AU-KFAS Research Grants

Publications Report

Academic Year
2023/2024

EXECUTIVE SUMMARY

This detailed report serves to highlight the Australian University (AU) and Kuwait Foundation for the Advancement of Sciences (KFAS) joint Research Grants achievements across a range of disciplines for the academic year 2023/2024.

Over the last few years, research at AU has undergone a fundamental transformation where the university has redesigned its strategy and governance framework to ensure that research is a core function and strategic priority.

To support the university's research vision, AU's Scientific Research Center has been establishing thematic lines of research that address areas of priority aligned with the National Development Plan of Kuwait (Kuwait Vision 2035). The university has broadened its research scope and implemented schemes to fund multidisciplinary research that focus on key national priority issues.

During 2023/2024, AU faculty members have published a total of 14 research works funded by KFAS (9 journal papers and 5 conference papers). Many peer-reviewed papers were published in Q journals: 7 publications in Q1 journals, 2 in Q2 journals, 0 in Q3 journals and 0 in Q4 journals.

The pages of this report outline the strong research trajectory between AU and KFAS. Please refer to the full report for additional details, figures, and the journal publications.

RESEARCH AT AU

Research at AU has undergone a fundamental transformation within the last few years. The University redesigned its strategy and governance framework to ensure that research with impact becomes a core function and a strategic priority. The University has been focusing on the following research areas: water and environment, energy, materials, mechatronics and automation, learning philosophies and frameworks in higher education, innovation and entrepreneurship, business management and finance, as well as marketing and communication. To better exchange knowledge, the College progressed to establish national and international partnerships to strengthen its research capabilities. These partnerships provided the College with access to resources and networks. For instance, the University signed agreements with its international partners to allow faculty to conduct joint research collaborations. On a national level, it broadened its research scope through collaborations with local funding institutions such as KFAS. Internally, it implemented grant schemes to fund multidisciplinary research that focuses on key national priority issues. Furthermore, incentive plans were designed and executed to encourage faculty to engage in research and publications in renowned journals. AU has diverse, highly qualified faculty members with extensive levels of expertise over a broad range of subject areas. Our faculty members strive to produce graduates at the highest level that can face the constantly changing and challenging demands of the industry

In support of this vision, the Research Center is establishing and sustaining thematic lines of applied research that address priority areas aligned with the National Development Plan of Kuwait (New Kuwait Vision 2035). In addition, the research conducted is focused on real-life problems and is led by a strong engagement with the industry. AU's research program works to increase the impact and productivity of research and scholarly activities across and between the disciplines within and outside the University.

VISION AND MISSION

Vision

Our research vision is to enhance the profile of AU as a higher educational institution by contributing to the pursuit of original research aimed at extending the boundaries of applied knowledge.

Mission

The research mission is as follow:

- To enhance the research profile of AU locally, regionally, and internationally
- To create national and international impact in the field of applied research
- To establish a research program supportive of the applied teaching model at AU
- To create interdisciplinary and collaborative research
- To sustain strong partnerships with research funding organizations such as, KFAS, Kuwait Institute for Scientific Research (KISR), and the industry.

AU-KFAS Research Grants

AU is keen to play an important role in development and capacity building in research and technology through KFAS funded joint research projects with international universities. These proposals address national research priorities aligned with Kuwait National Development Plan. For the academic year 2023/2024, AU faculty members have published a total of 15 research work related to the funded KFAS grants (9 Journal papers and 5 Conference papers) as depicted in Figure 1. Many peer-reviewed papers were published in Q journals (ranking based on Scopus) as depicted in Figure 2. According to Scopus, 7 publications in Q1 Journals (research paper published in top 25% of the international journals), 2 publications in Q2 Journals (research paper published in the middle-high position – between top 50% and top 25%), 0 publications in Q3 Journals (middle-low position), and 0 publication in Q4 journals.

Type	Total
Journal Paper	9
Conference Paper	5
Grand Total	**14**

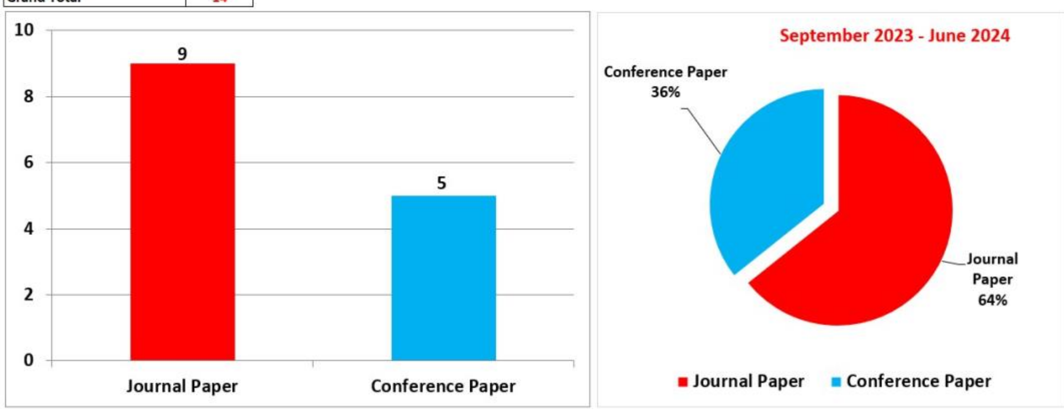

Figure 1. Summary of published research by AU faculty members as related to KFAS grants for the academic year 2023/2024

Quartile (From Scopus)	Number of Published Jounal Paper
Q1	**7**
Q2	**2**
Q3	**0**
Q4	**0**
No Quartile	**0**
Grand Total	**9**

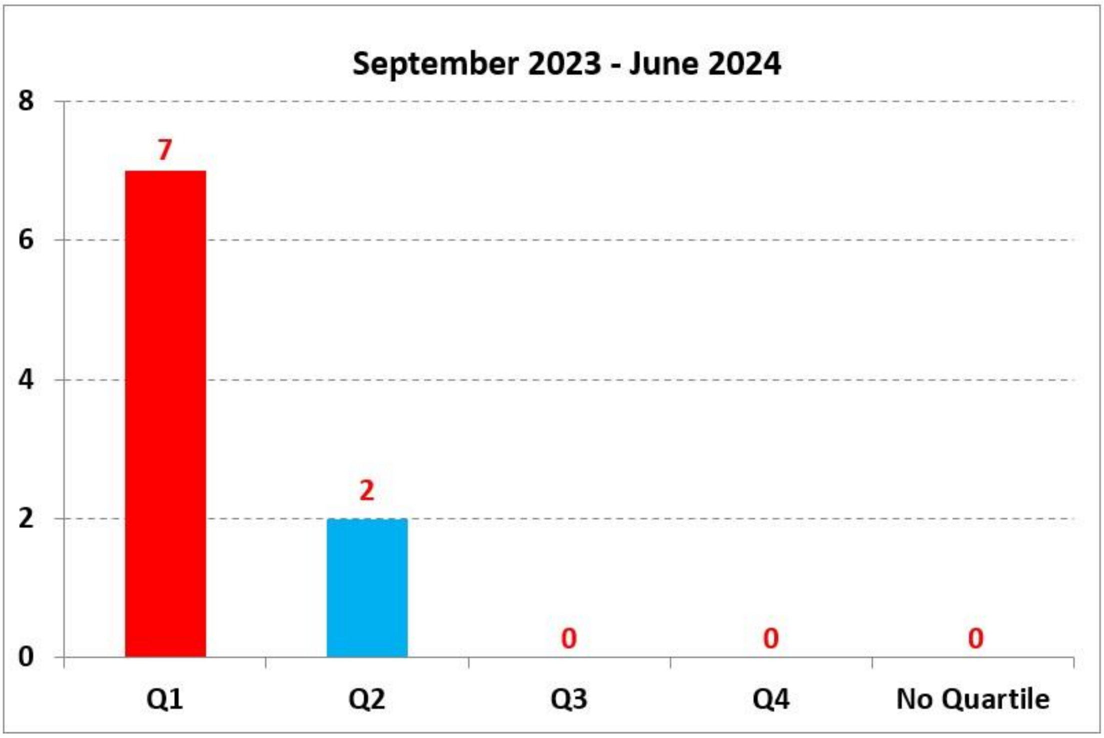

Figure 2. AU Research Faculty Output in Q-Journals for academic year 2023/2024

Full Details of Publications

Department : **Scientific Research Centre**

Academic Year : **2023-2024**

1- AU Faculty Research Output

Publications – KFAS Grants (Academic Year 09/2023-06/2024)						
Sr. التسلسل	**Authors** المؤلف	**Publication Title** عنوان النشر	**Name of Journal/ Conference** اسم المجلة/المؤتمر	**Category / Impact Factor** الفئة / عامل التأثير	**Date** التاريخ	**KFAS Grant #**
College of Engineering						
1.	**Ahmad Sedaghat**, Rasool Kalbasi, Ali Al-Masri	A new approach for selecting and implementing phase change materials in Kuwaiti Buildings: Practical considerations	Journal of Energy Storage	Journal (Q1, IF: 9.64)	23/3/2024	CN19-35 EM-06
2.	A. Sedaghat1, S. Soleimani, M. I. Al-Khiami, M. Sabati, W. K. Hussam, H. J. Salem, M. Rasul, et al.	Case studies on energy performance of walling materials in various regions	International Journal of Environmental Science and Technology	Journal (Q2, IF: 3.69)	14/2/2024	CN19-35 EM-06
3.	A Sedaghat, R Kalbasi, R Narayanan, A Mehdizadeh, S. M. Soleimani, et al.	Integrating solar PV systems for energy efficiency in portable cabins: A case study in Kuwait	Solar Journal	Journal (Q1, IF: 6.47)	20/6/2024	CN19-35 EM-06

