



THERMAL PERFORMANCE OF CLASSROOM BLOCK: A COMPARISON OF HOBO DATALOGGER AND DESIGN- BUILDER

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Abstract:

The study intended to compare the effectiveness of the two distinctive methods of measuring the school buildings' thermal performance using a classroom block as a specimen. The building under study is located in the Birnin-kebbi area of the Kebbi state of Nigeria. The methods are Design builder, energy efficiency software (Computer Simulation), and Hobo Data-logger (Physical temperature measurement). At the end of the analysis, the two instruments' output was further scrutinized using the SPSS package for correlation. The two results show a positive and significant relationship at 0.05 ($p < 0.05$). However, based on the established strong relationship between the two approaches, it is concluded that either technique can be employed to measure the building's thermal performance and yield a satisfactory result, provided the procedures are maintained and followed judiciously.

Keywords:

Thermal Performance, Design Builder, Meteorological Temperature, Energy Simulation, and Hobo Data-logger

Introduction

The thermal performance of the building and the indoor thermal comfort depends on using energy-efficient building materials. With effective utilization of abundant natural resources as a building material, some of these materials are inexhaustible, such as earth, rock and, timber, etc. Furthermore, these materials are renewable, recyclable, readily available, and affordable but are not utilized optimally (Akande, 2010). Thermal performance in buildings encompasses energy optimization through the appropriate selection of energy-efficient building materials, which aids in minimizing the lifecycle costs while maximizing energy savings. And other several energy-efficient design measures which including window glazing thickness types, wall sizes, and other components of the building (Gorse et al., 2016) and (Kwag et al., 2018). In developing countries, located in tropical regions where the climatic conditions are characterized by extreme temperature, the building envelopes are more prone to solar heat gain due to their exposure to the external environment. Moreover, as a result, occupants of the building enclosure are faced with uncomfortable interior spaces, which have detrimental health consequences such as insomnia, fatigue, boredom, headache, and asthma (Akande, 2010; Sharma, 2016; Press & Range, 2018).

The north-western part of Nigeria falls in a tropical region of the African country, and School buildings in those areas suffered from the intensive climatic condition, which negatively affects the academic learning process and learning activities on the part of the students and the academic staff. However, it has become necessary to embrace sustainable building materials with excellent thermal properties, environmentally friendly, and economically viable. Also, such materials should be affordable, available, and recyclable. Most of these sustainable building materials that possess these sound characteristics are not effectively utilized, as Akande (2010) stated, despite their availability.

Sustainable building material has manifold benefit, economically it has a less operational cost, environmentally it does not cause any harm to the environment during its extraction, or during the production of their products, and socially its enhanced healthy living condition for learning activities in case of the school building environment, it enhances the productivity and work efficiency (Building, 2017). The thermal performance of buildings elucidates energy transfer interaction between the buildings and their surrounding environments (Joseph et al., 2015). The thermal performance focuses on reducing the negative impact of the external environment, which will enhance indoor living conditions. In a tropical area, all necessary measures need to be taking into consideration to exclude solar radiation into the building enclosure, such as proper spaces configuration, construction techniques, finishes, and appropriate selection materials (Ahsan, 2017; Korniyenko, 2015; Taylor, 2015)

In a region where extreme weather conditions are experienced, such as high temperature, less humidity, and rainfall, those areas with such characteristics are hot-dry climate zone. School buildings and other building typologies in those areas require attention to avert the solar heat transfer into the building interiors. Whenever there is a temperature difference between two spaces, where the temperature is higher tends to flow towards where the temperature is lower as nature hates imbalance. As it is a natural occurrence daily, sunrises and air temperature increase, and heat is transferred through components of building directly or indirectly (Olaniyan et al., 2013 in Sani 2015). Elements of the buildings such as walls and windows glazing should be oriented based on their thermal-physical property towards the effect of heat. Embracing the strategy can drastically reduce thermal transmittance, minimizing the building's

energy consumption rate for cooling to achieve indoor comfort for the building's occupant (Bella et al., 2015).

