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Effects of Building Materials on Building Thermal Load in Malaysian Institutional Library

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ABSTRACT

Green building, net-zero energy building, low energy building, and sustainable building are the common terms being used in the building industry nowadays, with the primary aim to produce buildings with low energy and low carbon dioxide (CO_2) emissions. Different types of building materials can have significant implications for energy efficiency, especially in the warming climate. The energy crisis, future global warming, and climate change can be mitigated by choosing the right building materials, which will also lower the building's energy consumption and carbon dioxide emissions. This paper presents the effects of different building materials on the cooling capacity and cooling energy consumption of a building for four (4) different climate change weather data, namely, the present time scenario, the 2020s, 2050s, and 2080s time scenario using TRNSYS simulation software. The main library of a university in Petaling Jaya, Malaysia, was chosen as the case study. Three (3) types of building materials were studied, namely, Type 1 (brick walls with single-glazed windows), Type 2 (foam insulation cavity walls with double-glazed windows), and Type 3 (air gap cavity walls with double-glazed windows). The simulation results showed that the Type 2 building materials could reduce the yearly cooling energy consumption by 14.5%, compared with the current building materials (brick walls with single-glazed windows). The Type 3 building materials (air gap cavity walls with double-glazed windows) with the lower installation were wound to reduce the yearly cooling energy consumption by 9% compared with the Type 1 building materials. For architects, designers, politicians, and library administrators, the research's conclusions have immediate practical implications that will help them make decisions and implement energy-saving plans. In the end, this research helps libraries in Malaysia remain sustainable and resilient in the face of global warming and the energy crisis.

Keywords:
Green building; building materials; building thermal load; cavity walls

1. Introduction

Green building, net-zero energy building, low energy building, and sustainable building are the common terms being used in the building industry nowadays, intending to produce low-energy buildings with low carbon dioxide (CO_2) emissions. The fastest-growing end-use of energy in buildings is space cooling, which more than tripled between 1990 and 2016 and may do so again by 2050 [1].

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It was expected that the energy consumption of buildings will increase to 50% of the total global energy in 2030. In Malaysia, it was mentioned by Hisham *et al.,* [2] in his findings that the average energy consumption by household air conditioning systems was 3.9kWh/day, and it was approximately 20% of the total maximum demand was contributed by air conditioning systems. In another research conducted by Hussin *et al.,* [3] for 5 sample mosques in Penang Malaysia revealed that the highest yearly electricity bill was RM446,000.00 caused by the air conditioning system. According to Ali *et al.,* [4], air conditioning systems chipped in with 34% of the total energy consumption in a Research and Development (R&D) building in Malaysia, whereas in China, buildings consume more than 38% of the total energy [5]. In addition, global energy consumption for space cooling is anticipated to increase from 2 020 terawatt hours (TWh) in 2016 to 6 200 TWh in 2050, according to the International Energy Agency [6]. And in the annual Energy Outlook 2022, the U.S. Energy Information Administration (EIA) published that about 10% of the total U.S. electricity consumption in 2021 was used for cooling purposes [7]. A study on 30 buildings in Hong Kong found that 68% of the total energy building was contributed by heating, ventilating, and air conditioning (HVAC) systems [8]. It was found that the climate change and urban heat island effects have significant implications on the energy consumption for HVAC systems in Hong Kong [9,10]. Given that the air conditioning (AC) systems significantly contribute to the overall energy consumption of buildings, it becomes crucial to investigate the thermal load of buildings in Malaysia to anticipate and address future climate challenges.

In addition, buildings contribute 35% of CO_2 emissions in the United States America while they contribute 9% of CO_2 emissions worldwide [11]. A spike in CO_2 emissions as much as 40% was recorded from 2000 to 2016 [12]. Based on these findings, it can be anticipated that there will be energy crisis in the future. For this reason, most developed countries are looking seriously into harnessing renewable energy such as wind energy, tidal energy, and solar energy. In addition to inventing renewable energy technologies, it is crucial for users to be proactive in reducing their daily energy consumption. Since AC systems are the main contributor to the energy consumption of buildings, it is important to find ways to minimize the energy usage of AC systems, which have direct influence on the building thermal load. The higher the building thermal load, the higher the capacity of the AC systems. Therefore, to calculate the cooling capacity of the AC system accurately, the building thermal load must first be determined precisely. This is the main objective of the green building or low energy building design, which is to minimize the building energy consumption. This objective can be achieved by reducing the effect of external and internal heat loads. If both of these factors can be controlled, the building thermal load can be kept at a minimum level. According to Wikipedia, “green building (also known as green construction or sustainable building) refers to a structure and using a process that is environmentally responsible and resource-efficient throughout a building’s life-cycle” [13]. The green building concept covers the overall aspect of economic, utility, durability, and comfort for the building owner [14]. According to Zero Energy Buildings Resource Hub, Department of Energy, Net-zero energy building is built to consume as little energy as possible. When a renewable source of energy is added to these buildings, they are capable of producing enough energy to meet or exceed their requirements to run and it is also defined as “a building with zero net energy consumption and zero carbon emissions annually” [15,16]. On the other hand, a low-energy building is defined as a building that uses less energy than a contemporary building [17]. Regardless of whether the building is a green building, low-energy building, or net-zero energy building, the building design should minimize the total energy consumption by reducing the energy consumption for heating/cooling or by reducing the energy consumption for lighting. In brief, the ultimate goal is to minimize energy usage. Global warming and ozone depletion are prevalent issues, which have been of concern to scientists and researchers since decades ago. Therefore, the construction of buildings is no longer following the market trend; rather, the focus is driven by the need to save planet Earth. There is growing concern about the thermal performance of buildings, which has been the focus of many studies. For instance, Baskara *et al.,* [18] was using the Building Performance Simulation to simulate the building energy consumption with different strategies to improve the building energy performance. Prakash *et al.,* [19] studied the thermal performance due to the lighting of a retail building in Ranchi, India. In their research, eQuest software was used for the simulation purposes [19]. Likewise, an analysis to the energy consumption for a building with and without the wall insulation has revealed that the energy consumption will be reduced by 13% - 16% with the external wall insulation [20]. The effects of climatic conditions will affect the amount of heat gain/loss through the building envelope [21]. Therefore, a low building thermal load is crucial to minimize the energy usage of AC systems for all buildings as this will directly reduce the CO_2 emissions.