Publications – KFAS Grants (Academic Year 09/2023-06/2024)						
Sr. التسلسل	**Authors** المؤلف	**Publication Title** عنوان النشر	**Name of Journal/ Conference** اسم المجلة/المؤتمر	**Category / Impact Factor** الفئة / عامل التأثير	**Date** التاريخ	**KFAS Grant #**
4.	**Sedaghat, A.;** Mahdizadeh, A.; Narayanan, R.; Salem, H.; Hussam, W.K.; Al-Khiami, M.I.; Malayer, M.A.; Soleimani, S.M.; Sabati, M.; Rasul, M.; et al.	Implementing Cool Roof and Bio-PCM in Portable Cabins to Create Low-Energy Buildings Suitable for Different Climates	Sustainability	Journal (Q2: IF: 4.39)	10/10/2023	CN19-35 EM-06
5.	**Wisam K. Hussam**, El Manaa Barhoumi, M. Abdul-Niby, Gregory J. Sheard	Techno-economic analysis and optimization of hydrogen production from renewable hybrid energy systems: Shagaya renewable power plant-Kuwait	International Journal of Hydrogen Energy	Journal (Q1: IF: 7.67)	14/1/2024	CN22-15SE-1612
6.	Majdi M. Alomari, Hania EL-Kanj	Exploring the impact of the COVID-19 pandemic on energy literacy and conservation behaviour in Academic buildings of Kuwait.	Heliyon	Journal (Q1: IF: 4.49)	4/11/2023	PN19-15 EM-02
7.	M Farhat, Y Mazloum, S Wakim , W Bou Nader, M AL Ebrahim, Ghareeb	Energy optimization of parabolic dish solar concentrator coupled to organic Rankine cycle: Experimental and analytical investigation of cavity receiver design and covering effects	International Journal of Thermofluids	Journal (Q1: IF: 8.98)	11/6/2024	CN22-15EE-1626

Publications – KFAS Grants (Academic Year 09/2023-06/2024)						
Sr. التسلسل	Authors المؤلف	Publication Title عنوان النشر	Name of Journal/ Conference اسم المجلة/المؤتمر	Category / Impact Factor الفئة / عامل التأثير	Date التاريخ	KFAS Grant #
8.	**Simovic, Vladimir.,** Domazet, I., Bugarcic, M., Safi, Mirna., Sarhan, Hamsa., Bhagat, Rupali., & Martinovic,	The association of sociodemographic characteristics of university students and the levels of their digital entrepreneurial competences	Heliyon	Journal (Q1: IF: 4.49)	1/10/2023	CN21-18IQ-1382
9.	Mohammad Hany Yassin, Zainab Al Hajaj , Rana Lakys, Zein-Eddine Merouanid, Adel Jumaah	The Influence of Palm Tree Fiber Addition on the Physical, Mechanical and Thermal Properties of 2 High Strength Concrete	Materials and Structures	Journal (Q1: IF: 3.14)	In press	PN2035EV-02
Conference Publications						
1	**Ahmad Sedaghat,** Arash Mahdizadeh, Hayder Salem, Wisam K. Hussam, Mohamad Iyad Al-Khiami, Aiyad Gannan,	Development of Novel Portable Cabins for Low Energy Buildings Research in Kuwait	The first GCC Engineering Symposium (GCCENG23) , Kuwait University	**Conference**	29-31/10/2023	CN19-35 EM-06

Publications – KFAS Grants
(Academic Year 09/2021-06/2022)

Sr. التسلسل	Authors المؤلف	Publication Title عنوان النشر	Name of Journal/ Conference اسم المجلة/المؤتمر	Category / Impact Factor عامل التأثير / الفئة	Date التاريخ	KFAS Grant #
2.	**Ahmad Sedaghat**, Ali Al-Masri, Mohamad Iyad Al-Khiami, Mahdi Ashtian Malayer,	Practical Considerations for Phase Change Materials in Kuwaiti Building Envelopes: A Data-driven,	Proc. International Conference on Computer Applications and Technological Solutions (CATS2023), GUST -Kuwait	Conference	29-30/10/2023	CN19-35 EM-06
3.	R Soleimanpour, Mohammad Yassin, Naser Khaled Mohammad, et al.	Detecting debonding in FRP retrofitted concrete beams using nonlinear ultrasonic waves	8th International Conference on Civil Engineering	Conference	22-24/3/2024	PR1915EC-09

Publications – KFAS Grants (Academic Year 09/2021-06/2022)						
Sr. **التسلسل**	**Authors** **المؤلف**	**Publication Title** **عنوان النشر**	**Name of Journal/ Conference** **اسم المجلة/المؤتمر**	**Category / Impact Factor** **الفئة / عامل التأثير**	**Date** **التاريخ**	**KFAS Grant #**
4.	Hayder Salem and Ahmad Sedaghat	Comparative Analysis of Thermal Performance of Painted, Finned, and Plain Roofs in Arid and Temperate Climates: Insights from Kuwait City and Vancouver	2024 9th International Conference on Sustainable and Renewable Energy Engineering will be held in Marseille, France	Conference	9-11/5/2024	CN19-35 EM-06
5.	M. Farhat, M. Yassin, and M. Nahas	Fiber Bragg Grating Sensors vs Strain Gauges for Static Bridge Monitoring System	IEEE Instrumentatio n and Measurement Technology Conference (UK)	Conference	20-23/5/2024	PR2015EE-01

Journal Publications

International Journal of Thermofluids 23 (2024) 100730

Contents lists available at ScienceDirect

International Journal of Thermofluids

journal homepage: www.sciencedirect.com/journal/international-journal-of-thermofluids

Energy optimization of parabolic dish solar concentrator coupled to organic Rankine cycle: Experimental and analytical investigation of cavity receiver design and covering effects

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ARTICLE INFO

Keywords:
Solar receiver
Parabolic dish concentrator
Organic Rankine cycle
Optical efficiency
Thermal losses
Dynamic modeling

ABSTRACT

Concentrated solar power (CSP) systems offer a promising solution for sustainable energy, but achieving high and stable efficiency requires careful design optimization. This study evaluated the overall performance of a parabolic dish solar concentrator coupled to an Organic Rankine Cycle (ORC) system through experimental and analytical assessments. The research examined the impact of cavity receiver shape (cylindrical vs. spherical) and the use of a glass cover on thermal efficiency. Additionally, the effectiveness of a cone structure to reduce spillage losses and improve optical efficiency was explored. Testing showed a significant improvement in system performance, with an increase from 75 % for the open cavity to 90 % for the sealed cavity equipped with the cone structure (15 % increase). This highlights the importance of receiver design in reducing heat loss. To further optimize the system, a numerical model was developed and validated against experimental measurements. The simulation demonstrated that the overall system performance is significantly influenced by the water outlet temperature from the cavity receiver and the pressure drop within it. The model suggests that overall performance could be enhanced from 4.6 % to higher than 6 % by optimizing factors like water mass flow rate, cavity tube diameter, and the selection of a more suitable ORC working fluid (e.g., R245fa instead of R134a).

1. Introduction

Concentrated Solar Power (CSP) is a promising renewable energy technology that utilizes concentrated sunlight to generate electricity. It offers several advantages, including reduced greenhouse gas emissions, integration with energy storage systems, and potential for economic development. This study explores the application of CSP coupled with an Organic Rankine Cycle (ORC) system for electricity production. ORC systems employ organic fluids with lower boiling points than water, allowing them to vaporize at lower temperatures. In a CSP-ORC system, concentrated sunlight is directed onto a receiver, heating a heat transfer fluid (HTF) like oil or molten salt. The heated HTF then transfers its thermal energy to the ORC system, driving a turbine connected to a generator to produce electricity. CSP-ORC systems are attractive due to their high energy conversion efficiency, scalability, and suitability for integrating with intermittent renewable energy sources [1–4].

Parabolic Dish Collectors (PDCs) are highly efficient at converting solar energy into thermal energy. Their applications include power generation, space heating, and desalination. A crucial component of a PDC system is the cavity receiver, which absorbs concentrated sunlight and transfers heat to a Heat Transfer Fluid (HTF). Both the PDC and receiver designs are crucial for maximizing solar energy capture and minimizing optical and thermal losses [1].

Extensive research has been conducted to improve cavity receiver designs and reduce heat losses. Studies by Hassan et al. [2] and Dabbo et al. [3] compared the performance of cylindrical, conical, and spherical cavity receivers. Conical receivers exhibited better thermal and optical efficiencies than cylindrical or spherical. Investigated the impact of using a glass cover on cavity receivers, finding that it can improve

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https://doi.org/10.1016/j.ijft.2024.100730

Available online 11 June 2024

and revealed that minimizing pressure drops and maximizing hot water temperature are critical for efficiency improvement. Furthermore, using R245fa as the working fluid instead of R134a has the potential to increase system efficiency from 4.6 % to over 6 %. Future research should explore the effects of pressurized water and high-temperature thermal oils on system performance through simulations. These investigations will pave the way for optimizing CSP-ORC systems and promoting their adoption as a clean and efficient renewable energy technology, contributing to a low-carbon future.

