Optimizing Energy Efficiency and Thermal Comfort Through HVAC Duct Design of Mechanical Building

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Abstract

This project focuses on enhancing indoor thermal comfort and optimizing energy efficiency in a mechanical building by employing the Cooling Load Temperature Difference (CLTD) method for cooling load calculation and duct design using the equal friction method. The CLTD method estimates cooling loads by considering outdoor conditions, building materials, and internal heat gains, facilitating optimized HVAC system sizing. Duct design with the equal friction method ensures uniform airflow distribution, improving system efficiency and maintaining thermal comfort across the building. By integrating these methods, this project aims to provide valuable insights for building designers and engineers seeking to achieve optimal thermal comfort and energy performance in new building constructions.

Keywords— Thermal Comfort, CLTD, Equal Friction, HVAC

1 Introduction

In modern building design, achieving thermal comfort where occupants feel neither too hot nor too cold is essential for productivity and well-being. A key element in achieving this is the efficient design and operation of HVAC systems, which regulate indoor temperature, humidity, air quality, and airflow.

The Cooling Load Temperature Difference (CLTD) method is a popular approach for calculating a building's cooling load by considering external weather, building materials, and internal heat gains. This ensures HVAC systems are properly sized for optimal performance and energy efficiency. Equally important is duct design; using the equal friction method helps maintain uniform airflow and pressure, contributing to consistent thermal comfort.

HVAC systems include components like air handlers, chillers, boilers, ductwork, and controls that work together to provide heating, cooling, ventilation, and humidity control. Efficiently designed and configured HVAC systems are crucial for maintaining thermal comfort while minimizing energy use and operational costs. This project focuses on enhancing thermal comfort and energy efficiency by integrating the CLTD method, equal friction duct design, and efficient HVAC systems. It aims to offer practical insights and strategies for architects, engineers, and building designers to create comfortable, sustainable, and energy-efficient indoor environments.

2 Literature Review

The heating, ventilation, and air conditioning (HVAC) system plays a pivotal role in building energy consumption, indoor thermal comfort, and air quality. HVAC systems are recognized as major contributors to energy use in buildings, especially in commercial settings, often exceeding 50% of total energy consumption in tropical climates. Retrofitting HVAC systems is imperative for energy conservation, particularly in densely populated urban areas like Hong Kong, where buildings account for a significant portion of energy consumption. Additionally, HVAC systems significantly impact indoor thermal comfort and air quality, influencing occupant health and productivity. Changes in HVAC design and operation can lead to variations in indoor temperature, humidity, and air pollutant concentrations, affecting occupants' well-being and work performance. Despite potential challenges, such as increased humidity levels or ingress of outdoor pollutants, there are strategies to achieve both energy efficiency and optimal indoor conditions through HVAC retrofitting. By considering energy consumption alongside thermal comfort and air quality, sustainable building development can be achieved, promoting the health and productivity of occupants while mitigating environmental impact (Bhatia, 2006).

The review paper by (Teli, 2015) explores a spectrum of energy efficiency technologies for Heating, Ventilation, and Air Conditioning (HVAC) systems, addressing the pressing need to reduce energy consumption amidst escalating costs of fossil fuels and environmental concerns. With HVAC systems being significant energy consumers in buildings, the paper delves into various strategies for enhancing their performance while maintaining indoor comfort and air quality. By examining approaches such as evaporative cooling systems, ground-coupled HVAC systems, thermal storage systems, heat recovery systems, and the impact of building behavior on energy usage, the authors highlight the potential of novel configurations and component combinations to achieve substantial energy savings. The review underscores the importance of understanding specific design requirements within each HVAC discipline and emphasizes the role of integrating existing technologies to realize effective solutions for energy conservation and thermal comfort.

Thermal comfort research has been a cornerstone of building design and operation for nearly a century, with a vast body of literature guiding standards and practices in creating indoor environments conducive to occupant well-being and productivity. Over time, two distinct methodologies have emerged: deterministic stimulus-response standards, such as those based on Fanger's PMV-PPD model, primarily developed through laboratory-based research, and field studies aimed at validating these standards in real-world settings. While climate chamber methods have provided rigorous data amenable to analysis, questions persist regarding their experiential realism and external validity. Field studies, commissioned by organizations like ASHRAE, have sought to bridge this gap by validating laboratory findings in diverse climatic contexts worldwide. However, despite the potential contributions of environmental psychology, its role in thermal comfort research has been relatively limited. Nonetheless, the dominance of HVAC engineering in this field, epitomized by figures like P.O. Fanger, underscores the importance of interdisciplinary collaboration in advancing our understanding of thermal comfort and its practical implications for building design and operation (Gogineni et al., 2020).

The design and analysis of air distribution ducting systems play a crucial role in the overall efficiency and performance of HVAC (Heating, Ventilation, and Air Conditioning) systems within buildings. As highlighted by (Sambasiva Rao et al., 2019), air distribution systems, comprising components such as air handlers, ductwork, and diffusers, are essential for maintaining indoor air quality and thermal comfort by delivering conditioned air to occupied spaces. Effective design and operation of these systems are vital for energy conservation, as they account for significant energy consumption within buildings. Various factors, including duct efficiency influenced by parameters such as aspect ratio, location, insulation, and leakages, impact the overall performance of air distribution systems. Therefore, research efforts have been directed towards understanding the effects of these parameters and optimizing the design and layout of ducting systems to maximize energy efficiency and system performance.

The design and calculation of HVAC systems, particularly for buildings like schools, are crucial for ensuring optimal thermal comfort and indoor air quality while minimizing energy consumption. Emphasizes the growing necessity of energy-efficient HVAC systems due to technological advancements, increased construction in enclosed spaces, and changing ambient temperatures influenced by global warming. HVAC system design involves intricate processes such as psychometric analysis and refrigeration principles to determine the cooling load requirements and select appropriate equipment and components. Research in this field has focused on developing efficient HVAC systems that utilize variable refrigerant flow (VRF) technology, among other advancements, to achieve energy savings and improve system performance (Dubey, 2020). The integration of psychometric processes and advanced refrigeration technologies enables engineers and designers to optimize HVAC system design, considering factors like building layout, occupancy patterns, and local climate conditions, to meet the specific requirements of school buildings while ensuring energy efficiency and cost-effectiveness.

