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Research Article

Development of the Cooling Load Calculation Program Using MATLAB as a Stand-Alone Application

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Abstract
A stand-alone MATLAB application was developed for cooling load calculations and cooling system design. The program enables quick and accurate calculations without requiring a MATLAB license, reducing costs and improving accessibility. It significantly expedites the cooling load calculation and system design process, cutting time by 50%. The application serves as an educational tool and supports research in efficient cooling technologies, particularly radiant cooling systems. By facilitating better-designed cooling systems, the program contributes to energy conservation and the reduction of greenhouse gas emissions.

Keywords: *MATLAB, Cooling Load Program, Stand-Alone, Mechanical Engineering Education*

1. Introduction

The development of the cooling load calculation program using MATLAB as a stand-alone application is of major significance for energy conservation and improving cooling efficiency. EnergyPlus, Carrier HAP, and TRACE 700, among other widely used cooling load calculation programs in HVAC design, primarily target conventional air-conditioning systems and lack features for radiant cooling, particularly floor cooling. With the rising popularity of radiant cooling due to its energy efficiency, there is a gap in the availability of tools that allow for precise modeling of its effects.

This research fills this gap by introducing a MATLAB-based program that specifically calculates cooling loads for radiant cooling systems, including floor cooling. This stand-alone application allows engineers and designers to perform accurate and rapid cooling load calculations without requiring a MATLAB installation or license, making it both accessible and cost-effective. Properly designed cooling systems help reduce energy consumption and greenhouse gas emissions, positively impacting the environment. Furthermore, the program is an effective teaching tool for educational institutions and supports future research in efficient cooling technologies, particularly in designing cost-effective radiant cooling systems.

The primary objective of this program is to provide an easy-to-use standalone MATLAB application for calculating cooling loads and selecting between convective air and floor cooling systems.

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The researcher developed the application, wrote the program code, and conducted trials by distributing it to users or testers via email to gather feedback on its usability and performance.

Sunti Tuntrakool [1] presented "MATLAB and Educational Applications," emphasizing MATLAB's popularity and versatility across various disciplines and industries. The researcher highlighted that MATLAB is widely used in fields such as healthcare, engineering, and audio applications, as well as in interdisciplinary collaborations. Its adaptability makes it a valuable tool in educational settings and other real-world scenarios. While MATLAB's core functionalities are often applied in similar ways, the benefits can vary greatly depending on the specific industry and context. This unique flexibility allows users to tailor the tool to their needs, achieving diverse outcomes across different applications.

Mohammed H.Ali [2] presented A MATLAB/Simulink model was created to forecast soil temperature distributions and aid in the efficient design of Earth-to-Air Heat Exchangers (EAHEs). This model evaluates four distinct EAHE configurations: single-pipe, multi-pipe, multiple single pipes (MS-pipes), and twisted single pipes (TS-pipes). It has been validated with dependable results and can be easily modified to enhance final designs. The findings highlight that the MS-pipe EAHE excels in terms of minimizing pressure losses while providing notable cooling capacity. The research illustrates that installing EAHE systems in Kufa, Iraq, proves to be highly efficient, achieving a cooling capacity of 1626 W in August and 129.8 W in March. Furthermore, the study emphasizes how geometric configuration significantly influences both airflow behavior and thermal performance, offering a formula to compare pipe lengths at various soil depths. This work fills a gap in the use of MATLAB-based simulations for EAHE design and soil temperature prediction.

Chokechai Jitmonmana [3] presented the development of an optimal pipeline system design program using MATLAB. The program aimed to create a mathematical model to determine the most cost-effective pipeline system, focusing on minimizing annual costs. The study examined 19 parameters related to pipeline system design, including Internal diameter (D), pipeline length (L), pressure drop, fluid velocity (V), fluid density and viscosity, interest rate, project lifespan, annual maintenance rate, electricity cost rate, annual operating time, pipe price, cost of other materials in the pipeline system, ratio of pipeline system capital expenditure to total pipeline material cost, pipe friction coefficient, and total head loss from friction in various pipeline fittings. The study concluded that the internal diameter (D) of the pipeline had the highest sensitivity ratio for total cost change, while fluid viscosity had the least impact. The program predicted a fluid velocity that aligned with general design rules.

Tul Manewattana [4] presented the development of an AI function for calculating cooling loads in HVAC systems, focusing on providing convenience and precision in selecting air conditioning unit sizes. In the past, this process was often complicated, especially for those with limited experience in HVAC system design, as it involved considering multiple factors, such as internal load, ventilation, number of occupants, and electrical appliances. The AI function was designed to reduce time and complexity in the calculation process by using globally recognized standards, such as ASHRAE standards for ventilation and cooling load management. The AI automatically processes all the necessary data, minimizing the risk of errors that might occur when users are uncertain about the input data. *Additionally, by calculating the optimal air conditioning unit size for each space, we can tailor the AI to suit a variety of spaces, such as offices, bedrooms, or even movie theaters.* This enables faster and more confident decision-making when selecting air conditioning units. Furthermore, it enhances energy efficiency by selecting the appropriate unit size, leading to a gradual reduction in energy waste. This AI function revolutionizes cooling load calculations in the HVAC industry, not only improving accuracy but also saving time and resources in the design and installation of air conditioning systems.