The external and internal heat loads of a building are two (2) aspects that influence the building thermal load. External heat load refers to outdoor climatic conditions that are beyond the users' control. Climate change, which is caused by human activities, has a significant impact on the building thermal load. However, these external effects can be minimized by choosing the appropriate building materials such as the type of walls, doors, and building orientation. Internal heat load refers to the heat load contributed by the number of occupants, electrical appliances, lighting, and occupant activities. The building orientation plays an important role in reducing the impact of outdoor climate on the building thermal load. A research has been carried in Korea and found that the windows facing West has increased the building load during winter [22]. Studies have been conducted to analyse the wall insulation thickness in order to minimize the effect of external heat load on the building thermal load [23]. The underlying reason was that the total area of the wall exposed to solar radiation was significant. Studies have been carried out to assess the possibility of reducing the effect of solar radiation by manipulating the insulation thickness of the building envelope. Previous studies did not focus solely on walls; these studies also examined the effects of window type and size on the building thermal load. Windows were identified to be the retardant in reducing the building energy consumption. Lately, many research have been carried out that using Phase Change Material (PCM) as part of the building walls material and proven that it can reduce the building energy [24-27]. A double-glazed window unit with a sandwich 12mm gap filled with technical grade paraffin as a phase change material (PCM) was examined on its thermal performance and the results show the PCM curtailed the energy consumption effectively [28]. In the United States of America, it was reported that about 3% of total energy was lost via windows. And in another study by Ahmad *et al.,* [29] type of windows will affect the building thermal load as well. In general, buildings with good building insulation and well-glazed windows have lower building energy consumption owing to the lower cooling and heating demands. In many countries, research has been conducted to understand the implications of building materials, including expensive ones like Phase Change Materials (PCM), on building thermal load. In this study, the authors aimed to investigate the effects of different building materials and future weather scenarios on the thermal load and energy consumption of a university library in Malaysia. The library was chosen as the study building due to its significance in maintaining the quality of collections, books, and archives housed within it. The library's air conditioning system operates 24/7 to maintain indoor temperature and relative humidity within specified ranges of 21.1 °C and 30% to 50%, respectively [30]. Therefore, the best alternative to minimize building energy consumption can be determined.

2. Methodology

The methodology used to simulate the thermal load of the building under study is presented in this section. The main library of a university in Petaling Jaya, Malaysia was chosen as the case study. The thermal load simulations were run to study the effects of different wall types and windows on the building energy consumption for cooling purposes. Transient Energy System Simulation Tool (TRNSYS), which is building thermal load simulation software, was used in this study. The simulations focused on the building materials' implications on the energy consumption of the AC system. Cavity walls and double-glazed windows were the main focus of this study. It is expected that these materials will significantly reduce the cooling demand of the building.

2.1 Weather Data

The Typical Meteorological Year (TMY2) weather files for four (4) different weather file time scenarios of the city of Kuala Lumpur, Malaysia (latitude: 3.11°N, longitude: 101.55°E, altitude: 27 m) were used.

2.2 Building Description

The case study is a four-storey building (latitude: 101°39′07″E, longitude: 3° 07′12.95″N). The building has two (2) wings, namely, new wing and old wing. The two (2) wings have their chiller plant to serve their AC system. The capacity of the chillers is 330 and 320 RT for the new wing and old wing, respectively. The old wing was built in 1991 whereas the new wing began its operation in 1997. The total area is 6,750 and 7,100 m^2 for the new wing and old wing, respectively. Figure 1 shows the satellite view of the studied building. In this study, the library was divided into thirteen (13) zones for simplicity, with four (4) zones and nine (9) zones in the new wing and old wing, respectively. There are eight (8) and ten (10) air handling units (AHUs) serving the new wing and old wing, respectively. Table 1 and Figure 2 to Figure 5 show the zone distribution of the main library.

Fig. 1. Satellite view of the main library

Table 1
Zone distribution of the main library

No.	Description	Zone
1.	Old wing lower ground floor	O-LGF
2.	Old wing ground floor – A	O-GF/A
3.	Old wing ground floor – B	O-GF/B
4.	Old wing ground floor – C	O-GF/C
5.	Old wing ground floor – D	O-GF/D
6.	Old wing ground floor – E	O-GF/E
7.	Old wing 1st floor – A	O-1F/A
8.	Old wing 1st floor – B	O-1F/B
9.	Old wing 2nd floor	O-2F
10.	New wing ground floor	N-GF
11.	New wing 1st floor	N-1F
12.	New wing 2nd floor	N-2F
13.	New wing 3rd floor	N-3F

