



Original Article

Rethinking Facade Materials in Hot-Humid Cities: Low-E Glass as a Thermal Competitor to Concrete in Dubai's Urban Climate



Slefani Nada Salih Ammo , Md Azree Othuman Mydin* , Nooriati Taib , Sharifah Fairuz Syed Fadzil 

School of Housing, Building and Planning, Universiti Sains Malaysia, 11800, Penang, Malaysia

* Correspondence email: azree@usm.my

Abstract

The extreme temperatures and high humidity levels in Dubai intensify the urban heat island (UHI) effect across the metropolitan region. This study investigates whether the increasing use of advanced glass technologies contributes to the UHI effect, given the widespread presence of glass-clad buildings within the city skyline. A case study was conducted on a high-rise commercial building located near Dubai International Airport, featuring a U-shaped architectural design with a double-layer glass façade consisting of tempered Low-E glass, an air cavity, and clear glass, complemented by aluminium curtain wall elements. A combination of thermal cameras, laser distance meters, and heat loggers was employed to assess surface temperatures, relative humidity, and thermal radiation across different building orientations. Data were collected between April and September 2024, with heat loggers installed on multiple façade orientations, including the south-facing concrete wall. Thermographic images and laser measurements were manually recorded, while temperature and humidity readings from the heat loggers were stored in CSV format. A custom Python-based application was developed to process and validate the collected data, which was subsequently presented through tables, charts, and visualisations. The findings indicate that modern glass façades do not significantly intensify the urban heat island effect in Dubai and may instead contribute positively to urban sustainability.

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Article Info

Received: 12 April 2026

Received in revised form: 8 June 2026

Accepted: 23 June 2026

Available online 21 September 2026

Keywords

Glass Façade
Extreme Temperatures
High Rise Buildings
Thermal Dynamic
Urban Heat Island

1. Introduction

Urban heat islands (UHI) represent a significant challenge for cities worldwide, particularly in densely built environments where urban design and construction materials contribute to higher temperatures compared to surrounding rural areas [1]. Fenestration systems, which include windows and glass façade elements in buildings, play a critical role in thermal gain by allowing increased solar radiation penetration, thereby elevating the thermal load within urban environments. However, with continuous

advancements in glazing technologies, modern glass systems have emerged as potential mitigation solutions capable of reducing the UHI effect while also offering substantial economic and energy-efficiency benefits [2]. Globally, urban areas continue to experience intensified UHI effects due to rapid urbanisation, reduced vegetation coverage, and the prevalence of impermeable grey surfaces such as asphalt and concrete, which absorb and retain heat, particularly during summer periods. Consequently, cooling features such as water bodies, trees, and vegetation are increasingly recognised as essential components for mitigating UHI effects and enhancing urban liveability.

In hot climatic regions, modern construction materials, especially advanced glass façades, play an important role in improving energy efficiency and supporting urban thermal balance. The integration of high-performance glazing systems can reduce solar heat gain, improve building energy performance, and contribute to urban cooling effects. Coastal cities such as Dubai present a unique context in which sea breezes, urban morphology, and architectural design collectively influence the thermal environment and UHI intensity [3].

Located in an arid desert climate, Dubai often records summer temperatures approximately 2–5°C lower than the surrounding desert due to its urban planning strategies, which emphasise wide setbacks, extensive landscaping, and shaded pedestrian pathways that enhance the city's microclimate [4]. Frequently described as an oasis within the desert, Dubai's urban landscape combines skyscrapers, vegetation, and water features that collectively contribute to temperature moderation and urban cooling. Nevertheless, the extensive use of glass façades on high-rise buildings presents both opportunities and challenges for energy efficiency and UHI mitigation. While advanced fenestration systems can reduce building energy consumption by up to 50%, glass façades may also contribute to localised heat accumulation through reflection and radiation, potentially intensifying UHI effects [5]. To address these concerns, modern glazing technologies such as Low-E glass are increasingly adopted to minimise reflectivity and reduce solar heat absorption, thereby lowering the thermal load on buildings [6].

In parallel, Dubai's urban planning policies have progressively incorporated green roofs, shaded walkways, artificial lakes, intelligent façade systems, and district cooling technologies to further mitigate urban heat island effects and enhance urban sustainability. Although reflective glass surfaces can generate localised thermal hotspots, the city's integrated architectural and planning strategies aim to alleviate these impacts by improving airflow and reducing heat concentration areas [7]. Overall, the management of UHI in Dubai relies on a comprehensive approach that integrates advanced materials, innovative urban planning, and sustainable mitigation strategies to address the complex interactions between heat, airflow, and the built environment. As the city continues to develop, understanding the role of construction materials, particularly advanced glass façades, in urban sustainability and UHI mitigation remains essential for creating a more livable, energy-efficient, and climate-responsive urban environment [8]. This study therefore investigates the role of advanced glass façades in Dubai's urban thermal dynamics, with particular emphasis on their interaction with the city's unique climatic conditions and urban design characteristics in influencing the UHI phenomenon.

2. Methodology

This research adopts a quantitative and experimental methodology to investigate the thermal behaviour of glass façades in comparison with conventional construction materials within the context of the urban heat island (UHI) phenomenon. The study was conducted using an actual high-rise commercial office building in the urban area of Dubai as the primary case study. Due to its advanced glazing systems and strategic placement in a densely built metropolitan setting that faces severe weather conditions like elevated temperatures, intense solar radiation, and high humidity, the selected building was the preferred option. The research methodology focused on evaluating the influence of glass façade systems

on local thermal dynamics and determining their potential contribution to or mitigation of urban heat island effects.

To achieve the research objectives, a comprehensive field measurement campaign was carried out over several months to capture real-time environmental and thermal performance data under actual operating conditions. Multiple scientific instruments and monitoring devices were employed to assess key thermal parameters, including surface temperature, ambient air temperature, relative humidity, and thermal radiation across different orientations of the building façade. Thermal imaging cameras were used to capture thermographic distributions and identify heat concentration zones on the façade surfaces, while laser measurement devices were utilised to verify distances and improve the accuracy of façade-related thermal assessments. In addition, heat loggers equipped with temperature and humidity sensors were strategically installed on various façade orientations, including the south-facing concrete wall and glazed sections, to continuously record environmental data throughout the study period.

The data collection process was conducted systematically between April and September 2024 to ensure that measurements reflected the peak summer conditions typically associated with severe UHI intensity in Dubai. Thermographic images and laser measurements were manually recorded during selected daytime periods to capture the influence of solar exposure and façade orientation on thermal performance. Simultaneously, the heat loggers continuously stored temperature and relative humidity data in CSV format at predefined time intervals to ensure consistency and reliability in the dataset. The collected data were subsequently processed, validated, and analysed using a custom-developed Python-based application designed specifically for thermal performance evaluation. The analytical procedures included data filtering, validation, comparative thermal analysis, and the generation of graphical visualisations, charts, and tabulated summaries to facilitate interpretation of the results. Through this integrated experimental methodology, the study provides a detailed assessment of the thermal performance of modern glass façades and their implications for urban sustainability and urban heat island mitigation in hot-arid urban environments.

2.1. Tools and Instruments

The research methodology employs three principal instruments: a thermal camera (TC), a laser meter (LM), and heat loggers (HL). These instruments were systematically positioned across various orientations of the building to collect data at different intervals throughout the summer of 2024. Each device provided distinct insights into the thermal characteristics of the building, thereby enabling a comprehensive assessment of urban heat dynamics.

- a) Thermal Camera (TC): Utilised to obtain thermographic images that depict surface temperatures on the building façade. The thermal camera identifies infrared radiation, enabling the visual depiction of temperature fluctuations, which are beneficial for recognising heat loss, reflection, and absorption patterns on glass and conventional materials.
- b) Laser Meter (LM): A temperature laser meter was utilised to acquire accurate surface temperature measurements of items at proximity. The LM functioned as a calibration instrument for validating thermal measurements obtained from the thermal camera.
- c) Heat Loggers (HL): The Testo 174H heat loggers were strategically positioned at critical sites to continually monitor temperature and relative humidity for a duration of six months. The loggers supplied real-time data for analysis, facilitating the evaluation of environmental conditions near both glass and concrete surfaces.

The temperature data acquired from these instruments were analysed utilising a blend of established formulae and bespoke data-processing algorithms, which are elaborated upon below.

