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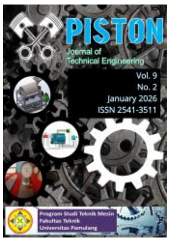

Analysis of Cooling Load Performance with CLTD Method Case Study: Al-Furqon Mosque

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Abstract: Thermal comfort in worship spaces is an important aspect that affects the quality of religious activities. However, intermittently occupied worship spaces, such as mosques during Jummah prayers, often experience spikes in heat load due to the accumulation of sensible and latent heat from occupants and solar radiation. This study aims to analyze the actual cooling load and determine the cooling load required to achieve a comfortable room temperature based on the Cooling Load Temperature Difference (CLTD) method. Temperature measurements were taken using data loggers at one outdoor point and nine indoor points during five Fridays between October 10 and November 7, 2025, from 11:00 a.m. to 1:00 p.m. Western Indonesian Time. Cooling load calculations were based on occupancy variations of 100, 300, and 600 people and comfort temperature targets of 23°C, 25°C, and 27°C. The results showed that the temperature in the worship hall was well above the thermal comfort limit. The actual cooling load increased significantly between 12:00 p.m. and 1:00 p.m. WIB and during peak occupancy, reaching a peak load of 570,116.3 Btu/h. To achieve a comfortable room temperature, the cooling capacity needs to be increased by 8–35%. The final capacity recommendation based on the measurements and ASHRAE standards ranges from 44–69 TR. It can be concluded that the cooling system of Al-Furqon Mosque is currently under capacity and requires increased capacity and adaptive operational strategies to achieve thermal comfort in intermittently occupied worship spaces in a tropical climate.

Keywords: CLTD, Cooling Load, Temperature, Prayer Room.

Abstrak: *Kenyamanan termal pada ruang ibadah menjadi aspek penting yang memengaruhi kualitas aktivitas keagamaan. Namun, ruang ibadah berokupansi intermiten, seperti masjid saat salat Jumat, sering mengalami lonjakan beban panas akibat akumulasi panas sensibel dan laten dari penghuni serta radiasi matahari. Penelitian ini bertujuan untuk menganalisis beban pendingin aktual dan menentukan kebutuhan beban pendingin yang diperlukan untuk mencapai temperatur kenyamanan ruang berdasarkan metode Cooling Load Temperature Difference (CLTD). Pengukuran temperatur dilakukan menggunakan data logger pada satu titik luar ruangan dan sembilan titik dalam ruangan selama lima hari Jumat antara 10 Oktober hingga 7 November 2025 pada rentang waktu 11.00–13.00 WIB. Perhitungan beban pendingin dilakukan berdasarkan variasi okupansi 100, 300, dan 600 orang serta target temperatur kenyamanan 23°C, 25°C, dan 27°C. Hasil penelitian menunjukkan bahwa temperatur ruang ibadah berada jauh di atas batas kenyamanan termal. Beban pendingin aktual meningkat signifikan pada pukul 12.00–13.00 WIB dan saat okupansi padat, dengan beban puncak mencapai 570.116,3 Btu/h. Untuk mencapai temperatur kenyamanan ruang, kapasitas pendingin perlu ditingkatkan sebesar 8%–35%. Rekomendasi kapasitas akhir berdasarkan hasil pengukuran dan standar ASHRAE berkisar antara 44–69 TR. Dapat disimpulkan bahwa sistem pendingin Masjid Al-Furqon saat ini berada dalam kondisi under-capacity dan memerlukan peningkatan kapasitas serta strategi operasional yang adaptif untuk mencapai kenyamanan termal pada ruang ibadah berokupansi intermiten di iklim tropis.*

Kata kunci: *CLTD, Beban Pendingin, Temperatur, Ruang Ibadah.*

INTRODUCTION

Places of worship play a crucial role as venues for spiritual and social activities of the community. Thermal comfort in worship spaces affects the quality of worship and influences the concentration of worshippers

[1]. Thermal comfort is greatly influenced by HVAC design [2]. Therefore, comprehensive cooling load calculations are required for HVAC systems to support thermal comfort in worship spaces.

