shanmugam et al. (2020)

Due to its seamless adaptability to buildings, the aerogel paint shows promise as a solution for enhancing the thermal performance of buildings without altering their outward appearance. For instance, in a recent year, a study was done by Abdul Halim et al. (2025) developing a method that uses aerogel paint, which is interconnected with many Sustainable Development Goals (SDGs), predominantly by facilitating energy efficiency and mitigating environmental impact. Yet, despite this potential, the application of aerogel materials in painting formulations remains underexplored, particularly in real-world outdoor conditions. Most existing studies focus on aerogels in bulk form or within composite panels, while limited attention has been given to their behavior in thin-film coatings subjected to solar exposure.

Although aerogel paint offers numerous advantages, it is also essential to consider potential disadvantages. A notable limitation of aerogels is their fragility and rigidity, which can restrict their wide-ranging uses. The application of aerogel coating is reported to be challenging due to inadequate adhesion resulting from either a deficiency in physicochemical bonding or a disparity in the thermal expansion coefficient between the coating and the substrate, especially in real-world applications where paint is exposed to extreme conditions or weather. This ultimately leads to the formation of cracks and spalling. Furthermore, the production of composites may be restricted due to the paint's elevated viscosity. Besides, aerogel paint can be more expensive than conventional acrylic paint, limiting its affordability for many households. Although aerogel paint is expected to reduce heat transmission and indoor temperatures, its effectiveness may be limited in scorching climates or regions with significant humidity. The thermal conductivity of the aerogel might increase as it is exposed to continuous high temperatures, and the hydrophobicity of the aerogel will also disappear after exposure (Gao et al., 2023). In conclusion, although aerogel paint offers numerous advantages, it is crucial to consider these possible disadvantages before selecting it for thermal insulation in a residential setting. Applying a coating made of aerogel is challenging because of the specific characteristics of aerogel powders, such as their granulometric and morphological qualities, which are crucial for successful deposition (Abu Talib & Bheekhun, 2018; Bheekhun et al., 2014, 2018). Therefore, it is necessary to create a paint solution that contains aerogel, specifically focusing on its application in areas with extreme weather conditions or climate, and evaluate the performance for real field conditions.

Furthermore, there is a noticeable lack of comparative experimental studies that directly evaluate the thermal performance of aerogel-based paints against conventional paints. Assessments that combine surface temperature monitoring, solar heat absorption characteristics, and effective thermal conductivity measurement under outdoor environmental conditions are limited. This gap restricts the broader adoption and validation of aerogel-based coatings in practical building applications.

The present study details continuing research into the potential of using aerogel-based paint. A case study was conducted where aerogel-based paint was used to coat the exterior wall of a building located in Pasir Mas, Kelantan, Malaysia. An experimental home model is utilized to conduct a case study evaluating the enhancement of thermal comfort by adding aerogel-infused coatings/paint on the outer surface of the building wall. The study also seeks to assess the potential of aerogel-infused coating and identify anticipated uses for this technology. These coatings, infused with aerogels, were developed through a partnership with Maju Sainstifik Sdn. Bhd. and Bina Paint Sdn. Bhd., a Nano silica specialist and a paint manufacturing specialist, respectively. The aerogel-infused coating can be applied the same way as regular construction paint, making it highly convenient for application in real-world conditions.

The main goal is to analyze the long-term thermal characteristics of the painted surfaces. A monitoring system was established to achieve this goal, allowing the direct observation of temperature and humidity levels using a wireless sensor system called LoRa technology. These experiments aim to compare the thermal properties of a house building treated with aerogel-based paint and regular paint. In addition, a constant array of sensors monitors the indoor and exterior circumstances and those in the neighboring rooms. The findings of the initial comprehensive in-situ monitoring campaign, which aimed to compare the thermal performance of a house building treated with aerogel-based paint and regular paint, are presented and analyzed.

METHODOLOGY

This section introduces the case study building and outlines the methods used to evaluate the thermal advantages derived from aerogel-infused paint. The section will also encompass a comprehensive depiction of the sensor measuring system, incorporating the utilization of LoRa technology for thermal and humidity measurement and monitoring purposes.

