Validating the Simulation Model for the Investigation of Applying Saudi Building Code 601 to Najran Governmental Office Building in Saudi Arabia

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The application of the Saudi Building Code (SBC) 601 to the building envelope improved the monthly thermal performance by 1.75 °C was conducted in the Saudi Arabia, Governmental office building in Najran. The building industry accounts for a significant portion of the nation's electrical energy usage, consuming 29% of the country's primary energy. This is partly a result of the country's hot and dry environment, which necessitates a lot of energy to ensure thermal comfort in buildings. The absence of thermal insulation in many Saudi buildings, which results in a greater reliance on air conditioning, is another contributing cause. According to the Kingdom's 2030 vision, which includes an emphasis on energy conservation. This study uses DesignBuilder simulation software to examine the impact of implementing the various SBC 601 provisions on the cover of the building to validate the software a base case comparison was carried and the validation report is presented in this study. It is important to validate the model while evaluating the building's thermal performance. This helps make the adjustments made during the study effective and realistic, however, there can be significant differences between real data and simulated results. With many software available, the choice of DesignBuilder has proven to be a reliable software within the industry through various energy standards as the validation results show the compact ability of the software and real-life scenario measurement carried out.

Keywords: Validation, Simulation, SBC-601 Najran, Government, Office, Saudi Arabia.

1. Introduction

Buildings contribute for 40% of all energy utilized globally, which is a substantial amount of energy consumption. The utilization of organic energy and resources in the building industry has a significant impact on the production of CO_2 gas, both domestically and globally [1]. Consequently, the emission of greenhouse gases is contributing to the escalation of global warming, thereby resulting in the pervasive phenomenon of climate change, which is currently under investigation and examination [2]. In addition, it is noteworthy that Saudi Arabia ranks among the top 10 countries in terms of per capita energy consumption in 2014, as well as being one of the top 10 countries with the highest global carbon dioxide emissions, as reported in reference [3]. It is irrefutable that Saudi Arabia heavily depends on oil and natural gas as primary energy sources [4]. Saudi Arabia consumes three times more primary energy per person than the global average, according to the 2013 Saudi Energy Efficiency Report [3]. Furthermore, the General Authority for Statistics said in a report released in 2021 that per capita electricity increased 6.98% from 2020 to 8,841 kilowatt hours per hour [5]. Saudi Arabia's electricity sector consumes one third of daily oil production as shown in the. Saudi Arabia's General Authority for Statistics noted that electricity consumption in the building sector in 2021 was 47.25% residential, industrial 19.47%, commercial 15.09%, governmental 12.64%, agricultural 1.88%, and other sectors 3.67% as shown in Figure .1 However, there is an annual growth in electricity consumption of about 5-8%. Based on these realities, as energy consumption increases, oil production could be equal to its consumption by 2035[3].

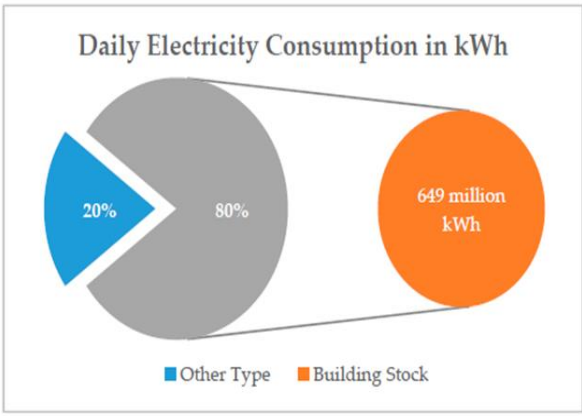

Figure 1. Consumption of the building sector in Saudi Arabia from total electricity production per day [3]

The building sector is experiencing significant urbanization and demand due to the country's economic growth of 6-8% annually, making it one of the fastest-growing economies globally [6]. The building sector consumes about 80% of the total electricity generated by Saudi Electricity Company per day [3].

Along with the huge energy demand in the building sector in Saudi Arabia, 70% of the total domestic electricity demand is consumed in building cooling to provide better indoor environmental quality for buildings due to Saudi Arabia's dry hot climate [6].