Cooling Load Temperature Difference (CLTD) is a cooling load calculation method developed by ASHRAE that estimates heat transfer into a room through building elements based on equivalent temperature differences corrected for solar radiation, building orientation, and climate conditions. Previous studies have analyzed cooling loads in buildings and rooms using the CLTD method. Saeed et al. (2025) [3] calculated the cooling load of a mosque in Duhok, Iraq, using three methods, including traditional CLTD, Carrier HAP, and Revit. The results showed that the CLTD method produced the lowest cooling load, while the HAP and Revit calculations were approximately 2.33% and 2.93% higher than CLTD, respectively. This difference occurred because the assumptions and calculation processes for each method were different. The use of the CLTD method is supported by research by Jaya et al. (2020) [4], who analyzed the cooling load of the Dhammasala room at Padumuttara Temple in Sumatra, Indonesia. From the initial condition of a hot room with an average temperature of around 28.6°C, a recommendation was obtained to use an HVAC cooling system in the form of a chiller with a capacity of around 30–40 TR, with the aim of lowering the room temperature to a comfortable zone. These findings confirm that the CLTD method can be used to determine AC capacity.

Research related to cooling load analysis in worship spaces has also been conducted by Alqadhi et al. (2019) [5] at AlFahad Mosque, Saudi Arabia, using the E20 method with CLTD and HAP software. The manual CLTD method produced a total cooling capacity that was 8.8% greater than that of the HAP software. Although the CLTD method provided a higher value, both results were still within a range that was feasible for the mosque's needs. This study emphasizes that CLTD can be used for initial load estimation, but differences with the software must be taken into account when designing an AC system. Additionally, Prawibowo et al. (2024) [6] conducted research comparing cooling load calculations for hotel buildings using the traditional CLTD method with Carrier HAP 5.01. It was found that CLTD consistently provided higher cooling load estimates, with a difference of 3%–14% compared to HAP calculations. The HAP analytical method calculates hourly loads and usage schedules. The largest differences occurred in large rooms with extensive glass areas and high internal loads. These results indicate that HAP is more accurate for detailed design, while CLTD is useful for quick initial estimates. This research provides important findings for selecting calculation methods that meet HVAC design accuracy requirements.

Based on the literature reviewed previously, there are important points related to the CLTD method and its application. The Cooling Load Temperature Difference (CLTD) method developed by ASHRAE is one of the most effective methods for determining the cooling load of a room. This method considers various factors such as building orientation, material type, number of occupants, and local climate conditions [7]. However, research using this method has not yet been widely applied to worship spaces with intermittent occupancy in tropical climates such as Indonesia. This research gap indicates that the thermal comfort of worship spaces in Indonesia is often overlooked. Therefore, this study is necessary to determine the current cooling load and the cooling load required to achieve a comfortable temperature in worship spaces such as the Al-Furqon Mosque in Bekasi City, Indonesia. This study was conducted by measuring the temperature difference between the outdoor temperature, influenced by solar radiation, and the indoor temperature, followed by calculating heat transfer performance using the CLTD method. Thus, the cooling load can be calculated using this method.

METHODS

Cooling Load Temperature Difference (CLTD) Method

Cooling load calculations are necessary to determine the required HVAC system capacity [8]. The method commonly used for calculating cooling load is the CLTD method [9]. CLTD is a method for calculating cooling load that combines the temperature difference between indoor and outdoor air, daily temperature range, solar radiation, and heat from building construction [10]. This method is divided into two parts, namely external load and internal load.