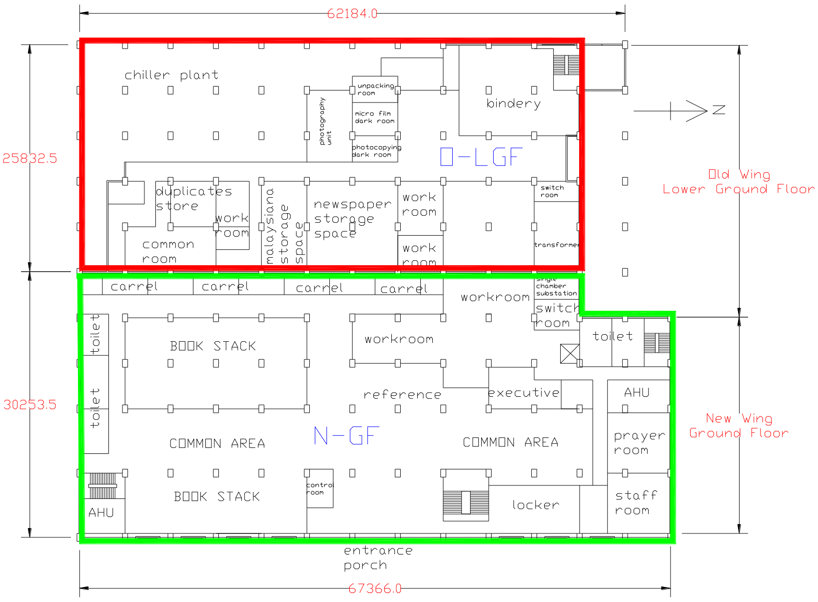

Fig. 2. Ground floor layout of the main library

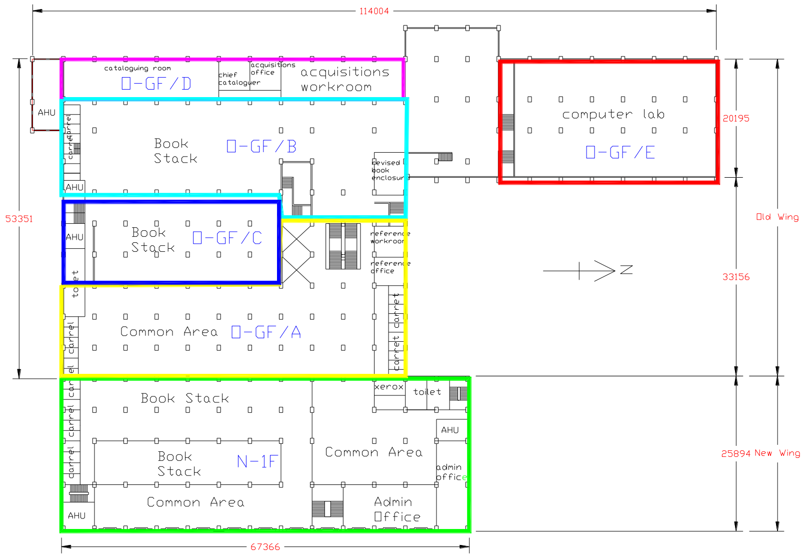

Fig. 3. First floor layout of the main library

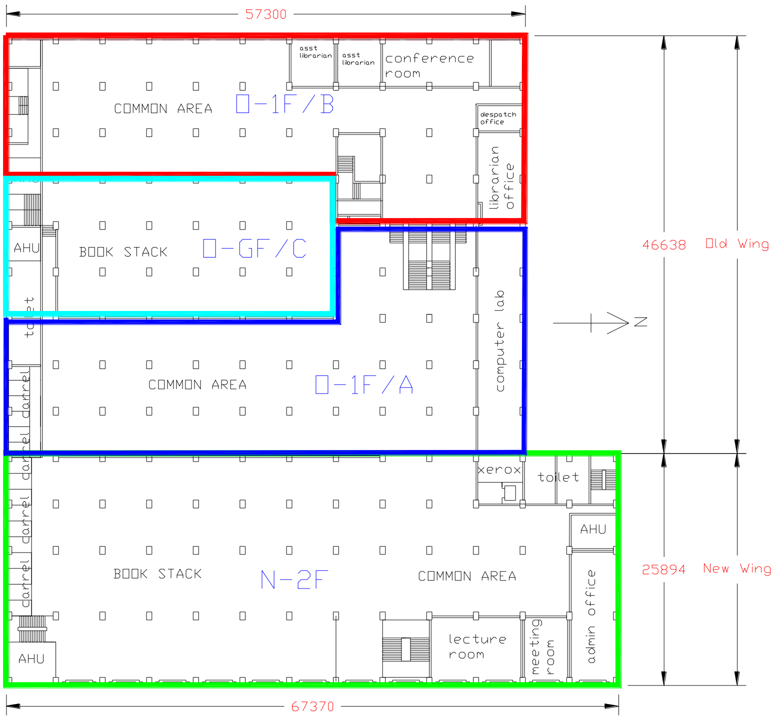

Fig. 4. Second floor layout of the main library

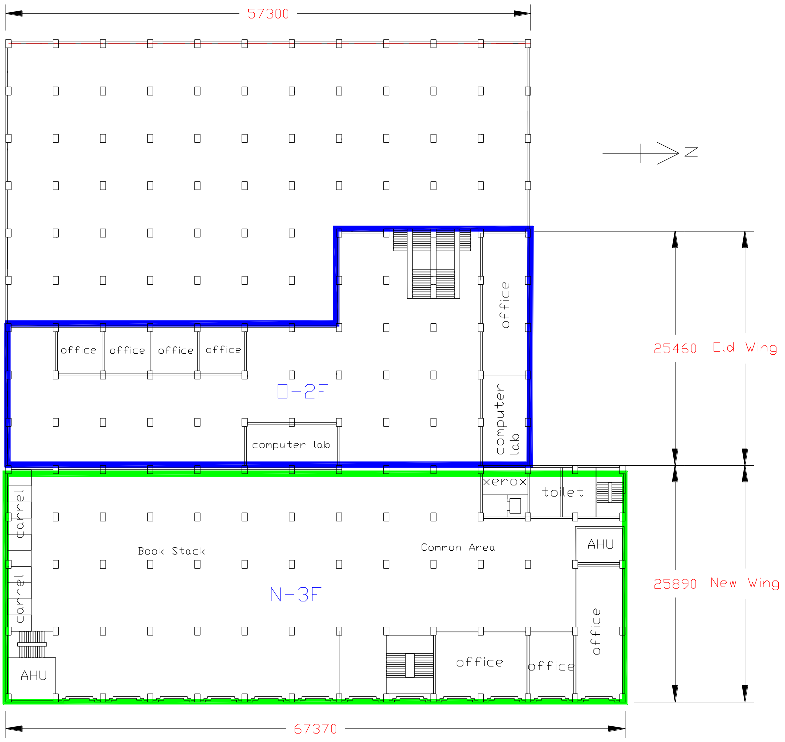

Fig. 5. Third-floor layout of the main library

2.3 Building Load Simulation

TRNSYS building thermal energy simulation software was used in this study. The simulations were focused on the implications of the building materials, wall type, and window type on the building cooling energy consumption (kWh) for four (4) weather file time scenarios. The weather file time scenarios comprise the present time scenario as well as 2020s, 2050s, and 2080s time scenarios generated by Climate Change Weather File Generator software created by Jentsch *et al.,* [31]. The cooling capacity of all zones was investigated in order to evaluate the impact of climate change. The simulations were run on the actual HVAC system design set points with an indoor temperature of 24 °C. There is no relative humidity control in the existing design.

The library was modelled as a multi-zone module (Type 56a), where the room geometry, building orientation, percentage of window portion, type of window, wall and roof, along with heat gain from people, computers, lighting, and electrical appliances were defined by Type 56a. The HVAC system consisted of the cooling coil module (Type 32), water-cooled chiller module (Type 666), cooling tower module (Type 51b), and air flow mixer module (Type 11). The actual cooling capacity was defined by the Type 666 module. In order to maintain good indoor air quality, the following settings were made to the HVAC system: (1) fresh air intake of the total air flow supply from each AHU: 15% and (2) return room air: 85%. These settings were defined by Type 11 air flow mixer module. The operating hours for the HVAC system were set from 9.00 a.m. to 10.30 p.m. daily. The simulation