2.2. Case Study Building

The selected case study involves an office building located in Dubai Silicon Oasis at geographic coordinates 25.1220906°N and 55.3712034°E. The building features a U-shaped architectural configuration, with glass façades covering three sides of the structure, while the southern façade consists primarily of a concrete wall. Heat loggers were systematically installed at a height of 18 metres above ground level on both the glass and concrete surfaces to monitor variations in surface temperature and relative humidity throughout the summer period from April to September 2024. Figure 1 shows the isometric view of a case study in Dubai, Silicon Oasis, and its architectural plan. Red markers indicate the location of the heat logger (HL) 18 metres above the ground floor. Figures 2 (a-d) show the thermographic images of the east roof car parking, west car parking, north building, and south building.

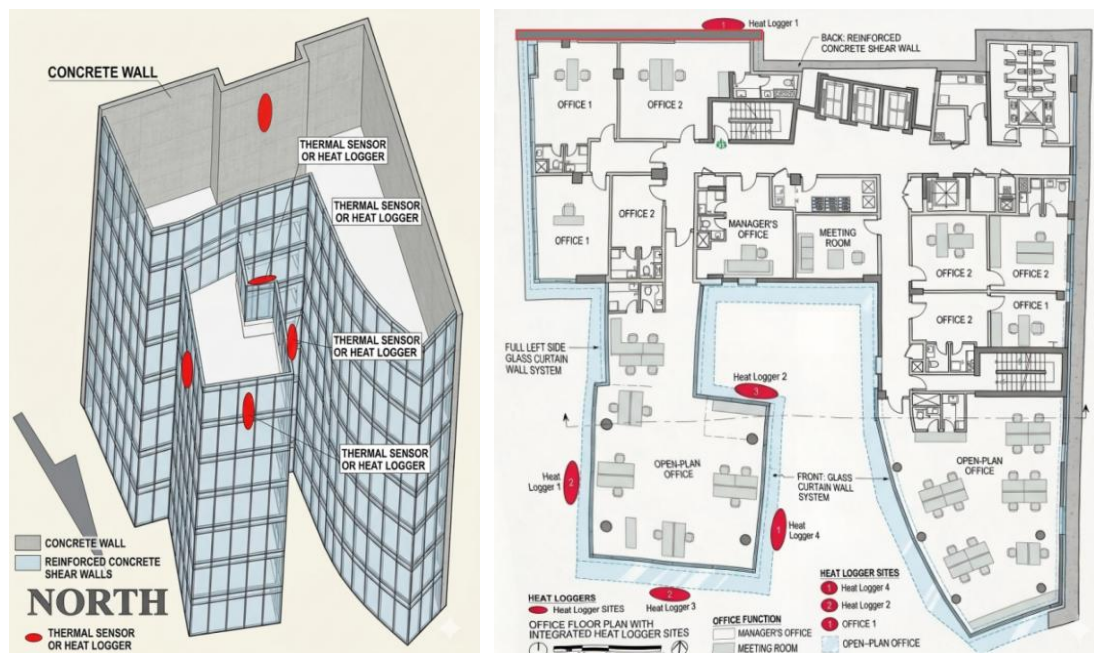


Figure 1. Isometric view of case studies in Dubai, Silicon Oasis, and its architectural plan.

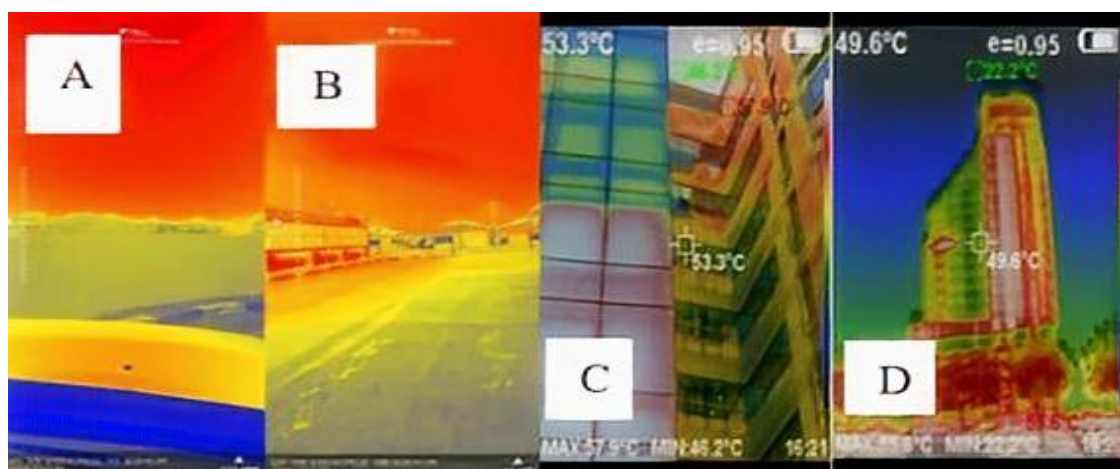


Figure 2. Thermographic image of: A-East roof car parking. B-West car parking. C-North building. D-South building.

2.3. Data Collection Procedures

The data collection procedure encompassed several phases, as detailed below:

- a) Infrared thermographic images were obtained via a high-resolution, professional thermal camera. Data was gathered at two distinct times: 10:00 AM and 4:00 PM, to document temperature fluctuations resulting from solar exposure. The selected times are based on prior studies, indicating they correspond to peak periods for collecting temperature swings.
- b) The laser meter was employed to ascertain the surface temperatures of glass and concrete, serving as a benchmark for the thermal camera's data. The measurements were obtained concurrently with the thermal pictures, ensuring data set alignment.
- c) Heat loggers were positioned at five distinct orientations on the structure, encompassing both the glass and concrete façades. The loggers gathered hourly data on temperature and relative humidity. The logger data were archived in CSV format and then analysed. A comprehensive time-series analysis was performed to assess temperature trends over the summer.

Although implementing the thermal camera (TC) technique required considerable operational effort, time, and financial resources, the method provided highly valuable and detailed thermal-performance data that could not be obtained through conventional visual inspection alone. The use of infrared thermography enabled non-destructive, real-time assessment of heat-transfer behaviour across the building envelope, thereby offering deeper insight into thermal bridging, air leakage pathways, and localised heat accumulation within the office enclosure. This approach enhances the reliability of the thermal-performance evaluation and contributes additional novelty to the study through the integration of spatial thermal mapping with façade-performance assessment under actual climatic exposure conditions.

Figures 3 (a-e) illustrate the surface thermal distributions recorded during the field investigation, where temperature magnitudes in degrees Celsius are represented through a calibrated colour spectrum. The thermographic analysis clearly demonstrates variations in thermal behaviour across different façade components and orientations, reflecting the combined influence of solar radiation, material properties, glazing characteristics, and ambient environmental conditions.

From the northern orientation shown in Figure 3(a), distinct cold-air exfiltration can be observed around the aluminium gaps of the window assembly, represented by the continuous blue contours surrounding the occupied office zone. This thermal anomaly indicates the existence of localised air leakage and potential thermal bridging at the frame junctions. The ceiling region appears predominantly yellow, indicating moderate surface temperatures due to the presence of insulation without direct cooling exposure. In contrast, the glazing surfaces exhibit red and orange colouration, signifying elevated temperatures caused by intense solar heat gain and external heatwave conditions during the monitoring period.

Figure 3(b) presents the western façade thermal condition at 10:00 AM, characterised mainly by blue regions intermixed with yellowish gradients. This thermal pattern suggests the occurrence of heat reflection and thermal refraction effects originating from adjacent surfaces and surrounding environmental elements. The variation in colour intensities reflects different rates of heat transfer and localised thermal-flow gradients, demonstrating the sensitivity of the façade system to directional solar exposure and surrounding microclimatic influences.

As illustrated in Figure 3(c), the window frame exhibits greater heat absorption than the glazing surface, despite the aluminium frame being partially concealed. This behaviour is attributed to the higher thermal conductivity of aluminium relative to glass, resulting in intensified heat accumulation within the frame components. The observation further confirms the role of metallic framing systems as

significant thermal bridges that may adversely affect indoor thermal performance and cooling efficiency.