Janthasri et al. [5] evaluated the impact of double-pipe heat exchangers (DPHExs) on energy consumption (EC) and thermal performance in agricultural postharvest refrigeration. The research compares two refrigerating systems using HFC-32 fixed-speed (FSC) and variable-speed compressors (VSC) across four experimental setups. Installation of DPHExs significantly reduced EC—by up to 52.33% for FSC and 50.63% for VSC at 18°C, and by 17.19% for FSC and 20.00% for VSC at 22°C. The VSC system with DPHExs showed improved energy efficiency and more stable conditions compared to FSC systems, offering valuable insights for optimizing refrigeration systems in fluctuating climates.

Janthasri et al. [6] explored traditional vapor compression and new radiant floor cooling systems in both non-heat-loaded and heat-loaded storage rooms. The radiant floor systems, used alone or combined with compression systems, were found to reduce energy consumption and minimize temperature and humidity fluctuations. When tested at 18°C and 22°C, the radiant floor systems improved stability and efficiency. The combined systems are particularly recommended for sensitive products like ready-to-eat and fresh fruits, offering valuable insights into operational costs and storage effectiveness.

Pramuanjaroenkij et al. [7] tested the performance of air conditioning systems equipped with inverter-controlled compressors and fixed-speed compressors, working in conjunction with a floor cooling system. The test involved installing chilled water pipes in the floor of the air-conditioned room and assessing the energy efficiency ratio of both types of split air conditioning systems. The results of this project can be used to inform the selection of split air conditioning systems combined with floor radiant cooling to improve efficiency and achieve greater energy savings compared to conventional air conditioning systems.

This research demonstrates the use of MATLAB to create a specialized tool for engineering applications. The researchers focused on developing a program for calculating cooling loads and designing radiant floor cooling systems. The study involved creating a MATLAB application for efficient cooling load calculations and radiant cooling system design. The application features a user-friendly interface that prompts users to enter the necessary data for the calculations. The application was tested on a sample supermarket case study in Columbus, Ohio, and successfully reduced the time required for cooling load calculations and radiant cooling system design by half. The results of this research highlight the application's ability to provide simple access, improve efficiency in engineering projects, and emphasize its usefulness as an educational tool in this field.

2. Related Theories

2.1 Heat Transfer Theory

The three main mechanisms of heat transfer are thermal conduction, convection, and radiation. These are fundamental for calculating cooling loads in buildings or various systems [8].

2.2 Cooling Load Theory

Cooling load calculations are used to calculate the quantity of heat energy that needs to be extracted from a space to maintain the desired temperature. The design of air conditioning systems (HVAC) for buildings or other areas typically utilizes this technique. The heat load can be classified as:

- Sensible Heat Load

This heat, which includes heat from sunlight entering a room, heat from occupants, and heat from electrical equipment, affects the temperature change in a space.

- Latent Heat Load

The heat that changes the state of water, such as sweat evaporation or other processes that increase air humidity [9].

2.3 Temperature Control Theory

This theory involves managing the temperature within a space using systems like HVAC (Heating, Ventilation, and Air Conditioning) and calculating the system's response to changes in thermal load [10].

2.4 Software Development Theory

This involves developing a MATLAB application that requires knowledge of software development theory, including algorithm design, object-oriented programming, and user interface design [11].

2.5 Energy Management System Theory

Emphasizes the use of technology for efficient energy management, particularly in the context of managing thermal energy in buildings and cooling systems [12].

2.6 Computer Simulation Theory

Developing a cooling load calculation program in MATLAB relies on computer simulation theory to model heat transfer and temperature distribution within a space [13].

2.7 Cooling Load Calculations Formulas

Cooling load calculations can be broken down into components based on the sources of heat. Examples include:
The cooling load Q through a wall is calculated based on the wall's thermal properties and temperature difference, as shown in Equation (1)

$$Q_{wall} = U \times A \times \Delta T \tag{1}$$

Here, U reflects the insulation properties of the wall; a lower U-value indicates better insulation. A is the total wall area, and ΔT represents the temperature difference between the interior and exterior environments.

Relative Humidity (%RH)
The percentage represents the ratio of the actual vapor pressure present in the air at a given condition to the vapor pressure of saturated air at the same temperature.

$$\%RH = \frac{P_W \times 100}{P_{W,T_{sat}}} \tag{2}$$

This equation calculates the average outside temperature, which is essential for cooling load calculations in building designs. It accounts for the daily temperature range, which helps in determining baseline cooling requirements. which can be calculated from

$$t_a = t_o - \left(\frac{DR}{2}\right) \tag{3}$$

This equation calculates the heat transfer (Qc) through external surfaces, such as walls, roofs, and windows, based on the temperature difference and heat transfer coefficient.

$$Q = U \times A \times CLTD_c \tag{4}$$

This equation computes heat gain through external structures such as walls, roofs, and windows using the cooling load temperature difference (CLTD) approach.

$$CLTD_c = CLTD + LM + (78 - t_R) + (t_a - 85) \tag{5}$$

This correction formula adjusts the base CLTD for local conditions. The latitude multiplier LM accounts for geographical variations, and temperature differences adjust for actual outdoor conditions.

Room Sensible Heat Ratio (RSHR) along with Airflow Rate in the Supply Duct
The calculation of the Room Sensible Heat Ratio (RSHR) can be determined using

$$RSHR = \frac{RSCL}{RTCL} \tag{6}$$

RSHR is calculated as the ratio of room sensible cooling load (RSCL) to room total cooling load (RTCL), which helps determine the balance between latent and sensible loads for air conditioning systems.