The estimation of cooling loads, crucial for sizing HVAC systems, is a fundamental aspect of building design to ensure thermal comfort and energy efficiency (Virendra V. Khakre, Avinash Wankhade, 2017) present the Cooling Load Temperature Difference (CLTD) method as an approach for calculating sensible cooling loads, particularly for evaporative cooling systems aimed at reducing energy consumption in comparison to conventional air conditioning units. This method allows for the estimation of cooling loads by considering factors such as building materials, insulation levels, solar gains, and internal heat gains. By manually calculating cooling loads using the CLTD method and comparing the results with those obtained from sophisticated software like HAP 4.5, the study highlights the effectiveness and reliability of the CLTD method in estimating cooling loads for various climatic conditions and building types.

Cooling load estimation is a critical aspect of HVAC design, ensuring the effective sizing and operation of air conditioning systems to maintain thermal comfort in buildings. (Walunj et al., 2021) address this necessity by employing the Cooling Load Temperature Difference (CLTD) method to estimate the cooling load of an academic building, specifically the Mechanical Engineering Building at Nnamdi Azikiwe University, Awka. This method considers various factors such as building orientation, construction materials, and occupancy patterns to determine the cooling load requirements for different spaces within the building. By accurately estimating the cooling load, engineers can appropriately size HVAC equipment and optimize system performance while minimizing energy consumption and capital costs. This study emphasizes the importance of thorough cooling load calculations in HVAC design to ensure the comfort and efficiency of building environments.

The study conducted by (Samuel et al., 2023) delves into the design and optimization of HVAC duct systems, focusing on enhancing air flow efficiency and minimizing pressure losses. Duct design is crucial for the effective distribution of conditioned air throughout air-conditioned spaces, impacting both capital and running costs of HVAC systems. The authors highlight the significance of duct optimization in improving energy efficiency by reducing duct leakage and conductive heat gains/losses. Utilizing computational fluid dynamics (CFD) analysis, the study investigates various parameters related to air flow characteristics within the duct system. Through theoretical and software-based tools, the research provides a comparative analysis of different duct shapes, considering factors such as velocity distribution, pressure difference, and air flow distributions. While circular cross-sectional ducts are proposed as a means to reduce pressure losses, the study acknowledges the complexities and cost implications associated with their fabrication and installation. Additionally, alternative solutions like incorporating divergent sections to minimize the impact of sharp bends on air flow are discussed. This comprehensive approach to HVAC duct design and optimization underscores the importance of considering various design elements to enhance system performance and efficiency in air conditioning applications (Khakre et al., 2017).

3 Methodology

Extensive reference was made to the ASHRAE Handbook editions of 2021, 2020, 2016, and 1997, which provided essential information on CLTD data, duct design procedures, cooling load calculation methods, and thermal comfort standards. These handbooks offered comprehensive guidelines and industry standards crucial for achieving optimal HVAC system performance.

Data collection included building layout design, occupancy specifics, and lighting configurations, forming the basis for calculating cooling loads using the CLTD method. Weather data from JNEC was also gathered to facilitate these calculations. The cooling load for each room on the first and second floors was meticulously determined using CLTD formulas, considering room orientation, construction materials, occupancy, lighting, and equipment usage. The peak cooling load for each room was calculated in tons of refrigeration, ensuring precise estimation of cooling requirements.

Duct sizing was executed using the Equal Friction method in an Excel spreadsheet, calculating mass and volume flow rates for each room. An initial air velocity of 8 m/s was set to meet noise requirements, with both round and rectangular duct sizing methodologies employed. The first and second floor models were designed in SOLIDWORKS, predominantly featuring rectangular ducts for height efficiency and fabrication simplicity, with 2D designs created in AUTOCAD 2021 for material usage comparison.

3.1 Flow Chart

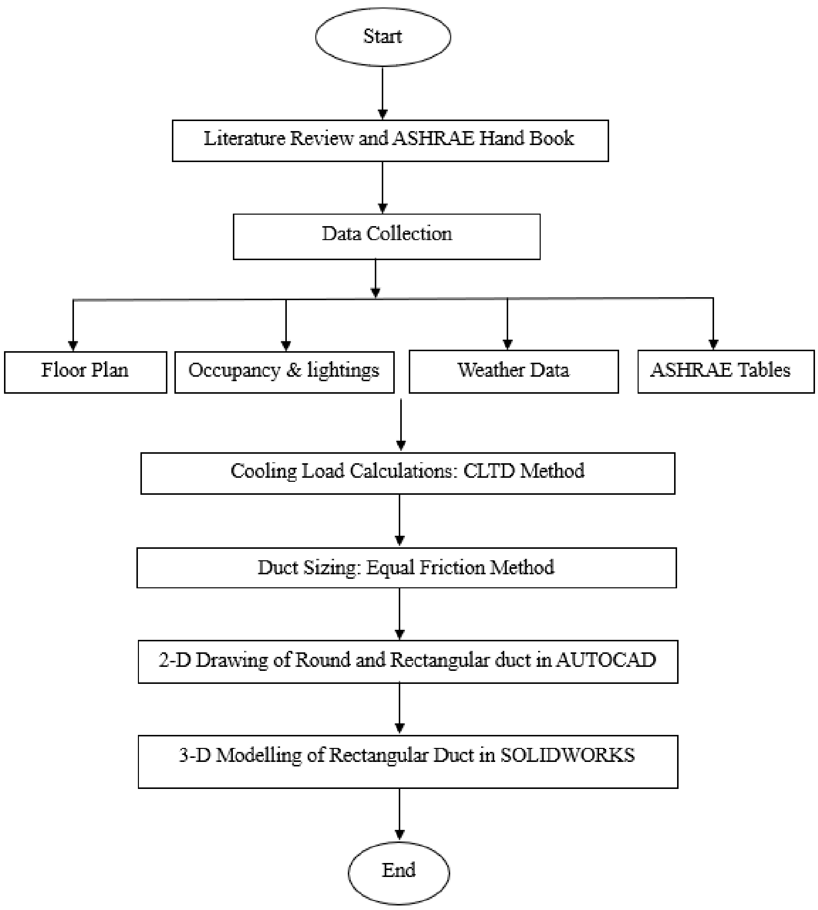

Figure 1: Methodology Flow Chart

The methodology flow chart (figure 1) illustrates the project's progression from planning and research to implementation and monitoring. It provides a concise visual representation of the systematic approach used to accomplish the project's goals.