Wall Partitions and Sensor Installation

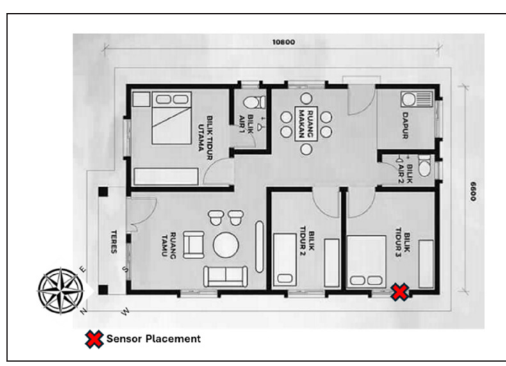
The advanced aerogel-based paint has been put on the concrete block walls of two test buildings in Pasir Mas, Kelantan (Figure 2). This test aims to evaluate the effects of the thermal properties of the Aerogel-based paint panels examined in this study. The thermal conductivity of the entire wall is measured. The wall's thermal conductivity contributes to the building's comfort level. It was expected that the thermal insulation paint could reduce the heat transfer conducted through the wall, which would reduce the ambient temperature inside the building, increasing the level of comfort for the residents. Applying this thermal coating or paint in "real conditions" might substantially alter the thermal conditions, mainly when used for wall insulation. However, several external factors will affect the performance of the insulator, such as ventilation and weather. These factors, especially the weather, are uncontrollable when conducting actual condition or site testing. Despite concerns about the weather control, this study will concentrate on the potential to enhance the thermal performance of the building by implementing aerogel-enhanced systems.

This study used two identical houses, as shown in Figure 2a with the same orientation to evaluate the effectiveness of wall insulation technologies. Both houses were built based on the standard set by the Syarikat Perumahan Negara Berhad (SPNB) in terms of the brick and material used. Besides that, the paint application procedure also follows the standard application method, which includes the number of layers and the other preparation requirements before applying the paint. What makes the difference is the paint used to coat the house's external wall. One house had an external wall coated with aerogel-infused paint. In contrast, the other house had its exterior wall coated with the standard wall paint provided by the same manufacturer as the baseline scenario.

The wall partitions were identical in their exposure to sunlight during the afternoon, as one side was entirely exposed without any obstructing structures. The paint was applied with a roller, with the same number of coats and approximately similar thickness in both cases. Besides that, white was chosen for both paints to maximize the thermal reflectivity on the wall. This is because darker hues or even colored paint can increase heat absorption on the wall. A complete thermal performance comparison can be made for aerogel and conventional acrylic paint. The house floor plan is shown in Figure *2*b. Based on the figure, the house has one room facing the sunrise and the other two rooms facing the sunset. The testing wall will be the one that faces the sunset. Therefore, the sensor will be placed on the room wall exposed to the evening sun, as indicated by the cross sign in Figure *2*b. The room was empty without any furniture, and even the fan or heating, ventilation, and air conditioning (HVAC) system was set to be off for the duration of the testing. So, the room was set up to control conditions for both houses.