Funding

This project was supported by the Kuwait Foundation for the Advancement of Sciences (KFAS) under project code CN22-15EE-1626. The authors gratefully acknowledge the financial support of KFAS and the Australian University in Kuwait.

CRediT authorship contribution statement

Mohamad H Farhat: Writing – original draft, Project administration, Methodology, Funding acquisition, Conceptualization. **Youssef Mazloum:** Writing – original draft, Validation, Supervision, Conceptualization. **Samer Wakim:** Methodology, Investigation, Conceptualization. **Wissam Bou Nader:** Methodology, Investigation, Conceptualization. **Meshari ALEbrahim:** Writing – review & editing. **Nader Ghareeb:** Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Mohamad Hussein Farhat reports financial support was provided by Kuwait Foundation for the Advancement of Sciences. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Heliyon 9 (2023) e21474

Contents lists available at ScienceDirect

Heliyon

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Exploring the impact of the COVID-19 pandemic on energy literacy and conservation behavior in academic buildings of Kuwait

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ARTICLE INFO

Keywords:
Energy literacy
Energy conservation behavior
Kuwaiti university occupants
COVID-19 pandemic

ABSTRACT

This study investigates the impact of the COVID-19 pandemic on energy literacy and conservation behavior among occupant groups in academic buildings in Kuwait. It explores influential factors, focusing on the pandemic's effect on attitudes, intentions, and behaviors related to energy conservation. The research adopts a mixed-methods approach, incorporating quantitative and qualitative data collection methods. Participants, including students, faculty, and staff, completed surveys, participated in questionnaires, focus groups, and took part in interviews. Statistical tests are used to validate the survey data, while thematic analysis is applied to the qualitative data. The findings of the research showed that COVID-19 had a significant impact on participants' attitudes, intentions, and behavior regarding energy literacy and conservation. Specifically, the student group experienced a significant increase in the relationship between their intentions and behavior, while the faculty group exhibited a strong correlation between intention and behavior. The study also found that education, awareness, personal motivation, values, religiosity, and culture were all crucial factors in promoting energy literacy and conservation behavior. The study recommends specific educational interventions, fostering a culture of conservation, providing access to information and resources, promoting community engagement, incorporating religiosity, and improving policies and infrastructure to enhance energy literacy in academic buildings. Additionally, the study highlights the importance of tailored educational interventions that consider the specific needs and challenges of different occupant groups and suggests incorporating religious perspectives to align with the cultural and religious context of the Kuwaiti population. The study's findings offer comprehensive insights into the impact of unforeseen events, such as pandemics, on energy literacy and conservation behavior. These insights have practical implications for policymaking and implementation. Future research could explore the effectiveness of various educational interventions and examine the role of social and cultural factors in shaping energy literacy and behavior.

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https://doi.org/10.1016/j.heliyon.2023.e21474
Received 17 May 2023; Received in revised form 9 October 2023; Accepted 22 October 2023
Available online 4 November 2023

7. Limitations and future study

Some limitations of the study include the restricted sample of university students from a specific region, which may limit the generalizability of the findings. The use of self-report measures introduces the potential for bias or inaccuracies. As the study focuses on academic buildings, it may not be applicable to other types of structures or contexts. The study's use of a mixed-methods strategy may pose methodological hurdles in terms of data integration and interpretation.

Future research can address these limitations by exploring the effectiveness of various educational interventions, investigating the relationship between energy literacy and actual energy consumption behaviors, considering the influence of social and cultural factors, and identifying strategies to promote energy literacy and sustainable behavior among diverse populations.

Data availability statement

The data that has been used is confidential.

Funding

This project was fully funded by the Kuwait Foundation for the Advancement of Sciences (KFAS), Kuwait under project code PN19-15 EM-02.

CRediT authorship contribution statement

Majdi M. Alomari: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Hania EL-Kanj:** Writing – review & editing, Writing – original draft, Validation, Software, Methodology, Data curation, Conceptualization. **Ayse Topal:** Writing – review & editing, Writing – original draft, Project administration, Investigation, Formal analysis, Data curation, Conceptualization. **Nafesah I. Alshdaifat:** Writing – review & editing, Writing – original draft, Software, Resources, Project administration, Methodology, Data curation.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Majdi M. Alomari reports financial support was provided by Kuwait Foundation for the Advancement of Sciences.

Acknowledgement

This project was completed with the support of the Electrical Engineering Department, IT Department, facilities, and our colleagues at Australian University, Kuwait.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e21474.

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The Influence of Palm Tree Fiber Addition on the Physical, Mechanical and Thermal Properties of High Strength Concrete

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rate by up to 51% and thermal conductivity by 21%. These findings demonstrate the potential of PTF as a promising material for concrete production. By lowering heat transfer and enhancing thermal insulation, PTF contributes to energy savings in buildings, supporting the development of sustainable construction practices. However, it is important to note that this research is preliminary, focusing on the use of PTF in high-strength concrete. Further tests, such as concrete durability tests and rheological tests, including concrete creep and shrinkage, are required. Additionally, SEM tests should be conducted to consider material aging.

6. Acknowledgment

The authors wish to thank Mr. Tahir Afrasiab (Australian University, Kuwait) for his assistance and guidance with the civil lab facilities.

7. Data Availability:

Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

8. Funding

This work was supported by the Kuwait Foundation for the Advancement of Sciences (KFAS) for providing the financial support through the grant [PN20-35EV-02 and CN20-35-EM-04].

9. Author contributions

M.H. Yassin: Conceptualization, Methodology, Validation, Resources, Supervision, Project Administration, Writing - Original Draft & Review & Editing

Z. Al Hajaj: Conceptualization, Validation, Formal Analysis, Investigation, Writing - Original Draft & Review & Editing, Visualization, Supervision

R. Lakys: Conceptualization, Literature Review & Validation of NDT (Non-Destructive Testing)

International Journal of Environmental Science and Technology
https://doi.org/10.1007/s13762-024-05518-7

ORIGINAL PAPER

Case studies on energy performance of walling materials in various regions

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Received: 27 February 2023 / Revised: 16 December 2023 / Accepted: 14 February 2024

Abstract

The energy consumption of buildings, particularly for space heating and cooling, is a major global concern. It accounts for a substantial portion of household energy use and varies based on environmental factors and climate conditions. Environmental factors highly influence energy-saving strategies of buildings in different climate areas. Addressing this challenge necessitates innovative approaches to building design and materials. This study aims to explore the energy performance of different walling materials in varying climates, including desert, subtropical, and tropical regions. Using transient systems simulation program multi-zone software, simulations were conducted on five room models with ten different walling materials. Notably, autoclaved aerated concrete and cellular lightweight concrete consistently demonstrated better performance in both Kuwait and Australia, resulting in reduced cooling and heating demands. The study emphasizes the significance of selecting building materials based on local climate conditions. It highlights the potential for future exploration of advanced materials like phase change materials and cool roofs. By considering local climate conditions, energy-efficient buildings can be constructed. Future research should focus on advanced materials to further enhance energy efficiency.

Keywords Building · Climate · Energy performance index · Solar energy · Transient systems simulation program

Editorial responsibility: Ta Yeong Wu.

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Abbreviations

AAC	Autoclaved aerated concrete blocks
Bio-PCMs	Bio-phase change materials
CEPT	Centre for environmental planning & technology
CLC	Cellular lightweight concrete blocks
CO_2	Carbon dioxide
CR	Cool roof
CSB	Calcium silicate blocks
CSEB	Compressed stabilised earth blocks
E	East
EPI	Energy performance index
FAB	Fly ash bricks
FCBE	Extruded moulding fired-clay bricks
FCBH	Hand-moulding fired-clay bricks
FCBS	Soft mud moulding fired-clay bricks
GRIHA	Green rating for integrated habitat assessment
IE	Infrared emissivity
N	North
NE	North-East
NW	North-West
S	South

Published online: 20 March 2024

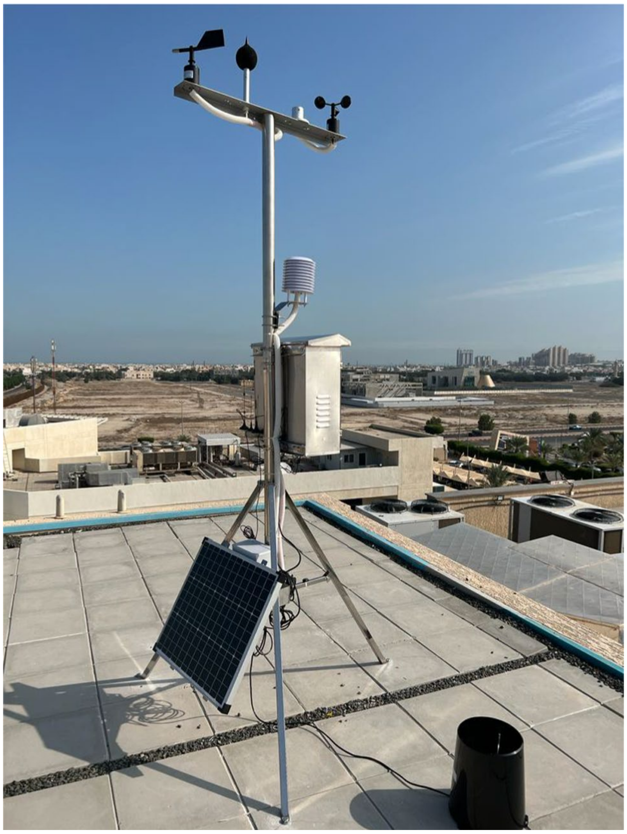

Fig. 18 Weather station installed at Australian University in Kuwait

modest annual energy-saving of only 2–3%. In this study, the energy performance index (EPI) was calculated for heating/cooling demands and total energy consumption using TRNSYS simulations. The environmental impacts of the desert and subtropical cities were compared to the tropical city of Kodaikanal in India. The benchmark EPI limit of 70 kW/m^2/year set by GRIHA in tropical climates proved to be a valuable target for improving EPI values in Kuwait and Australia.