The airflow rate in the supply duct (cfm_{sa}) can be calculated by

$$cfm_{sa} = \frac{RSCL}{1.1\times(t_R - t_{sa})} \tag{7}$$

The airflow rate cfm_{sa} through the supply duct is derived based on the room sensible cooling load and the temperature difference between the room (t_R) and the supply air (t_{sa})

The latent cooling load loss due to cooling load loss can be estimated from

$$Q_T = Q_S \times LF \tag{8}$$

This equation estimates the latent cooling load loss using a latent factor (LF) multiplier. Latent loads are influenced by factors like humidity and occupant activities.
Where: The variable indicating the latent factor can be found in Fig. 1.

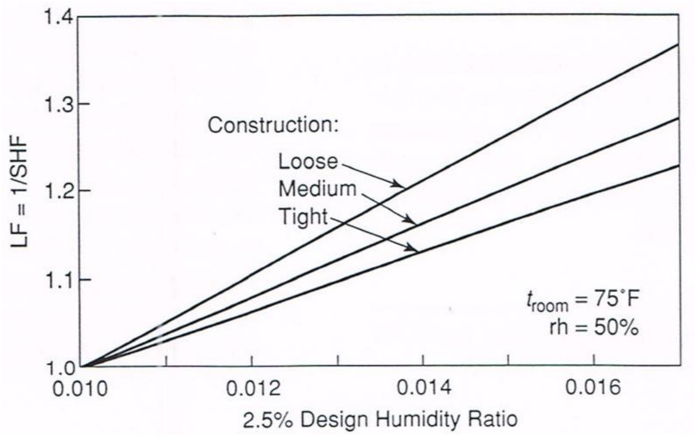


Fig. 1. Latent Factor (LF) [14].

2.8 Thermal Output for Heating and Cooling of the Radiant Floor Cooling System

The ISO 11855 standards dictate the structure and type of distributed heating and cooling.

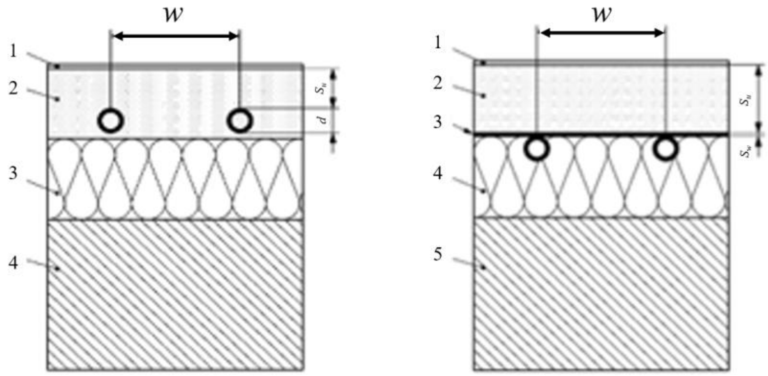
- *Type A and C: radiant pipes embedded in the screed as shown in* (*Fig. 2a*)

Thermally decoupled from the structural base of the building by thermal insulation
$W \geq 0.050$ m $S_u \geq 0.01$ m
0.008 m $\leq d \leq 0.03$ m
$S_u / \lambda_e \geq 0.01$
1. Floor covering
2. Weight-bearing and thermal diffusion layer (cement screed, anhydrite screed, asphalt screed)
3. Thermal insulation
4. Structural bearing

Type C: additional screed between layer 1 and 2

- *Type B: radiant pipes below the screed, in insulation with conductive devices as shown in* **(***Fig. 2b)*

Not wooden constructions except for weight-bearing and thermal diffusion layers
0.05 m $\leq W \leq 0.45$ m
0.014 m $\leq d \leq 0.022$ m
0.01 m $\leq S_u / \lambda_e \geq 0.18$
1. Floor covering
2. Weight-bearing and thermal diffusion layer (cement screed, anhydrite screed, asphalt screed, wood)
3. heat diffusion devices
4. Thermal insulation
5. Structural bearing



(a) (b)

Fig. 2. Radiant pipes embedded in cement (a) and radiant pipes are located under plaster (b) [15].

Heat exchange coefficient between surface and space
For floor heating and ceiling cooling, the heat flow density (q) is expressed as

$$q = 8.92\left(\theta_{s,m} - \theta_i\right)^{1.1} \text{ W/m}^2 \quad (9)$$

Heat flow density (q) for radiant floor cooling is determined by the difference between the mean surface temperature (θs, m) and the indoor air temperature (θi), scaled by a constant.

Temperature difference in the cooling medium:
The following formula (ISO 11855-2) determines the temperature difference of the cooling medium $\Delta\theta_c$

$$\Delta\theta_C = \frac{\theta_R - \theta_V}{\ln \dfrac{\theta_V - \theta_i}{\theta_R - \theta_i}} \quad (10)$$

This equation calculates the temperature difference for the cooling medium, a critical factor in ensuring adequate cooling performance by setting temperature boundaries for circulating fluids.

$$q = K_H \times \Delta\theta_C \quad (11)$$

For floor heating and cooling, the design flow rate (m) of the heating medium for a surface heating circuit is determined by the following calculation:

$$m = \frac{A_F \cdot q}{\sigma \cdot c_W}\left(1 + \frac{R_o}{R_u} + \frac{\theta_i - \theta_u}{q \cdot R_u}\right) \quad (12)$$

3. Methodology

3.1. Application Development

In this research, firstly, the relevant theories to the advancement of calculation of cooling loads programs, including the design of radiant floor cooling systems, were studied and used in designing the cooling load calculations required for both convection and radiant floor cooling systems (Fig. 3). Then, all equations were coded in MATLAB software on a compatible computer system. The program also included reference materials and data for the cooling load calculations in its user interface. The program was designed to be user-friendly and flexible, allowing users to input necessary data and quickly obtain cooling load calculation results.