Figures 3 (a-e) collectively present thermographic images captured and processed simultaneously at 10:00 am on May 15, 2024, under varying façade orientations. The synchronised image acquisition enhances the consistency and comparability of the thermal analysis by minimising temporal variations in weather conditions and solar intensity. The results reveal that elevated sections of the building envelope generally exhibit lower surface temperatures, which may be associated with increased solar elevation angles, improved convective heat dissipation, and reduced atmospheric pollutant concentration at higher elevations. Additionally, the bluish thermal signature observed on portions of the office ceiling indicates relatively low heat accumulation during the early operational hours of the building.

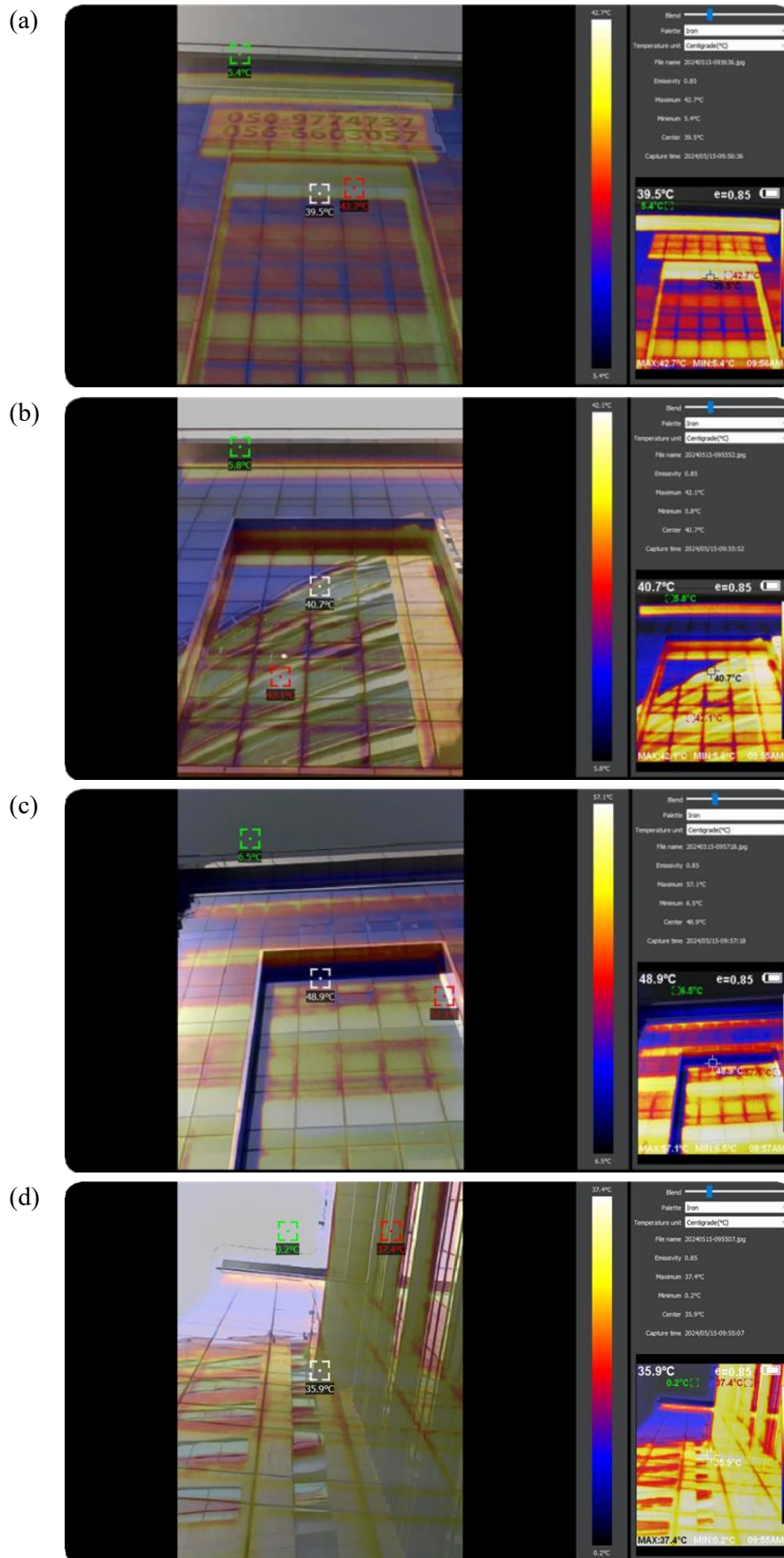
The incorporation of long-term thermographic monitoring throughout 2024, as provided in the Appendix, further strengthens the contribution of this study by enabling continuous evaluation of façade thermal behaviour under varying climatic conditions. Unlike conventional single-point temperature measurements, the adopted thermographic methodology provides comprehensive spatial visualisation of heat-transfer mechanisms, thereby offering a more advanced framework for diagnosing building-envelope inefficiencies and improving energy-conscious façade design strategies in tropical climates.

Figures 3(d) and 3(e) present a comparative thermographic assessment between conventional construction materials, namely concrete and stone, and glazing surfaces. The thermal images reveal that these materials exhibit nearly identical colour distributions under the same environmental exposure conditions, indicating comparable surface-temperature responses during the monitoring period. This observation suggests that both material categories possess similar heat-reflection and heat-retention characteristics under the prevailing climatic conditions, with no significant thermal-performance advantage observed for either material system.

The consistency of these outcomes is further validated by the corresponding temperature readings displayed alongside the thermographic images. The employed methodology is both systematic and reliable, whereby the thermal-camera software allows the operator to select any specific point within the captured image and immediately obtain its precise surface temperature. This capability enables accurate point-by-point thermal evaluation and enhances the precision of comparative façade-performance analysis.

Beyond experimental observation, the thermal camera also plays a critical role in on-site commissioning and building-performance verification. In professional engineering practice, infrared thermography is widely utilised to evaluate glazing-system performance, detect thermal bridging, and assess airtightness in compliance with local building regulations and energy-efficiency standards. The instrument provides measurable evidence of thermal emissions from certified mechanical and electrical systems located in various building zones, including rooftop installations and elevated architectural components.

The thermographic data presented in this study were systematically collected throughout the summer period of 2024 under actual operating and environmental conditions. By observing thermal changes over time and across various façade directions and material surfaces, the long-term monitoring method strengthens the findings' dependability and accuracy. The compiled dataset therefore contributes not only to the validation of building-envelope thermal behaviour but also to the development of more energy-efficient façade design and performance-evaluation strategies for buildings located in hot climatic regions.



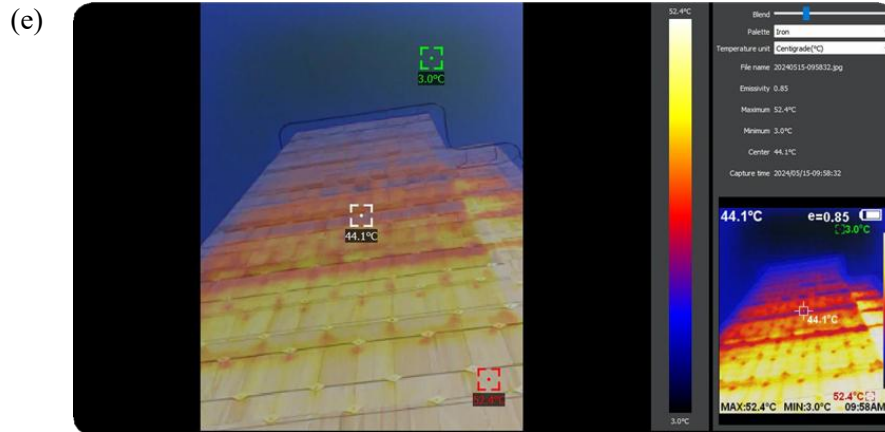


Figure 3. (a) Northern part illustrates the exfiltration of cool air from the glass edges; (b) Infiltration at the glass edges on the western façade; (c) Red line observed in the eastern direction corresponds to the frame behind the glass; (d) Glass (G) on the southern facade, displaying a yellow colouration as thermal emission commences; (e) Concrete surface on the southern facade exhibiting a pervasive yellow colouration at 10:00 AM as solar elevation increases.