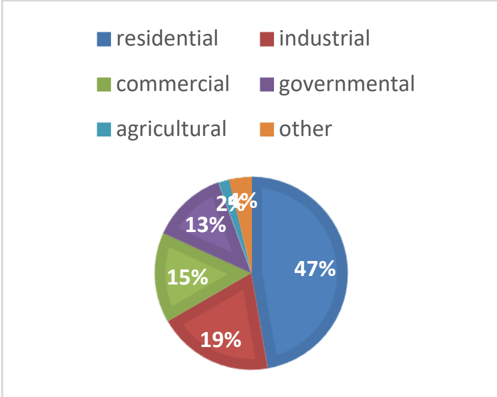

Figure 2. Electricity consumption in building sectors in Saudi Arabia [5]

According to studies, 70% of Saudi Arabia's buildings lack insulation., resulting in lower-quality of indoor environment buildings and increased demand for cooling and heating [7, 8]. Accordingly, Decree No. 6927/MP.22/9/1431H was issued approving the mandatory installation of thermal insulation in all newly constructed homes, businesses, and other comparable to governmental facilities in the main cities of Saudi Arabia [7]. However, the application of thermal insulation in all buildings is not enough of a solution for Saudi Arabia's summer climate of more than 50 degrees Celsius, leaving buildings in constant need of active cooling to provide comfort to the thermal environment, as Saudi Arabia continues to spread awareness, solutions and initiatives that urge the upgrading of energy efficiency in buildings and that are among the objectives of its Vision 2030 [9].

The governmental Office buildings are among the most significant structures that aid in the expansion of the country's economy, stimulate investments, and facilitate services for all members of society. The Saudi Press Agency stated that in 2024 the Kingdom of Saudi Arabia will apply a resolution regarding international companies and dealing with them. This is to follow the Kingdom's Vision 2030 to diversify the resources of the Saudi economy and attract foreign investment. Accordingly, there is a high turnout of governmental office buildings, and this may result in a future increase in energy consumption [10]. Because of the weak climate design of the governmental office buildings in Saudi Arabia most of which came on a unified design distributed throughout the country, without considering the climate of each administrative region, most of the energy is consumed in cooling internal spaces to provide thermal relief to employees and visitors [8].

The major goal and contribution of this study is to apply SBC 603 as a guideline to improve building energy performance efficiency and thermal comfort in Saudi Arabian commercial buildings (office). It is important to note that our findings indicate that computer simulation is one of the realistic techniques to assess a building's overall energy performance and thermal comfort to achieve the required output and to offer comprehensive conclusions. Furthermore, real-life implementation of these solutions is expected to incur significant economic costs and require further maintenance and modernization. However, adherence to the requirements of Saudi construction law will make the process simpler and more sustainable for the building, albeit with less long-term security. Therefore, the most obvious and efficient approach to enhancing the energy efficiency and thermal performance of buildings will be to apply the Saudi Building Code to both new and existing alternative buildings

1.1 Problem statement

Most of the government office buildings in Saudi Arabia rely on a uniform design distributed throughout the country, without considering the climate of each administrative region while 80% of the power produced by the electricity company is consumed in the building sector and there is an increase in consumption and per capita.

1.2 Aim and Objectives

To Validate the Simulation Model to be used to assess the current thermal performance of a modern governmental office building in Najran Governmental Office Building in Saudi Arabia.

2. BACKGROUND

Every nation's energy consumption is inextricably related to its people's economic status, standard of living, and environmental factors. The vast Arabian Peninsula has a severe desert climate. In certain areas of the region, the average temperature can rise to 53 °C. The climate of Saudi Arabia, the largest nation in the Arabian Peninsula, is primarily hot and dry. Saudi Arabia's land elevation ranges from 0 to 2600 meters above mean sea level. One of the highest levels of solar radiation intensity on the planet is received by Saudi Arabia. Extreme heat and aridity are features of Saudi Arabia's climate. The average summer temperature in rural parts is between 27 and 43 °C, whereas in coastal regions it is between 27 and 38 °C. Moreover, Saudi Arabia's climate makes it difficult for people to stay comfortable indoors without using too much energy. Rainfall is low, about 100 mm per year, making it one of the driest countries in the world [11].

2.1 Climate classification by Saudi building code

The various Saudi Arabian climate conditions are described in the Saudi Building Code. According to According to the Saudi Building Code, the nation is split into three primary climate zones. The necessary cooling degree days (DDH) are used to categorize climates [12]. Degree day is a frequently used approach for conducting energy analysis for the following purposes: (a) relative consistency of internal achievements; (b) building occupancy; (c) room temperature; and (d) HVAC equipment efficiency. A building's need for weather-related cooling energy is measured by the cooling degree-day value. [13].

SRBEC mandates a fixed and relatively low base temperature of 10°C for estimating degree-days of cooling. Based on a constant base temperature of 10°C, KSA has been divided into the following three climate zones:

1. Zone 1 is extremely hot with 10 ° C CDD greater than 5000.

2. Zone 2 is extremely hot with 10 ° C CDD less than 5000 and greater than 3500.

3. Zone 3 is less than or equal to 3500.

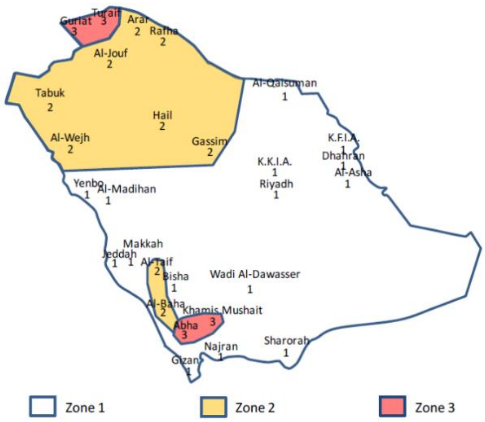

Figure 3. Thermal Zoning in Saudi Arabia [12]