External load is the load resulting from outdoor heat transfer through walls, roofs, floors, window glass, doors, and partitions, as shown in Equations (1), (2), (4), (5), and (6), as well as infiltration and ventilation loads in Equations (7) and (8) [11]. The cooling load calculation in this study refers to the *ASHRAE Handbook Fundamentals* [8].

$$Q_{wall} = U_{wall} \times A_{wall} \times CLTD_{corr} \quad (1)$$

$$Q_{roof} = U_{roof} \times A_{roof} \times CLTD_{corr} \quad (2)$$

$$CLTD_{corr} = \{(CLTD + LM) \times K + (25.5 - T_r) + (T_o - 29.4) \times f\} \quad (3)$$

$$Q_{glass} = (U_{glass} \times \Delta T \times A_{glass}) + (A_{kaca} \times SC \times SHGF \times CLF) \quad (4)$$

$$Q_{door} = U_{door} \times A_{door} \times \Delta T \quad (5)$$

$$Q_{partition} = U_{partition} \times A_{partition} \times \Delta T \quad (6)$$

$$Q_{s,inf\ \&\ vent} = 1.23 \times CFM \times \Delta T \quad (7)$$

$$Q_{l,inf\ \&\ vent} = 3010 \times CFM \times \Delta\omega \quad (8)$$

The cooling load (Q), expressed in Btu/h, is determined using the overall heat transfer coefficient (U) of each building component, the corresponding surface area (A), and the corrected Cooling Load Temperature Difference ($CLTD_{corr}$) and air duct factor (f). Conductive heat transfer is calculated using the indoor–outdoor temperature difference (ΔT), while heat gain through glazing includes both conductive and solar radiation components influenced by the shading coefficient (SC), maximum solar heat gain factor (SHGF), and cooling load factor (CLF). In addition, sensible and latent heat gains due to infiltration and ventilation are determined based on the airflow rate (CFM) and the difference in indoor–outdoor humidity ratio (Δω) [8].

In addition to external loads, internal loads are also generated within the room. These loads originate from heat produced by occupants, as shown in Equations (9) and (10), as well as from lamps and other electronic equipment, as shown in Equations (11), (12), and (13) [12].

$$Q_{s,human} = n \times SHG \times CLF \quad (9)$$

$$Q_{l,human} = n \times LHG \quad (10)$$

$$Q_{lighting} = P_{lamp} \times Ballast\ Factor \times CLF \quad (11)$$

$$Q_{s,electronics} = Heat\ Gain \times CLF \quad (12)$$

$$Q_{l,electronics} = Heat\ Gain \quad (13)$$

Internal cooling loads originate from occupants, lighting systems, and electronic equipment within the conditioned space. Occupant-related heat gains are calculated based on the number of occupants (n), considering both sensible heat gain (SHG) and latent heat gain (LHG) resulting from human activity, with the sensible component adjusted using the cooling load factor (CLF) to account for occupancy duration. Heat gains from lighting are determined using the installed lamp power and ballast factor, corrected by the cooling load factor to reflect the actual thermal contribution to the space. In addition, electronic equipment contributes sensible and latent heat depending on its operating characteristics. All internal heat gain components are summed to obtain the total internal cooling load, which is combined with the external cooling load to determine the overall cooling load required for HVAC system design [8].

Experimental Setup and Data Analysis Method

The CLTD cooling load calculation method requires actual measurements of outdoor and indoor temperatures in the worship space. Therefore, temperature measurements were taken using a Tzone Digital Temperature and Humidity Data Logger at 10 points, consisting of one point outside and nine points inside the room. The object of this study is the prayer room of Al-Furqon Mosque, located on Jalan Boulevard Hijau Raya, Kelurahan Pejuang, Kecamatan Medan Satria, Bekasi City, Indonesia. The geographical coordinates of the location are latitude −6.18706 and longitude 106.98105823743266. A sketch of the Al-Furqon Mosque prayer room is shown in Figure 1, where the X marks indicate the temperature measurement points.