4 CLTD Method

The CLTD (Cooling Load Temperature Difference) method is a practical tool in HVAC engineering for estimating a building's cooling load. It involves identifying design conditions, including outdoor temperature, solar radiation, and internal heat gains from lighting, equipment, and occupants. Pre-calculated CLTD values, available in the ASHRAE Handbook, are used based on building materials and dimensions (Spitler et al., 1993). This method accounts for unsteady state processes, considering peak cooling loads during daytime and varying outdoor conditions due to solar radiation.

Cooling loads consist of heat transferred through the building envelope (external loads) and heat generated by occupants, equipment, and lights (internal loads). The total cooling load includes both sensible and latent components, affecting temperature and moisture content, respectively. Externally loaded buildings experience variable cooling loads due to external conditions, while internally loaded buildings have more constant loads from internal heat sources.

The design basis typically includes information on:

1. Geographical site conditions (latitude, longitude, wind velocity, precipitation etc.)
2. Outdoor design conditions (temperature, humidity etc.)
3. Indoor design conditions
4. Building characteristics (materials, size, and shape)
5. Configuration (location, orientation and shading)
6. Operating schedules (lighting, occupancy, and equipment)

Table 1: Building specifications of first floor

Sl. No.	**Rooms**	**Area (m^2)**	**Occupancy**	**Lightings**	**Equipment**
1	Classroom 1	57.423	41	10 LED bulbs	1 Projector 1 Laptop
2	Classroom 2	55.645	41	10 LED bulbs	1 Projector 1 Laptop
3	Classroom 3	57.906	41	10 LED bulbs	1 Projector 1 Laptop
4	Classroom 4	64.074	41	10 LED bulbs	1 Projector 1 Laptop
5	Classroom 5	61.465	41	10 LED bulbs	1 Projector 1 Laptop
6	Classroom 6	60.043	41	10 LED bulbs	1 Projector 1 Laptop
7	Drawing Hall	72.850	61	13 LED bulbs	1 Projector 1 Laptop

Table 2: Building specifications of second floor

Sl. No.	Rooms	Area (m^2)	Occupancy	Lightings	Equipment
1	Office 1	58.410	11	10 LED bulbs	3 Laptops
2	Office 2	57.337	6	10 LED bulbs	3 Laptops 1 Printer 1 Tea Kettle
3	HOD Office	34.316	4	3 LED bulbs	1 Laptop 1 Printer
4	Office 3	20.580	3	2 LED bulbs	1 Laptop
5	DMPM Office	150.702	30	24 LED bulbs	12 Laptops 1 Printer 1 Tea Kettle
6	Office 4	29.147	6	5 LED bulbs	2 Laptops
7	Office 5	22.869	4	3 LED bulbs	1 Laptop
8	Conference Hall	72.202	61	13 LED bulbs	1 Laptop 1 LED Flat Screen

5 Load Components

The total heat required to be removed from the space in order to bring it at the desired temperature 21 degrees Celsius and relative humidity (50%) by the air conditioning equipment is known as cooling load or conditioned load (Bhatia, 2012). This load consists of external and internal loads.

5.1 External and Internal heat gains

External heat gains arrive from the transferred thermal energy from outside hot medium to the inside of the room. The heat transfer takes place from conduction through external walls, solar radiation through windows and doors and infiltration. Other sources are internal heat gain like people, electric equipment and light (ASHRAE, 1997).

a) Heat Gain through Opaque Surface (Walls and Doors)

$$Q = UACLTD \tag{1}$$

Where,

- Q = Heat gain (W)
- U = Overall heat transfer coefficient (W/m^2°C)
- A = Surface area (m^2)
- $CLTD$ = Cooling Load Temperature Difference (°C)

Values of U:

- For walls: $U = 2.97$ W/m^{2}K
- For doors: $U = 2.61$ W/m^{2}K

b) Heat Gain through Floor and Ceiling

$$Q = U_C A_C CLTD_C + U_f A_f CLTD_f \tag{2}$$

Where,

- A_C = Area of ceiling (m^2)
- U_C = Overall heat transfer coefficient of ceiling ($W/m^2°C$)
- A_f = Area of floor (m^2)
- U_f = Overall heat transfer coefficient of floor ($W/m^2°C$)
- $CLTD_C$, $CLTD_f$ = Cooling Load Temperature Difference for ceiling and floor respectively (°C)

Values:

- $U_C = 2.1$ W/m^2K
- $U_f = 2.1$ W/m^2K

c) Heat Gain through Glass

$$Q = U_g A_g CLTD_g \tag{3}$$

Where,

- Q = Heat gain through glass (W)
- U_g = Overall heat transfer coefficient of glass ($W/m^2°C$)
- A_g = Area of glass (m^2)
- $CLTD_g$ = Cooling Load Temperature Difference for glass (°C)

d) Occupancy

Q = (No. of people) (Sensible heat gain/person)

e) Equipment (Lighting Load)

$$Q = W F_{ul} F_{sa} CLF_{el} \tag{4}$$

Where,

- Q = Heat gain from lighting (W)
- W = Total light wattage = 34 W
- F_{ul} = Lighting use factor = 1
- F_{sa} = Lighting special allowance factor = 1.20
- CLF_{el} = Lighting cooling load factor = 1

f) Infiltration Cooling Load

$$Q = 1.2ACHV(T_o - T_i) \tag{5}$$

Where,

- Q = Infiltration cooling load (W)
- ACH = Air Changes per Hour = 1
- V = Volume of the room (m^3)
- T_o = Outside temperature = 29 °C
- T_i = Room temperature = 28 °C

Note: The constant 1.2 represents the approximate product of air density and specific heat capacity of air (in SI units).