parameters for each zone are listed in Table 2 while the total areas of the windows and external walls on the building façades are presented in Table 3. The coil cooling capacity and airflow rate were the actual design values of the HVAC system, whereas the heat-gain contributors were based on the worst-case scenario in the library. Figure 6 shows the simulation model.

Table 2
Simulation parameters

Zone	Zone dimension: length × width × height (m)	Coil cooling capacity (kW)	Air flow rate (kg/hr)	Heat gain		
				No. of people	No. of computers	Lighting (W/m^2)
N-GF	67.37 × 30.18 × 2.62	309.14	38663	80	60	13
N-1F	67.37 × 25.00 × 2.62	245.55	32473	80	60	13
N-2F	67.37 × 25.00 × 2.57	210.73	33255	60	40	13
N-3F	67.37 × 25.00 × 2.57	309.14	40198	60	40	13
O-LGF	51.52 × 18.10 × 2.62	122.77	10660	30	20	13
O-GF/A	57.00 × 18.38 × 2.62	173.18	41962	100	60	13
O-GF/B	57.00 × 31.09 × 4.12	215.96	30380	30	60	13
O-GF/C	31.09 × 15.55 × 8.30	154.57	20692	80	0	13
O-GF/D	57.00 × 6.80 × 2.25	105.36	25678	30	40	13
O-GF/E	36.27 × 20.20 × 3.80	237.22	48971	100	120	13
O-1F/A	57.00 × 18.38 × 2.57	173.18	41962	100	60	13
O-1F/B	57.00 × 31.09 × 4.12	234.57	42504	100	60	13
O-2F	57.00 × 15.55 × 2.57	237.22	41962	100	60	13

Table 3
Window and external wall areas on the building façade

Façade	Window area (m^2)	External wall area (m^2)	Façade	Window area (m^2)	External wall area (m^2)
N-GF			O-GF/C		
North	13.95	79.07	South	—	255.89
South	1.86	79.07	O-GF/D		
East	29.15	140.58	North	—	15.30
N-1F			South	—	15.30
North	13.74	65.50	West	2.74	108.01
South	1.82	65.50	O-GF/E		
East	17.24	147.29	North	—	76.76
N-2F			East	38.38	107.29
North	13.48	64.25	West	38.38	107.29
South	1.79	64.25	O-1F/A		
East	16.91	144.48	North	2.41	48.13
N-3F			South	2.41	48.13
North	13.48	64.25	O-1F/B		
South	1.79	64.25	South	45.69	128.09
East	16.91	144.48	West	38.44	202.80
O-LGF			O-2F		
North	15.71	47.43	North	2.41	48.13
O-GF/A			South	2.41	48.13
North	2.41	48.13			
South	—	48.13			
O-GF/B					
South	45.69	128.09			
West	38.44	202.80			