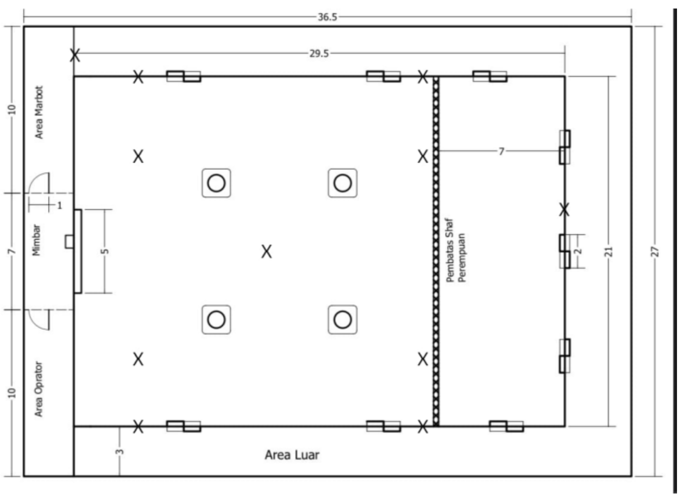


Figure 1. Sketch of the Prayer Hall of Al-Furqon Mosque

Room construction greatly affects the required cooling load [13]. The construction details of the Al-Furqon Mosque prayer room are shown in Table 1. Based on the floor plan and construction of the Al-Furqon Mosque, the heat transfer coefficient values, $CLTD_{corr}$, and SCL for each component are presented in Table 2 [14]. In addition to these components, other coefficients were obtained from ASHRAE standards and brand specifications, including U-values for walls, roof, doors, windows, infiltration and ventilation, as well as electronic heat gain and lamp ballast factors.

Table 1. Construction Details of the Al-Furqon Mosque

Component	Size	Quantity
Floor	619.5 m²	-
Wall area	21 m × 29.5 m × 9 m	4
Wall thickness	0.15 m	-
Door	2 m × 4 m	9
Glass window	2 m × 4 m	12
LED light	15 W	36
TV	-	2
Microphone	-	4
Passive speaker	-	9

Table 2. Room Component Variable Values

Component	U-Value (Btu/h·ft²·°F)	CLTD (°F)				SCL (°F)				SC
		U	S	T	B	U	S	T	B	
Roof	0.32	77	77	77	77	-	-	-	-	-
Walls	0.49	4	9	21	8	-	-	-	-	-
Doors	1.51	4	9	21	-	-	-	-	-	-
Door	1.04	4	9	21	-	8.475	11.23	15.373	-	1
Floor	0.217	-	-	-	-	-	-	-	-	-

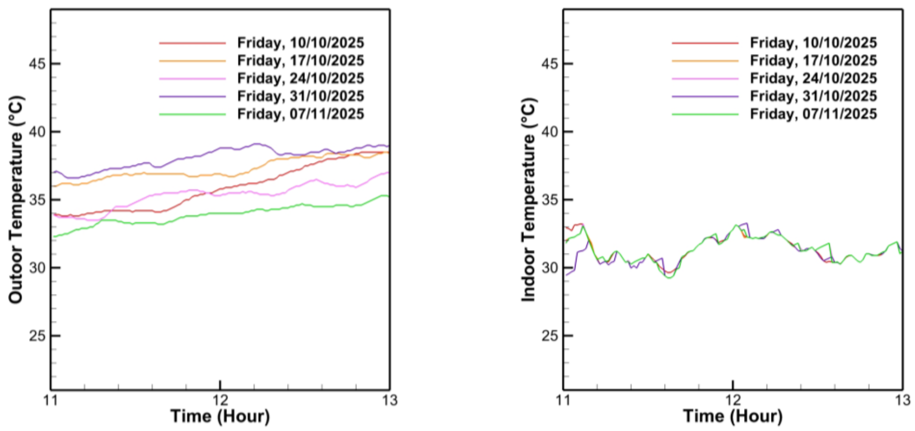
The density of room occupancy during working hours and the comfortable room temperature need to be considered to determine their impact on the cooling load [15]. Therefore, based on the average number of visitors, the occupancy rate in this study was varied into low occupancy (100 people), medium occupancy (300 people), and high occupancy (600 people). Additionally, this study measured temperatures from before to after Friday prayers (11:00 a.m. to 1:00 p.m. WIB) at one-minute intervals on Fridays over one month (October 10 to November 7, 2025). This period was selected because these hours and days represent peak occupancy times. In accordance with SNI 03-6572-2001, the comfortable room temperature range is between 23°C and 27°C. To compare the actual cooling load with the cooling load required for comfortable room temperatures, this study also calculated the cooling load needed to achieve comfort at temperature variations of 23°C, 25°C, and 27°C.