Figure 3: Thermal Zoning in Saudi Arabia [12] indicates that approximately 70% of Saudi Arabia's land area is classified as Climate Zone 1, which includes most major cities. Extreme weather conditions in this region, where temperatures can reach 50 ° C, make studying energy consumption a top priority in the country.

3. METHOD

This section presents a comprehensive quantitative methodology employed in the research endeavor. The research methodology comprises a series of interrelated techniques and processes designed to achieve the primary objective of the study. The present study centers on an integrated approach to address the objectives outlined. This methodology is widely applied in similar studies and proves solid performance. For example, a study [22, 23] employs a quantitative approach in residential buildings achieving high-performance accuracy. Our study specifically used a similar approach to investigate the implementation of the Saudi building code in government office buildings to provide insight into addressing the issues of thermal performance and energy consumption in government office buildings in Saudi Arabia, both in the present and future climate. In addition, the evaluation of solutions in envelope construction is carried out via simulations utilizing design builder software, as outlined in the research. Design building is one of the best-ranking building and construction simulation tools that offer a wide range of operations and applications such as assessment of building occupancy, thermal comfort level, energy performance, weather data for a wide range of operations and many more [22].

This chapter includes:

i. The stages of applying the research methodology.

ii. Selection of Najran city as climate zone in KSA.

iii. Choose an office governmental building. (case study)

iv. Obtaining architectural plans as well as all of the building's unique elements.

v. Obtaining current weather data files for simulations.

vi. Use simulation software for environmental design.

vii. Modelling and thermal verification of the Governmental office building.

3.1 Selection of Najran city as climate zone in Saudi Arabia

Situated close to the Yemeni border, in the southwest of the Kingdom of Saudi Arabia, is the city of Najran. With an average of 75 mm, April saw the most rainfall in the city. The city of Najran was chosen as a case study for this research because of its zone 1 location, which is based on SRBEC and has an extremely hot environment. Zone 1 weather is so intense that energy research is necessary in this city because it's one of the main issues the nation is currently experiencing.

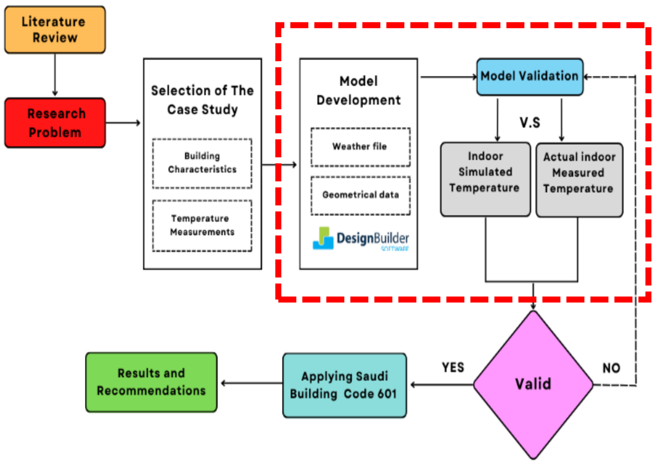

Figure 4. Flow chart research of the study methodology with the area reported in this study mapped out in red

Moreover, Zone 1 represents 70% of Saudi Arabia's area and it needs more than 5000 CDD. As mentioned (above) and based on the SRBEC.

3.2 Najran climate analyses

3.2.1 Average Temperatures and Precipitation

The highest temperature for an average day in Najran for each month is shown on the "mean daily maximum" (solid red line). The "mean daily minimum" (solid blue line) indicates the average minimum temperature. The mean of the warmest day and the coolest evening of each month are represented by the hot days and cold nights (dashed red and blue lines, respectively) according to Figure 5.