3.2. Application Evaluation

After the cooling load calculation program was developed by using MATLAB as a stand-alone application, the program was tested to assess its performance and identify any errors. Results from these preliminary tests were analysed to improve the program's accuracy and stability. After the developer test, users with expertise in cooling load calculations tested the cooling-load-calculation application. The same calculation test, as shown in Figure 4, was given to all users. The application evaluation involved assigning the participants the task of calculating the cooling load for a supermarket in Columbus, Ohio, based on a case study that included comprehensive details regarding the commercial structure of the building, including details like roof, floor, walls, windows, doors, and operational data such as occupancy, lighting, and operating hours. Example details for the air conditioning system design of a supermarket in Columbus, Ohio. The supermarket is a single-story building with a basement for storing goods. The building structure consists of the following components:

- Roof: Composed of a 4-inch heavy-weight concrete slab, insulated with 2-inch-thick insulation, and a gypsum board ceiling. The total U-value is 0.09 BTU/hr·°F·ft².
- Floor: Composed of a 4-inch-thick concrete slab with a total U-value of 0.35 BTU/hr·°F·ft².
- Walls (all four sides): Composed of 4-inch-thick face brick, 4-inch-thick common brick, 2-inch-thick insulation, and ½-inch thick gypsum wallboard. The total U-value is 0.11 BTU/hr·°F·ft².
- Front Windows: Made of single-pane heat-absorbing glass, ¼ inch thick, with a height of 10 feet. The frame is made of aluminium, and there are no shading devices.
- Doors: The main doors are single-pane clear glass, ¼ inch thick, with aluminium frames.
- Receiving Door: Made of 1½-inch thick steel with a urethane core for insulation.
- Occupancy: The building has a capacity of 60 people.
- Structure: Classified as heavy-weight construction (H).
- Lighting: Fluorescent lighting is designed to provide an illumination power density of 3 watts per square foot.
- Operating Hours: The supermarket operates from 10:00 AM to 8:00 PM.

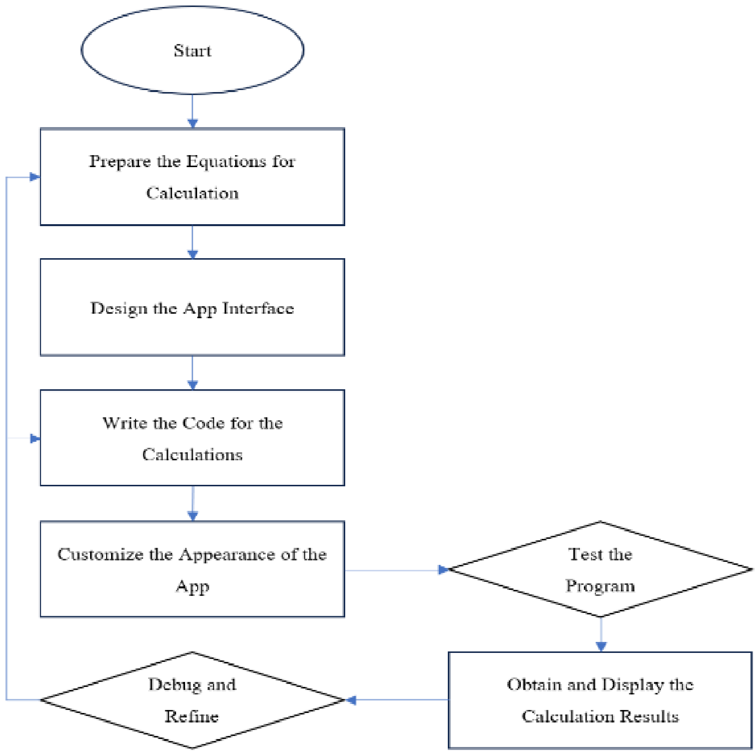


Fig. 3. Steps for Designing a Program in MATLAB App Designer.

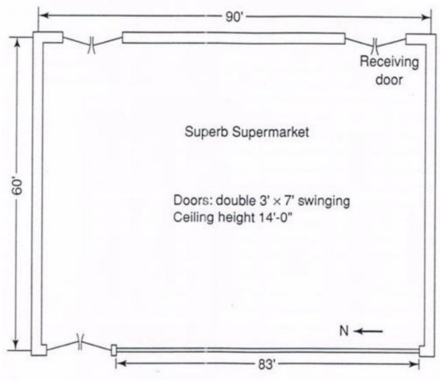


Fig. 4. Sample Supermarket in Columbus Ohio [14].

The users' satisfaction with the program was then evaluated to assess the effectiveness of the developed cooling load calculation program. This research evaluated and assessed the efficiency of cooling load calculation methods for designing air conditioning systems in commercial buildings, comparing manual calculations with the use of a developed software program. The study provides insights into the performance in terms of calculation speed, accuracy, and user experience, focusing on participants with basic knowledge of air conditioning design, including engineering students and graduates. The study recorded the time taken and examined errors in both methods and collected user feedback through a questionnaire to evaluate their satisfaction with the software and its performance. The results showed that the developed software significantly reduced calculation time and increased accuracy compared to manual methods. Furthermore, the software received positive feedback regarding its usability and user experience. Based on these findings, the software demonstrates potential for real-world industrial applications.