RESULT AND DISCUSSION

Temperature Measurement Results

The results of outdoor and indoor temperature measurements are shown in Figure 2. In general, the outdoor temperature trend over the five Fridays showed a gradual increase until it peaked at around 13:00 WIB. Friday, October 31, recorded the highest outdoor temperature of 39.1°C, making it the day with the most extreme environmental thermal conditions during the observation period. On the other hand, indoor temperatures showed a similar pattern on each measurement day, with peak increases occurring around 12:00 p.m. This increase is related to high occupancy and Friday prayer activities taking place during that time frame, which increased latent and sensible heat indoors. These findings are in line with the study by Al-Homoud et al. (2021) [15], which reported that rooms with intermittent occupancy experience a surge in heat load during peak activity hours.

Overall, the indoor temperature did not reach the thermal comfort zone. The average room temperature was recorded at 31.32°C, with a minimum temperature of 29.26°C and a maximum of 33.30°C. These values are well above the comfort temperature range of 23°C to 27°C according to SNI 03-6572-2001. This condition indicates that the available cooling capacity is unable to effectively lower the room temperature during periods of increased activity and occupancy, consistent with the findings of Li, X., and Yao, R. (2020) [16] on buildings with high occupant density.

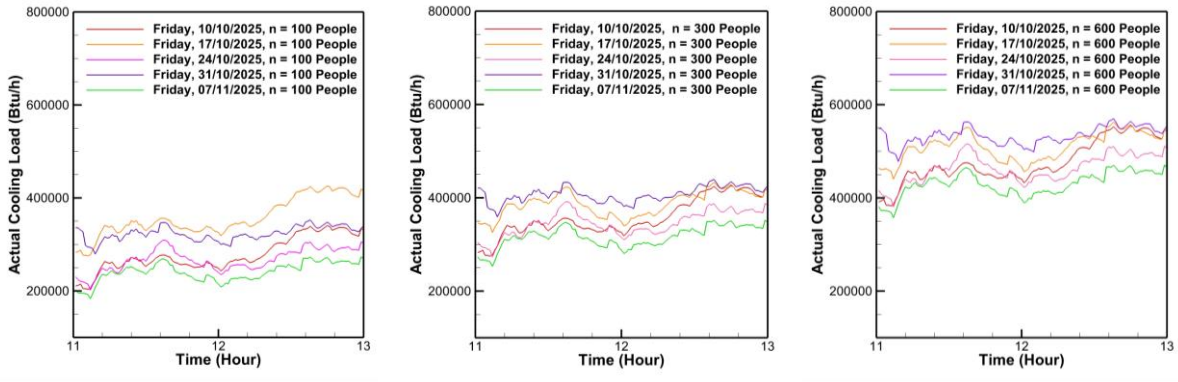


(a) (b)

Figure 2. Temperature Measurement Results: (a) Outdoor (surrounding environment), (b) Indoor

Cooling Load Calculation Results

The actual cooling load calculation results are shown in Figure 3. The actual cooling load was calculated based on the difference between the outdoor and indoor temperatures measured over five Fridays. The graph shows a consistent increase in cooling load between 12:00 p.m. and 1:00 p.m. This increase is due to a combination of higher ambient temperatures and an increase in the number of occupants during Friday prayers. These findings are in line with the study by Larhlida A et al. (2025) [13], which states that worship spaces with intermittent occupancy experience a significant surge in cooling load during peak hours of activity.