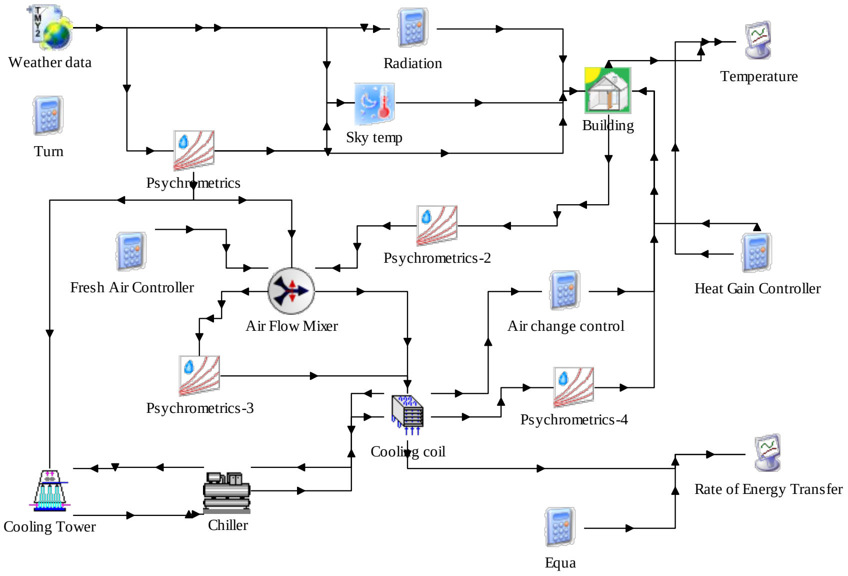

Fig. 6. TRNSYS simulation model

Simulations were run for three (3) different types of building materials, as follows:

i. Type 1: Normal brick walls with single-glazed windows.
ii. Type 2: Cavity walls filled with 50-mm thick foam insulation, with double-glazed windows.
iii. Type 3: Cavity walls with an air gap of 50 mm (Figure 7), with double-glazed windows.

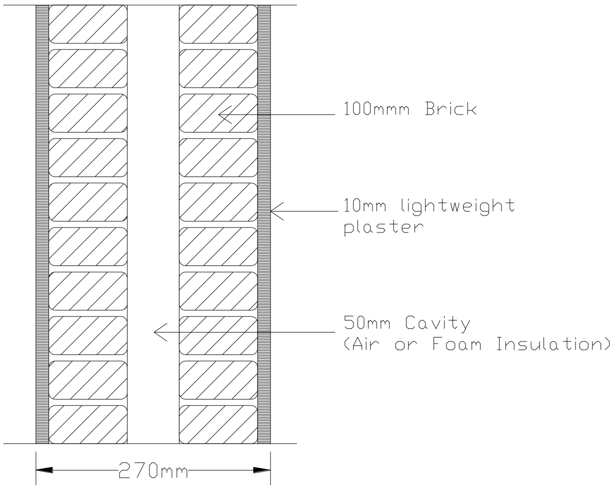

Fig. 7. Schematic of the cavity wall

The simulations were run for four (4) weather file scenarios (present time scenario and 2020s, 2050s, and 2080s time scenarios). The coefficients of transmission (U-values) (i.e., the reciprocal of thermal resistance (R-values)) for the different types of walls and windows are presented in Table 4. The yearly cooling energy consumption was analyzed in this study.

Table 4
Construction and U-value for different types of walls and windows

No.	Description	U-value ($W/m^2{\cdot}K$)
1.	Brick wall: 10-mm plaster +100-mm brick + 10-mm plaster	3.368
2.	Air gap cavity wall: 10-mm plaster + 100-mm brick + 50-mm air gap + 100-mm brick + 10-mm plaster	1.784
3.	Foam insulation cavity wall: 10-mm plaster + 100-mm brick + 50-mm foam insulation + 100-mm brick + 10-mm plaster	0.603
4.	Single-glazed window	5.68
5.	Double-glazed window	2.83

3. Results

This section presents the simulation results obtained using TRNSYS. The simulated cooling capacity for each zone for each climate change time scenario is discussed in Section 3.1. The yearly cooling energy consumption of the building for different weather file time scenarios was analyzed and discussed in Section 3.2, using three (3) building models with different types of building materials. The main objective of this study is to study the effects of wall and window types on the cooling capacity and yearly cooling energy consumption of the main library, and the implication of climate change on the cooling capacity of the AC system.

3.1 Cooling Capacity Analysis

Table 5 and Figure 8 show an increasing trend in the cooling capacity of the AC system for all weather file time scenarios considered in this study. The ambient temperature was predicted to increase whereas the relative humidity was forecasted to decrease owing to global climate change.

The cooling capacity shown in Table 5 was the worst-case scenario based on the maximum number of library users, lighting, and the number of computers (Table 2). Overall, the cooling capacity of each zone increases for the four (4) types of weather file time scenarios, except for Zone O-GF/C. This was most likely due to the location of this zone, which was in the middle of the building (Figure 3), and this zone was not exposed to external factors such as sunlight, infiltration, etc. that can lead to heat gain. The trend was similar for all three types of building materials. The yearly average ambient temperature was predicted to be 28.1, 29.2, and 30.8 °C for the 2020s, 2050s, and 2080s time scenarios, respectively, while the predicted yearly average relative humidity was predicted to be 80.7, 78.7, and 76.6%, respectively. The increase in the cooling capacity was attributed to these varying conditions. It was worth noting that the existing cooling capacity was insufficient to counteract the increase in capacity caused by climate change.