6 Duct Design

Duct design is essential for efficient HVAC systems, ensuring effective distribution of conditioned air. The equal friction method, a common design approach, maintains consistent air velocity and uniform friction loss throughout the ductwork, ensuring balanced airflow and minimizing pressure losses and energy consumption (G.S. Sharma and Brijesh Sharma, 2014).

Ducts come in various shapes, each with advantages and disadvantages. Round ducts offer low friction and efficient airflow but require more height for installation. Square ducts also have low friction and material efficiency but need more vertical space. Rectangular ducts require less height and are easy to fabricate on-site but have higher friction (Gokul et al., 2019). Ducts, often referred to as ductwork, are typically made from galvanized mild steel, aluminum, or black steel, with galvanized sheet metal being the most common due to its rust-resistant zinc coating. The sheet thickness varies from 0.55 mm to 1.6 mm.

General Rules for Duct Design

1. Air should be conveyed as directly as possible to economize on power, material and shape.
2. Sudden change in direction should be avoided.
3. Air velocities in ducts should be within the permissible limits to minimize losses.
4. Rectangular ducts should be made as nearly square as possible. This will ensure minimum ducts surface. An aspect ratio of less than 4:1 should be maintained.
5. Damper should be provided in each branch outlet for balancing the system.

Duct Sizing Procedure

1. Use the cooling load of each room, which is determined using the Cooling Load Temperature Difference (CLTD) method.
2. Determine the required volume flow rate for each room using the following formulas:

   Mass Flow Rate

$$\dot{m} = \frac{Q}{c_p \Delta T} \tag{6}$$

Volume Flow Rate

$$\dot{V} = \dot{m}v \tag{7}$$

Where,

- $\dot{m}$ = Mass flow rate of air (kg/s)
- Q = Cooling load (W)
- c_p = Specific heat capacity of air (typically 1005 J/kg°C)
- ΔT = Temperature difference between supply and room air (°C)
- $\dot{V}$ = Volume flow rate (m^3/s)
- $\dot{m}$ = Mass flow rate of air (kg/s)

3. Sketch out the ductwork route in AutoCAD, creating a rough layout with minimal duct bends and branch lengths to reduce friction loss and enhance airflow efficiency.
4. Prepare a table consisting of various parameters shown in the table.
5. Take the initial airflow velocity as 8 m/s, typically considered the standard velocity for residential buildings.
6. Use the friction loss chart provided by the ASHRAE handbook to complete the table.
7. Determine the fitting loss using following formula;

   Bend loss:

$$P_{\text{loss}} = C_0 \cdot \rho \cdot V^2 + 2 \tag{8}$$

   Where:

   - C_0 = Fitting coefficient (dimensionless)
   - ρ = Density of air (e.g., 1.2 kg/m^3)
   - V = Air velocity entering the fitting (m/s)

   For the Rectangular duct design, use the Circular Equivalents of Rectangular duct for Equal Friction and Capacity Chart (ASHRAE, 2001).

Table 3: First floors round duct sizing for AHU1

max width=

ID	Type	Volume Flow Rate (m^3/s)	ΔP (Pa/m)	Velocity (m/s)	Diameter (m)	Length (m)	Duct Loss (Pa)	Direction	Fitting Loss (Pa)
A	Duct	4.480	0.67	8.0	0.840	3.435	2.301		
B	Tee							A-D & A-C	11.510 & 6.480
C	Branch	1.477	0.67	6.0	0.359	3.980	2.667		
D	Duct	3.003	0.67	7.3	0.732	6.688	4.481		
E	Tee							D-G & D-F	3.344 & 5.419
F	Branch	1.285	0.67	5.7	0.490	2.725	1.826		
G	Duct	1.719	0.67	6.2	0.565	13.362	8.953		
H	90 Bend				0.565			G-I	3.228
I	Branch	1.719	0.67	6.2	0.565	3.980	2.667		

Table 4: First floors round duct sizing for AHU2

max width=

ID	Type	Volume Flow Rate (m^3/s)	ΔP (Pa/m)	Velocity (m/s)	Diameter (m)	Length (m)	Duct Loss (Pa)	Direction	Fitting Loss (Pa)
A	Duct	6.516	0.55	8.0	1.000	5.300	2.915		
B	Tee							A-D & A-C	4.476 & 4.440
C	Branch	1.651	0.55	5.8	0.578	3.841	2.113		
D	Duct	4.865	0.55	7.3	0.860	1.678	0.923		
E	Tee							D-G & D-F	3.884 & 6.266
F	Branch	1.748	0.55	5.9	0.604	3.491	1.920		
G	Duct	3.117	0.55	6.8	0.721	7.596	4.178		
H	Tee							G-J & G-I	2.924 & 6.235
I	Branch	1.224	0.55	5.3	0.539	3.841	2.113		
J	Branch	1.893	0.55	5.9	0.617	1.582	0.870		
K	90 Bend				0.617			J-L	2.715
L	Branch	1.893	0.55	5.9	0.617	7.390	4.065		

Table 5: Second floor's round duct sizing for AHU2

max width=

ID	Type	Volume Flow Rate (m^3/s)	ΔP (Pa/m)	Velocity (m/s)	Diameter (m)	Length (m)	Duct Loss (Pa)	Direction	Fitting Loss (Pa)
A	Duct	7.179	0.51	8.0	1.050	3.090	1.576		
B	Tee							A-D & A-C	4.725 & 5.804
C	Branch	2.267	0.51	6.1	0.681	3.652	1.862		
D	Duct	4.911	0.51	7.5	0.940	6.690	3.412		
E	Tee							D-G & D-F	3.453 & 6.684
F	Branch	2.187	0.51	5.9	0.664	3.652	1.862		
G	Duct	2.724	0.51	6.3	0.715	1.679	0.856		
H	Tee							G-J & G-I	2.352 & 6.352
I	Branch	1.483	0.51	5.5	0.565	7.162	3.652		
J	Duct	1.241	0.51	5.2	0.526	9.623	4.907		
K	Tee							J-M & J-L	1.387 & 7.188
L	Branch	0.842	0.51	4.8	0.470	8.061	4.111		
M	Branch	0.399	0.51	3.9	0.358	2.757	1.406		
N	90 Bend				0.358			M-O	1.551
O	Branch	0.399	0.51	3.9	0.358	3.336	1.701		