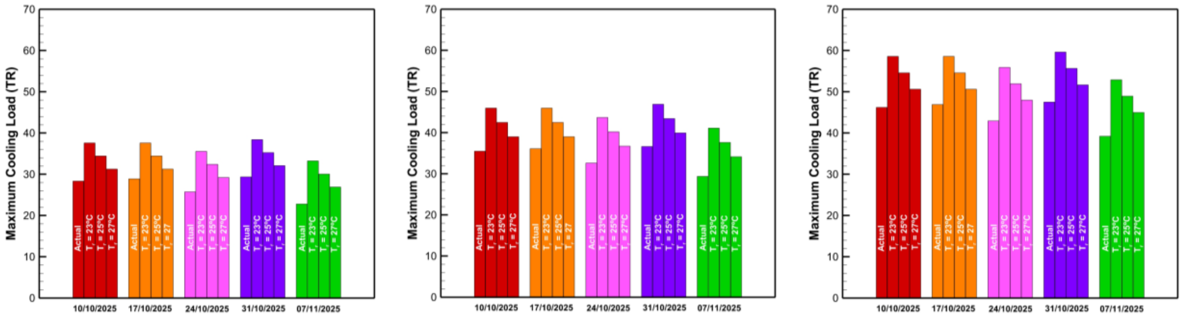


(a) (b) (c)

Figure 3. Actual Cooling Load Calculation Results: (a) Low Occupancy (100 People), (b) Medium Occupancy (300 People), (c) High Occupancy (600 People)

Friday, October 31, 2025, was recorded as the day with the highest cooling load, corresponding to the maximum outdoor temperature. Under high occupancy conditions, the average cooling load reached 482,786.8 Btu/h, with a peak of 570,116.3 Btu/h. Meanwhile, at medium occupancy, the average cooling load was 362,981.2 Btu/h, with a peak of 439,622.9 Btu/h. At low occupancy, the average cooling load was 283,110.8 Btu/h, with a peak of 352,627.3 Btu/h. This increase in cooling load is consistent with the findings of Chen et al. (2023) [17], which show that an increase in occupancy can raise the cooling load of a room by up to 40%.

Based on these calculations, it appears that the currently available cooling capacity is insufficient to reduce the room temperature to the thermal comfort zone recommended by SNI 03-6572-2001 (23–27°C). This indicates that the existing cooling system is undercapacity for the actual load, especially under high occupancy conditions.



(a) (b) (c)

Figure 4. Comparison of Actual Maximum Cooling Load and Setpoint: (a) Low Occupancy (100 People), (b) Medium Occupancy (300 People), (c) High Occupancy (600 People)

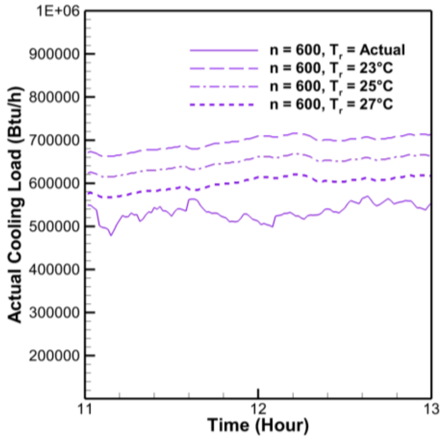


Figure 5. Comparison of Actual Cooling Load with Setpoints of 23°C, 25°C, and 27°C

The results of the cooling load calculations required to achieve comfortable room temperatures of 23°C, 25°C, and 27°C are shown in Figure 5. The graph presents calculation results based on the outdoor temperature and highest occupancy condition, which occurred on October 31, 2025, under high occupancy. It is clear that the current cooling capacity has not reached the level required to achieve thermal comfort. The average cooling load required to achieve a setpoint temperature of 23°C is 694,644.69 Btu/h, with a maximum value of 715,796.45 Btu/h under high occupancy. The average difference in cooling load for the 23°C setpoint is approximately 44% higher than the actual load during peak occupancy, while for the 25°C and 27°C setpoints, the differences are approximately 34% and 6% higher than the actual cooling load, respectively.