The main findings of this study highlight the significant variation in heating and cooling demands based on different climate types. Tropical climates require minimal heating and cooling, while desert climates pose the greatest challenges in terms of heating and cooling demands. The comparative study focusing on the EPI revealed that rooms with autoclaved aerated aoncrete (AAC) and cellular lightweight concrete (CLC) demonstrated the lowest EPI values for cooling.

In Mubarak Al Kabeer, Kuwait, AAC wall materials showed the potential for significant energy consumption reduction, with savings of up to 34% of the total annual energy. AAC achieved the lowest cooling, heating, and total EPI values of 751.9, 39.3, and 791.2 kWh/m^2/year, respectively. Similarly, in the urban city of Rockhampton, Australia, AAC wall materials had the lowest cooling, heating, and total EPI values of 531.4, 1.2, and 532.6 kWh/m^2/year, respectively, resulting in potential savings of up to 35% of the total annual energy.

An interesting observation from the study was the significant difference in EPI values between the mentioned cities and Kodaikanal in India. Specifically, when using AAC materials, EPI values in Mubarak Al Kabeer were ten times higher than in Kodaikanal, and in Rockhampton, they were seven times higher.

This study focused only on common materials, and further research is needed to explore and assess various smart materials for building envelopes. This includes investigating wall and roof insulation, combining insulation with phase change materials (PCM), implementing cool rooftops (CR) for walls and roofs, and utilizing solar-assisted air-conditioning (SAC) systems. These topics are currently being studied.

Acknowledgements This study is fully funded by the Kuwait Foundation for the Advancement of Sciences (KFAS), Australian University, Kuwait (AU) and Central Queensland University (CQU) under grant no. CN19-35EM-06, which is gratefully acknowledged.

Author contribution AS involved in writing-original draft preparation, conceptualization, methodology, software; SMS involved in conceptualization, writing-reviewing and editing; MIA involved in software, CAD drawings; MS involved in funding, supervision; WKH involved in software, writing-reviewing and editing; HJS involved in experiment, equipment, installation; MR involved in funding, supervision, reviewing and editing; RN involved in reviewing and editing; MMKK involved in supervision. MAM involved in data processing, data management, software. AM involved in data analysis, equipment.

Declarations

Conflict of interest The authors of this manuscript have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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Solar Energy 277 (2024) 112715

Contents lists available at ScienceDirect

Solar Energy

journal homepage: www.elsevier.com/locate/solener

Integrating solar PV systems for energy efficiency in portable cabins: A case study in Kuwait

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A R T I C L E I N F O

Keywords:
Building integrated solar systems
Energy saving
Off-grid solar system
PV-assisted AC system
Urban areas

A B S T R A C T

The rapid growth of energy consumption in densely populated urban areas with limited land space, especially in hot climates, poses significant challenges. The Australian University of Kuwait conducted a study using two portable cabins to explore energy-saving techniques. One cabin integrated an off-grid solar photovoltaic (PV) system to evaluate its impact on grid electricity demands for an airconditioning (AC) cooling system over 9 months, compared to the second cabin without a PV system. The PV system utilized rooftop space with four Monofacial Go Green 350 W/24 V solar panels, an off-grid maximum power point tracker (MPPT) inverter charger 3.5kVA/100A/24 V, and two Gel deep cycle batteries 12 V/200Ah. The PV panels were oriented south at a 30-degree latitude angle, providing power through the MPPT to a 1.5-ton AC split unit for cooling. Findings showed that the cabin with solar PV panels achieved a 24.1 % energy saving and a total CO_2 reduction of 129.4 kg, consuming 1,743 kWh over 237 days, compared to 2,296 kWh for the cabin without the PV system. The novelty of this study lies in the integration of off-grid solar PV systems with existing cooling technologies to evaluate potential energy savings and environmental benefits for comprehensive utilization and addressing urban and climate challenges. Enhancements can include flexible room temperature control using advanced systems, optimizing the PV system settings with more efficient AC systems, and connecting the PV system to additional loads like heating/cooling and lighting. These improvements would ensure the comprehensive utilization of captured solar energy in Kuwait and countries with similar climatic conditions throughout the year. Advancements in solar PV panel efficiency and high-intensity flexible PV panels offer opportunities for maximizing solar energy capture in dense residential buildings.

1. Introduction

The increasing concern over the environmental impacts of fossil fuels has led to a growing need for designing multi-energy systems for residential and office buildings. These systems aim to supply electricity for electric vehicle charging and meet the electricity demands of buildings using renewable energy sources while minimizing the impact on the grid [1]. The effectiveness of solar photovoltaic (PV) systems is strongly influenced by the climate in urban environments [1]. Designing buildings to optimize the capture of solar energy concerning energy demand can result in nearly zero-energy buildings in semi-arid urban environments [2].

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https://doi.org/10.1016/j.solener.2024.112715
Received 1 February 2024; Received in revised form 19 June 2024; Accepted 20 June 2024
Available online 27 June 2024

24 % to 28 %, with an average daily energy consumption of 16.8 kWh for the left cabin. The total energy saved was 26 %, resulting in a reduction of 28.15 kg of CO_2 emissions.

- In August 2023, the hottest month, the cabins recorded energy savings ranging from 15 % to 26 %. The left cabin consumed 442.7 kWh and achieved a 24.2 % energy savings, resulting in a reduction of 22.19 kg of CO_2 emissions. In September 2023, energy savings varied from 18 % to 34 %, with a monthly energy consumption of 284 kWh for the right cabin. The total energy saved was 24.44 %, corresponding to a reduction of 19 kg of CO_2 emissions.
- As the weather cooled in October 2023, the average daily energy savings ranged from 2 % to 22 %. The left cabin saved an average of 17.16 % of energy, resulting in a reduction of 5 kg of CO_2 emissions. In November 2023, negative energy savings were observed due to reduced cooling demand and lower efficiency of the AC fan in the right cabin, resulting in a monthly saving of only 4.3 % and a reduction of 0.5 kg of CO_2 emissions.
- In December 2023, being the coldest month, negative energy savings ranging from −1% to −72 % for cooling demands were experienced. The average daily energy consumption was minimal, resulting in an energy loss of 4 kWh and a slight CO_2 production of −0.83 kg, which can be attributed to the lower efficiency of the AC fan in the right cabin. The energy-saving percentage for December was −18.5 %.
- Overall, June offered the highest energy savings of 27.67 %, while December had the lowest value of −18.5 %. The average daily and monthly energy consumption were highest in July and lowest in December. In total, 553 kWh of energy was saved, with an average monthly energy saving of 24.1 %, and CO_2 emissions were reduced by 114.5 kg using the installed solar PV-assisted system for air conditioning the portable cabins over the nine-month study period.
- With an initial cost of $3,277.88 for a 1.4 kW solar system installation, annual maintenance costs of $140, and neglecting the 93 % subsidy provided by the Kuwait government on the cost of electricity, a cost analysis was conducted using the annual energy saving of 852 kWh/year for the solar system installed on the studied portable cabin at Australian University (AU), Kuwait. The net annual savings for a residential building is 213 US$, resulting in a payback time of approximately 15.4 years. The net annual savings for a business building is $456.40, resulting in a payback time of approximately 7.2 years. Thus, the solar system is a more viable option in business buildings based on these assumptions.

The future of this work involves several key developments. Firstly, the installation of a local weather station will be carried out to gather real-time weather data. This data will be combined with building simulation software to compare and validate experimental measurements, thereby enhancing the accuracy of the analysis.

- Additionally, the gradual installation of graphite-PCM24 in one of the cabins will take place. This phase change material will be extensively studied over a period of 12 months to evaluate its effectiveness in terms of energy savings and thermal management.
- Furthermore, new configurations of solar PV systems will be investigated to optimize land space utilization, enhance solar energy utilization, and maximize energy savings.
- This research will also involve simulations using software tools such as TRNSYS and Design Builder to model various cool rooftops (CR), solar-assisted air-conditioning (SAC) systems, and phase change materials (PCMs).