2.4. Analytical Methods

Data obtained from the thermal camera, laser meter, and heat loggers were processed using several mathematical models to assess heat transfer and thermal dynamics. The following equations were applied to analyse the data:

Stefan-Boltzmann Law: Used to calculate the radiant energy emitted from the surfaces of both the glass and concrete materials. The law provides insights into the thermal behaviour of each material when exposed to solar radiation. The equation is:

$$E = \varepsilon \sigma T^4 \quad (1)$$

where: E is the radiant energy emitted, ε is the emissivity of the material, σ is the Stefan-Boltzmann constant, T is the surface temperature in Kelvin.

Heat Transfer Law: The heat transfer equation was used to calculate the rate of heat transfer through the building materials. The equation is as follows:

$$Q = U \cdot A \cdot \Delta T \quad (2)$$

where Q is the heat transfer rate (watts), U is the thermal transmittance (U-value) of the material, A is the area of the material surface (m^2), and ΔT is the temperature difference between the two sides of the material.

Heat Index (HI): The heat index was used to combine temperature and relative humidity data to assess human comfort and the perceived temperature. The equation used was:

$$HI = T + (0.33 \times RH) - 0.7 \quad (3)$$

where T is the temperature in Celsius and RH is the relative humidity.

2.5. Data Organisation and Visualisation

The data gathered from all instruments were systematically arranged into a set of tables and charts for analysis. Custom Python programs were employed to validate the data and produce visualisations that contrasted the thermal behaviour of glass and concrete materials at various orientations and times of day. The findings were displayed using tables, heat maps, and bar charts, facilitating a comprehensive comprehension of the thermal dynamics throughout the structure.

3. Results

3.1. Applying EQ1

The data collected using the laser meter (LM), thermal camera (TC), and heat loggers (HL) at 10:00 AM and 4:00 PM over multiple monitoring days were comprehensively analysed using the $E = \varepsilon\sigma AT^4$ to evaluate the radiant energy emitted from glass and concrete surfaces. The application of the Stefan–Boltzmann principle enabled a more rigorous interpretation of surface thermal behaviour by quantifying the relationship between surface temperature and radiative heat emission. At the heart of this research is thermal equilibrium, the process by which glass and concrete surfaces dynamically adjust their temperatures in reaction to external conditions, solar radiation, and ambient heat transfer. By examining the thermal responses of these materials under varying orientations and climatic exposures, the study provides a deeper understanding of their respective thermal characteristics and their contributions to the urban heat island (UHI) phenomenon.

The comparative analysis of glass and concrete surfaces under identical orientations revealed no substantial difference in their immediate temperature behaviour, despite the intrinsic differences in their physical and thermal properties. Both materials demonstrated comparable responses to solar radiation and surrounding environmental conditions, particularly during periods of direct solar exposure between 10:00 AM and 4:00 PM. The results presented in Tables 1 and Figure 4 indicate that, at 10:00 AM, both glass and concrete emitted nearly equivalent levels of radiant energy. This finding suggests that glazing systems do not necessarily produce significantly higher radiant heat emissions than conventional concrete surfaces when subjected to the same solar exposure conditions. Such observations challenge the common assumption that glass façades inherently intensify urban thermal loads more severely than opaque building materials.

For the southern orientation, both glass and concrete surfaces were exposed to intense solar radiation, substantially influencing their thermal behaviour due to combined reflective, absorptive, and refractive mechanisms. The investigation confirmed that both material systems actively contribute to heat reflection and thermal radiation, particularly during peak solar-intensity periods around midday. As demonstrated in Table 2 and Figure 5, the radiant energy emitted by both materials at 4:00 PM remained relatively comparable, further reinforcing the conclusion that orientation and solar exposure exert a stronger influence on surface thermal behaviour than material classification alone.

The performance of low-emissivity (Low-E) coated glass was found to be superior compared to conventional opaque materials. This outcome aligns with the intended functional properties of Low-E glazing systems, which are specifically engineered to reduce solar heat gain and minimise thermal transmission through the building envelope. By limiting heat absorption and reflecting a significant portion of incoming infrared radiation, Low-E glazing effectively decreases internal cooling loads and improves overall thermal efficiency. These discoveries emphasise the increasing significance of cutting-edge glazing solutions as practical, passive methods to lessen the urban heat island effect and improve building energy efficiency.

An important observation from this study is that both glass and concrete possess relatively smooth and reflective surface characteristics, resulting in comparable surface-temperature responses under similar environmental conditions. However, the distinction between the two materials becomes more apparent when considering thermal mass and heat-storage behaviour over extended periods. Concrete, owing to its greater thermal mass, tends to absorb and retain heat more gradually, subsequently releasing stored heat over longer durations, particularly during evening and nighttime periods. This delayed heat-release mechanism may contribute to prolonged urban heat retention and intensified nocturnal UHI conditions. In contrast, glass surfaces, particularly those incorporating Low-E coatings, exhibit reduced

heat absorption and more controlled thermal transmission, thereby offering improved thermal regulation within urban environments.

The study also revealed that orientation significantly influences thermal performance. Northern-facing surfaces generally experienced lower thermal loads compared to southern and western façades, primarily due to reduced direct solar exposure. Western orientations exhibited elevated afternoon temperatures as a result of prolonged solar incidence and cumulative heat accumulation. These findings demonstrate that façade orientation remains a critical parameter in building thermal performance and should be carefully considered during the design stage of urban developments and high-rise buildings.

The results indicate that although glass and concrete may exhibit similar radiant energy emissions at specific measurement intervals, the key distinction lies in their long-term heat-regulation characteristics. While concrete's high thermal mass may offer certain benefits in moderating short-term temperature fluctuations, modern glazing technologies, particularly Low-E coated glass systems, provide greater adaptability, energy efficiency, and thermal optimisation in contemporary urban architecture. The findings further suggest that the thermal-performance differences between glass and concrete under identical exposure conditions are less pronounced than commonly perceived, thereby offering new perspectives regarding the role of façade materials in urban heat island mitigation strategies.

The evidence demonstrates that advanced glazing systems, especially those incorporating Low-E coatings, can perform competitively with conventional construction materials such as concrete in controlling thermal loads within urban environments. Integrating thermographic analysis, radiant-energy modelling, and long-term environmental monitoring strengthens the novelty and practical significance of this research. While further investigations under different seasonal and climatic conditions are recommended to establish long-term performance trends, the present findings provide valuable insights into the potential of advanced façade technologies to reduce urban heat accumulation, improve building energy efficiency, and support the development of more sustainable and climate-responsive cities.

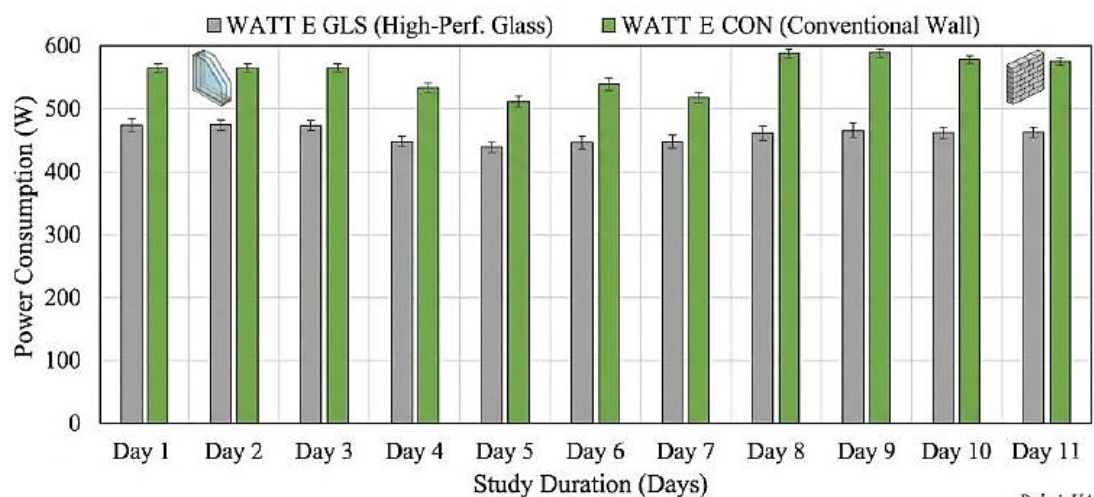


Figure 4. Radiant energy emitted at 10am.