Table 5
Maximum cooling capacity (kW) for different types of walls and windows for different weather file time scenarios

Zone	Maximum cooling capacity (kW)											
	Type 1: Brick walls & single-glazed windows				Type 2: Foam insulation cavity walls & double-glazed windows				Type 3: Air gap cavity walls & double-glazed windows			
	Present	2020s	2050s	2080s	Present	2020s	2050s	2080s	Present	2020s	2050s	2080s
New wing												
N-1F	250.65	257.8	259.71	270.11	249.13	254.94	259.05	262.64	250.43	253.53	259.97	265.6
N-GF	329.13	332.81	343	356.74	324.25	332.21	336.67	350.42	325.46	333.77	338.57	351.96
N-2F	254.25	258.48	262.81	274.27	252.97	257.73	261.58	268.85	254.29	258.57	263.4	268.97
N-3F	279.75	314.96	320.14	333.62	274.69	279.38	321.25	327.81	276.86	282.42	323.45	330.23
Total	1,113.78	1,164.05	1,185.66	1,234.74	1,101.04	1,124.26	1,178.55	1,209.72	1,107.04	1,128.29	1,185.39	1,216.76
Old wing												
O-1F/A	262.94	265.25	272.78	273.46	255.58	258.55	265.78	267.7	256.45	259.35	266.92	268.77
O-1F/B	324.89	324.88	324.86	324.57	324.87	324.88	324.88	324.88	324.85	324.87	324.87	324.87
O-GF/A	246.09	249.08	255.25	260.62	230.62	235.76	240.48	249.45	230.82	235.97	240.89	250.19
O-GF/B	311.91	315.02	322.26	324.76	260.17	297.42	302.35	310.51	291.91	295.81	305.1	313.77
O-GF/C	24.17	24.17	24.17	24.17	24.17	24.17	24.17	24.17	24.17	24.17	24.17	24.17
O-GF/D	125.3	126.69	130.39	134.78	117.92	120.82	123.12	127.57	118.73	121.71	124.28	128.59
O-GG/E	58.31	63.2	68.91	77.3	50.72	55.09	60.57	67.48	51.93	56.52	62.14	69.53
O-LGF	161.84	162.69	163.26	170.97	148.38	152.53	155.9	158.73	148.63	153.09	156.52	159.18
O-2F	246.02	252.98	258.77	264.47	235.41	238.74	243.96	251.4	233.82	239.5	244.68	251.94
Total	1,761.47	1,783.96	1,820.65	1,855.10	1,647.84	1,707.96	1,741.21	1,781.89	1,681.31	1,710.99	1,749.57	1,791.01
Total	2,875.25	2,948.01	3,006.31	3,089.84	2,748.88	2,832.22	2,919.76	2,991.61	2,788.35	2,839.28	2,934.96	3,007.77

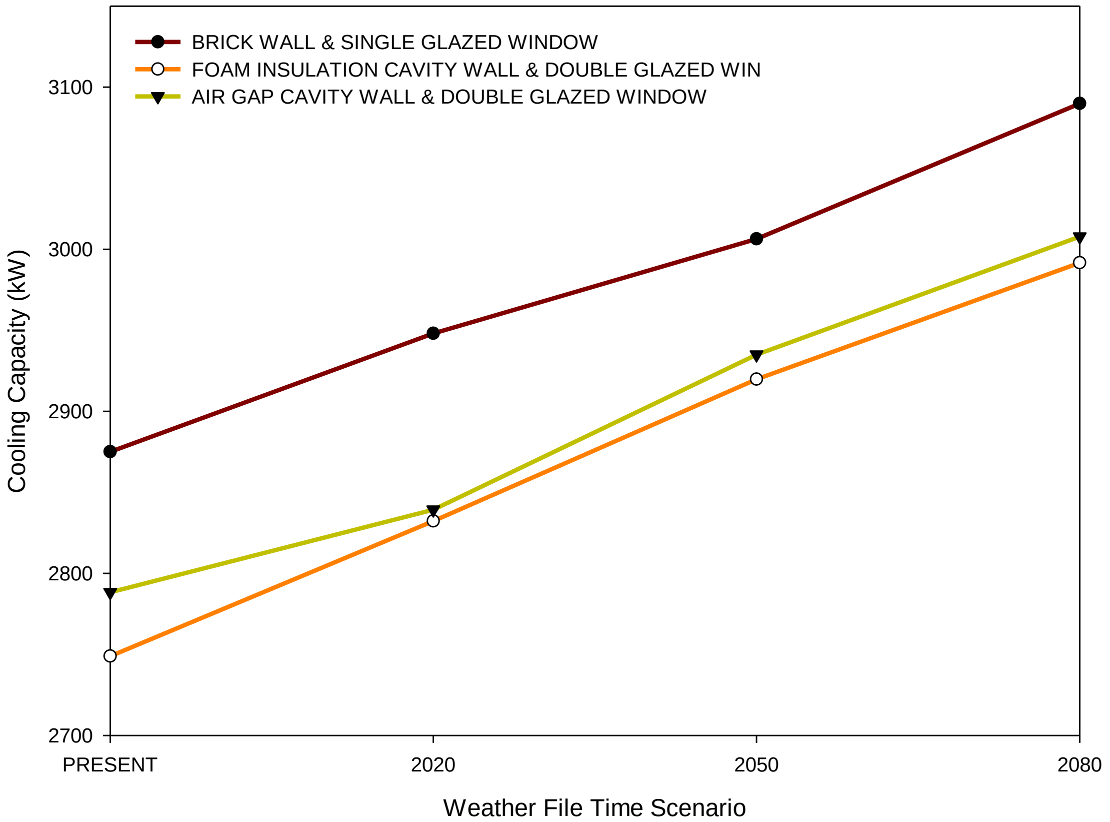

Fig. 8. Cooling capacity (kW) for different types of walls and windows versus different weather file time scenarios

The cooling capacity per area for the present time scenario for the three (3) building materials (Types 1, 2, and 3) were ~200, ~198, and ~201 W/m^2, respectively. These figures were in good agreement with the rule of thumb practiced in the building industry. For each type of building material, the cooling capacity per area was predicted to be higher by 2–3% for each weather file time scenario.