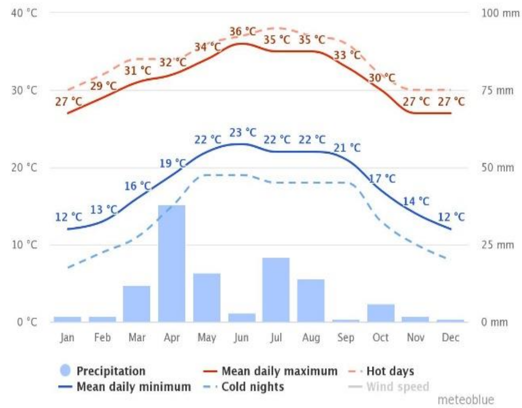

Figure 5. Average temperatures and precipitation in Najran 14]

3.2.2 Maximum temperatures

Figure 6 shows maximum temperatures and number of days for certain temperatures

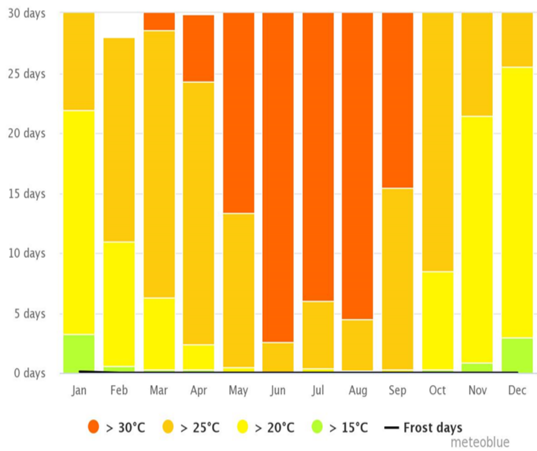

Figure 6. Maximum temperatures in Najran [14]

3.2.3 Precipitation amounts

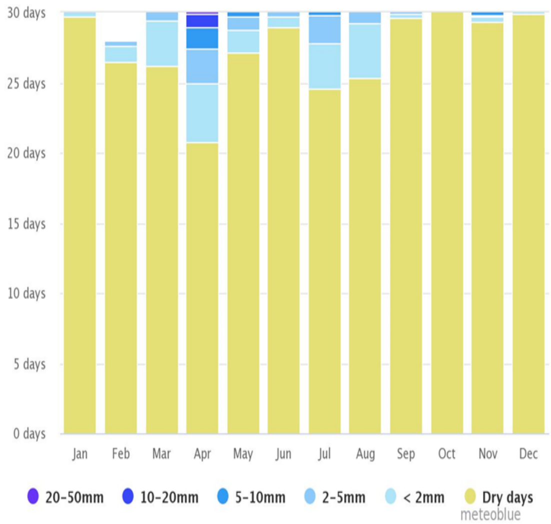

Figure 7. Precipitation amounts in Najran [14]

3.2.3 Selection of the case study

To achieve the main objectives of the research, a government office building was selected in the city of Najran, based on several factors on which it was selected:

- Easy access to the site because it is situated near us.
- The capacity to obtain the required blueprints and building data.
- The building is located in 13 cities with the uniform design which made us choose it as a case study.
- Due to the limited amount of scientific research that has been published on government office buildings.
- The climate of the city of Najran in Zoon 1 according to the Saudi code classification, as this Zoon is the largest in Saudi Arabia. According to Saudi building code, the current construction of KSA (SBC-602E) is distinct between construction specifications to 3 zones based on climatic conditions. The city of Najran, where the case study was selected, was classified in Zone 1, which is very hot and dry.

3.2.4 Data Collection

Sensor data has been a key player with the full potential to be a significant contributor to building technologies and infrastructure that enable dynamic responsive approaches to optimally manage energy usage. Consequently, the foundation for more intelligent, effective control and energy savings is laid by the incorporation of sensors, such as temperature, and occupancy sensors, with building control systems. The study chose the governmental office building for the purpose. Najran is situated on King Abdulaziz Road near the Najran

Regional Airport. The building is contemporary in design and is presently unoccupied (see Figure 8).

Through fieldwork, the information and details of the building were collected in two phases, the first phase by collecting the plans of the building and the details of its envelope from the walls, roof, floors, and windows. The second activity is to collect the temperature measurements using the data loggers we will show their characteristics in this research.

Figure 8. A view of the main facade of the governmental office building in Najran

3.2.5 Data preprocessing

The quality of the dataset is one of the major factors that contribute to the performance of the model. Previously in [23], an interactive technique was applied to provide a classifier to ensure room temperature reading tally with occupancy numbers during data collection to deal with incorrect values used in model training. In the same vein, this study used a similar approach (see Figure 10) to record data during data collection enabling self-estimation or labeling. Furthermore, checking the normality distribution of data is essential to determine whether the data is normally distributed. However, the graphical depiction for evaluating normalcy necessitates a high level of knowledge to avoid erroneous readings.

Geometrical Drawings - In Table 1, details of the building's area are shown. Figure 8 shows the building used the Najran Government Office Building

Table 1: Cadastral characteristics of the building

Characteristics	Description
Number of floors	3 Floors with Underground parking
Total height	20.5m
Land area	13720 m²
Gross floor areas	6963 m²
Gross wall area	4636 m²

Overall WWR	29.5%
Skylight-Roof Ratio	16.4%

On-site measurements

At this stage, pertinent data has been gathered to evaluate the building's thermal performance. The internal temperature measurement apparatus was installed, and an outdoor weather measurement station was established.