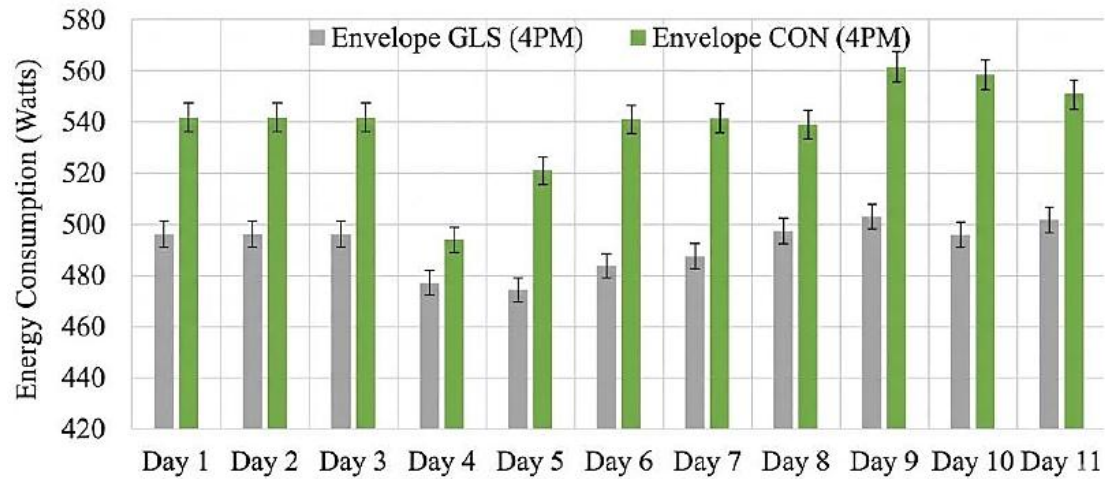


Figure 5. Radiant energy emitted at 4pm.

Table 1. TC results for EQ1 at 10am.

T _{ext} -TC glass south	Watt	T _{ext} -TC concrete ⁰ C	Watt
42.90	480.90	56.40	568.48
42.90	480.90	56.40	568.48
38.60	455.26	51.90	538.06
36.90	445.41	48.70	517.18
38.20	452.92	52.50	542.04
38.80	456.43	49.40	521.70
41.00	469.44	59.90	593.02
41.30	471.23	59.70	591.60
41.00	469.44	58.30	581.70
40.80	468.24	58.00	579.60

Table 2. TC results for EQ1 at 4pm.

T _{EXT} -TC glass south	Watt	T _{EXT} -TC concrete	Watt
45.50	496.9	52.60	542.7
45.50	496.9	52.60	542.7
42.40	477.9	45.10	494.4
42.00	475.4	49.40	521.7
43.50	484.6	52.50	542.0
44.10	488.2	52.50	542.0
45.70	498.2	52.10	539.4
46.60	503.8	55.50	562.3
45.50	496.9	55.00	558.9
46.40	502.6	53.90	551.4

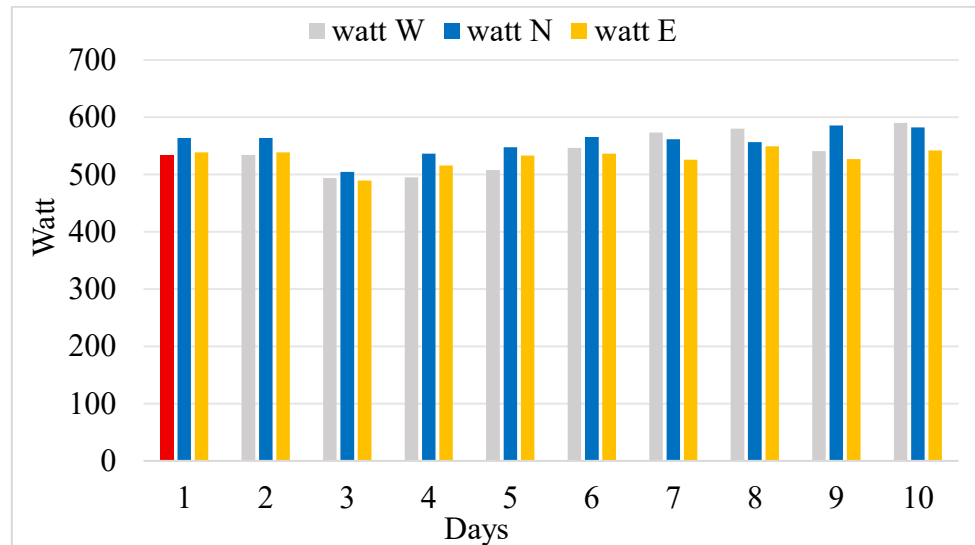


Figure 6. Glass at various orientations, with north is best orientation.

Figure 6 illustrates that the northern orientation of the building displays enhanced thermal performance relative to all other orientations. This is mostly attributable to the shielding effect of the building's environment, where heat reflection from adjacent structures significantly influences surface temperatures. In this case, the intensity of light reflection and heat exchange within the building's microclimate undermines the expected benefits of conventional materials like concrete. The thermal performance of glass, regardless of its orientation, equals or exceeds that of concrete, especially when subjected to direct sun radiation.

The statistics in the tables unequivocally demonstrate that, in terms of radiant heat emission, glass performs comparably to or superior to concrete in all orientations. It is crucial to acknowledge that these findings predominantly depend on measurements acquired from the thermal camera (TC), as the data from the laser meter (LM) and heat loggers (HL) were not directly comparable. The variances in the instruments' accuracy and functionality substantially affected the interpretation of the findings. The thermal camera, although proficient in detecting surface temperature fluctuations, delivers a comprehensive thermal profile of the building's facade, in contrast to the localised observations provided by the LM. Conversely, the HL consistently records temperature and humidity data over time; but its precision in measuring radiant heat is constrained [17].

The association between the surface temperatures recorded by the thermal camera and the ambient air temperature is markedly significant. These measures correspond within the same domain, thereby validating their comparative analysis and the results derived from the temperature data. It is essential to underscore that the findings presented are derived only from data obtained by the thermal camera, which may be repeated using alternative instruments capable of measuring surface temperatures similarly. The uniformity among various instruments enhances the dependability of the thermal camera as a principal device for quantifying radiant heat [19,20].

Markedly, a clear trend appears when comparing the data from LM and TC. The data captured by the LM, which provides more focused and accurate measurements, regularly indicates greater temperature levels than the thermal camera. This contrast underscores the intrinsic limitations of TC, which, although proficient in collecting general thermal trends, lacks the accuracy that the LM provides for identifying localised temperature fluctuations. Furthermore, the measurements from the HL are significantly lower, highlighting the differing degrees of precision and use of each instrument. The disparities indicate that the strategic placement of the thermal camera is essential for achieving optimal

accuracy, as a little alteration in location can considerably influence the data. The discrepancies noted among the results from each instrument highlight the limitations associated with utilising portable measurement devices for thermal data acquisition. To ensure accuracy, it is crucial to properly calibrate instruments and choose a tool that fits the study's specific thermal measurement needs, as indicated by the precision discrepancies.

3.2. Applying EQ-2

This analysis involved calculating the temperature differential (ΔT) between the external ambient temperature (T_{ext}) and the internal design temperature (T_{int}), which was maintained at 20°C in accordance with HVAC design guidelines commonly adopted in Dubai. In the context of Dubai's extremely hot summer climate, particularly during August, maintaining an indoor temperature of 20°C represents a critical requirement for occupant comfort, energy management, and building-performance optimisation. The calculated temperature differential was subsequently integrated with the thermal transmittance coefficient (U-value) of the respective materials to determine the thermal load required to resist heat transfer from the external environment into the conditioned indoor space. A material's insulating capacity and energy efficiency are reflected in its U-value, a vital thermal performance metric that quantifies heat transfer.

The findings revealed a substantial disparity between the thermal properties of glass and concrete. Based on the Dubai Municipality (D.M.) Code 2021, the U-value for standard glazing was identified as 2.1 W/m²·K, whereas a conventional concrete wall exhibited a significantly lower U-value of 0.3 W/m²·K. This difference highlights the superior insulating performance of concrete relative to standard glass systems. To ensure consistency and eliminate geometric bias, the comparison between the materials was conducted using identical surface areas across all façade orientations. The results presented in Table 3 demonstrate that concrete requires a substantially lower thermal load to resist external heat transfer due to its lower U-value and higher thermal mass. The inherent thermal mass of concrete enables it to absorb, store, and gradually release heat over extended periods, thereby reducing fluctuations in indoor temperature and minimising the need for continuous cooling energy input.