Analysis of peak cooling loads under both actual and setpoint conditions is necessary to determine the optimum cooling system capacity. The peak cooling load results for each condition are shown in a bar graph in Figure 6, expressed in TR (tons of refrigeration). The graph indicates that the existing cooling capacity must be increased to meet the cooling load required for comfortable room temperatures. To achieve a room temperature of 23°C, the cooling capacity needs to be increased by approximately 25% to 35% compared to the actual conditions. Meanwhile, to achieve the minimum comfort temperature of 27°C, the existing cooling capacity needs to be increased by approximately 8% to 15%. Based on occupancy variations, the cooling load required to achieve a temperature of 23°C is 38.43 TR at low occupancy, 46.91 TR at medium occupancy, and 59.65 TR at high occupancy. The relationship between the actual cooling load and the setpoint temperatures highlights the inadequacy of the currently available cooling capacity. These findings support the research by Mousavi Navaee, S. A. et al. (2025) [18], which emphasizes the relationship between setpoint temperature and cooling load.

In cooling system design, ASHRAE recommends a cooling load safety factor of approximately 15% to account for load uncertainty. With this factor applied, the recommended cooling capacities are approximately 44 TR for low occupancy, 54 TR for medium occupancy, and 69 TR for high occupancy, enabling the proposed system to achieve and maintain thermal comfort in accordance with SNI and ASHRAE standards.

CONCLUSIONS

This study successfully calculated the cooling load of the worship hall using the Cooling Load Temperature Difference (CLTD) method based on outdoor and indoor temperature measurements conducted over five Fridays and variations in room occupancy. The analysis results show that the current temperature of the worship hall is well above the thermal comfort range specified in SNI 03-6572-2001, indicating that the existing cooling system is unable to meet the comfort requirements of the space. The actual cooling load increases significantly during periods of high activity and occupancy, as well as on days with extreme ambient temperatures. Calculations of the cooling load required to achieve comfortable room temperatures indicate that the cooling capacity needs to be increased. Based on the analysis results and ASHRAE standards, the recommended cooling system capacity ranges from 44 to 69 TR, depending on the occupancy level. These findings confirm that cooling capacity planning for intermittently occupied worship spaces in tropical climates must consider daily load fluctuations, occupancy variations, and adequate design margins. In addition, this study provides insights into cooling system optimization, natural ventilation integration, and the use of building materials that are more adaptive to heat in order to improve the thermal comfort of worship spaces.

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REFERENCES

[1] A. P. Sulistiawan, S. Wandri, E. Fauzan, and M. N. Bahari, "Thermal Comfort Investigation on Holy Mosque in Bandung Case Study : Lautze 2 Mosque Bandung," *J. Archit. Res. Educ.*, vol. 2, no. 1, pp. 82–89, 2020, doi: https://doi.org/10.17509/jare.v2i1.24105.

[2] J. C. Solano, E. Caamaño-Martín, L. Olivieri, and D. Almeida-Galárraga, "HVAC systems and thermal comfort in buildings climate control: An experimental case study," *Energy Reports*, vol. 7, pp. 269–277, 2021, doi: https://doi.org/10.1016/j.egyr.2021.06.045.

[3] D. N. Saeed, H. M. Rashad, B. SardarAbdullah, and Z. abdulghani Ramadhan, "Cooling Load Estimation in a Mosque: A Comparative Study of Traditional and Software-Based Methods," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 1507, no. 1, p. 12074, 2025, doi: https://doi.org/10.1088/1755-1315/1507/1/012074.

[4] A. K. Jaya, C. O. Harahap, and R. Andarini, "Analisis Perhitungan Beban Pendinginan Ruang Dhammasala Vihara Padumuttara menggunakan Metode CLTD," *Ultim. Comput. J. Sist. Komput.*, vol. 12, no. 2, pp. 57–64, Nov. 2020, doi: https://doi.org/10.31937/sk.v12i2.1709.

[5] F. AlHarbi *et al.*, "Comparison of Cooling Load Calculations by E20 and HAP Software," *Univers. J. Mech. Eng.*, vol. 7, no. 5, pp. 285–298, 2019, doi: https://doi.org/10.13189/ujme.2019.070505.