- Indoor measurement devices

HOBO's data measurement equipment has been selected and is the recipient of several awards in the field of renewable energy and verification of the performance of green buildings [15]. It measures relative temperature and humidity and has many features:

Advantages of HOBO device:

- Easy-to-view LCD
- Burst and Statistics logging modes.
- User-replaceable Relative Humidity sensor
- Compatible with HOBO ware and HOBO ware Pro software for logger setup and graphing & analysis.
- Wireless communication via Bluetooth technology
- Easy to deploy and offload using the free HOBO connect app.
- Visual and audible high & low alarm thresholds
- Stores 84,000 measurements.
- Accuracy: +/- 0.2C and +/- 2%RH
- Find me/pager feature.
- Patented connectivity technology

Figure 10. HOBO data loggers [15]

Indoor measurement devices calibration

A calibration process was performed to guarantee that the data loggers were accurate and that they were using the specified accuracy requirements. Each data logger was given a label before being placed in a controlled setting for 12 hours, 10 minutes at a time, to be temperature recorded. Loggers were calibrated in groups. This calibration showed that every logger worked with roughly the same level of required accuracy, ruling out the possibility of inaccurate or inconsistent readings caused by logger flaws devices when calibrated.

The data presented in Figure 11 pertains to the calibration of internal temperature measurement devices. Figure 11 demonstrates that the measurements obtained from these devices are accurate, as per the specifications outlined in their respective features. The devices installed on the left side of the building have been referred to as L-starting devices, while those installed on the right side of the building have been designated as R-starting devices. Figure 12 shows where these devices are installed

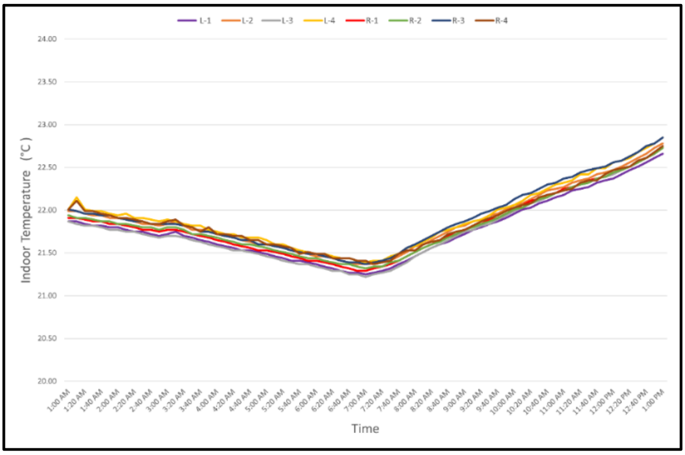

Figure 11. Indoor measurement devices calibration data

Installing indoor measurements devices

To prevent radiation or emissions from objects or surfaces, the logger should be positioned in the middle of the room and left hanging freely [16]. Data loggers could be placed on posts or walls so that the devices were stacked on top of each other on each floor of the building. As already mentioned, the building is empty. The data logger was fixed in a 2-meter-high in pillar or wall with double-sided tape to prevent it from falling. This tape was attached to posts and walls to prevent loggers from falling to the ground. The 2-meter-long data logger is installed at a sufficient distance from the sun, roofs, and windows to avoid sources of heat, radiation and cold. Also, for security reasons. The loggers is set to record temperatures every hour. Figure 12 shows the installation of measurement devices in the building.

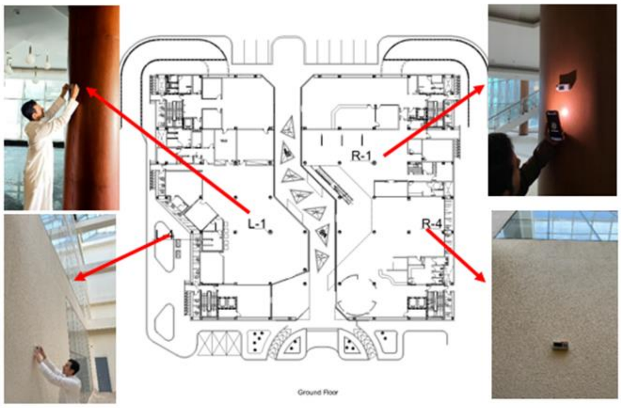

Figure 12. Installing the measurement devices on the ground floor

Outdoor measurement device

LSI LASTEM is a manufacturer of environmental monitoring devices specializing in providing advanced and high-quality environmental monitoring solutions. Their product range includes sensors, data recorders, software, installation, and installation accessories [17]. The E-Log device has been selected and has many features:

Advantages of E-Log Device:

- Extremely low power consumption

- Internal library for calculating derived quantities and mathematical calculations.

- 8MB Flash Memory.

- Connection to the PC via RS232 (USB/Ethernet/Modem GPRS with external accessories).