Sustainable building materials can be referred to as green building materials. The materials are energy efficient as they do not produce any harmful effect on the environment during their source, product making, and assembly. They possess an excellent thermal property, which guarantees less operational cost (Radwan et al., 2016). Building envelopes' thermal performance depends on the thermo-physical properties of the building materials and other factors such as the materials thickness, type of insulation, quality of workmanship, etc. (Tarabieh & Aboulmagd, 2019). The thermal behaviors of exterior walls of the building components' have to look into the thermal property of the material to be determined to ensure the use of energy-efficient materials that have an excellent thermal performance to protect solar heat gain (Bienvenido-huertas et al., 2018). Uncomfortable indoor space of the building as a result of solar heat gain has a detrimental health effect on the occupants of the buildings ranging from insomnia, fatigue, boredom, headache, reduces the rate of productivity and work efficiency (Haruna & Oraegbune, 2018; Munonye, 2018)

According to Sadat et al. (2016), Students spent most of their time in academic enclosed spaces more than any other building enclosures except their dwelling spaces. This expresses how crucial it is to provide an encouraging indoor thermal environment for the learning process. The author further opines that a comfortable indoor thermal environment is related to the building occupants' productivity and well-being. An uncomfortable thermal indoor environment in educational buildings can lead to unsatisfactory conditions because of the student's reduced level of concentration, assimilation of information, and the other side of the educator's low productivity rate regarding knowledge impacting and low work efficiency. The challenge is the appropriate selection of sustainable building materials that are energy efficient to facilitate the learning process and to avoid indoor discomfort with minimal energy consumption (Sadat et al., 2016). Climatic conditions vary from region to region in which each has determined the suitability and applicability of the particular sustainable building material on their building structures (Fields, 2018).

Despite the nature of the climate in north-western Nigeria, which is classified under hot and dry climate regions, desertification and deforestation in Nigeria have contributed potentially to devastating the environmental impacts, increasing the ambient temperatures and declining rainfall (Kwag et al., 2018). To Curbed the environmental problems associated with extraction and production of material for building components in the construction industry, and to enhance building energy efficiency through appropriate selection of sustainable building materials to curtails energy consumption, and maintain indoor comfort, and improving the well-being of the building occupant (Al-hafiz, 2017).

There is an indicator that architects and engineers should always consider when selecting a building material to construct the building considering the human comfort. Health, impact on the environment, energy-saving materials, embodied energy, the operation cost of the buildings (annual energy consumption for cooling) that is life cycle cost of the building (Mahmoudkelaye et al., 2018). Furthermore, human activities have caused tremendous adverse effects on the ecosystem, and the natural environment was well balanced. However, human activity threatens shelter, health, life, food, productivity, and work efficiency, as stated by (Kwag et al., 2018).

The government regulatory body that regularized the professional body such as the Architects registration council of Nigeria (ARCON) and other architectural associations like the Nigerian Institute of Architects (NIA), Association of Nigerian Chartered Architects (ANCA), Association of Architectural Educators in Nigeria (AARCHES), and Society of Landscape Architects of Nigeria (SLAN) to jointly organized seminars, workshops, a symposium for more enlightenment on the benefits of preserving the natural environment, and selection of sustainable building material. Moreover, extend the awareness to the communities, all the professional bodies, the Association of Nigerian chartered architect (ANCA), the Nigerian Institute of Architect (NIA), the society of landscape Architecture of Nigeria (SLAN), the association of architectural educators in Nigeria (AARCHES), and the regulating body Architect's registration council of Nigeria (ARCON) collaborate with other government developmental control organizations to ensure adherence to the policy regarding conserving the ecosystem. Furthermore, the National University Commission (NUC) and the National Board for technical education (NBTE) that responsible for curriculum development to follow up ensure issues relating to sustainability (sustainable building materials and preserving ecosystem) have been taught in the respective institution.

According to Fields (2018), there is a need for more enlightenment, training, and more education to the local communities on technological advancement with regard to the use of earth (Compressed earth blocks) for construction of the building due to its manifold benefit apart from been renewable, recyclable and affordable building material, it also has an excellent thermal property that can avert the rate of heat penetration into the interior space of the buildings. The author further stated that utilizing the available local materials such as earth to produce building components and building structures reduces environmental impacts.