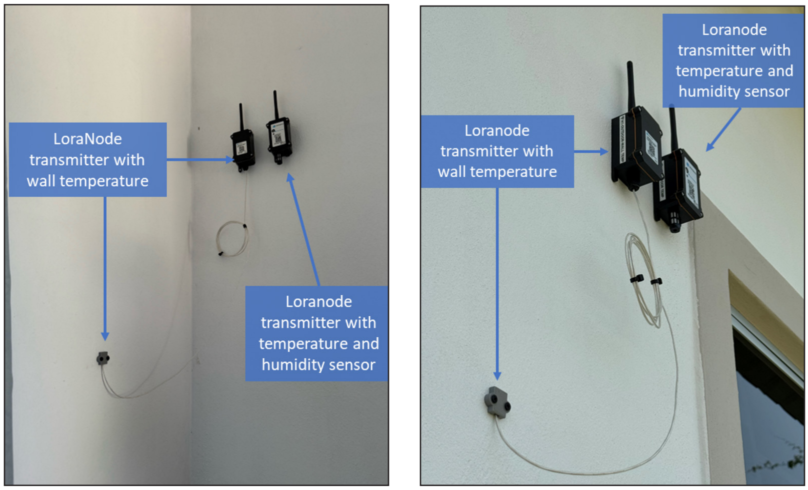
Sensors are placed on the inner (Figure 3a) and outside surfaces (Figure 3b) of all relevant wall partitions in early October 2023 to assess the thermal characteristics. These sensors are positioned at the same heights and locations to monitor the temperature of the walls, the surrounding temperature, and the relative humidity. This experimental effort aims to gather significant data to comprehend the thermal dynamics within the structure over a five-week data collection period. Furthermore, the external conditions remain beyond our control. This will result in many scenarios and possibilities that the applied paint has encountered. All sensors will be connected to LoRaWAN devices to make them more accessible remotely.

(a)



(b)

Figure 2. (a) Test house at Pasir Mas, Kelantan; (b) Floor plan of the houses
Note. Retrieved from SPNB (n.d.)



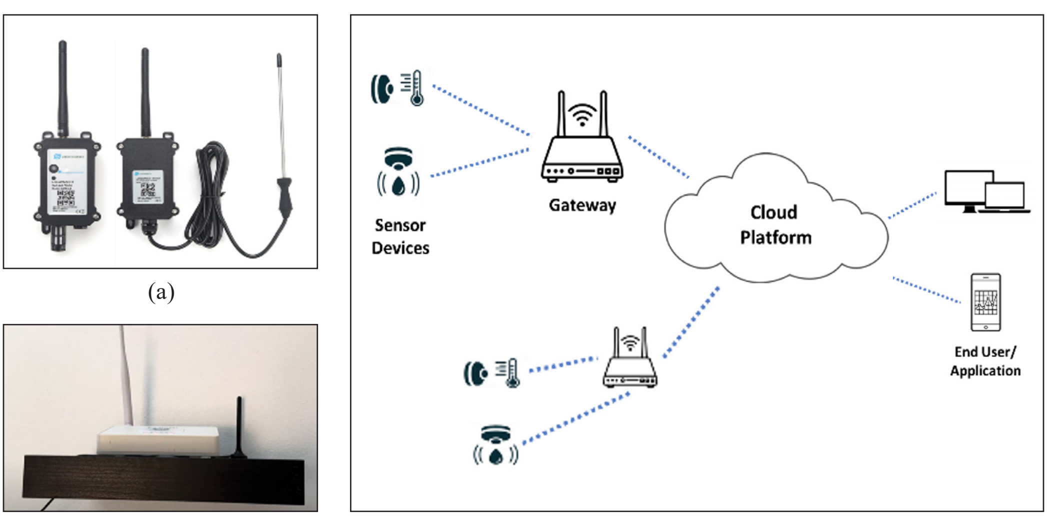
(a) (b)

Figure 3. LoraNode transmitter with temperature and humidity sensor positioning: (a) Indoor; (b) Outdoor

LoRaWAN networks are the preferred choice when there are many devices in a small area, and there is a need for low delays and high dependability, with the ability to adapt to different requirements. Therefore, the monitoring system attempts have chosen the LoRa/LoRaWAN composition due to its various advantageous properties, including bitrate, energy consumption, communication range, simplicity, use of unlicensed bands, and ease of management facilitated by its star-of-stars topology (Beltramelli et al., 2021; Chaudhari et al., 2020). The network will be cost-effective, energy-efficient, and capable of measuring thermal and humidity parameters and facilitating real-time monitoring.