4. Research Findings and Discussion

The results of this research indicate that the developed software is similar to standard cooling load calculation programs; however, the key difference lies in its ability to calculate floor cooling radiant heat. This feature sets the software apart from other programs that do not offer this function. The capability to compute floor cooling radiant heat enhances the accuracy of cooling load calculations, leading to more precise and effective air conditioning system designs tailored to real-world applications.

4.1. Results of the Study and Compilation of Research Data, Related Theories, and Operating Principles of Cooling Load in Refrigeration Systems

Utilization of MATLAB for Data Analysis and Compilation in Commercial Building Cooling System Design:

MathWorks developed MATLAB (Matrix Laboratory), a crucial tool for data analysis and engineering calculations. The program efficiently manages mathematical problems and system designs, enabling engineers and scientists to create accurate and systematic solutions. The use of MATLAB in cooling load calculations is particularly significant. Designing cooling systems for commercial buildings is a complex process that considers various factors, such as heat loads from lighting, people, equipment, and air leakage. MATLAB applications allow inputting these data and calculating their effects on the building's overall cooling system, facilitating the planning and design of highly efficient systems that reduce energy consumption and operational costs.

Analysis and Design of In-Floor Air Conditioning Systems

One of MATLAB's special features is its capability to calculate for cooling systems installed in floor surfaces, including managing chilled water pipes and evaluating material properties such as thermal conductivity and thermal resistance. Using MATLAB in this aspect enables accurate calculation of these values, resulting in cooling system designs that better suit building conditions and specifications.

Capability to Evaluate and Enhance System Efficiency

MATLAB provides the ability to simulate various scenarios and conduct multivariable experiments, allowing engineers to test and improve cooling systems in real situations. This enables the assessment of effectiveness and increases system reliability. Using this application also reduces actual testing time and costs through computer simulations.

Integration with Other Tools and Platforms

MATLAB's ability to integrate with other programming languages, such as C, Java, and Python, and other tools, like databases, allows engineers to create comprehensive and efficiently coordinated solutions. This is particularly beneficial in large-scale projects requiring extensive data analysis and integration from multiple sources. The use of MATLAB in designing and analyzing cooling systems exemplifies the application of modern technology to meet increasing demands in the design and engineering industry. It enables the creation of appropriate and highly efficient systems, supporting sustainable development and reducing unnecessary resource consumption.

4.2 Results of Developing the Cooling Load Calculation Program by Using MATLAB as a Stand-Alone Application

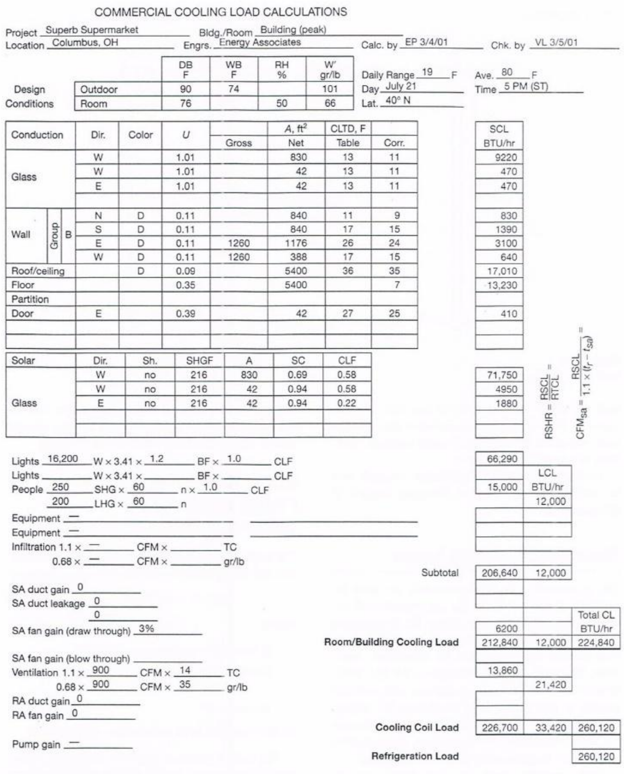
The cooling load calculation program for a cooling system starts with development using MATLAB App Designer to create the user interface (UI) or the appearance of the program, following the steps outlined in Figure 4.

4.3 Results of Testing the MATLAB Program for Creating an application

The researcher designed and developed an application interface for calculating the cooling load of a cooling system using MATLAB. When testing the functionality of the developed program, the application displays a window for cooling load calculations, featuring input fields where users can enter the necessary values for the calculations into white input boxes. These white boxes are used for input, and the entered values are then used to compute results, which are displayed in highlighted fields, as shown in Figs. 7 to 12. Users can input data according to Figs. 7 to 12. After all values have been entered, the user clicks the "Calculate" button, and the program displays the calculated results in the highlighted fields.