Design Builder

Design-Builder is a reliable and most compressive easy-to-use interface; its simulation engine allows the user to generate graphics that can quickly interpret the simulation results. And it also provides the user with a broader range of environmental performance data such as annual energy consumption, HVAC component sizes, and daylight analysis, and so on (Bahar et al., 2013).

Design builder is compatible with architectural models designed with either Revit Architecture, ArchiCAD, or MicroStation, e.t.c. Moreover, it enables the user to create a building geometry within it. Another file format, such as format gbXML and the dxf, can be imported into the DesignBuilder for data exchange (Li, 2017). Figure 1 is illustrating the application of the BIM model for indoor environmental performance analysis.

It is essential to optimize the simulation process as well as output performances, and architects and engineers need to know all the tasks to perform when applying BIM-based simulation.

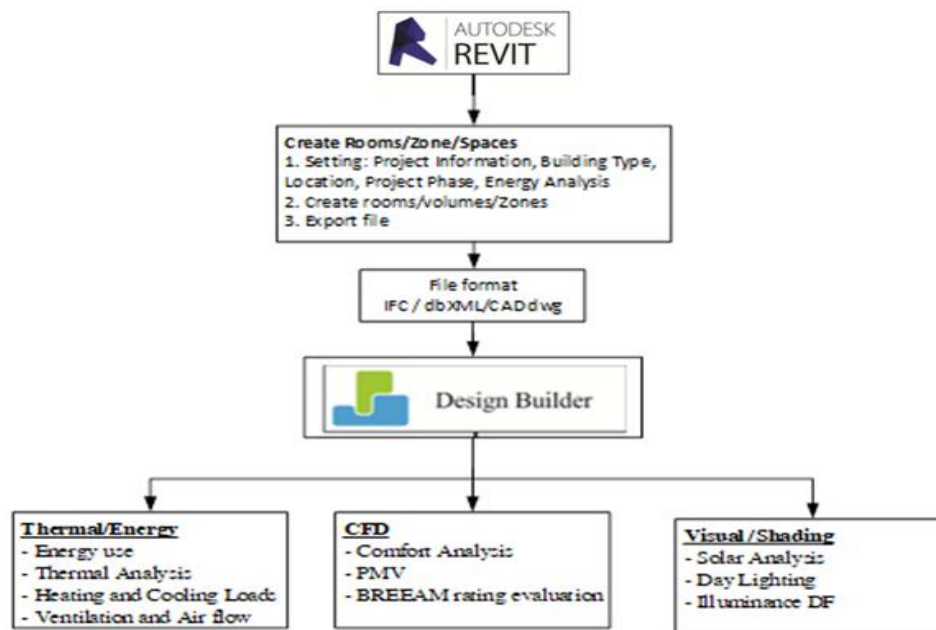


Figure 1: Illustrating the BIM Model Environmental Performance Analysis

Energy Simulation Software

Energy simulation tools are progressively used for energy performance analysis of buildings' buildings and thermal comfort to predict the building enclosure's energy.

In the modern day, architects and engineers required a tool that can respond to their specific inquiries right from the inception of the design stage. Thus, the use of energy simulation software packages assisted architects in predicting the buildings' thermal performance before the construction, simulate the cost of energy consumption of the existing buildings in their present conditions and establish the remedial measure to the best-retrofitting action be taken under analysis.

Furthermore, energy simulation is a vital, established technique that aids in performance and thermal comfort. Moreover, most energy simulation tools consist of an engine and a graphical user interface which distinguish several modes of calculation methods to determine many factors within the engine (Crawley et al., 2001; Lim, 2015; Tobias Maile et al., 2007).

Analyzing and understanding the building envelope's thermal performance before its construction. It also allows architects to predict buildings' operational energy consumption. Besides the energy consumption, simulation tools can be to calculate the listed variables as follows: Consumption needs for the HVAC system, Interior comfort of the inhabitants, Indoor temperature, Natural lighting needs of the occupants, level of ventilation, need for heating and cooling and calculate the cost of the energy used. (Sousa, 2015; Yilmaz, 2019; Zhu et al., 2015).

The use of energy simulation software to the architects and engineers is crucial as it is aids in making building energy performance predictions before its construction, it gives the designers room for making appropriate decisions before erecting the building structure, and if there is

any need for design adjustment, it will resolve to ensure the building is considered energy efficient before it is constructed.