Table 6: Second floor's round duct sizing for AHU1

max width=

ID	Type	Volume Flow Rate (m^3/s)	ΔP (Pa/m)	Velocity (m/s)	Diameter (m)	Length (m)	Duct Loss (Pa)	Direction	Fitting Loss (Pa)
A	Duct	7.523	0.5	8.0	1.075	1.532	0.766		
B	Tee							A-D & A-C	4.740 & 3.169
C	Branch	0.915	0.5	4.9	0.490	4.644	2.322		
D	Duct	6.609	0.5	7.8	1.025	3.355	1.676		
E	Tee							D-G & D-F	3.640 & 3.710
F	Branch	1.572	0.5	5.3	0.565	1.837	0.919		
G	Duct	5.036	0.5	7.3	0.980	2.447	1.224		
H	Tee							G-J & G-I	3.969 & 1.399
I	Branch	0.319	0.5	3.6	0.324	6.675	3.338		
J	Duct	4.719	0.5	7.0	0.900	0.935	0.468		
K	Tee							J-M & J-L	3.549 & 4.382
L	Branch	1.572	0.5	5.3	0.565	1.837	0.919		
M	Duct	3.144	0.5	6.5	0.783	3.546	1.773		
N	Tee							M-P & M-O	2.528 & 5.056
O	Branch	1.572	0.5	5.3	0.565	1.837	0.919		
P	Branch	1.572	0.5	5.3	0.565	2.799	1.399		
Q	90 Bend				0.565			P-R	2.275
R	Branch	1.572	0.5	5.3	0.565	1.837	0.919		

Table 7: First floor's rectangular duct sizing for AHU1

ID	Type	Volume Flow (m^3/s)	Velocity (m/s)	Diameter (m)	Length (m)	Width (m)	Height (m)
A	Duct	4.480	8.0	0.840	3.435	1.0	0.6
B	Tee						
C	Branch	1.477	6.0	0.359	3.980	0.4	0.275
D	Duct	3.003	7.3	0.732	6.688	0.8	0.55
E	Tee						
F	Branch	1.285	5.7	0.490	2.725	0.6	0.35
G	Duct	1.719	6.2	0.565	13.362	0.6	0.45
H	90 Bend			0.565		0.6	0.45
I	Branch	1.719	6.2	0.565	3.980	0.6	0.45

Table 8: First floor's rectangular duct sizing for AHU2

ID	Type	Volume Flow (m^3/s)	Velocity (m/s)	Diameter (m)	Length (m)	Width (m)	Height (m)
A	Duct	6.516	8.0	1.000	5.300	1.1	0.75
B	Tee						
C	Branch	1.651	5.8	0.578	3.841	0.7	0.40
D	Duct	4.865	7.3	0.860	1.678	0.9	0.70
E	Tee						
F	Branch	1.748	5.9	0.604	3.491	0.7	0.45
G	Duct	3.117	6.8	0.721	7.596	0.8	0.55
H	Tee						
I	Branch	1.224	5.3	0.539	3.841	0.6	0.40
J	Branch	1.893	5.9	0.617	1.582	0.7	0.45
K	90 Bend			0.617		0.7	0.45
L	Branch	1.893	5.9	0.617	7.390	0.7	0.45

Table 9: Second floor's rectangular duct sizing for AHU1

ID	Type	Volume Flow (m^3/s)	Velocity (m/s)	Diameter (m)	Length (m)	Width (m)	Height (m)
A	Duct	7.523	8.0	1.075	1.532	1.1	0.90
B	Tee						
C	Branch	0.915	4.9	0.490	4.644	0.6	0.35
D	Duct	6.608	7.8	1.025	3.355	1.1	0.80
E	Tee						
F	Branch	1.572	5.3	0.565	1.837	0.6	0.45
G	Duct	5.036	7.3	0.980	2.447	1.1	0.75
H	Tee						
I	Branch	0.319	3.6	0.324	6.675	0.4	0.225
J	Duct	4.719	7.0	0.900	0.935	0.9	0.75
K	Tee						
L	Branch	1.572	5.3	0.565	1.837	0.6	0.45
M	Duct	3.144	6.5	0.783	3.546	0.8	0.65
N	Tee						
O	Branch	1.572	5.3	0.565	1.837	0.6	0.45
P	Branch	1.572	5.3	0.565	2.799	0.6	0.45
Q	90 Bend			0.565		0.6	0.45
R	Branch	1.572	5.3	0.565	1.837	0.6	0.45

Table 10: Second floor's rectangular duct sizing for AHU2

ID	**Type**	**Volume Flow** (m^3/s)	**Velocity** (m/s)	**Diameter** (m)	**Length** (m)	**Width** (m)	**Height** (m)
A	Duct	7.179	8.0	1.050	3.090	1.00	0.90
B	Tee						
C	Branch	2.268	6.1	0.681	3.652	0.80	0.50
D	Duct	4.911	7.5	0.940	6.690	1.00	0.75
E	Tee						
F	Branch	2.187	5.9	0.664	3.652	0.75	0.50
G	Duct	2.724	6.3	0.715	1.679	0.70	0.60
H	Tee						
I	Branch	1.483	5.5	0.565	7.162	0.60	0.45
J	Duct	1.241	5.2	0.526	9.623	0.60	0.40
K	Tee						
L	Branch	0.842	4.8	0.470	8.061	0.55	0.35
M	Branch	0.399	3.9	0.358	2.757	0.40	0.275
N	90 Bend			0.358		0.40	0.275
O	Branch	0.399	3.9	0.358	3.336	0.40	0.275

7 Results

Table 11: Cooling load of first floor

Room	**Cooling Load** (kW)	**Cooling Load** (TR)
Classroom 1	14.865	4.226
Classroom 2	10.591	3.011
Classroom 3	14.285	4.285
Classroom 4	15.130	4.302
Classroom 5	11.122	3.162
Classroom 6	12.785	3.635
Drawing Hall	16.380	4.657