4.4 Research results and benefits that users will receive

Past research has shown the benefits of using heat exchangers and floor cooling systems in conjunction with cooling load calculations to improve efficiency and reduce energy consumption. Janthasri et al. [5] investigated double-pipe heat exchangers (DPHExs) and how they affect energy use in post-harvest refrigeration systems. They discovered that installing DPHExs greatly decreased the energy use in the refrigeration system and made the system more stable. Janthasri et al. [6] also investigated the floor cooling system compared with the conventional vapor compression refrigeration system. It was found that the combination of floor cooling and vapor compression reduced the temperature and humidity fluctuations in the storage area of sensitive products such as fresh fruits and ready-to-eat foods, resulting in improved efficiency and reduced operating costs. Furthermore, Pramuanjaroenkij et al. [7] studied the operation of an air conditioning system using an inverter-controlled compressor in conjunction with a floor cooling system. The test results indicated that the use of a floor cooling system increased the Energy Efficiency Ratio (EER) of the air conditioning system, resulting in better energy consumption reduction than conventional air conditioning systems. These studies highlight the benefits of using floor cooling systems in terms of improving performance, reducing energy consumption, and improving system stability under fluctuating weather conditions. Meanwhile, the use of MATLAB to develop the cooling load calculation program significantly improved the calculation efficiency. In this research, Table 1 shows that using the program can reduce the calculation time from 147.71 minutes for manual calculations to only 36.43 minutes, which is a significant time reduction. Users can save both time and operating costs because using the developed program reduces the need to use MATLAB directly, which requires an annual license fee. It also provides the highest calculation accuracy with a variable value of up to 1*10^307. In conclusion, all related research confirms that the development of a cooling load calculation program that integrates the use of a cooling floor system can help increase the efficiency of cooling system design, reduce energy consumption, and reduce costs in the long run. The program was tested by comparing the results with the manual calculation method from Figure 5-6. The manual calculation will be rounded to make it easier to calculate. As shown in Figs. 7 to 12, the program's calculation remains unrounded, making it more accurate than the manual calculation. It is also a valuable tool in education and training for those working in energy and environmental engineering.



COMMERCIAL COOLING LOAD CALCULATIONS

Project Superb Supermarket Bldg./Room Building (peak)
Location Columbus, OH Engrs. Energy Associates Calc. by EP 3/4/01 Chk. by VL 3/5/01

Design Conditions	DB F	WB F	RH %	W' gr/lb
Outdoor	90	74		101
Room	76		50	66

Daily Range 19 F, Ave. 80 F, Day July 21, Time 5 PM (ST), Lat. 40° N

Conduction	Dir.	Color	U	A, ft² Gross	A, ft² Net	CLTD, F Table	CLTD, F Corr.	SCL BTU/hr
Glass	W		1.01		830	13	11	9220
	W		1.01		42	13	11	470
	E		1.01		42	13	11	470
Wall, Group B	N	D	0.11		840	11	9	830
	S	D	0.11		840	17	15	1390
	E	D	0.11	1260	1176	26	24	3100
	W	D	0.11	1260	388	17	15	640
Roof/ceiling		D	0.09		5400	36	35	17,010
Floor			0.35		5400		7	13,230
Partition								
Door	E		0.39		42	27	25	410

Solar	Dir.	Sh.	SHGF	A	SC	CLF	SCL BTU/hr
Glass	W	no	216	830	0.69	0.58	71,750
	W	no	216	42	0.94	0.58	4950
	E	no	216	42	0.94	0.22	1880

RSHR = RSCL / RTCL = ; CFM$_{sa}$ = RSCL / 1.1 × ($t_r - t_{sa}$) =

Item	SCL BTU/hr	LCL BTU/hr	Total CL BTU/hr
Lights 16,200 W × 3.41 × 1.2 BF × 1.0 CLF	66,290		
People 250 SHG × 60 n × 1.0 CLF; 200 LHG × 60 n	15,000	12,000	
Equipment —			
Infiltration 1.1 × — CFM × TC; 0.68 × — CFM × gr/lb			
Subtotal	206,640	12,000	
SA duct gain 0; SA duct leakage 0; 0			
SA fan gain (draw through) 3%	6200		
Room/Building Cooling Load	212,840	12,000	224,840
SA fan gain (blow through); Ventilation 1.1 × 900 CFM × 14 TC; 0.68 × 900 CFM × 35 gr/lb	13,860	21,420	
RA duct gain 0; RA fan gain 0			
Cooling Coil Load	226,700	33,420	260,120
Pump gain —			
Refrigeration Load			260,120