These future endeavors aim to further improve the understanding of energy efficiency and thermal management in the context of the studied cabins, ultimately leading to more sustainable and effective energy solutions.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used ChatGPT grammar check in order to improve grammar and check for spelling error. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

CRediT authorship contribution statement

Ahmad Sedaghat: Conceptualization, Data curation, Funding acquisition, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Rasool Kalbasi:** Conceptualization, Data curation, Formal analysis, Methodology, Visualization, Writing – review & editing. **Ramadas Narayanan:** Investigation, Resources, Writing – review & editing. **Arash Mehdizadeh:** Data curation, Investigation, Methodology, Writing – review & editing. **Sayed M. Soleimani:** . **Mahdi Ashtian Malayer:** Data curation, Formal analysis, Software, Validation, Visualization. **Mohamad Iyad Al-Khiami:** Conceptualization, Funding acquisition, Project administration, Supervision. **Hayder Salem:** Investigation, Methodology, Project administration, Supervision. **Wisam K. Hussam:** Data curation, Resources, Software, Writing – review & editing. **Mohammad Sabati:** Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing – review & editing. **Mohammad Rasul:** Conceptualization, Funding acquisition, Project administration, Supervision. **M. Masud K. Khan:** Conceptualization, Funding acquisition, Investigation, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This study is fully funded by the Kuwait Foundation for the Advancement of Sciences (KFAS), Australian University, Kuwait (AU), and Central Queensland University (CQU) under grant no. CN19-35EM-06, and we sincerely acknowledge their support. The first author would also like to express gratitude to the students, Ali Abdulrahman AlMutairi, Ayoub Abdullah Akbar, Mai Mohammad Abdullah Alamhooj, Rawan Khaled AlRumaidhin, and Sarah Ibrahim Fnahi, who, as part of their final graduation project, assisted in communication and the procurement of a solar PV system for one of the portable cabins from Solar Albowardi company. The authors are also thankful to Solar Albowardi for their services.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.solener.2024.112715.

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Article

Implementing Cool Roof and Bio-PCM in Portable Cabins to Create Low-Energy Buildings Suitable for Different Climates

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Abstract: The building sector's energy consumption has significantly increased due to climate change, emphasizing the need to develop sustainable low-energy buildings using experimental and computational tools. As a joint project between Kuwait and Australia, two portable cabins with internal sizes of 2 m $\times$ 2 m $\times$ 2.80 m, made from 75 mm thick sandwich panels and metal frames, were built in Kuwait to investigate their thermal and power consumption characteristics under various energy-saving techniques and different climates. This is the first attempt to analyze the energy-saving aspects of portable cabins made from sandwich panels for future sustainable cities. Each cabin has an indoor air-quality-sensing device and a novel power-monitoring system to measure their thermal and power consumption characteristics. First, shingles and novel finned metal cool roof (CR) techniques were experimentally investigated. Then, a new multi-zone SketchUp model of the portable cabins was created and simulated in TRNSYS. Next, the energy saving data of the portable cabins were investigated by adding PCM on the walls and the roof using built-in models of bio-phase change materials (Bio-PCMs) in TRNSYS. The annual energy performance index (EPI) as an important sustainability index was explored for determining heating/cooling/total demands of the portable cabins in the desert climate of Kuwait and in various climate regions of Australia. The findings reveal that both shingles and finned metal roofs contributed to higher power consumption. Meanwhile, the use of sustainable Bio-PCMs in Kuwait demonstrates a significant energy-saving potential of 30%, with variations ranging from 25% to over 45% across different climate regions in Australia.

Keywords: building; Bio-PCM; climate; cool roof; energy saving; sustainability; TRNSYS

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Citation: Sedaghat, A.; Mahdizadeh, A.; Narayanan, R.; Salem, H.; Hussam, W.K.; Al-Khiami, M.I.; Malayer, M.A.; Soleimani, S.M.; Sabati, M.; Rasul, M.; et al. Implementing Cool Roof and Bio-PCM in Portable Cabins to Create Low-Energy Buildings Suitable for Different Climates. *Sustainability* **2023**, *15*, 14700. https://doi.org/10.3390/su152014700

Academic Editor: Antonio Caggiano

Received: 12 September 2023
Revised: 2 October 2023
Accepted: 9 October 2023
Published: 10 October 2023

1. Introduction

The demand for reducing cooling energy consumption in Kuwait's buildings is steadily increasing for developing sustainable cities. Despite the existence of energy savings codes dating back to 1983, implementation has been suboptimal. With the rapid rise in electricity demand in the building sector, many residential buildings lack energy reduction strategies [1]. Non-renewable hydrocarbons are heavily relied upon for electricity generation and water desalination, making up about 50% of the country's economy, and these includes using solar reflective paints on the roof and walls and applying cool roof paints for the finned metal roof. Long-term experimental work on sustainable PCM performance studies and techno-economic analysis will be conducted in a continuation of the present work. Additionally, TRNSYS models may be extended to simulate sustainable portable cabins with cool roofs and various PCM models.

Author Contributions: A.S.: writing—original draft preparation; conceptualization; methodology; software. A.M.: editing; data analysis; equipment. R.N.: writing—reviewing, editing, and reformatting. H.S.: experiment; equipment; installation. W.K.H.: software; writing—reviewing and editing. M.I.A.-K.: software; CAD drawings. M.A.M.: data processing; data management; software. S.M.S.: conceptualization; writing—reviewing and editing. M.S.: funding; supervision. M.R.: funding; supervision; writing—reviewing and editing. M.M.K.K.: supervision. All authors have read and agreed to the published version of the manuscript.

Funding: This study is fully funded by the Kuwait Foundation for the Advancement of Sciences (KFAS), Australian University, Kuwait (AU) and Central Queensland University (CQU) under grant no. CN19-35EM-06, which is gratefully acknowledged.

Institutional Review Board Statement: KFAS Peer reviewer has evaluated our second annual research report by statements like: "The team seems to have employed the suggested techniques and tools resourcefully and to their fullest potential. Evidence from the progress report points to considerable advancements in reaching the research goals, encompassing experiment execution, data examination, and model creation. Additionally, the report underscores a number of inventive strategies employed to tackle obstacles faced throughout the research. In general, the team appears to be progressing well and effectively implementing their proposed methodology to attain their objectives"; "The individual tasks outlined in the proposal appear to have been comprehensively tackled. The progress report offers an in-depth overview of the advancements made for each task, encompassing the work carried out, data gathered, and outcomes achieved. For instance, Task 1 entailed performing a literature review to pinpoint pertinent research on the subject. The progress report demonstrates that this task was accomplished effectively, with an extensive evaluation and summary of the relevant literature. Likewise, Task 2 required the design and construction of an experimental building, which has been executed according to the plan. In summary, it appears that every task has been thoroughly addressed and is advancing as anticipated"; "The research team has proficiently utilized the proposed resources in an efficient, effective, and economical manner. The proposed resources appear to have been employed efficiently, effectively, and economically. The research team used various instruments, such as thermocouples and infrared cameras, and developed models using software like EnergyPlus and MATLAB to simulate building performance, and many experiments and simulations are conducted. The team's budget is also well-illustrated, prioritizing essential equipment purchases and minimizing unnecessary expenses".

Informed Consent Statement: Not applicable.

Data Availability Statement: Research data are available on request.

Acknowledgments: We would like to express our profound gratitude and appreciation to the Workshop and Facility Department at Australian University, Kuwait, for their unwavering support. We extend special recognition to Nader Ghareeb, Osama Albdo, Joshith Valiyaparambath, Waqar Jan Zafar, and Joseph Larida for their exceptional technical assistance and dedication. Their contributions have been invaluable to our work, and we are truly grateful for their commitment to our success.

Conflicts of Interest: The authors declare no conflict of interest.

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Heliyon 9 (2023) e20897

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

The association of socio-demographic characteristics of university students and the levels of their digital entrepreneurial competences

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A R T I C L E I N F O

Keywords:
Digital entrepreneurial competences
EmDigital
University students competence assessment
Identification of opportunities

A B S T R A C T

The aim of this article is to provide empirical evidence on the level of digital entrepreneurial competences (DEC) that higher education students acquire during their higher education and to investigate the relationship between their socio-demographic characteristics and the level of DEC. The first competence area (Identification of opportunities) of the DEC EmDigital competence framework was assessed together with its three sub-competence areas (Search for and analysis of information, Creativity and innovation, and Prospecting), and the relationship between the level of DEC and various socio-demographic characteristics of higher education students was investigated using logistic regression. The results show a relatively low DEC level of the participating students for the first EmDigital competence area. Location, field of study, level of study and employment status were found to be statistically significant for the acquisition of DEC, while the variables age and gender had little impact. The results of this study are a step towards the development of an DEC online assessment tool (using the Digital Competence Wheel as a role model) that universities and other stakeholders could use to assess the level of DEC their students acquire during university education. This research is the first study to assess the acquisition of DEC during university studies and the impact of different socio-demographic characteristics of students on their level of DEC.

1. Introduction

The dynamic nature of today's society requires a new approach to educating our future professionals that takes into account global economic development and the demands of a turbulent labour market [1]. New models that enable students to acquire knowledge, skills and attitudes suitable for a real work environment relevant to them should replace the old model based on knowledge transfer and memorisation. In addition to new educational models, special attention should be paid to the new types of skills and competences

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https://doi.org/10.1016/j.heliyon.2023.e20897
Received 10 November 2022; Received in revised form 25 September 2023; Accepted 10 October 2023
Available online 12 October 2023

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Vladimir Simovic: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing. **Ivana Domazet:** Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Resources, Writing – original draft, Writing – review & editing. **Milica Bugarcic:** Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing, Data curation. **Mirna Safi:** Investigation, Resources, Supervision, Writing – original draft, Writing – review & editing. **Hamsa Sarhan:** Investigation, Resources, Writing – original draft, Writing – review & editing. **Rupali Bhagat:** Investigation, Resources, Writing – original draft, Writing – review & editing. **Aleksandra Bradic Martinovic:** Conceptualization, Methodology, Writing – review & editing.