Table 12: Cooling load of second floor

Room	**Cooling Load** (kW)	**Cooling Load** (TR)
Office 1	19.625	5.580
Office 2	18.923	5.381
HOD Office	7.284	2.071
Office 3	3.458	0.983
DMPM Office	54.536	15.507
Office 4	7.917	2.251
Office 5	2.768	0.787
Conference Hall	12.831	3.648

The Total Cooling Load for First and Second Floor = 63.714 TR

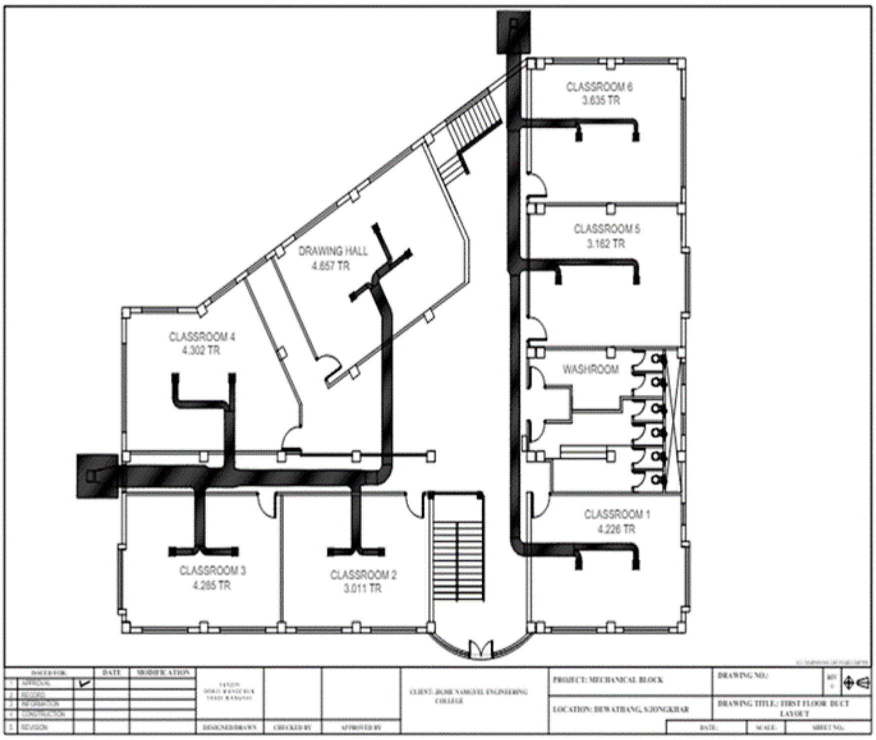

Figure 2: Round duct layout for first floor

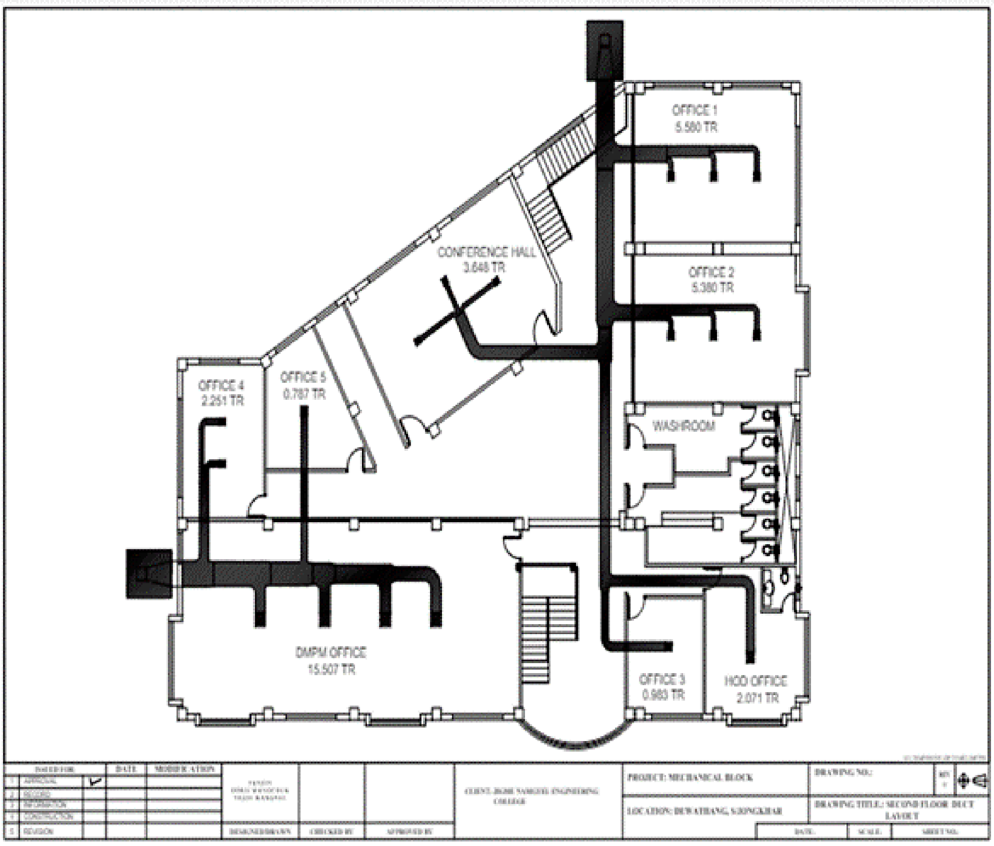

Figure 3: Round duct layout for second floor

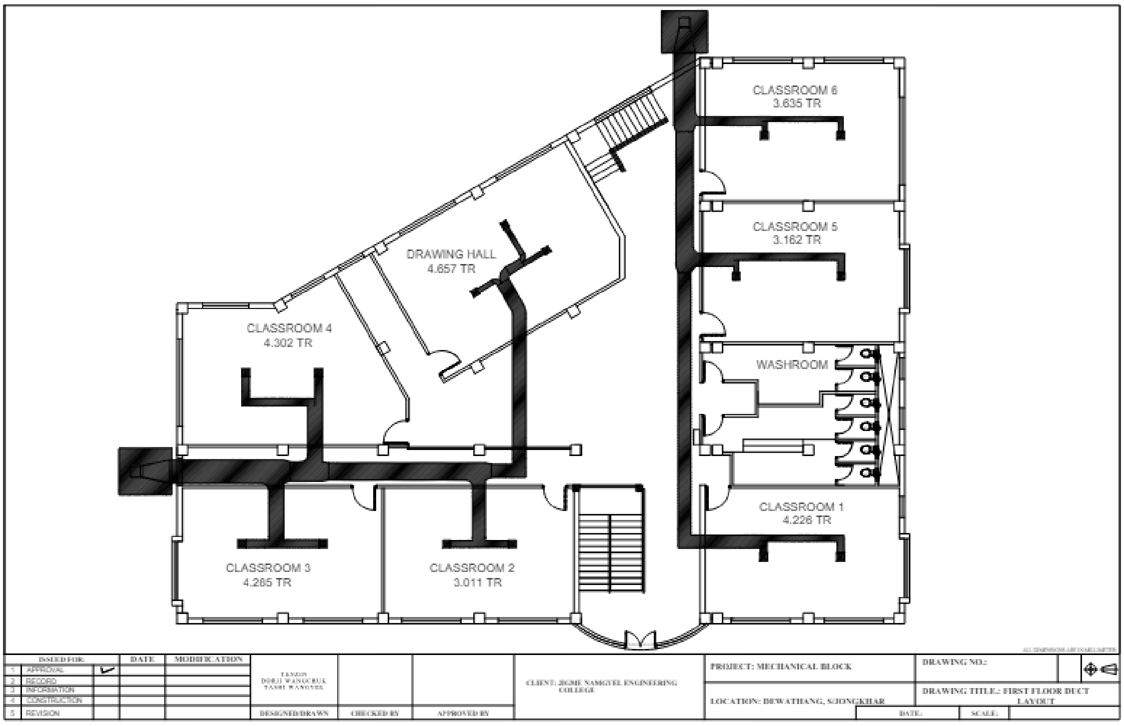

Figure 4: Rectangular duct layout for first floor

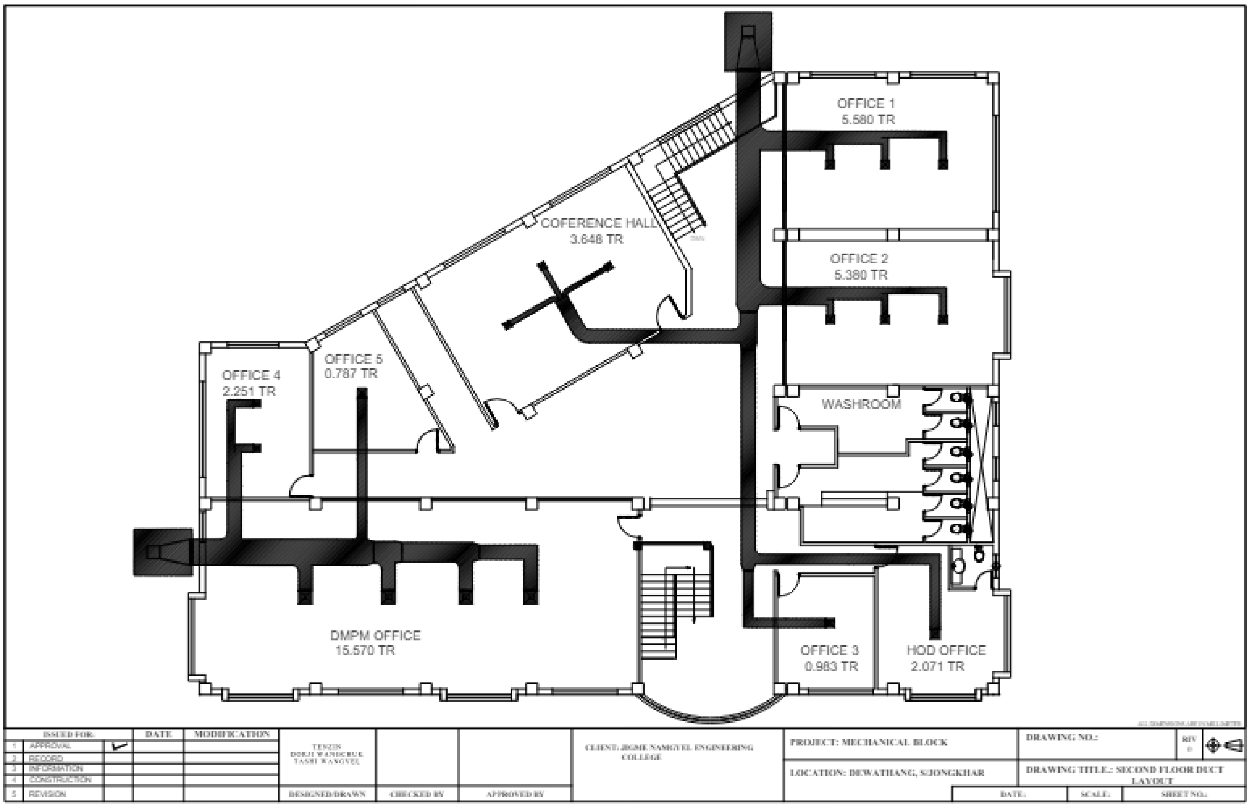

Figure 5: Rectangular duct layout for second floor

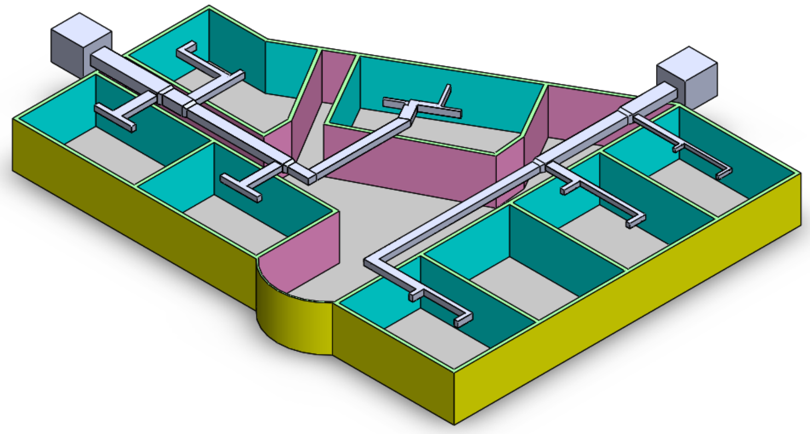

Figure 6: 3-D Rectangular duct design of first floor

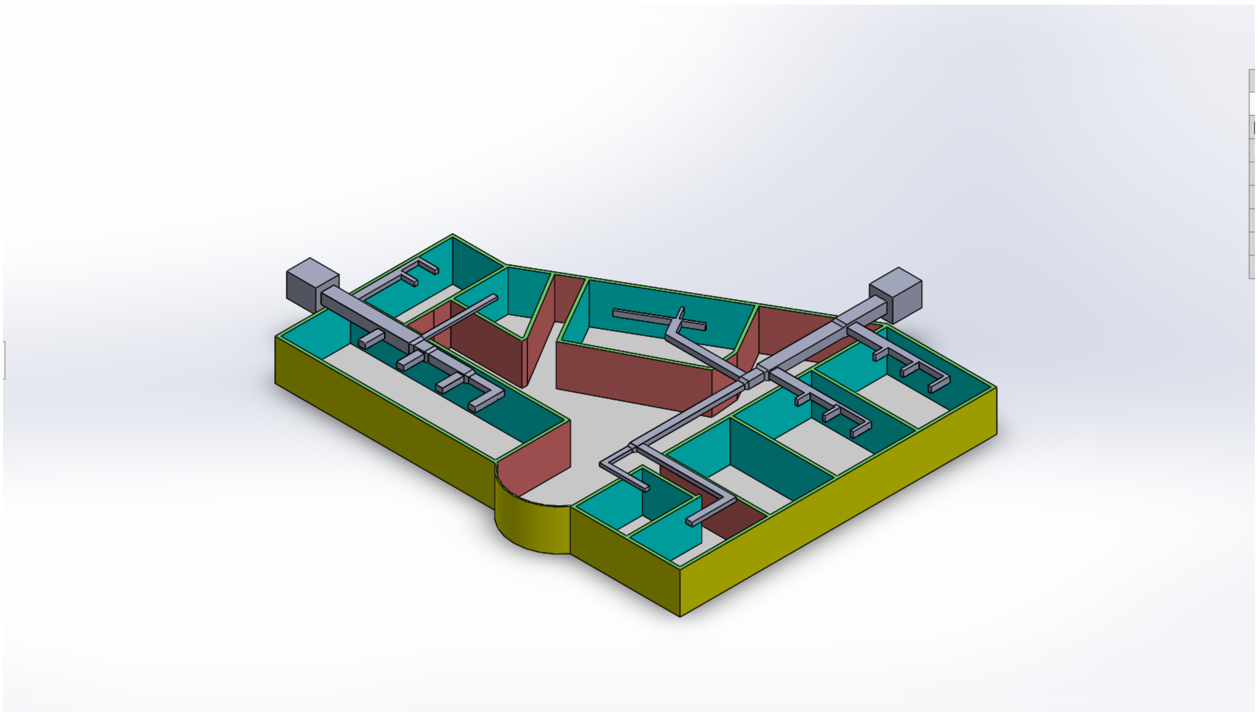

Figure 7: 3-D Rectangular duct design of second floor

8 Conclusion

In conclusion, the project "Optimizing Energy Efficiency and Thermal Comfort through HVAC Duct Design of New Mechanical Building" has provided valuable insights and recommendations for enhancing the performance and sustainability of HVAC systems in modern buildings. Through meticulous analysis, calculation and several key findings have emerged.