3.2 Yearly Cooling Energy Consumption Analysis

The yearly energy consumption (kWh) was shown in Figure 9 and Table 6 for different types of walls and windows and different weather file time scenarios. It can be observed that the Type 2 building materials can reduce the cooling energy consumption for all the weather file time scenarios. This was likely because foam insulation cavity walls and double-glazed windows have the lowest U-value, which can maintain the indoor air temperature over extended periods. In addition, Type 2 building materials can minimize the effects of external factors such as ambient temperature, sunlight, and radiation on indoor temperature. Eq. (1) shows the relationship between the heat transfer and the U-value and the indoor-outdoor temperature difference. The lower the U-value of the wall, the lower the heat transfer from outdoors to indoors.

$$Q_c = U \times A \times (T_{outdoors} - T_{indoors}) \quad (1)$$

where

Q_c = heat transfer
U = U-value of the building material
A = Surface area
$T_{outdoors} - T_{indoors}$ = Temperature difference between indoors and outdoors

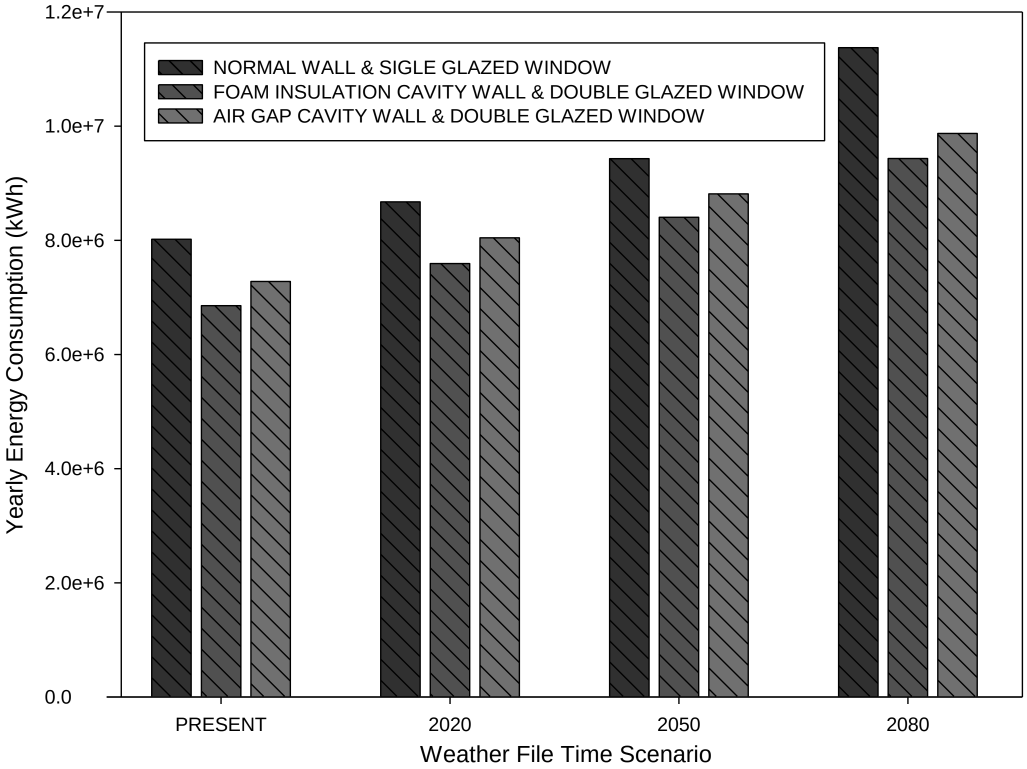

Fig. 9. Yearly energy consumption (kWh) for different types of walls and windows versus different weather file time scenarios

Table 6
Yearly energy consumption for different types of walls and windows for different weather file time scenarios

	Wall and Window Types		
Weather file time scenario	Type 1 Brick walls & single-glazed windows	Type 2 Foam insulation cavity walls & double-glazed windows	Type 3 Air gap cavity walls & double-glazed windows
	(kWh)	(kWh)	(kWh)
Present	8,018,710	6,853,920	7,278,840
2020s	8,671,900	7,591,060	8,043,150
2050s	9,429,500	8,402,600	8,813,000
2080s	11,373,000	9,432,800	9,872,300