The study further explored the potential enhancement of glazing performance through the incorporation of advanced multilayer systems, particularly double-glazed configurations. Introducing additional glazing layers significantly improved the thermal resistance of the glass assembly, thereby reducing heat transfer and enhancing overall energy efficiency. The results indicated that double-glazed systems achieved substantially improved thermal performance compared to conventional single-pane glazing, demonstrating the capability of modern glazing technologies to compete more effectively with traditional opaque construction materials. Nevertheless, façade orientation remained a dominant factor influencing thermal behaviour. Even under northern orientations, where direct solar exposure is comparatively lower, glazing systems continued to exhibit higher thermal loads than concrete walls, emphasising the limitations of conventional glass façades in extreme climatic conditions. These findings suggest that further advancements, including triple-glazed or quadruple-glazed systems combined with inert gas cavities and advanced coatings, may be necessary to significantly improve glazing competitiveness in hot, arid climates. Table 4 illustrates the progressive reduction in U-value achieved through incorporating additional glazing layers, confirming the effectiveness of multilayered glazing strategies in enhancing thermal insulation performance.

Despite the promising advancements in glazing technology, the study demonstrates that the thermal advantages of glass remain constrained by the fundamental principles of heat transfer. Although surface treatments such as low-emissivity (Low-E) coatings are capable of reducing solar heat absorption and reflecting portions of incoming infrared radiation, they do not completely eliminate conductive and

radiative heat transfer through the façade system. As the temperature differential between the outdoor and indoor environments increases, the thermal stress imposed on both glazing and concrete surfaces correspondingly intensifies. Consequently, even highly insulated façade systems remain susceptible to significant heat transfer during periods of peak solar intensity, particularly in regions characterised by prolonged exposure to extreme temperatures.

An important observation derived from this investigation is the phenomenon of thermal saturation and equilibrium. Under prolonged solar exposure, both glass and concrete surfaces eventually reach thermal equilibrium with the surrounding environment and begin re-emitting absorbed heat back into the urban atmosphere. This process contributes directly to the urban heat island (UHI) effect. However, the behaviour of the two materials differs significantly in terms of heat-storage dynamics. Glass surfaces tend to heat rapidly during daytime conditions and may retain elevated surface temperatures into the evening period, thereby reducing indoor thermal comfort even after external temperatures decline. In contrast, concrete surfaces, owing to their higher thermal mass and slower heat-transfer rate, release stored heat more gradually and achieve more stable nocturnal cooling behaviour. This distinction highlights the complex thermal interactions between façade materials and urban microclimatic conditions.

The study also confirms that thermal efficiency is strongly influenced by material density and thermal mass characteristics. Table 4 demonstrates that denser construction materials are generally more effective in reducing heat transfer due to their capacity to absorb and slowly dissipate thermal energy. In glazing systems, however, thermal performance is additionally affected by frame design and detailing. The presence of poorly insulated framing systems can significantly increase thermal bridging, thereby compromising the overall efficiency of the façade. Consequently, contemporary architectural practices increasingly favour concealed or thermally broken frame systems that minimise conductive heat transfer while preserving the aesthetic transparency of glazing façades. These design strategies contribute to improved thermal performance and reduced cooling-energy demand in modern high-rise buildings.

Although glass façades offer considerable advantages in terms of aesthetics, daylight penetration, and architectural modernity, their thermal performance remains a significant challenge in extreme climatic regions such as Dubai. The findings of this study indicate that integrating advanced glazing technologies, including multilayered systems, Low-E coatings, and thermally efficient frame designs, can substantially improve the thermal behaviour of glass façades. Nevertheless, concrete continues to demonstrate superior thermal resistance due to its lower U-value and higher thermal mass. Therefore, achieving optimal building energy performance and indoor thermal comfort in hot climates requires a balanced and integrated façade strategy that combines high-performance glazing systems with appropriate insulation materials, shading mechanisms, and passive design approaches. The study contributes meaningful insight into the comparative thermal behaviour of contemporary glazing systems and conventional construction materials, thereby supporting the development of more sustainable and climate-responsive urban architecture.

Table 3. EQ2 results.

Glass $\Delta T.S$	Glass South	Con. $\Delta T.S$	Con. South	Glass $\Delta T.W$	Glass West	Glass $\Delta T.N$	Glass North	Glass $\Delta T.E$	Glass East
23	481	37	109	29	613	31	651	41	857
23	481	37	109	29	613	31	651	41	857
19	391	32	96	23	491	24	512	37	769
17	355	29	86	21	443	25	523	38	601
18	382	33	98	22	468	30	622	37	777
19	395	30	88	24	498	28	578	35	731
21	441	40	120	25	533	27	557	42	874
21	447	40	119	26	544	27	565	37	773
21	441	39	115	26	538	27	561	48	1008
21	437	38	114	24	498	28	590	45	951

Table 4. Various glass U-values.

Element Type	Double glass	Triple glass	Quadruple glass
No frame U-value W/m ² .K	1.6-1.8	1.1-1.2	0.6-0.8
SC as EN410	0.5-0.6	0.4-0.46	0.29-0.35
SHGC as EN410	0.50-0.55	0.3-0.4	0.25-0.3

3.3. Applying the Heat Index using (HL) Data

The study employed heat index algorithms akin to those utilised by climatologists, meteorologists, and environmental agencies, like the EPA and NOAA, to examine temperature and humidity data gathered from five heat loggers. During the first week of August 2024, loggers were strategically placed on various parts and surfaces of the building to collect data. The data was converted into a CSV file (original data located in the appendix) and utilised to compute the heat index employing three separate equations: HI-EQ1, HI-EQ2, and HI-EQ3. After converting the Celsius temperature readings to Fahrenheit, the relative humidity data was employed to determine the heat index for each calculation. The heat index calculations were utilised to create visual representations of the thermal environment for various time intervals, including Figures 7, 8, and 9, which depict the heat index readings over one day, three days, and seven days, respectively. The data unequivocally illustrates the asynchronous correlation between temperature and humidity, with temperature frequently reaching its zenith at a different interval than humidity, resulting in variable perceptions of heat. Figure 7 illustrates the daily fluctuations of temperature and humidity, which affect the heat index at different intervals. As illustrated in Figure 8, which presents data from three days, the heat and humidity display comparable trends, yet their influence on the heat index shifts during this period. Figure 9 broadens this examination to a full week, illustrating that both concrete and glass surfaces display converging thermal behaviour, suggesting that with prolonged exposure, the materials exhibit comparable heat retention capabilities. The examination of these data indicates that glass exhibits superior performance in the morning, as illustrated in Figure 7, owing to its reduced heat absorption; however, the efficacy of both glass and concrete converges as the day advances, especially at night, when both materials dissipate the absorbed heat at comparable rates.

Subsequent investigation utilising HI-EQ1 (shown in Figures 10, 11, and 12) demonstrated that this equation, despite its simplicity, was deceptive in this situation. The findings from HI-EQ1 demonstrated that heat and humidity exhibit analogous patterns; nevertheless, this oversimplification neglected the intricate and dynamic interplay between the two factors. In Figure 10, the heat index values derived from HI-EQ1 seemed to oversimplify the relationship between temperature and humidity, indicating that while the variables exhibited comparable trends, they did not accurately reflect the true discomfort

experienced by individuals in those conditions. The HI-EQ1 data was uninformative and deceptive, inadequately representing the complexities of thermal discomfort. Figures 11 and 12 corroborated this finding, indicating that the data patterns failed to reflect the extent of variance in perceived heat, rendering the methodology insufficient for assessing the UHI effect and thermal comfort in an urban setting such as Dubai.

The study indicated that concrete exhibited superior thermal stability owing to its elevated thermal mass, whereas glass, despite the application of advanced coatings like Low-E glass, demonstrated optimal performance in the morning but failed to sustain thermal comfort during the day, especially as temperatures increased [13]. Table 6 illustrates the comparison of heat transfer estimates utilising EQ2 for both glass and concrete. The research indicates that concrete possesses a substantially lower U-value compared to glass, enabling it to provide superior insulation and diminish the thermal load within the building's interior. This illustrates that with an appropriate glazing technique; glass can vie with concrete regarding thermal insulation. Nevertheless, the heat transfer principles elucidated in EQ2 demonstrate that although the addition of glass layers enhances thermal efficiency, the advantage is considerably diminished by the considerable indoor heat transmission that persists. The thermal mass of concrete offers an effective means of regulating temperature variations, especially in urban areas such as Dubai, where the urban heat island effect is most significant [20].