- Display and keyboard.

- Built-in Temperature sensor (accuracy 0.5°C).

4. SIMULATION METHOD

Thermal performance cannot be monitored throughout the year due to the length of time given by the State Real Estate Authority. However, this study covers several important aspects of research using one simulation program. Computer-based simulation technology is the best tool for this situation, as it allows design and usage changes to be accurately modeled through a number of iterations. This technology is recognized as an adequate tool for sustainable building design research. Simulation research can help in testing the conceptual system in an empirical venue and answering the question of how physical environments can enhance some aspect of thermal comfort.

4.1 Selection of the simulation tool

DesignBuildder is among the best and most crucial tools for thermal comfort and energy performance analysis as discussed in [22, 23]. These research demonstrate the flexibility and simplicity of DesignBuilder to examine various building envelope parameters including thermal comfort, energy, solar shading and support simulation from renewable technologies with the aid of graphical interface options to make adjustments as necessary. In both naturally ventilated and adapted ventilated buildings, key performance parameters such as energy consumption, CO2 emissions, thermal comfort, daylight availability, and cost can be collected during the design process [18].

To optimize temperature measurement the study adopted [26] to ensure the reliability of the dataset record, an interval of 5 min was set between the previously captured record and the next candidate record. The dynamic assessment of temperature data is also considered for effective modeling to ensure dataset collection produces good performance for cross-validation.

Some typical uses are:

1. Evaluation of different façade options for overheating, energy consumption, and impact on appearance.

2. Calculation of temperature, velocity, and pressure distribution in and around the building using CFD visualization of property layout and sunscreen.

3. Thermal simulation of naturally ventilated buildings. HVAC design, including heating and cooling equipment sizing.

4. Communication support in design meetings.

4.2 Weather data

The study utilized external data sourced from the E-LOG outstation, as referenced above. The weather file was subsequently modified using elements precise programs within the simulation software. The data for the period spanning from 12 January 2023 to 15 May 2023 was selected based on the initiation of internal temperature measurement within the building. This approach was employed to achieve a calibration that closely approximates real-world condition

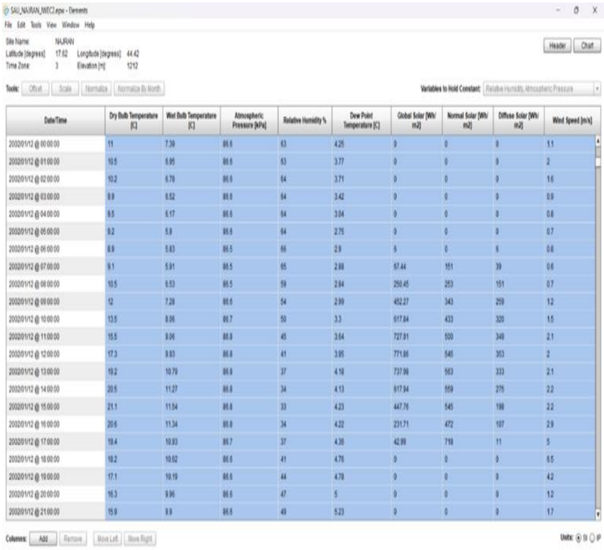

Figure 13. Processes for modifying weather file conditions via Elements software.

5. MODELLING

The actual building was modeled using DesignBuilder based on the Geometrical drawings and details of the building's envelope of walls, roof, windows, and floors for which a dish was performed. All these data have been incorporated through the building's frequent field visits, which are mentioned in section above.

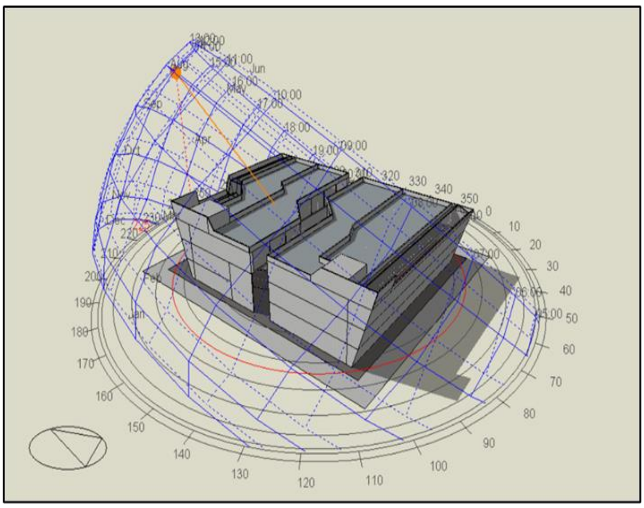

Figure 14. The building after modeling using DesignBulder with sun path

Table 2. Actual building of Window layers after modeling in DesignBuilder software.