HOBO Data-Logger

The data logger is an electronic device that can record data over a long time about a particular location, either with an instrument built-in or a sensor or via external instruments and sensors. Data loggers can collect data automatically on a 24-hour basis. A data logger is a device that combines analog and digital measurement with a programming procedure that senses temperature, relative humidity, and other parameters ranging from voltage and pulse. (Badhiye et al., 2015).

Data-Logger Operation

The data logger has unique characteristics of taking sensor measurements and store the data for future usage, and the stored data can be retrieved. Moreover, in most cases, data logging requires data collection and storage only. It is necessary to interpret and present the data to assess results and make decisions based on the logger information. Generally, a complete application for data logging includes most of the elements/components shown below.

i. Experiment: Different parameters whose values are recorded from a particular environment or object are called input to the experiment's sensors. ii. Sensors: The data logger receives inputs from different sources through different sensors to calculate different parameters such as temperature, humidity where electrical signals are converted to temperature and humidity values. iii. User interface: There is a provision of the interface that allows a smooth interaction with software and the sensors. The aid of using implemented algorithm analysis is done for the storage of data. iv. Software: the software enables displaying all stored data from the sensor and preserving data retrieved when needed. Figure 2: illustrating the sequential stage of the procedure of the data logging process.

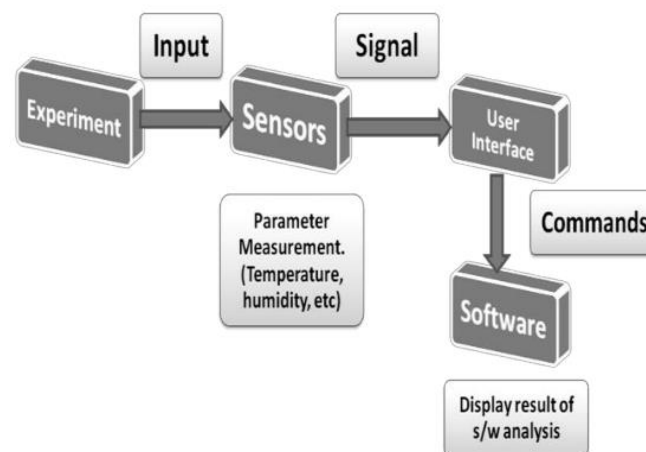


Figure 2: The Procedure of Data Logging Process

Source: (Badhiye, Chatur, & Wakode, 2015)

Study Area

Birnin kebbi is the capital city of kebbi state, Nigeria, and based on geopolitical zoning falls under the North-western zone of Nigeria. Moreover, the climate classification falls within the hot-dry climate region that has characteristics of high temperature, very low relative humidity, and low rainfall (Aminu et al., 2018)

Furthermore, the Birnin kebbi is located geographically at the latitude 12.4539 0 N and longitude 4.1975 0 E in the northern hemisphere. Kebbi state shares boundaries internally with Sokoto state to the northeast, Zamfara state to the east, and Niger state to the south, and also shares borders with other African countries, Niger Republic to the northern part and Benin Republic to the western part of kebbi state (Aminu et al., 2018). Birnin kebbi has an average temperature in the year of 28.9oC. The coolest month is January, with an average temperature of 25.1°C, and the hottest month of the year is April, with a temperature of about 33.6 °C, as shown in figure 4.