As previously explained, the temperature and relative humidity were remotely monitored and measured using LoRa technology. All the sensors that have been installed will be linked to the LoRaNode transmitter as shown in Figure 4a. Consequently, each house will have a LoraNode transmitter that includes a Temperature and Humidity sensor and a LoraNode transmitter that measures the wall temperature indoors and outdoors. The LoraNode transmitters will consistently transfer the data signal to the LoRaWAN Gateway, Figure 4b located within each residence. The data sampling was transmitted every minute, and the sampling duration was 24 hours daily (total data collected per sensor was 50,400 samples). However, for comparison purposes, only data collected in the evening were considered since the peak exposure of the testing walls is around evening. This consideration was made because heat sources come from the sun's radiation. Therefore, during the early morning, the radiation was not as intense as during the evening. Besides that, it also reduces the uncertainty of the measurement as the measurement was done only on one wall surface, which faces the direction of the evening sun. This helps reduce the data size but also helps focus on the optimum comparison between the paints. The gateway functions as a relay to provide smooth data transmission between the sensor and the end devices using LoRa frequency bands. The user can access the sensing information through their terminal, which can be done either through a web-based dashboard or an IoT cloud platform. This can be done using laptops, personal computers (PCs), or smartphones. The fundamental operational mechanism of the sensor system is illustrated in Figure 4c. LoRaWAN technology was proven to help remotely monitor real-time data. This has opened new possibilities for testing, such as expanding the range of testing areas from a small area to a much bigger region with different environmental conditions.

The summary of the site testing, which employs the IoT monitoring system using the LoRaWAN technology, is shown in Figure 5. With all the advantages that have been mentioned, these technologies still have some drawbacks, which need proper networking planning. Proper networking planning is critical for LoRaWAN performance because it relies on long-range, low-power radio signals sensitive to surrounding factors. Structures like other buildings, trees, and terrain can disturb the signal of the LoRaWAN. Besides that, gateways must be strategically located to ensure full signal coverage while avoiding dead zones and redundant overlap. Poor networking planning can lead to weak signal strength and frequent retransmissions, which can drain the device's batteries. Therefore, to avoid issues related to this technology, a professional group that was well-versed in this technology reached out for help. The devices were installed by technicians from the Wireless and Photonic Networks (WiPNET) team. Besides the installation, this team also provided help regarding the monitoring process for both houses during the duration of the testing, which was for five weeks.



(a) (b) (c)

Figure 4. (a) LoraNode; (b) LoRaWAN Gateway with 4G; (c) The simplified basic working mechanism of the sensor system

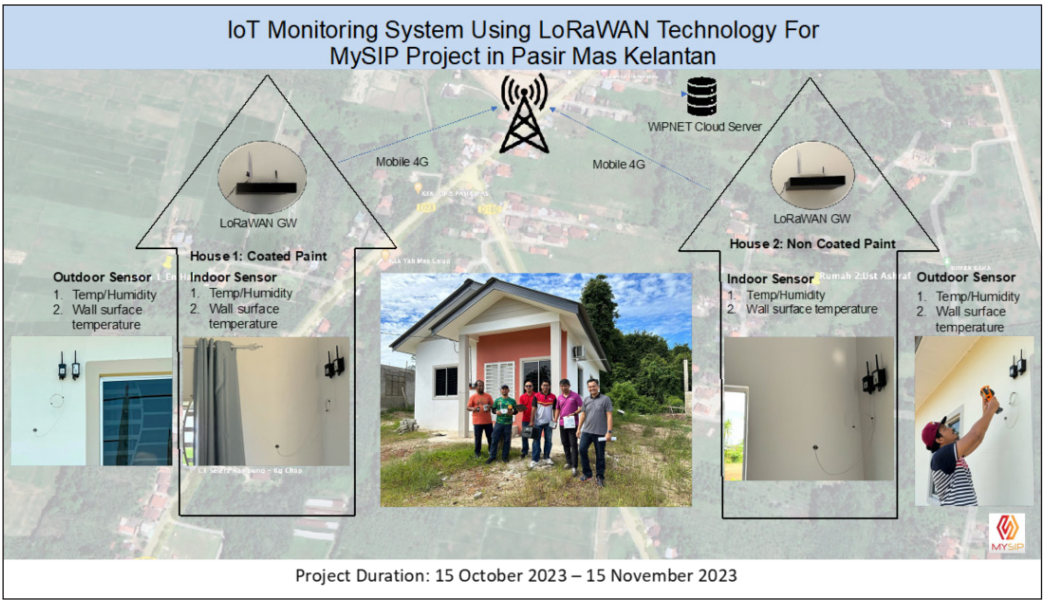


Figure 5. Summary of the Internet of Things (IoT) monitoring system using LoRaWAN technology for the project
Note. WIPNET = Wireless and Photonic Networks; GW = Gateway