Window	Layers	Thickness (mm)	U-Value	SHGC
WI 1	Green Glass Air space Clear Glass	6 mm 16 mm 6 mm	2.673 W/m²K	0.366
WI 2	Clear Glass Air space Clear Glass	6 mm 16 mm 6 mm	2.673 W/m²K	0.703

Table 3. Actual building Skylight layers after modeling in DesignBuilder

Skylight	Layers	Thickness (mm)	U-Value	SHGC
S1	Double glass lamination (type-G1) 6mm out said + 16mm Air + lamination (4mm+0.76PVB+4mm)	30.67 mm	2.581 W/m²K	0.681

Table .4 Actual building of External wall (North, South) layers after modeling in DesignBuilder

External Wall	Section	Layers outside to inside	Thickness (mm)
W1		Pre-cast	150 mm
		Air space	350 mm
		Polystyrene	50 mm
		Cement bricks	200 mm
		Cement plaster	20 mm
		Paint	2 mm
	U-Value= 0.473W/m²K	R-Value= 2.113 m²K /w	

6. THE MODEL'S VALIDATION

It is important to validate the model while evaluating the building's thermal performance. This helps make the adjustments made during the study effective and realistic, the best way to assess the performance of the building's operational capacity during the design phase and in current and future conditions is through computer simulation. However, there can be significant differences between real data and simulated results. DesignBuilder has proven to be a reliable software within the industry through various energy standards [19]. However, to ensure confidence in the results of simulating DesignBuilder models under current climatic conditions, a technique has been used to verify this research knowing that the building has not yet occupied users.

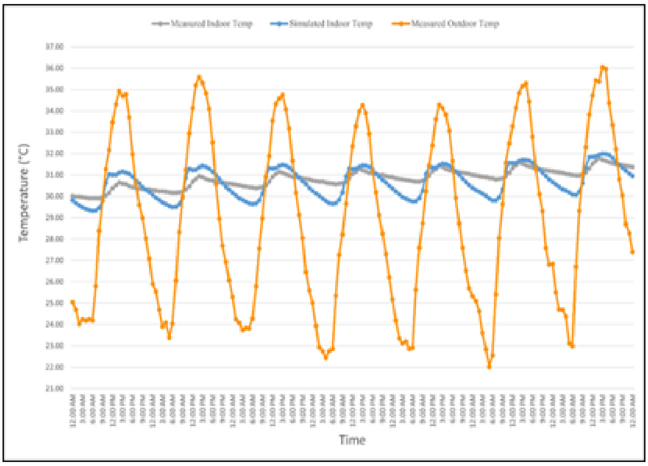

Figure 15. Comparison L-1 temperature data measured with simulation

Research in [21, 22, and 23] has demonstrated various scenarios indicating the impact of occupancy on building energy consumption, thermal comfort, and variation in indoor temperature. An increase in building occupancy relatively increases the room temperature which has a greater impact on energy consumption and thermal comfort perception. Figure 15 and Figure 16 indicate the state of the indoor temperature with and without the occupancy. As can be seen in Figure 15, the software readings of the temperature on L-1 when the room is vacant indicate moderate ambient temperature unlike in Figure 16 where the room is occupied by random occupancy.

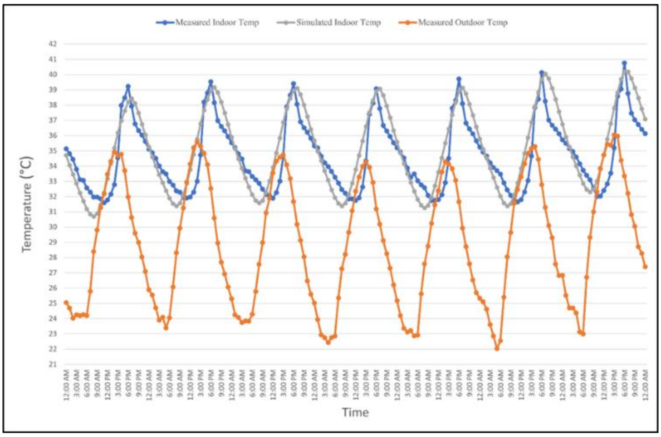

Figure 16. Comparison L-4 temperature data measured with simulation

Similarly, Figure 17 indicates a little variance in the ambient temperature when the room is not occupied in comparison with Figure 15. Likewise, Figure 18 shows almost the same reading in L-1 and R-4 when the room is occupied. This indicates the model verification where field measurements are used to compare the model-based temperature. Figure 15 and Figure 16 indicate that software readings are compatible with the actual measurement with a little variance. Likewise, the comparison of R-1 temperature data measured with simulation as shown in Figure 17 and Figure 18.