The study concludes that the heat index, especially when utilising HI-EQ3, offers significant insights into the thermal properties of construction materials such as glass and concrete in the extreme environmental conditions of Dubai. Although HI-EQ1 was insufficient, HI-EQ3 offered a more precise and thorough comprehension of the dynamic interaction between temperature and humidity, facilitating a clearer evaluation of the material's influence on thermal comfort. The findings emphasise the need to employ modern glazing technologies to enhance the thermal efficiency of glass, while simultaneously reaffirming the enduring value of conventional materials such as concrete, which provide superior thermal mass and improved long-term heat management [15].

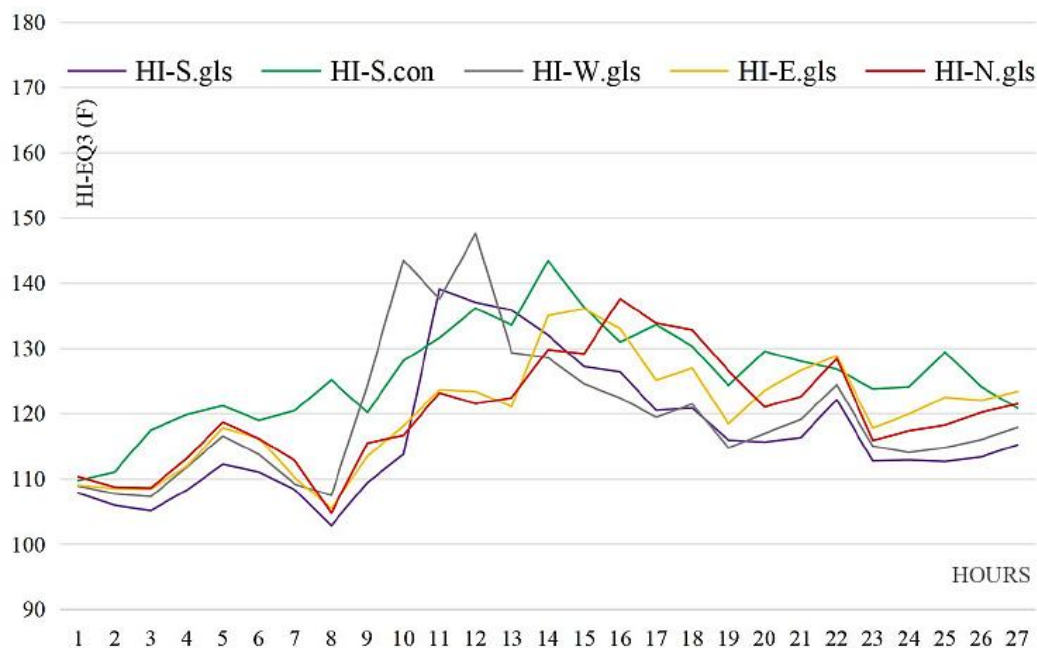


Figure 7. HI-EQ3 results comparison of 1 day all full orientation.

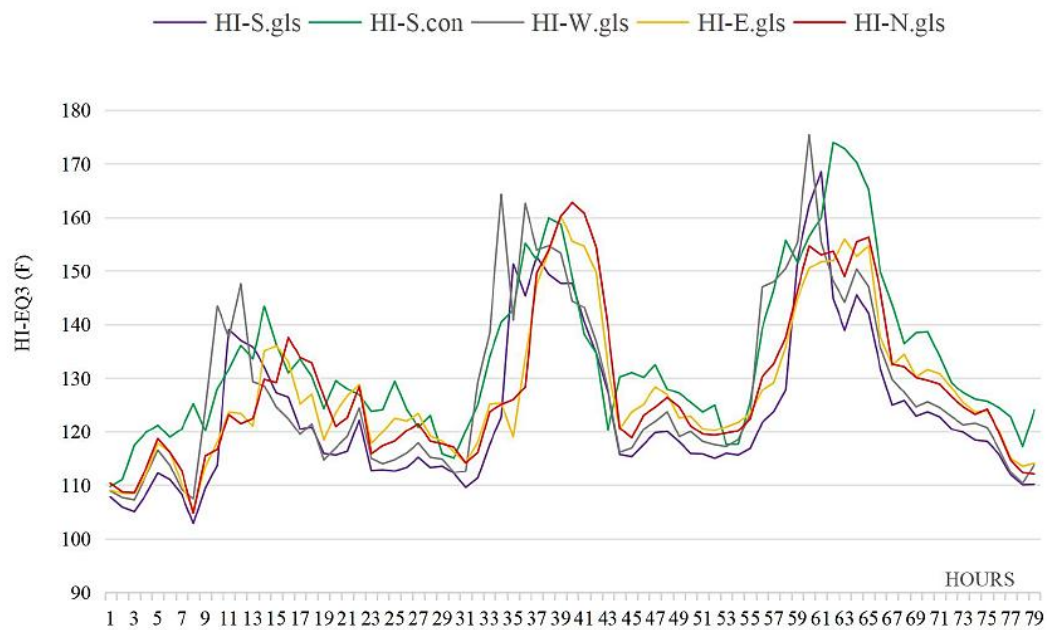


Figure 8. HI-EQ3 results comparison of 3 days all full orientation.

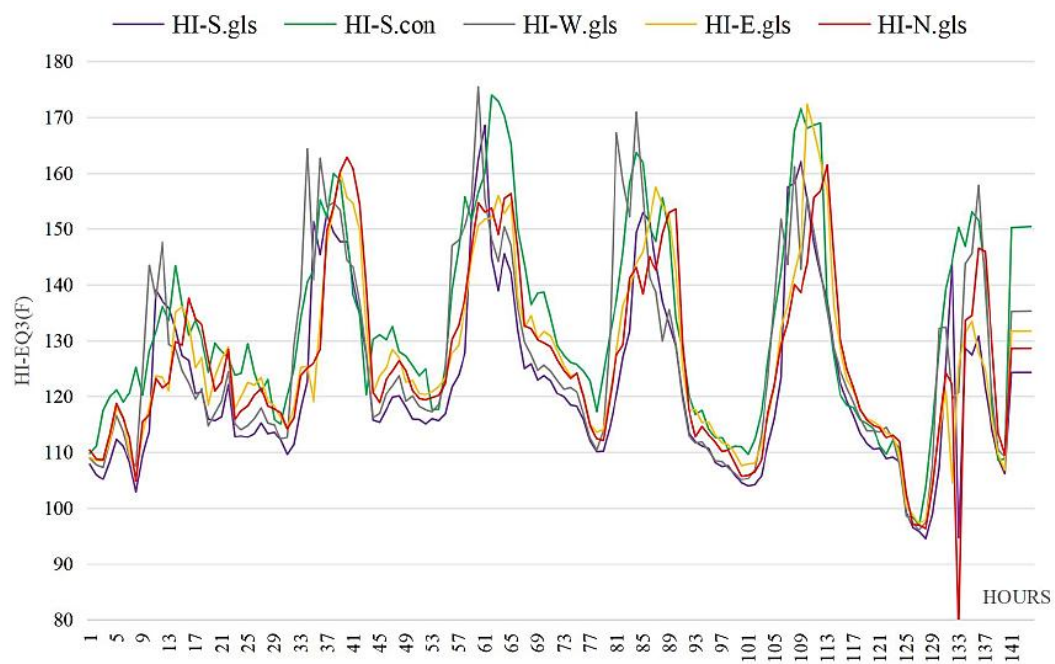


Figure 9. HI-EQ3 results comparison of 7 days all full orientation.