Fig. 5. Manual cooling load calculation

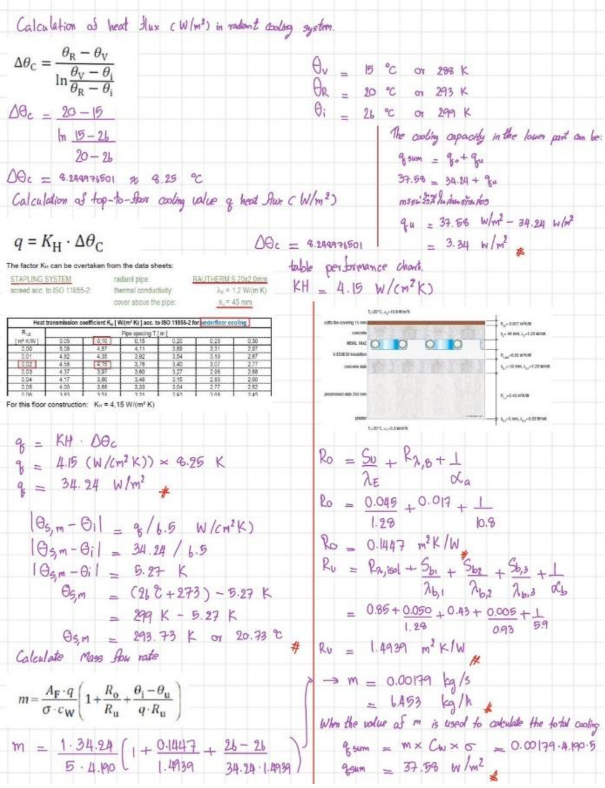
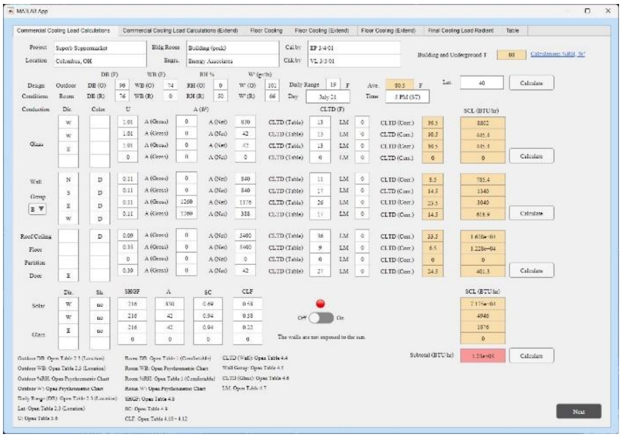


Fig. 6. Manual calculation of radiant floor cooling



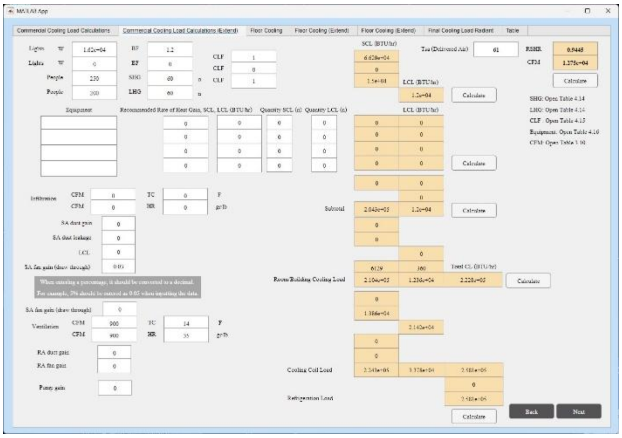
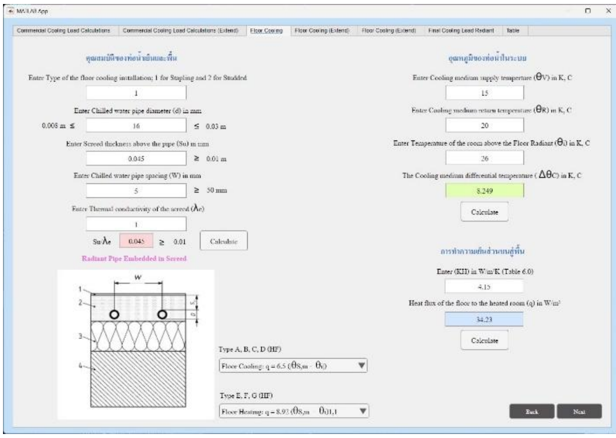


Fig. 7. Results of calcul ations by program and the input window for calculating the cooling load for commercial spaces.

Fig. 8. Results of calculations by program and the input window for air leakage and infiltration calculations



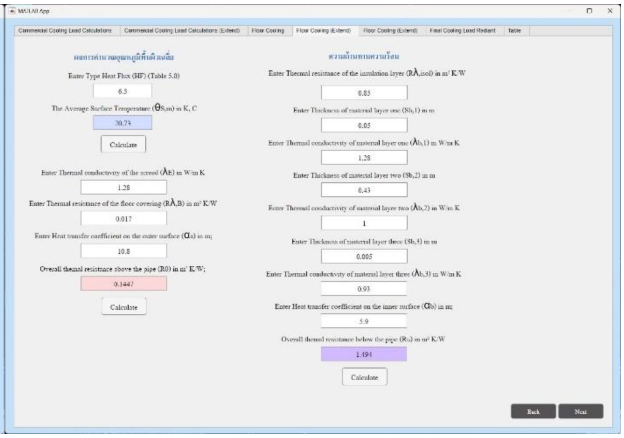
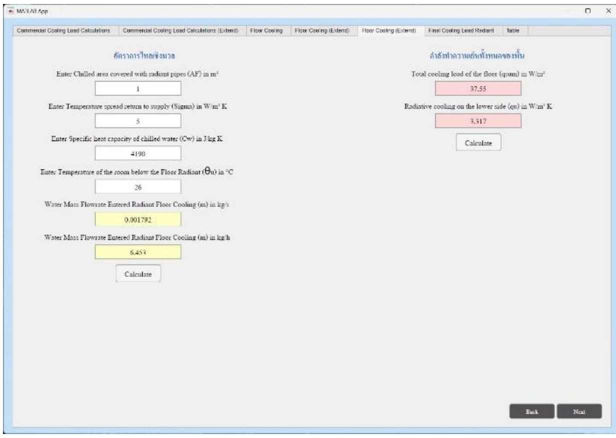


Fig. 9. Results of calculations by program and the input window for calculating the air conditioning system for the floor.