RESULTS AND DISCUSSION

The case study is on Pasir Mas, a Kelantan town renowned for its tropical climate. The city is located at a latitude of 6.0424° N and a longitude of 102.1428° E. The weather dataset is from the NASA Prediction of Worldwide Energy Resources, an internet portal with geographic information system (GIS) capabilities. The company provides customized data solutions for three primary user segments: Renewable Energy, Sustainable Buildings, and Agroclimatology. Figure 6 illustrates the cumulative daily solar energy received in the specified climate. Solar radiation increases the temperature of the walls of buildings. As mentioned, walls and windows significantly contribute to the building's rising temperature. Depending on the region, in most buildings, whether residential buildings or industrial ones, the walls and windows are fully exposed to the sun's rays or radiation. In the Malaysian region, where the weather is a tropical climate, Malaysian regions receive about six hours of direct sunlight daily throughout the year since Malaysia is not a four-season country. Based on Figure 6, on average, the solar radiation is at the level of 250 W/m^2, as observed during cloudy days. This number can increase with fewer clouds during a clear sky or good weather. This long exposure to direct sunlight will increase the building's temperature.

An initial observation was done a few weeks before utilizing LoRa technology for thermal and humidity measurement and monitoring purposes using an Infrared sensor camera, as shown in Figure 7. The measurements were made every half an hour for each house from around 10 a.m. until 5 p.m. Even though the camera could capture the whole

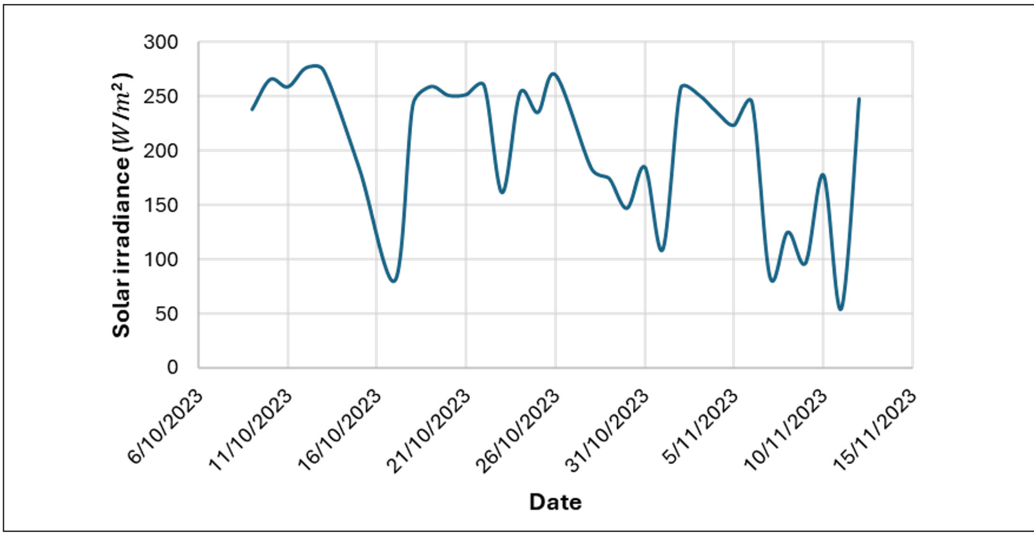
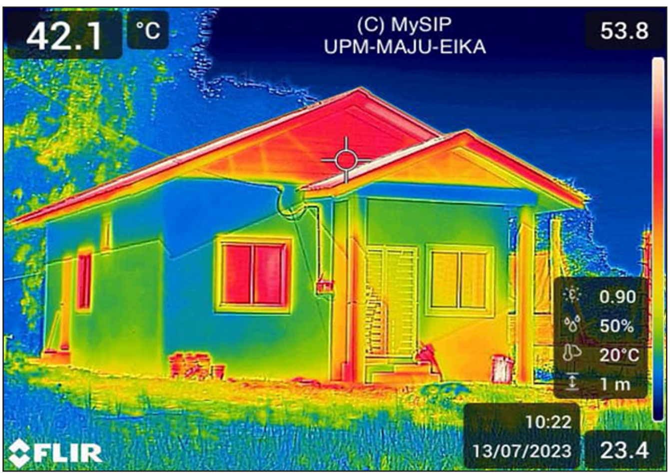