Figure 3. Map of Birnin-Kebbi Extracted from Map of Nigeria

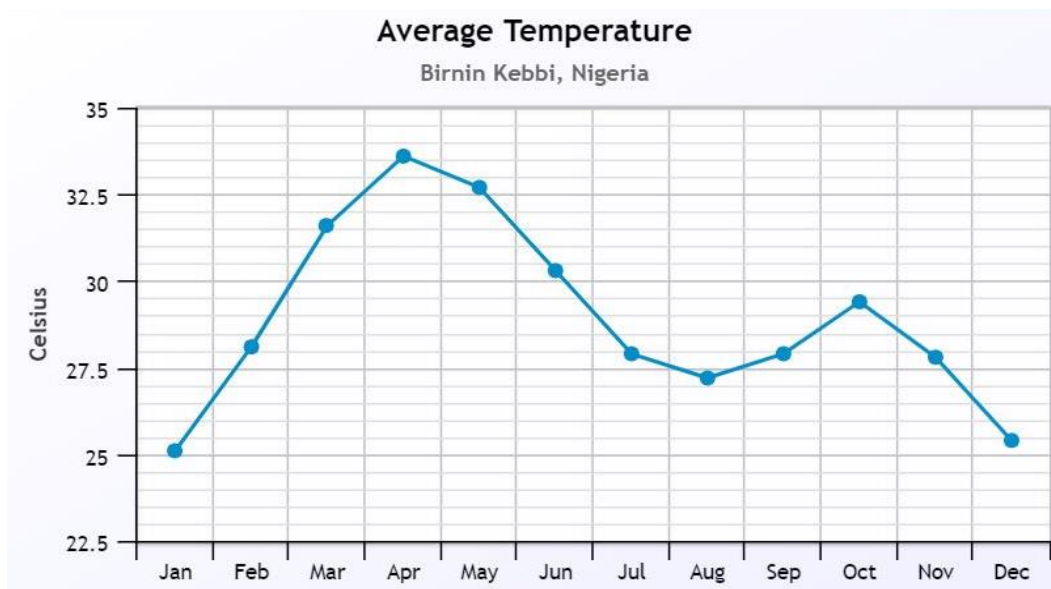


Figure 4: Graph Indicating Monthly Average Temperature Graduation

Data Collection Procedure

Design Builder is a simulation tool that has a series of progressive phases. The inception phase is creating a new project file, the setting of units SI and PI unit, then input the study area coordinates, for example with the context, Nigeria, Birnin kebbi, Kebbi State, import the weather file, and import the building geometry (BIM) into the package as gbXML format as exported from Revit architecture, and the last phase is running the simulation as shown in figure 5: shows the sequence of simulation, the design-builder simulation package can run folds of energy simulation analysis as indicated in Figure 6.

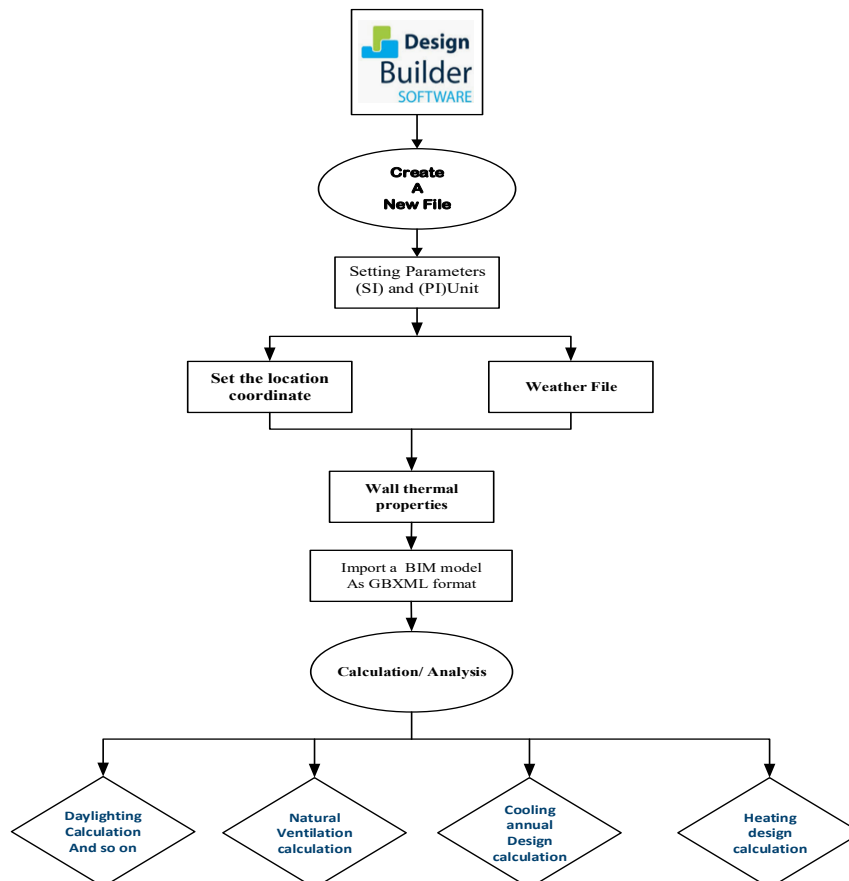


Figure 6: Illustrating the Design-Builder Sequence of Simulation

The design-builder simulation package checks a range of Built Environment issues, such as energy performance of the building, lighting, comfort performance, and so on. As indicated in the last section of Figure 6.