Firstly, the cooling load calculation using methods such as the Cooling Load Temperature Difference (CLTD) method has provided a comprehensive understanding of the thermal characteristics of the building. By accurately estimating the cooling loads under various conditions, we can tailor HVAC system designs to optimize energy efficiency while ensuring adequate thermal comfort for occupants.

Secondly, the duct sizing process, particularly utilizing the equal friction method, has highlighted the importance of balanced airflow distribution and pressure management within the HVAC system. By carefully sizing and designing ductwork, we can minimize energy losses, reduce operational costs, and mitigate potential issues such as uneven airflow and noise.

Moreover, the project has underscored the significance of integrating sustainable design principles into HVAC system design. By prioritizing energy efficiency, indoor air quality, and occupant comfort, we can create healthier and more environmentally responsible built environments.

Looking ahead, the insights gained from this project can serve as a foundation for further research and practical implementation in the field of building HVAC design and energy management. By continuing to refine and innovate HVAC system designs, we can contribute to a more sustainable and resilient built environment for future generations. In summary, this project has advanced our understanding of optimizing energy efficiency and thermal comfort through HVAC duct design, reaffirming the critical role of engineering in creating sustainable and comfortable indoor environments.

9 Recommendation

We recommend conducting a comprehensive project that thoroughly examines a comparative analysis between insulated and uninsulated buildings to assess cooling load variations and their resulting impact on duct sizing. This investigation will offer invaluable insights into the effectiveness of insulation in reducing energy consumption and improving indoor comfort levels.

It is crucial to integrate ductwork considerations into the building design process right from the outset to strengthen cost-effectiveness and streamline installation procedures. Employing advanced simulation tools such as computational fluid dynamics (CFD) or energy modeling software will facilitate precise prediction of performance outcomes, thereby enabling informed design decisions.

Furthermore, embracing cutting-edge technologies like variable air volume (VAV) systems, smart thermostats, and energy recovery ventilation can significantly enhance efficiency and comfort levels within the building. By incorporating these innovations, we can develop sustainable and energy-efficient building solutions that effectively address economic and environmental imperatives. This holistic approach to design and implementation will not only optimize operational costs but also contribute to creating healthier and more comfortable indoor environments for occupants

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