[6] M. Prawibowo and Komarudin, "Comparative Analysis of Cooling Load Calculations: CLTD Method vs. Carrier HAP 5.01 Software for Hotel HVAC Design," *Int. J. Innov. Mech. Eng. Adv. Mater.*, vol. 6, no. 1, pp. 46–56, 2024, doi: http://dx.doi.org/10.22441/ijimeam.v6i1.23781.

[7] ASHRAE, "ANSI/ASHRAE Standard 55," *ASHRAE Standard 55*, vol. 2013. ASHRAE, 2020.

[8] C. Mao, J.-C. Baltazar, and J. S. Haberl, "Comparison of ASHRAE peak cooling load calculation methods," *Sci. Technol. Built Environ.*, vol. 25, no. 2, pp. 189–208, Feb. 2019, doi: https://doi.org/10.1080/23744731.2018.1510240.

[9] I. Omar, A. M. Mohsen, K. A. Hammoodi, and H. A. Al-Asadi, "Using total equivalent temperature difference approach to estimate air conditioning cooling load in buildings," *J. Eng. Therm. Sci.*, vol. 2, no. 1, pp. 59–68, 2022, doi: https://doi.org/10.21595/jets.2022.22684.

[10] A. Setyawan, "Effect of room temperature setting on the cooling load, supply air quantity, and apparatus dew point," *J. Eng. Sci. Technol.*, vol. 15, no. 3, pp. 1799–1814, 2020.

[11] H. Oktay, R. Yumrutaş, and M. Z. Işık, "Comparison of CLTD and TETD Cooling Load Calculation Methods for Different Building Envelopes," *Mugla J. Sci. Technol.*, vol. 6, no. 1, pp. 18–26, 2020, doi: https://doi.org/10.22531/muglajsci.631222.

[12] M. R. Fadilla and A. W. Biantoro, "Analisis Jumlah Beban Pendingin Pada Ruangan Test Stand Menggunakan Metode Cltd (Cooling Load Temperature Difference)," *J. Tek. Mesin*, vol. 11, no. 3, pp. 230–237, 2022, doi: https://dx.doi.org/10.22441/jtm.v11i3.15939.

[13] A. Larhlida, A. Mana, A. Fathi, B. Ouhammou, Z. Sadoune, and A. Jamil, "Towards Sustainable Mosques: A Review of AI and ML Approaches for Energy Use Forecasting," *Designs*, vol. 9, no. 6. p. 124, 2025. doi: https://doi.org/10.3390/designs9060124.

[14] R. Kalbasi and P. Hassani, "Buildings with less HVAC power demand by incorporating PCM into envelopes taking into account ASHRAE climate classification," *J. Build. Eng.*, vol. 51, p. 104303, 2022, doi: https://doi.org/10.1016/j.jobe.2022.104303.

[15] M. S. Al-Homoud and M. Krarti, "Energy efficiency of residential buildings in the kingdom of Saudi Arabia: Review

of status and future roadmap," *J. Build. Eng.*, vol. 36, p. 102143, 2021, doi: https://doi.org/10.1016/j.jobe.2020.102143.

[16] X. Li and R. Yao, "A machine-learning-based approach to predict residential annual space heating and cooling loads considering occupant behaviour," *Energy*, vol. 212, p. 118676, 2020, doi: https://doi.org/10.1016/j.energy.2020.118676.

[17] S. Chen *et al.*, "Occupant-centric dynamic heating and cooling loads simplified prediction model for urban community at energy planning stage," *Sustain. Cities Soc.*, vol. 90, p. 104406, 2023, doi: https://doi.org/10.1016/j.scs.2023.104406.

[18] S. A. Mousavi Navaee, A. Falavand Jozaei, A. Ghafouri, and M. Mahdavi Adeli, "The Impact of HVAC Setpoint Temperature on Reducing Building Energy Consumption in Different Climatic Regions of Iran," *J. Comput. Appl. Mech.*, vol. 56, no. 2, pp. 470–487, 2025, doi: https://doi.org/10.22059/jcamech.2025.391603.1400.