Figure 6. Cumulative daily solar radiation at Pasir Mas, Kelantan

house's thermography, only the interior and outer wall surface temperature was measured and recorded. This means that the temperature of the other parts of the house, such as the window's glass and the house's roof, was not recorded since the region of interest for the current test is the walls that were applied with the aerogel paint. Before the thermograph of the house wall was captured, the emissivity setting of the wall surface was refined accordingly based on the American Society for Testing and Materials (ASTM) E1933 to ensure accurate temperature measurement. For the current case, the emissivity of the wall surface has been estimated using the reference emissive materials method. Based on this method, part of the wall was placed with a piece of electrical tape with known emissivity, which was then used to provide the reference temperature for measuring the emissivity of the wall surface. Based on the thermal images captured, a house coated with aerogel paint shows a significant temperature difference between the indoor and outdoor wall surfaces compared to the conventional acrylic paint. On average, the temperature difference is around 2.1 to 2.4°C for aerogel paint, while it ranges from 0.8 to 1.6°C for conventional acrylic paint. Figure 7a shows the minimum and maximum temperature difference for each house over time. These values indicate that the aerogel-painted house managed to reduce the indoor temperature of the house based on the contribution of the wall alone.

Figure 8 illustrates that the house coated with aerogel paint had a much lower outside wall temperature than the outdoor ambient temperature. This indicates that the insulation effectiveness of the wall will improve, and the influence of the aerogel can become more noticeable. This is because the paint could reduce the absorption of solar radiation. This outcome illustrates the paint's capacity to act as a thermal reflector for the wall. On average, aerogel paint reduces more than 2.5°C, representing about 7% of solar heat reflection compared to around 2%, as shown by the typical paint in Figure 9. This was contributed by the aerogel properties of high porosity, which have been reported by many previous studies, which reduce the heat transfer by conduction, which leads to a lower level of heat energy being transferred to the outer wall from solar radiation. Besides that, aerogels were engineered to block infrared radiation effectively. For instance, silica aerogel exhibits strong scattering and reflection of infrared waves, which makes it ideal for thermal insulation against radiative heat transfer.



(a)

Aerogarde Paint

Time	Temperature Difference
10:50 am	2.1°C
13:50 pm	2.4°C

(b)

Normal Paint

Time	Temperature Difference
09:45 am	1.6°C
14:00 pm	0.8°C

(c)

Figure 7. (a) Whole house Infrared camera observation sample; (b) House 1 Temperature difference at two different times; (c) House 2 Temperature difference at two different times