Fig. 10. Results of calculations by program and the input window for calculating the mean surface temperature and thermal resistance.



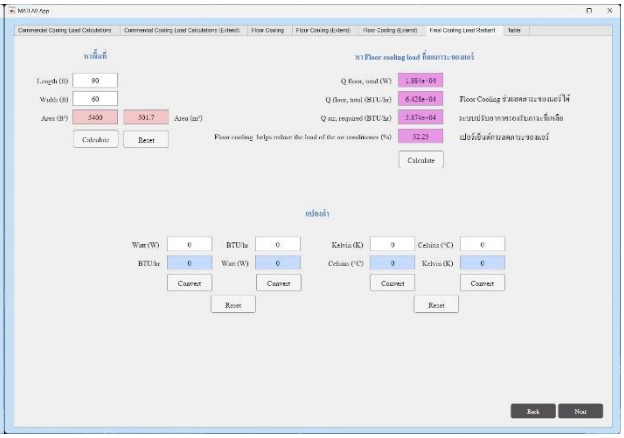


Fig. 11. Results of calculations by program and the input window for calculating the mass flow rate and total cooling capacity.

Fig. 12. Results of calculations by program and the input window is for calculating the area and cooling load per unit area.

According to Table 2's survey results on satisfaction with the cooling load calculation program for cooling systems, overall satisfaction with the program is at its highest level (mean $\bar{x}$ = 3.94 and SD = 0.69). The program can significantly reduce the time required for data entry when calculating the cooling load of the cooling system.

Table 1: Duration of manual calculation and use of the program for calculation.

(n=7)

Calculate Work and Time	Average $\bar{x}$ (minutes)	S.D.	t	Sig.
1. Manual Calculation Method	147.71	19.84	13.99	0.0000083
2. Program Calculation Method	36.43	3.10		

5. Conclusion

This research focuses on developing a MATLAB-based cooling load calculation program as a stand-alone application. The program is designed to improve the ease and accuracy of cooling load calculation, and it has been satisfied by a number of users as shown in Table 2, including cooling load specialists, HVAC engineers, and mechanical engineering students. The study reveals that the sample group showed a high average satisfaction when using the program compared to the traditional manual calculation. The average time spent by the entire sample group was 147.71 minutes, while the developed program could reduce the time to 36.43 minutes, as shown in Table 1, effectively saving time in cooling load calculation. The MATLAB application is effective in improving the calculation process and reducing errors. Therefore, this research has developed a MATLAB-based stand-alone application that can greatly assist those responsible for cooling load calculation, while also serving as a tool to reduce license costs for professionals interested in improving the design of air conditioning systems.

Table 2: Satisfaction level in using the cooling load calculation program for the cooling system.

Details assessed	Most (n)	More (n)	Moderate (n)	Less (n)	Least (n)	$\bar{x}$	%	S.D.	Results
1. The program is user-friendly and not complicated to use.	2	3	2	0	0	4.00	80.00	0.76	More
2. The program is stable and available for use at all times.	1	5	1	0	0	4.00	80.00	0.53	More
3. The design of the data entry is simple and easy to input values.	2	1	4	0	0	3.71	74.29	0.88	More
4. The program installation is easy to set up.	1	4	2	0	0	3.86	77.14	0.64	More
5. Reduces the time required to design the cooling load of the cooling system.	2	4	1	0	0	4.14	82.86	0.64	More
sum	8	17	10	0	0	3.94	78.86	0.69	More

Nomenclature

A	Area of the wall and the surface (ft^2)
AF	Area factor (m^2)
cfm_{sa}	Airflow rate in the supply duct (cfm, cubic feet per minute)
$CLTD$	Base cooling load temperature difference (°C)
$CLTD_c$	Corrected cooling load temperature difference (°C)
DR	Daily temperature range (F)
K_H	Heat exchange coefficient ($W/m^2 \cdot K$)
LF	Latent factor
LM	Latitude multiplier
m	Mass flow rate (kg/s)
P_w	Partial pressure of water vapor (Pa)
$P_{w,Tsat}$	Saturation vapor pressure at the same temperature (Pa)

Q	Cooling load (BTU/hr)
Q_{wall}	Heat gain through the wall (BTU/hr)
Q_S	Sensible cooling load (BTU/hr)
Q_T	Total cooling load (BTU/hr)
$RSCL$	Room sensible cooling load (Btu/hr)
$RSHR$	Room Sensible Heat Ratio
$RTCL$	Room total cooling load (W)
R_0	Base thermal resistance (m²·K/W)
R_u	Thermal resistance of underfloor heating system (m²·K/W)
σ	Specific heat of air (J/kg·K)
t_a	Average outside temperature (°C)
t_o	Outdoor temperature (°C)
t_R	Return air or room temperature (°C)
t_{sa}	Supply air temperature (°F)
U	Thermal transmittance or U-value of the wall (W/m²·K)
ΔT	Temperature difference across the wall (°C or K)
$\Delta\theta_c$	Cooling medium differential temperature (°C or K)
θ_i	Indoor air temperature (°C or K)
θ_R	Reference temperature (°C or K)
$\theta_{s,m}$	Mean surface temperature (°C or K)
θ_u	Outdoor or lower floor temperature (°C)
θ_V	Ventilation temperature (°C or K)
c_w	Specific heat capacity of water (J/kg·K)
q	Heat flow density (W/m²)
$\%RH$	Relative humidity (%)

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