Referring to Table 6, the Type 2 building materials can reduce the yearly cooling energy consumption by 1,164,790 kWh for the library for the present weather file scenario. This was a significant amount of energy savings, which corresponds to a reduction in cooling energy consumption of 14.5%. However, the installation cost of this cavity wall was higher, and therefore, an alternative cavity wall was studied. The air gap cavity wall (Type 3) was chosen in place of the foam insulation cavity wall since air is free. With this building material, the yearly cooling energy consumption can be reduced by 739,870 kWh relative to that for Type 1 building materials, which corresponds to a reduction of 9%. The electricity bills per year were tabulated in Table 7 and Figure 10. The library was expected to have sizeable savings on the electricity bill, with a value of RM 407,676.50 per year (based on RM 0.35 per kWh) by using Type 2 building materials for present time scenario. In contrast, electricity savings of RM 258,954.50 can be achieved by using Type 3 building materials for the same time scenario. For the present weather file time scenario, the monthly cooling energy consumption per area (m^2) for Type 1 building materials was about RM 17.90, which was predicted to increase to RM 24.00 in the 2080s climate change time scenario. However, the monthly cooling energy consumption per area (m^2) for Type 2 and 3 building materials were only RM 14.40 and RM 15.30, respectively, for the present weather file time scenario, and it was estimated that the value will increase to RM 19.90 and RM 20.80 for Type 2 and 3 building materials in the 2080s time scenario. It shall be noted that the estimation was made based on the current tariff of RM 0.35/kWh. Owing to the energy crisis as well as the increase in the operation, generation, and fossil fuel costs, the total affected cost will be transferred to the building owners in the future.

Table 7
Yearly electricity bill for different types of walls and windows for different weather file time scenarios

	Wall and Window Types		
Type of walls and windows	Type 1 Brick walls & single-glazed windows	Type 2 Foam insulation cavity walls & double-glazed windows	Type 3 Air gap cavity walls & double-glazed windows
	RM/year	RM/year	RM/year
Present	2,806,548.50	2,398,872.00	2,547,594.00
2020s	3,035,165.00	2,656,871.00	2,815,102.50
2050s	3,300,325.00	2,940,910.00	3,084,550.00
2080s	3,980,550.00	3,301,480.00	3,455,305.00

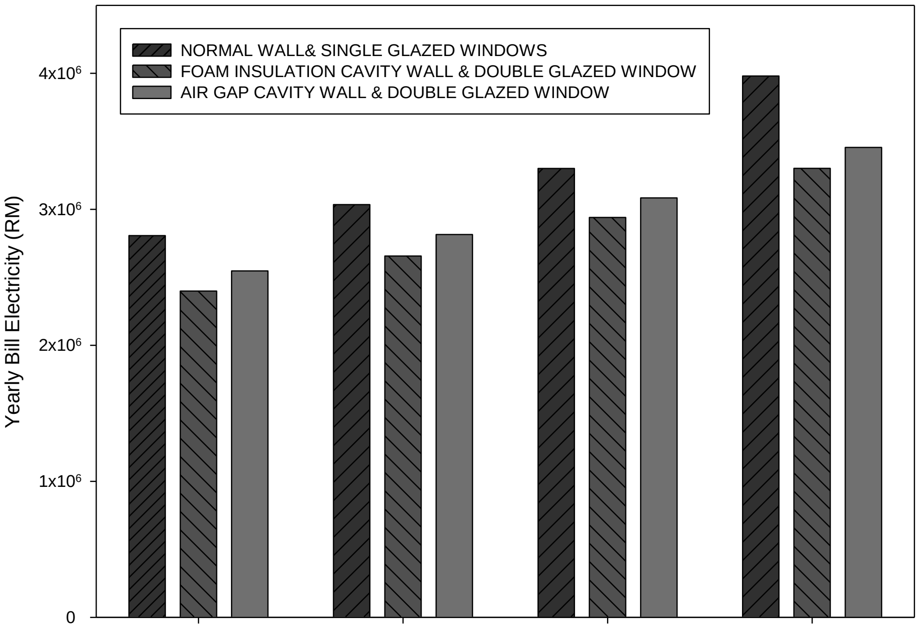

Fig. 10. Yearly electricity bill (RM) for different types of walls and windows versus different weather file time scenarios

The yearly cooling energy consumption was predicted to increase tremendously in the 2080s time scenario, regardless of the type of building materials used for the building construction. Nevertheless, Type 2 building materials were still the best option among the three (3) types of building materials to minimize cooling energy consumption.

4. Conclusions

In this study, the simulation results showed that the use of cavity walls with double-glazed windows can indeed minimize the operation cost of the AC system in the library because it reduced the cooling capacity required to provide comfort to library users. The cooling capacity per area (W/m^2) was estimated to increase by 2–3% for every weather file time scenario. Type 2 building materials have proven to be a good option to reduce the cooling capacity and cooling energy consumption for the library. The use of foam insulation cavity walls with double-glazed windows provided a significant reduction in the yearly cooling energy consumption of 14.5%, relative to that for brick walls with single-glazed windows. The use of air gap cavity walls with double-glazed windows reduced the yearly cooling energy consumption by 9%, which was a feasible alternative since the installation cost of these walls were lower than that of foam insulation cavity walls. Reducing the cooling capacity and cooling energy consumption in turn reduced CO_2 emissions to the atmosphere. This will help mitigate climate change issues as well as address the energy crisis in the future. Each green building plays a role in minimizing energy usage and CO_2 emissions, and the contribution of each green building will certainly help in mitigating climate change issues and promoting a greener environment for the next generation. In the future, the cost of building construction using cavity walls and double-glazed windows should be studied. The payback period should be analyzed in order to determine the feasibility of the implementation of cavity walls and double-glazed windows on green buildings in Malaysia. The findings of this research have practical implications for architects, designers, policymakers, and library administrators, enabling them to make informed decisions and implement energy-efficient strategies. Ultimately, this research contributes to the sustainability and resilience of libraries in the face of climate change and the energy crisis in Malaysia.

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