Declaration of AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used InstaText in order to improve language and readability of the paper. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Vladimir Simovic reports financial support, article publishing charges, and equipment, drugs, or supplies were provided by Kuwait Foundation for the Advancements of Sciences (KFAS).

Acknowledgments

This work is supported by Kuwait Foundation for the Advancements of Sciences (KFAS) under grant No.CN21-18IQ-1382 and the Ministry of Education, Science and Technological Development of the Republic of Serbia.

APPENDIX

Table 1
Identification of Opportunities as the first competence area of EmDigital

Competence Area	Sub-Competence	Indicator
Identification of Opportunities	C1. Search for and analysis of information	C1.1. Development of searches implementing information organization and management mechanisms. C1.2. Identification of entrepreneurship needs or opportunities within a virtual or based-on-technologies face-to-face environment. C1.3. Assessment of limitations, opportunities and risks of potential entrepreneurship with technologies.
	C2.Creativity and innovation	C2.1. Specification of the most adequate digital contents and tools to respond to the possibilities found C2.2. Specification of ideas and opportunities in a creative manner
	C3. Prospecting	C3.1. Exploration of the real possibilities of the development and implementation process of ideas within an immediate future team.

Source: Prendes-Espinosa et al. [21].

Table 2
Legend

Code	Label
EQ1	You are trying to identify the targeted audience(s) in a B2C segment for your digital business idea. In order to do it, you use.
EQ2	Where can you find useful information about your competitors using online search?
EQ3	A digital business model in which a part of features is free to use by the customer and the more advanced features need to be paid is called …
EQ4	For the purpose of testing the business idea and setting a value proposition of the digital business you will use …
EQ5	Distributed Denial of Service is a type of criminal activity associated with …
EQ6	Name an emerging technology and briefly explain how it can be used as a basis for digital business
EQ7	Research results show that product brochures with prices need to be on the website to earn more profit while gaining new customers. To make an eye-catching brochure you would use …
EQ8	You are looking to inform via email all your loyal customers about the pre-sale of some products/services of your digital business. Which tool would you use?
EQ9	Revenue streams, Cost structure and Key Activities are a part of the tool which is being used for the purpose of specifying digital business ideas. This tool is …
EQ10	If you were asked to specify the MVP (Minimum Viable Product) for your digital product or service, you would do one of the following …

(*continued on next page*)

International Journal of Hydrogen Energy 58 (2024) 56–68

Contents lists available at ScienceDirect

International Journal of Hydrogen Energy

journal homepage: www.elsevier.com/locate/he

Techno-economic analysis and optimization of hydrogen production from renewable hybrid energy systems: Shagaya renewable power plant-Kuwait

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ARTICLE INFO

Keywords:
Hybrid energy system
Photovoltaic
Wind turbine
Hydrogen
Fuel cells
Optimization

ABSTRACT

The present study examines the potential for hydrogen production using the hybrid energy system at the Shagaya renewable power plant. Techno-economic and optimization analyses are used to identify the optimum configurations that reduce costs while increasing the renewable fraction and lowering greenhouse gas emissions. Three configurations were considered, exploring on- and off-grid combinations of photovoltaic solar (PV), wind turbine (WT), fuel cells and batteries. Integrating PV solar with wind power connected to the power grid was found to achieve the lowest levelized cost of energy of 0.539 \$/kWh and a hydrogen production cost of 6.85 \$/kg. However, for the stand-alone system where battery storage banks or fuel cells are used, the cost of hydrogen increases to more than 8.0 \$/kg due to the larger capital cost of the system. The optimized system achieves annual green hydrogen production of 111 877 kg along with an annual carbon dioxide emission reduction of 14 819 kg. A sensitivity analysis proves that COE is more sensitive to PV price than wind turbines and electrolyzers. LCOE falls by 32.3% to 0.365 kWh when the PV unit price drops to 50%. The LCOE falls by 4% to 0.517 kWh when WT costs decrease by 50%.

1. Introduction

Awareness of the environmental impact of humanity's reliance on fossil fuels has progressively increased over recent years, motivating efforts towards sustainable development and reducing carbon emissions. Hydrogen is a clean and efficient alternative to fossil fuels, with potential applications in power generation, transportation, and industrial processes. However, its production is energy intensive. Renewable energy sources offer a solution to this dilemma. Studies estimate that hydrogen energy will meet 11% of global energy demand by 2025 and 34% by 2050, and project that renewable production of hydrogen has significant potential to meet global hydrogen demand [1]. To achieve this, cost-effective and sustainable methods for renewable hydrogen production, such as via wind or solar power, need to be developed.

Production costs render hydrogen relatively expensive compared to other energy sources. A disadvantage of either solar or wind power for hydrogen production is the intermittency of the generated power. Nasser et al. [2] suggests that a hybrid approach that integrates both wind and solar power may serve as a viable solution to reduce costs. Utilizing a hybrid system increases the efficiency of hydrogen-production due both to the elevated electricity input to and higher water temperature within the electrolyzer [3]. Electrolyzers utilize electricity to split water into hydrogen and oxygen. Furthermore, incorporating a battery system into the system setup reduces the number of electrolyzer cutoffs while simultaneously increasing working hours, efficiency, and overall lifespan [4]. The hybrid system's utilization factor exceeds that of a standalone system [5]. Further information may be found in the reviews by Qazi et al. [6] and Al-Enezi et al. [7].

Various forms of sustainable energy resources can be utilized independently or in conjunction with alternative energy sources to provide a reliable system that meets the required energy demands [8]. Photovoltaic-wind hybrid energy systems, which combine solar photovoltaic (PV) and wind turbines (WT), have been shown to have a high energy output and lower instability than standalone solar or wind systems. Furthermore, integrating such hybrid systems can decrease the expenses incurred in electricity generation and mitigate intermittency problems related to renewable energy sources [9]. The Shagaya renewable power plant located in Kuwait's western region, where sunlight and wind are abundant, is an example of a hybrid energy system that utilizes a range of sustainable resources such as solar, wind, and

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https://doi.org/10.1016/j.ijhydene.2024.01.153
Received 11 October 2023; Received in revised form 27 December 2023; Accepted 14 January 2024
Available online 19 January 2024

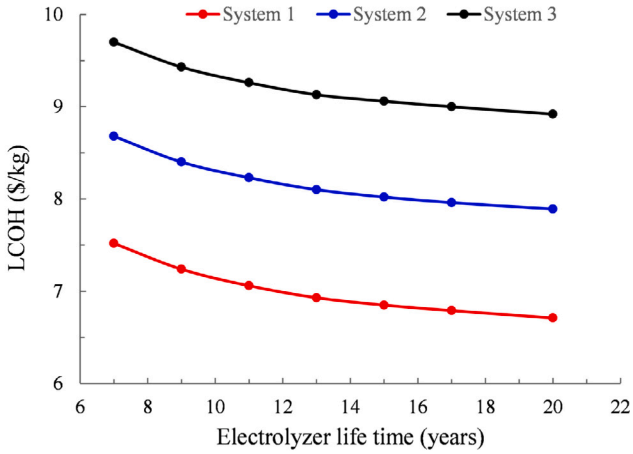

Fig. 13. Effect of the electrolyzer lifetime on LCOH.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This work is funded in part by the Kuwait Foundation for the Advancement of Sciences (KFAS) under project code CN22-15SE-1612. The authors are grateful for the support of the Mechanical Engineering Department of the Australian University of Kuwait.

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Conference Publications

Practical Considerations for Phase Change Materials in Kuwaiti Building Envelopes: A Data-driven Approach

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Abstract*— This research aims to enhance the comprehension of choosing efficient Phase Change Materials (PCMs) for energy conservation in buildings and addresses the gap in the literature concerning methodologies specific to Kuwait's context. A range of PCM materials, such as solid-state paraffin and liquid-state salt hydrates, have been developed. Eutectic mixtures, organic and inorganic PCMs, as well as bio-based PCMs, are gaining increasing popularity. Nonetheless, the transportation of liquid PCMs in Kuwait is challenging and expensive. In contrast, Graphite-based PCMs, which are in a solid state, provide a feasible transportation solution. This study aims to address the choice of melting point PCMs for buildings and practical considerations related to nano-graphite-based PCMs. Currently, there is a lack of a methodological approach in the literature for selecting the most effective PCM for buildings in Kuwait. To investigate this, two identical portable cabins were constructed at the Australian University of Kuwait, using 75mm sandwich panels with interior dimensions of 2m × 2m × 2.8m. Each room used a split unit air conditioner, with the temperature set at 22°C during measurements. A data logging system with SD memory storage collected temperatures from the interior sides of the cabin walls every 10 minutes between June 27th and July 2nd, 2023. The frequency distribution of wall temperatures ranging from 20°C to 29°C was analyzed. Results indicate that a PCM with a melting point of 24°C would take approximately 8 hours to melt and have 16 hours available for solidification, considering a 24-hour day/night cycle. The next question to be addressed is determining the appropriate thickness of PCM to be used in Kuwait.