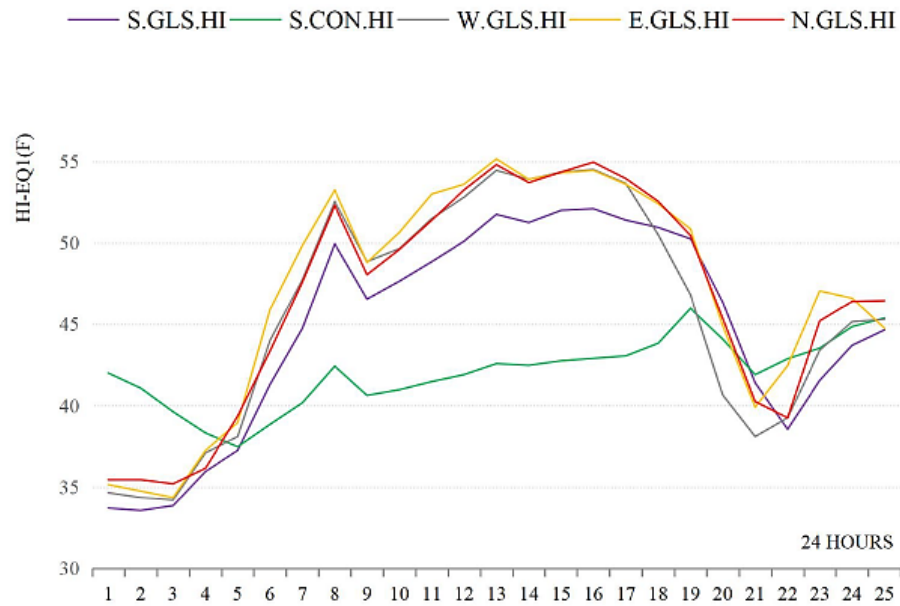


Figure 10. HI-EQ1 for 1 day.

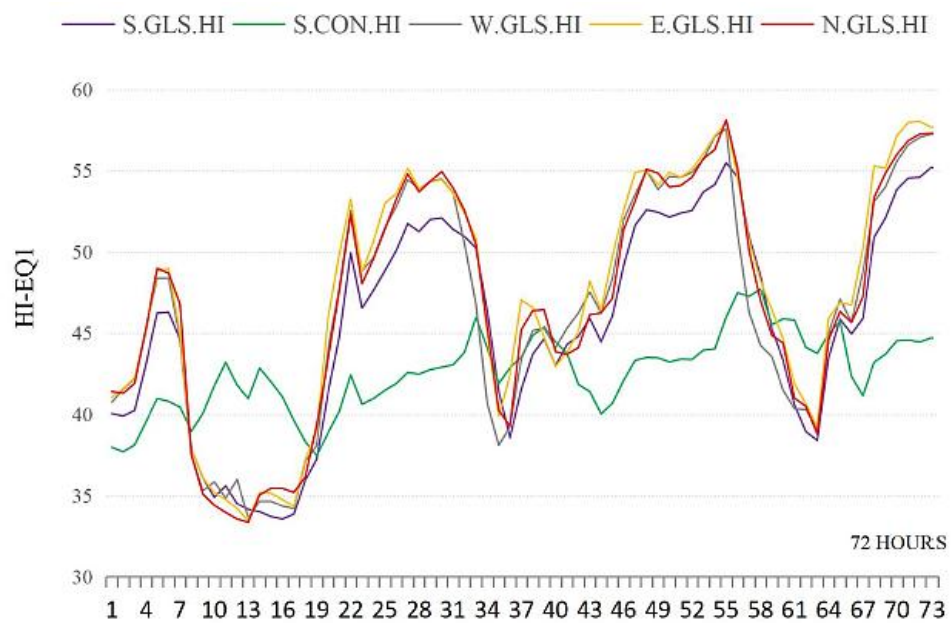


Figure 11. HI-EQ1 for 3 days.

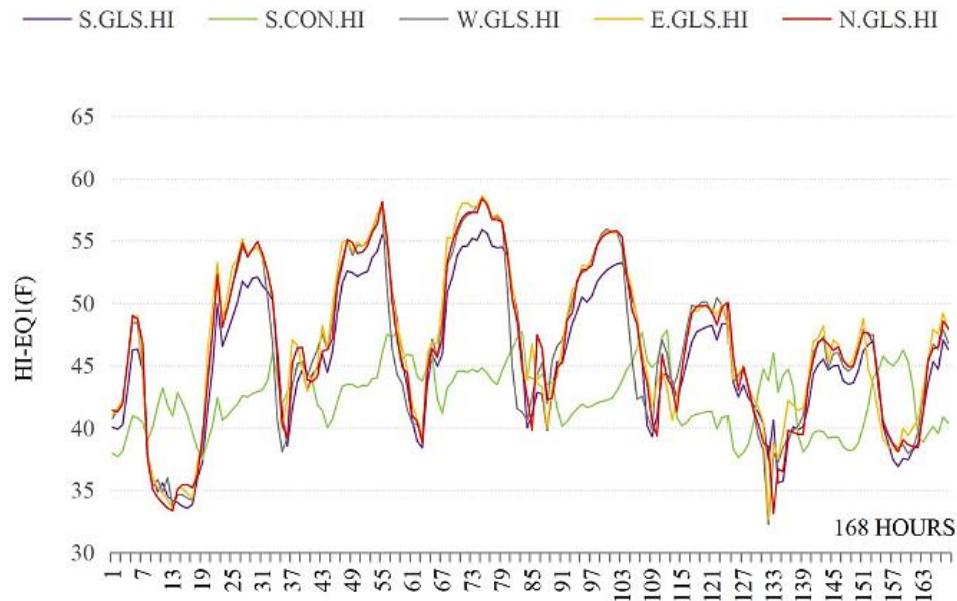


Figure 12. HI-EQ1 for 7 days.

4. Conclusion

From the study that has been conducted, the following conclusions can be drawn:

- The study demonstrated that both glass façades and conventional construction materials, such as concrete and stone, exhibit relatively comparable radiant heat emission characteristics when exposed to identical environmental and solar conditions. The thermal behaviour of building façades is influenced more significantly by façade orientation, solar exposure, urban configuration, and climatic conditions than by the material type alone. Southern and western orientations consistently experienced greater thermal loads due to prolonged solar radiation exposure.
- Advanced glazing technologies, particularly Low-E coated and multilayer glazing systems, were found to substantially enhance the thermal performance of glass façades by reducing solar heat gain and limiting heat transfer into indoor spaces. Conventional concrete walls exhibited lower U-values and higher thermal mass compared to standard glazing systems, enabling better resistance to heat transfer and more stable thermal regulation over extended periods.
- Despite the superior insulating properties of concrete, intelligent glazing systems demonstrated competitive thermal performance when integrated with appropriate insulation strategies, efficient framing systems, and sustainable façade designs.
- The findings revealed no substantial evidence to support the assumption that modern glass façades are the principal contributors to the urban heat island (UHI) effect in Dubai. Instead, the UHI phenomenon is influenced by a combination of environmental, climatic, and urban-planning factors.
- Dubai's urban planning strategies, including coastal zoning, setback regulations, wind-responsive skyscraper arrangements, green infrastructure, and water features, contribute significantly to regulating urban temperatures and improving the city's thermal environment.
- The study confirmed that both glass and concrete surfaces eventually reach thermal equilibrium under prolonged solar exposure and subsequently re-radiate heat into the surrounding environment. However, concrete demonstrated slower heat-release behaviour due to its greater thermal mass. The integration of thermal imaging analysis, radiant-energy modelling, U-value

assessment, and long-term environmental monitoring provided a comprehensive framework for evaluating façade thermal performance under real operating conditions.

- The research highlights the importance of adopting holistic and climate-responsive architectural strategies that combine high-performance glazing systems, insulation materials, shading devices, passive cooling techniques, and sustainable urban-planning approaches to reduce urban heat accumulation. Although intelligent glazing technologies showed promising thermal and energy-efficiency performance, additional investigations involving different climatic conditions, seasonal variations, and building typologies are recommended to further validate the long-term implications of glazing systems on urban thermal environments.
- Overall, the study concludes that advanced glazing systems, when appropriately integrated into sustainable architectural and urban-design frameworks, can contribute positively toward energy-efficient and environmentally responsive urban development without significantly intensifying the urban heat island effect.

Declaration of Conflict of Interest

The authors declared no conflict of interest with any other party on the publication of the current work.

ORCID

Md Azree Othuman Mydin  <https://orcid.org/0000-0001-8639-1089>

Acknowledgement

This paper acknowledges the invaluable support and funding provided by Hicorner Consultancy. Additionally, Engineer Abdullah Ihsan is credited with the design of the Python program.

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