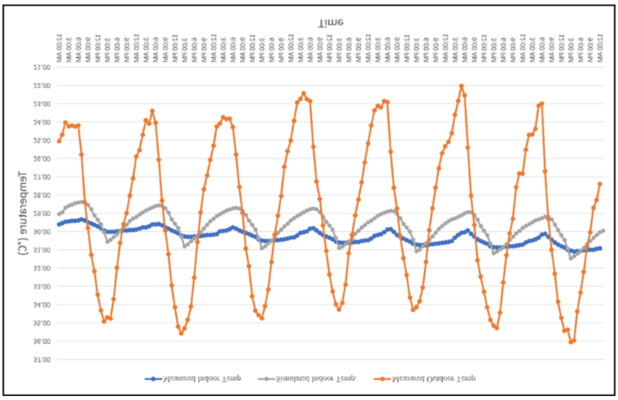

Figure 17. Comparison R-1 temperature data measured with simulation

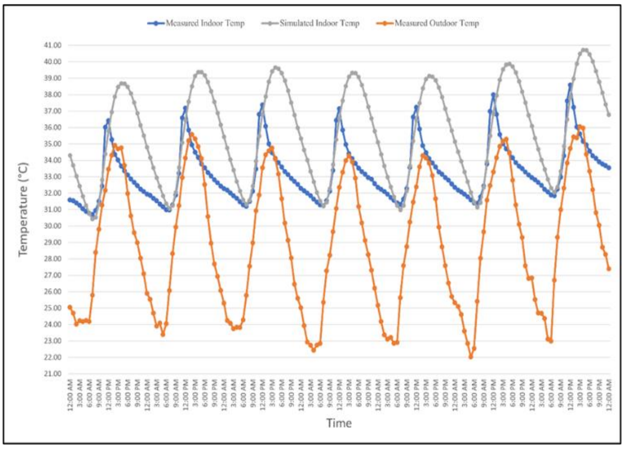

Figure 18. Comparison R-4 temperature data measured with simulation

7. CONCLUSION

Computer simulation is the depiction of how a real-world system or process changes over time. It is the most advanced method for rapidly assessing a building's overall energy performance. To study a building model's performance, it is utilized to simulate it. This method was employed, among other things, to produce the required output data on the energy performance of the building and to offer numerical conclusions. It offers the opportunity to simultaneously analyze multiple factors and is accurate. One of the first steps in simulating building energy efficiency is to develop a model that captures the fundamental characteristics, functions, and goals of the selected physical structure. The usage of computer simulation remains a potentially ideal choice to investigate due to the complex process of other types of techniques and their limitations. Our findings indicate the application of the Saudi Building Code (SBC) 601 to the building envelope can improve the monthly thermal performance by 1.75 °C in Saudi Arabia, the Governmental office building in Najran. The building industry accounts for a significant portion of the nation's electrical energy usage, consuming 29% of the country's primary energy. This is partly a result of the country's hot and dry environment, which necessitates a lot of energy to ensure thermal comfort in buildings. This is because the absence of thermal insulation in many Saudi buildings, which results in a greater reliance on air conditioning, is another contributing cause. According to the Kingdom's 2030 vision, which includes an emphasis on energy conservation. However, with implementation of SBC 601, the adjustments can be made during the study with differences between real data and simulated results. With many software available, the choice of DesignBuilder has proven to be a reliable software within the industry through various energy standards as the validation results show the compact ability of the software and real-life scenario measurement carried out.

Nonetheless, there may be notable discrepancies between simulated outcomes and actual data. Several energy standards have demonstrated to the industry that DesignBuilder is a dependable piece of software. However, even though the building has not yet been occupied by users, a technique has been employed to test this research to provide confidence in the outcomes of simulating DesignBuilder models under present climatic conditions.

It is important to note that the result of our finding can be extended in the development of an HVAC system controller to ensure air conditioners are utilized only when the room is occupied. The results also can be used to improve the thermal comfort performance and energy efficiency of the simulation study proposed in [22, 23] under different scenarios of occupant perception of indoor temperature.

8. STUDY LIMITATIONS

As reported by [20], the performance of the simulation program had a few limitations as follows:

a. Weather files with observed sun radiation data had to be included for simulation results to be accurate.

b. Using non-solar weather data would not have allowed for the accurate determination of thermal values.

c. It's not always possible to recreate real-world scenarios in computer simulations.

d. Some simulation software is expensive and necessitates regular updates and maintenance.

e. Not every program is available in every simulation program.

f. The simulation software's user skill determines the accuracy of the outcomes.

9. SUGGESTION FOR FURTHER RESEARCH

1. Research into how real-life scenarios can be achieved in simulation
2. Proffering solution to include the essential program in one computer
3. Researchers should be acquainted with the proposed software before engaging his/her self in the method

ACKNOWLEDGMENT

The authors are thankful to the Deanship of Scientific Research at Najran University for funding this work under the Promising Funding program grant code (NU/SRP/SERC/12/9).

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