Keywords— building, data analysis, energy saving, hot climate, phase change material.

I. INTRODUCTION

By using energy saving techniques and materials in buildings, the environment is greatly benefited. The greatest places to study the effects of various energy-saving techniques are hot climates with harsh weather, like Kuwait, as such regions are known for their high energy consumption Buildings are increasingly using phase change materials. Comparing phase change materials (PCMs) to regular bricks and concrete blocks used in building construction, PCMs typically have a larger heat storage capacity. Compared to conventional building materials, PCMs often have a higher latent heat capacity, which means they can store more thermal energy per unit mass. This is so that PCMs can absorb or release large amounts of heat without significantly changing temperature during a phase shift (such melting or solidification).

There are numerous types of phase change materials (PCMs), and each one has certain qualities that make them appropriate for applications. Here are a few typical instances [1]:

- Paraffin Wax: A popular PCM choice due to its high latent heat capacity and affordability, paraffin wax transitions between solid and liquid phases at precise temperatures.
- Salt Hydrates: High energy storage capacities characterize salt hydrates like sodium sulfate decahydrate and calcium chloride hexahydrate, which undergo phase changes between solid and liquid states.
- Eutectic Mixtures: Composed of two or more substances in specific proportions, eutectic mixtures melt and solidify at a constant temperature. Examples include fatty acid and alcohol mixtures.
- Organic PCMs: Derived from natural or synthetic sources, organic PCMs such as fatty acids and polyethylene glycols offer various melting points tailored to specific applications.
- Inorganic PCMs: Metals and alloys comprise inorganic PCMs, which are known for their high thermal conductivity and stability, making them suitable for high-temperature applications.
- Bio-based PCMs: Sourced from renewable resources like vegetable oils or fatty acids, bio-based PCMs provide environmental benefits and are increasingly popular in sustainable building applications.

These examples only scratch the surface of the diverse range of phase change materials available. For example, an experimental validation was conducted using two types of PCM, KNO3-NaNO3 and KNO3-NaNO3-NaNO2, embedded in solar parabolic dish collectors [2]. The results

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temperature variation, melted PCM velocity, and energy storage and release rates. It was observed that variable heat flux reduces the melting time compared to constant heat flux, and the melting time is shorter than the solidification time [18].

From the conducted study and analysis of the experimental data, it is clear that the duration of melting should be shorter than that of solidification. Based on the findings presented in Fig. 8, it is recommended to set the melting point of the PCM in the portable cabin at 24 °C. This approach can be applied to investigate other buildings with diverse wall materials as well. Further research is needed to measure the rate of melt down during the melting phase and ensure that only one side of the PCM starts melting (the side in contact with the wall), while the other side facing the indoor conditions of the room does not quickly reach the melting point. Exploring PCM materials with different thicknesses will be the focus of our future work.

V. Conclusions

This paper centers around the recent progress made in phase change materials (PCMs) and their application in building envelopes. The use of solid-state PCMs combined with nano-graphite as a stabilizing agent shows great potential for buildings in Kuwait, considering the country's specific customs regulations. However, the transportation of large amounts of these materials to Kuwait presents difficulties due to the intense heat experienced during the summer season.

To determine the most practical combination of melting point temperature and PCM thickness, a data logging system was developed to measure wall temperatures within a portable cabin. Based on the data analysis, the following conclusions can be drawn:

- A PCM with a melting temperature of 24 °C provides approximately 8 hours of melting time, allowing for a longer solidification period of 16 hours within a 24-hour cycle.
- Optimal PCM thickness can be investigated by attaching temperature sensors to the sides of the PCM layer and observing the speed at which both sides reach the melting point.

Further research is necessary to evaluate the suitability of PCMs in different months of the year in Kuwait. Additionally, an extensive analysis involving annual data and software simulations using tools like TRNSYS with Type 399 is being conducted to enhance our understanding of PCMs in Kuwaiti building envelopes.

Acknowledgment

We gratefully acknowledge the generous funding provided by the Kuwait Foundation for the Advancement of Sciences (KFAS), Australian University, Kuwait (AU), and Central Queensland University (CQU) for this study. The support received under grant no. CN19-35EM-06 has been instrumental in conducting the research. Additionally, we extend our special thanks to the AU facility team for their dedicated efforts in maintaining the two portable cabins used in this study.

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Detecting debonding in FRP retrofitted concrete beams using nonlinear ultrasonic waves

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Abstract. Fiber Reinforced Polymer (FRP) retrofitting is a widely adopted strategy for enhancing the structural performance of concrete beams due to its ability to impart increased strength and durability. However, FRP retrofitted structures are susceptible to various damage mechanisms, with debonding being a critical issue. In this context, Non-Destructive Testing (NDT) techniques play a crucial role in assessing and monitoring the structural health of FRP retrofitted concrete beams. Among these techniques, the application of the nonlinear guided wave technique emerges prominently as an efficient and effective approach. The nonlinear guided wave technique distinguishes itself for its inherent baseline-free characteristics and exceptional sensitivity to even minor damages. This feature set positions the nonlinear guided wave technique as a promising method for achieving accurate and precise debonding detection in FRP retrofitted concrete beams. The study delves into the challenges associated with debonding and underscores the advantages of utilizing the nonlinear guided wave technique as a standalone NDT method. This paper exclusively focuses on the application of Contact Acoustic Nonlinearity (CAN) for debonding detection in FRP retrofitted beams. Through extensive numerical simulations, various models are considered, incorporating different debonding dimensions and through-thickness locations. The numerical results demonstrate the capability of the nonlinear guided wave technique to accurately detect debonding, offering a promising approach for structural health monitoring. In summary, this paper not only sheds light on the exclusive use of CAN but also provides a nuanced understanding of the interaction of guided waves with damages, enhancing our insights into the phenomena associated with CAN. The research uniquely contributes to our comprehension of the effectiveness of nonlinear techniques, specifically CAN, in contrast to traditional NDT methods.

Keywords: NDT, CAN, Nonlinear guided wave, Concrete beam, FRP, Debonding.

In **Figure 6**, the β parameter escalates with the depth of debonding, reaching its peak when debonding occurs between the concrete beam and the 1st FRP lamina. Conversely, it registers the minimum for debonding between the 5th and 6th lamina. This is because the contact force between materials increases with debonding depth due to a larger area of separation. As the depth of debonding grows, the surface area over which the materials lose contact expands, leading to more extensive gaps. This larger contact gap results in increased force exerted when the interfaces attempt to interact, contributing to the heightened contact force. Thus, deeper debonding correlates with higher magnitudes of contact force, influencing the nonlinearity of wave propagation. As the contact force increases with greater debonding depth, it directly contributes to the amplification of nonlinear wave amplitudes.

6 Conclusion

This study employed A_0 guided waves to detect debonding in FRP retrofitted concrete beams. The 3D Finite Element simulations validated the effectiveness of the approach. The research revealed that larger debonding sizes and depths correlate with increased nonlinearity and higher harmonic amplitudes, showcasing the sensitivity of the proposed method to varying damage parameters. The use of the β parameter facilitated quantitative analysis, offering valuable insights into the influence of debonding on wave characteristics. This technique proves promising for detecting and characterizing debonding defects in structural elements. Nevertheless, additional experimental and field studies are imperative to assess the technique's efficacy and validate the obtained results in real-world structural scenarios.

7 Acknowledgements

This project received funding from Australian university and the Kuwait Foundation for the Advancement of Sciences (KFAS) with project codes PR19-15EC-09.

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Comparative Analysis of Thermal Performance of Painted, Finned, and Plain Roofs in Arid and Temperate Climates: Insights from Kuwait City and Vancouver

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Abstract. This paper presents a comparative analysis of the thermal performance of three common roofing types - painted, finned, and plain for buildings with customary materials without insulation- in two contrasting climatic contexts: Kuwait City and Vancouver. Utilizing simulation techniques, we investigated the dynamic thermal behaviour of these roofing materials to assess their suitability for mitigating energy demands and enhancing indoor thermal comfort. Our findings reveal distinct thermal characteristics associated with each roofing type in the respective climates. In Kuwait City's arid environment, the painted roof emerges as the optimal choice, demonstrating superior performance in reducing thermal loads during hot months while posing challenges related to increased heating demand in cooler seasons. Conversely, in Vancouver's temperate climate, the painted roof exhibits continuous outward conduction of heat, contributing to elevated heating demands throughout the year despite its effectiveness in maintaining lower temperatures compared to the indoor environment. This study highlights the importance of considering climatic factors and seasonal variations in selecting roofing materials to achieve optimal energy efficiency and indoor comfort. These findings can assist decision-making processes for architects, engineers, and policymakers aiming to enhance building performance and sustainability across diverse climatic regions.

1 Introduction

The demand for reducing cooling energy consumption in buildings has become a significant concern globally, particularly in regions like Kuwait where extreme temperatures necessitate heavy reliance on air conditioning for buildings built from customary materials without insulation. In this literature review, we explore the effectiveness of cool roof technologies in mitigating energy consumption and enhancing sustainability in building cooling systems. We focus on various cool roof methods, including cool roof coatings, composite roofs, and shingled roofs, and compare their performance in different geographical contexts.