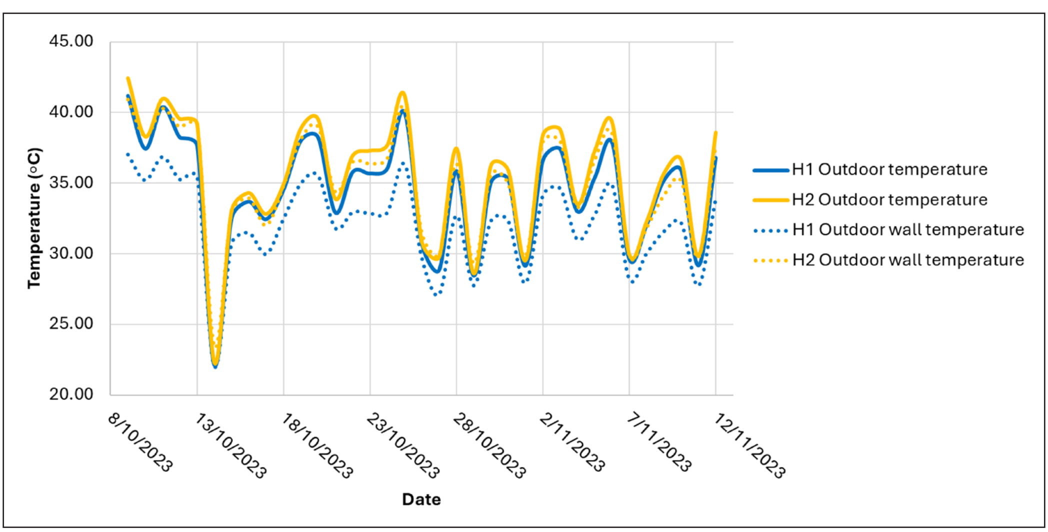


Figure 8. Outside wall temperature in comparison to the outdoor ambient temperature
Note. H1 = House 1; H2 = House 2

Following the analysis of surface temperature differences under solar exposure, where the wall coated with aerogel-based paint consistently exhibits lower surface temperature than the conventional acrylic paint-coated wall, a detailed thermal conductivity assessment was conducted to quantify their insulating performance. The wall coated with aerogel-based paint demonstrates a remarkably low thermal conductivity of $0.019\frac{\mathrm{W}}{\mathrm{m}^2{}^\circ\mathrm{C}}$, in contrast to $0.131\frac{\mathrm{W}}{\mathrm{m}^2{}^\circ\mathrm{C}}$ for the conventional acrylic paint. This represents an approximation of an 85% reduction, confirming that the aerogel enhancement formulation effectively suppresses heat transfer through the wall. The reduction in the surface temperature observed is attributed to both the low thermal conductivity and the high solar reflectance of the aerogel coating, which limits the amount of heat absorbed and conducted into the wall. The aerogel's nanoporous structure restricts conductive and convective heat flow, thus enabling the paint to function as a high-performance thermal barrier. These findings underscore the potential of aerogel-based coatings in improving thermal insulation of building envelopes, offering a passive and scalable solution for reducing indoor heat gain in hot climates.

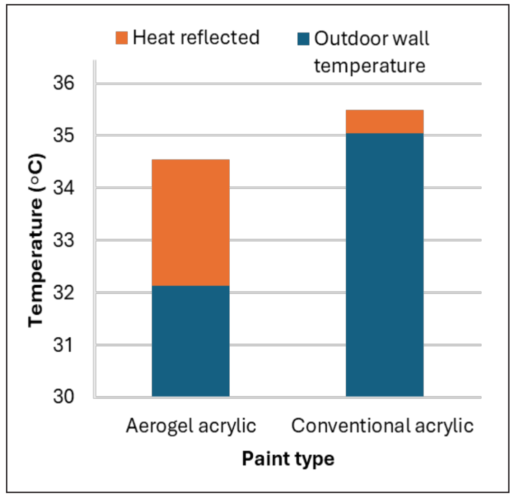


Figure 9. Solar heat reflection by aerogel and conventional acrylic paint

An extensive data analysis was performed to ascertain the variations in the conductivity of the wall structures. To carry out this study, it was essential to monitor the temperature on both the inside and outside sides of the wall (Figure 10).