However, the simulation software also allows the Architects and engineers to quickly generate results and compare the performance of the building or building designs, and deliver the outcomes of the analysis within a short time frame.

Result and Findings

This segment of the study presents the relationship between the measured values, simulated values, and the correlation between the analyzed results of the duo methods. Moreover, the graphical illustration of the sequential relationships of the physical measurement and

simulation processes is presented schematically, as indicated in figure 6. The correlation of the measured results is shown in Table 1 and Figure 7, and figure 8, respectively.

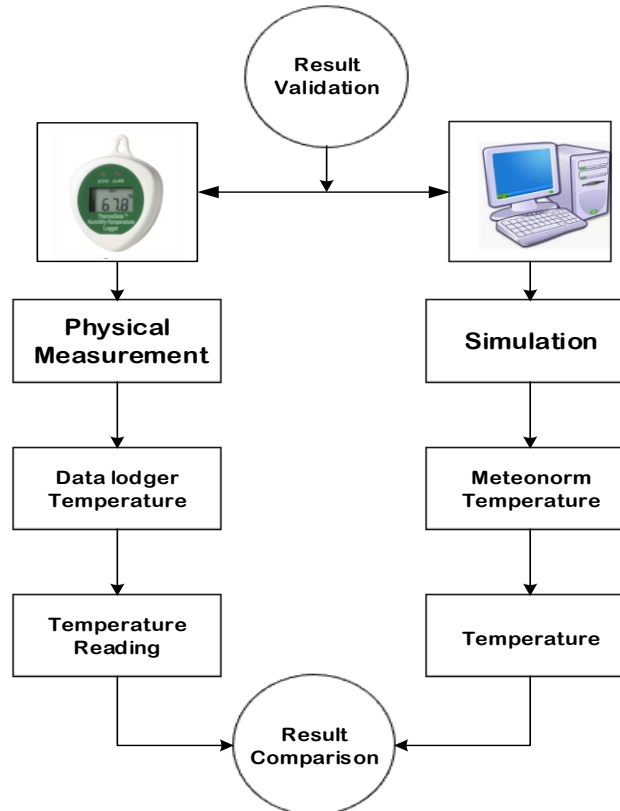


Figure 7: Sequence of Comparison Relationship of the Two Techniques

The Simulated and the Data Logger Measured Results

The Simulated result and Data Logger Measured Results presented in Table 1 show the hour, outside measured data. The simulated result and the data logger measured the result difference obtained from the two different techniques. The results show that the two methods' highest values are 35.3 and 35.61 for the Simulated and Data Logger Measured Results, respectively. However, the lowest is 29.9 and 29.5 Simulated and Data Logger Measured Results, respectively. Other levels were presented in order, and the highest difference was 0.49, and the lowest difference was -0.31.

Table 1: Simulated and Data Logger Measured Results

S/N	Hour	Outside	Simulated Result	Data Logger Measured Result	Difference
1	0	28.6	31.3	30.83	0.47
2	1	27.9	31	30.53	0.47
3	2	27.2	30.6	30.13	0.47
4	3	26.8	30.4	29.94	0.46
5	4	26.5	30.1	29.63	0.47
6	5	26.2	30	29.53	0.47
7	6	26.3	29.9	29.47	0.43