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City. During other months, particularly in the cooler seasons, the painted roof tends to maintain lower surface temperatures, leading to increased heating demand within the building. This phenomenon underscores the importance of considering seasonal variations and the overall annual energy balance when evaluating the suitability of roofing materials in arid climates like Kuwait City.

In contrast, the thermal performance of the painted roof in Vancouver, characterized by milder temperatures and higher precipitation levels, presents a different scenario. Figure 6 indicates that the painted roof consistently maintains lower temperatures compared to the indoor environment in Vancouver. While this may seem beneficial for reducing cooling demand during warmer periods, it also results in a continuous inward conduction of heat, contributing to higher heating demand throughout the year. This observation suggests that the advantages of the painted roof in terms of minimizing cooling requirements may be offset by its adverse impact on heating demands, particularly in climates with prolonged heating seasons such as Vancouver.

Funding

This study is fully funded by the Kuwait Foundation for the Advancement of Sciences (KFAS), Australian University, Kuwait (AU) and Central Queensland University (CQU) under grant no. CN19-35EM-06, which is gratefully acknowledged.

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Fiber Bragg Grating Sensors vs Strain Gauges for Static Bridge Monitoring System

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***Abstract*— As the architectural landscape evolves with advanced materials and innovative designs, the imperative to ensure the structural safety of modern edifices has escalated. Contemporary bridges must accommodate increasing traffic loads, requiring frequent inspections and maintenance to prevent structural wear. In this context, real-time monitoring systems have emerged as essential for the proactive management of both new and aging infrastructures. Fiber Optic Sensors (FOS) offer promising long-term Structural Health Monitoring (SHM) capabilities among the technologies contributing to this domain. This study evaluates the efficacy of Fiber Bragg Grating Sensors (FBGs) against traditional Strain Gauges in capturing strains, loads, and deflections in full-scale beams subjected to static loading. Comparing FOS-derived strain data with those from electrical strain gauges, our findings indicate superior reliability and adaptability of FBG sensors in structural monitoring, particularly noting their continued performance post-maximum load exposure. These insights advocate for a broader application of FBG in SHM systems, potentially enhancing the longevity and safety of bridge structures.**

Keywords: Fiber Bragg Grating, Structural Health Monitoring, Strain Measurements, Bridge Safety, Real-time Monitoring Systems

I. Introduction

Bridge collapses are not only common but also carry immense costs. Such incidents significantly affect society and the economy, leading to loss of life and substantial material damage. Bridge failures are caused by design flaws, component degradation, increased traffic loads, inadequate capacity assessment, and flawed inspections. Over the last two decades, there have been over 12 incidents of bridge collapses globally. Notable recent bridge failures in Florida, Miami, and Italy have led to numerous fatalities and widespread family devastation (NYTimes.com, 2020). For instance, Minnesota's 2007 I-35W Highway Bridge collapse was attributed to poor gusset plate design, excessive construction loads, and floor beam fractures (National Transportation Safety Board, 2008). Similarly, the De la Concorde overpass collapse in Laval, Quebec, in 2007 was due to insufficient shear and flexural reinforcement based on the then-current code, substandard construction, improper repair methods, and poor coordination during maintenance [1]. Statistical data in the report highlights the deficiencies of bridges in Canada and the US, which are presented in TABLE I.

TABLE I. Statistical data in the report highlights the deficiencies of bridges in Canada and the US.

Territory	Structurally Deficient (US) and Deficient Condition (QC)	Deficient Condition (QC) Functionally Obsolete (US) and Functionally Deficient (QC)
New Jersey	11%	24%
New York	12%	25%
Pennsylvania	25%	18%
The U.S.	12%	13%
QUÉBEC - PRN	46%	2%
QUÉBEC – MUNRN	49%	13%

Structural health monitoring involves two categories of sensing techniques: non-contact and contact sensing. Non-contact sensing techniques, such as thermal imaging, acoustic emission, and digital image correlation, use temperature measurement, vibration analysis, and image comparison to monitor the health of a structure without physically touching it [2]-[4]. They offer advantages such as non-intrusiveness, remote monitoring capabilities, and wide area coverage. Nevertheless, they have limitations in measuring internal health, are subject to environmental factors, and can be expensive and complicated to implement.

Contact sensing techniques, such as strain gauges, displacement transducers, and accelerometers, measure parameters like strain, displacement, and acceleration by physically contacting the structure. These methods offer precise measurements, a wide range of measurement options, and versatility in installation and material applicability [5], [6]. However, they risk damaging structures, have limited spatial coverage, and require regular maintenance and calibration.

Bridge health monitoring systems can provide an early warning for bridge safety issues and are used to monitor structural conditions and changes in real-time. They can also provide engineers with valuable data for asset management plans and bridge service life studies. Structural health monitoring (SHM) systems have been widely used in bridge condition evaluation [7]-[11]. However, the application of these systems in very hot regions is lacking, and very few

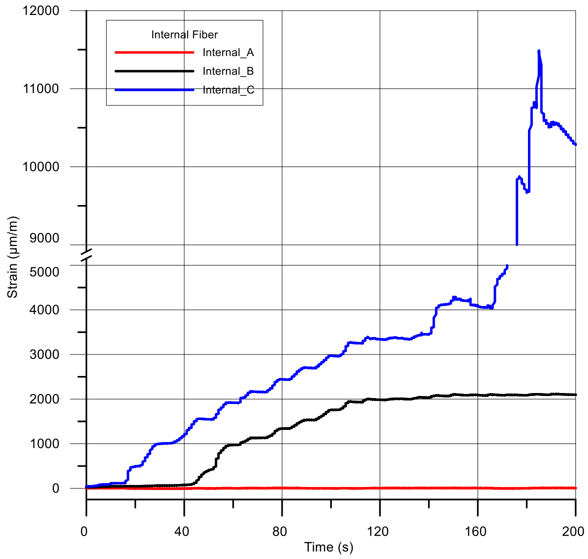

Fig. 11. Strain vs Time for Internal FBG

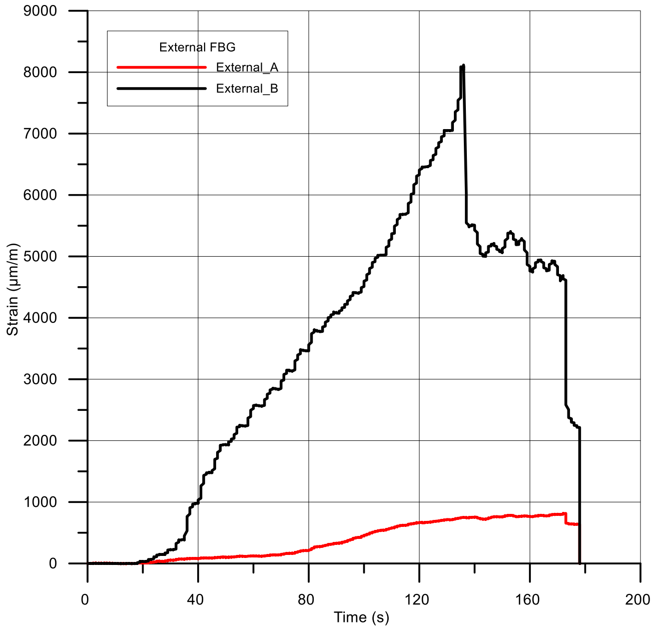

Fig. 12. Strain vs Time for external FBG

TABLE II. OVERALL COMPARISON BETWEEN THE FBG AND STRAIN GAUGES

	FBG	Stain gauges
Installation	All sensors are on one channel	Every sensor requires one channel
Output	Clear signal	Noisy signal
External sensor Setup	Simple and not affected by the inhomogeneities surface of the beam	Beam surface preparation is required
Internal sensor Setup	Special adhesive and careful setup are required.	Special adhesive and careful setup are required.
Result	Capturing strain up to 8 mm/m for external FBG Capturing strain measurements up to 11mm/m before the beam's failure.	Failing at just over 600 µm/m for external SG A maximum of 1300 µm/m was captured in the middle of the beam

Integrating all observations, the strategic placement of internal and external gauges, especially FBG sensors, is crucial for accurately capturing stress distribution within the beam. Their responses to loading conditions are essential for an effective sensor network, providing critical data that informs maintenance strategies and ensures the structural integrity and safety of the beam throughout its service life.

IV. Conclusion

In conclusion, this study has rigorously compared the performance of internal and external FBGs with traditional electrical SGs within the context of a static load application for bridge monitoring systems. The results have unequivocally demonstrated that FBGs, internally and externally attached, exhibit greater sensitivity and reliability than their electrical counterparts. Notably, FBG sensors successfully recorded strain until beam failure, which the strain gauges did not mirror. The ease of installation of FBG sensors, even on rough surfaces, and their operational resilience under load further underscore their superiority. Moreover, the data derived from electrical SGs were significantly noisier, necessitating additional smoothing processes. The findings of this study reinforce the value of FBG sensors in SHM systems, advocating for their broader application to enhance the longevity and safety of bridge structures. These insights contribute to the evolving field of structural monitoring, emphasizing the need for precise, reliable, and efficient sensor technology in carefully managing and repairing our valuable civil infrastructure assets.

Acknowledgment

This project was fully funded by the Kuwait Foundation for the Advancement of Sciences (KFAS) under project code PR20-15EE-01. The authors gratefully acknowledge the financial support of KFAS and the Australian University in Kuwait.

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