The thermal resistance, R, was determined using the mean method outlined in the ISO standard 9869 (International Organization for Standardization [ISO], 2014). The standard provides guidelines for determining the thermal performance of building elements (e.g., walls, roofs, floors) under real-world conditions. One key feature and benefit of using ISO 9869 is that, unlike laboratory tests, ISO 9869 captures real-world conditions, including environmental influences like wind, humidity, and temperature fluctuations, and this method does not require damaging the structure, which makes it ideal for assessing existing buildings. Besides that, the standards account for dynamic thermal behaviors such as thermal inertia and transient heat flow by taking long-term measurements, which typically take several days to weeks. To calculate the resistance, one can use this method by dividing the average temperature difference from the wall by the average heat flow density (Equation 1).

$$R = \frac{\sum_{j=1}^{n}\left(T_{si,j} - T_{se,j}\right)}{\sum_{j=1}^{n} q_j} \qquad [1]$$

According to the data, it was noticed that home 1, coated with aerogel paint, showed an average thermal resistance of $0.007 \pm 0.0004\frac{W}{m^2 °C}$ while the conventional acrylic paint records around $0.018\frac{W}{m^2 °C}$.

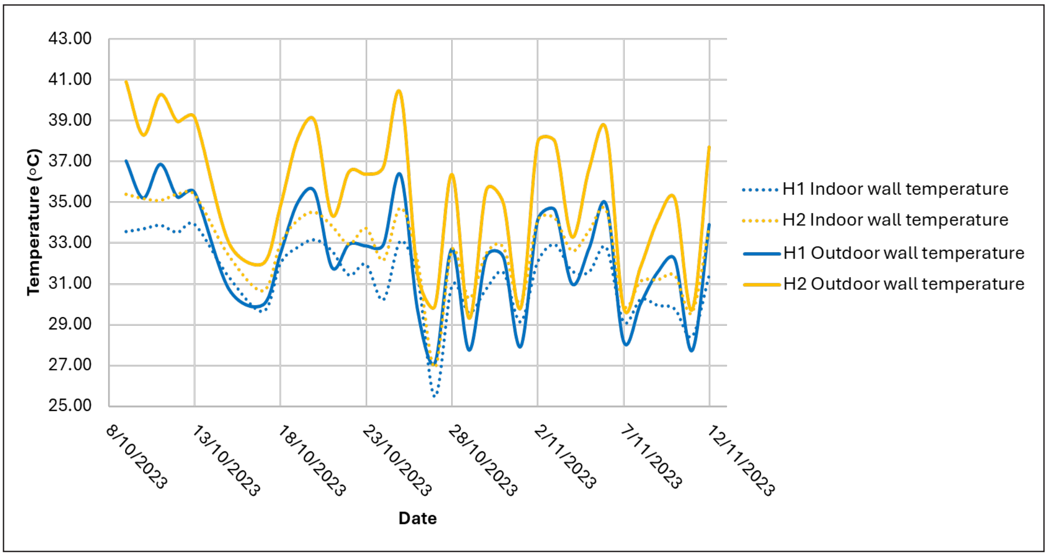


Figure 10. The temperature on both the inside and outside sides of the wall for both houses
Note. H1 = House 1; H2 = House 2

CONCLUSION

This article reported a preliminary study of an elaborate in-situ assessment of the thermal performance of two houses applied with aerogel-infused and regular paint, respectively. This analysis used a monitoring and measuring system that implements LoRa technology. The house coated with aerogel paint had a much lower outside wall temperature than the outdoor ambient temperature. This indicates that the insulation effectiveness of the wall will improve, and the influence of the aerogel can become more noticeable. This is because the paint could reduce the absorption of solar radiation. This outcome illustrates the paint's capacity to act as a thermal reflector for the wall. On average, aerogel paint reduces more than 2.5°C, representing about 7% of solar heat reflection compared to around 2%, as the typical paint shows. Based on the data, it was discovered that the thermal conductivity of the house that was coated with aerogel-infused paint was $0.019\frac{W}{m^2 °C}$ while the conventional acrylic paint has $0.1\frac{W}{m^{2}°C}$. The aerogel nanoporous structure, combined with high solar reflectance, plays a dual role in minimizing conductive heat transfer and radiative heat gain. These findings confirm that aerogel-infused coating or paint provides a passive thermal barrier that limits solar heat absorption. This contributes to improved indoor thermal comfort and potential reduction in cooling energy demand. As such, aerogel-infused paint represents a promising solution for enhancing the energy efficiency of a building, particularly in hot and sunny climates.

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