8	7	28.4	30.5	30.03	0.47
9	8	30.9	31	30.53	0.47
10	9	33.5	31.6	31.11	0.49
11	10	35.8	32.2	31.73	0.47
12	11	37.8	32.9	32.43	0.47
13	12	39.4	33.7	33.98	-0.28
14	13	40.4	34.3	34.57	-0.27
15	14	40.9	34.8	35.08	-0.28
16	15	41	35.2	35.48	-0.28
17	16	40.3	35.3	35.61	-0.31
18	17	38.9	35.3	35.61	-0.31
19	18	37.1	34.8	35.11	-0.31
20	19	35.8	34.4	34.71	-0.31
21	20	34.6	34	34.25	-0.25
22	21	33.3	33.6	33.85	-0.25
23	22	32.1	33	33.25	-0.25
24	23	30.8	32.4	32.65	-0.25

The result of Simulated and Data Logger Measured Results presented in figure 7 show a significant relationship between the simulated result and the data logger measured result. The result of the two methods reveals that each technique can be used to perform a similar study, and it is valid.

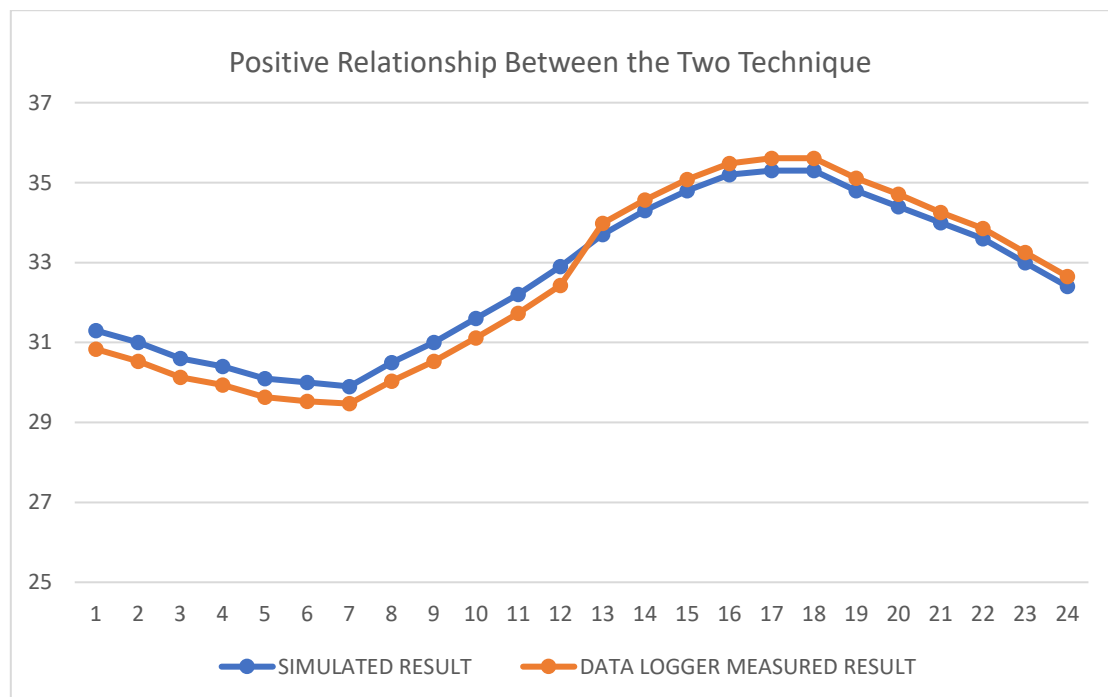


Figure 8: Shows the Positive Relationship of the Two Techniques

Descriptive Statistics

Table 2 presented a description of the results of simulated and data logger techniques. The results showed that the simulated result has a mean of 32.60 (SD 1.90) and the data logger 32.50 (SD 2.24).

Table 2: Descriptive Statistics

	Mean	Std. Deviation	N
SIMULATED RESULT	32.596	1.9011	24
DATA LOGGER MEASURED RESULT	32.5017	2.24686	24

Correlation between Simulated and Data Logger Measured Results

To test the correlation between Simulated and Data Logger Measured Results, a Pearson Product Moment Correlation Coefficient (PPMC) was applied using SPSS 25. As presented in Table 3, the results obtained showed a correlation (r-value) of 0.997 and a p-value of 0.000. This result means a strong positive correlation ($r=0.997$) between Simulated and Data Logger Measured Results. This result is also significant at 0.05 ($p<0.05$). The implication of this is that they indicate that the two methods correlate high and produced similar results. The strength of the correlation relationship, according to Rumsey (2016) and Cohen (1988), can be identified using the following guide: 1. $r = +/-0.50$ is considered to be reliable, 2. $r = +/-0.30$ is classified as moderate and 3. $r = +/-0.10$ is deemed to be weak.

Table 3: Correlations

		SIMULATED RESULT	DATA LOGGER MEASURED RESULT
SIMULATED RESULT	Pearson Correlation	1	.997**
	Sig. (2-tailed)		.000
	N	24	24
DATA LOGGER MEASURED RESULT	Pearson Correlation	.997**	1
	Sig. (2-tailed)	.000	
	N	24	24

** . Correlation is significant at the 0.01 level (2-tailed).

Table 4: Statistical Relationship of the Analyzed Result

Method	N	Mean	SD	r-cal	df	Sig(2-tailed)
Simulated Result	24	32.59	1.901			
				0.997	22	0.000
Data Logger Measured	24	32.50	2.247			

Scattered Graph

A scattered plot was generated to display the relationship's direction further and present a straight line, meaning a direct and strong correlation between the two methods as a positive correction. Figure 9: scattered plot indicating a positive and strong correlation.

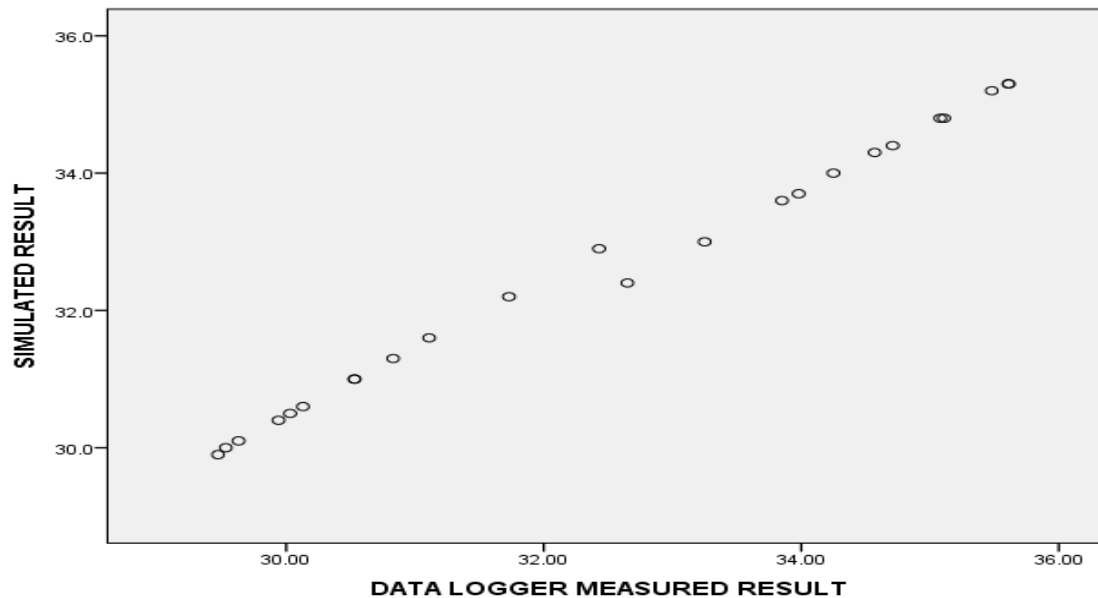


Figure 9: Scattered Plot Indicating a Positive and Robust Correlation

Conclusion

Conclusively, the two techniques for thermal performance evaluation, simulation, and Data-logger presented a similar outcome after thorough scrutiny. Tables 1 and 3 illustrate the positive and robust correlation between the simulated value and the data logger measured value result. This means the two methods yield a similar outcome, while figure 7 and figure 8 displayed in the graphical presentation the positive and valid relationship between the two methods signifying those approaches can be used to perform a similar study, and it is valid.

Recommendation

The two methods can yield a similar result with a positive and robust relationship, as indicated in the study. It is recommended that, based on the findings as mentioned earlier, each technique can be used in place of the other. Since the two methods can produce a similar result with a good relationship, they can perform a similar task and yield a positive outcome.

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