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INSTITUTE OF ENGINEERING
PULCHOWK CAMPUS

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**A Comparative Study of Cooling Load Between a Rana Era and a Modern Building
in Nepal**

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**A THESIS REPORT SUBMITTED TO THE DEPARTMENT OF MECHANICAL
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REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN
MECHANICAL SYSTEMS DESIGN AND ENGINEERING**

**DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING
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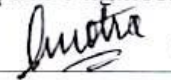
DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING

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ABSTRACT

Building consumes about one third of total energy of global energy demand. With HVAC constituting 35-50% of the total building energy use, focus needs to be given to exploring thermal performance of buildings to create energy efficient designs. This study compares the cooling load performance of Rana era A Block building at Pulchowk Campus with a modern building with same building geometry under Kathmandu climatic conditions with variations in wall, floor, roof U-value and air change per hour that contributes to infiltration in the building. Using CLTD method and Carrier HAP, cooling loads for 45 conditioned spaces were estimated manually and cooling input energy was obtained from HAP simulations. The results show that cooling demand in modern building is higher than the cooling demand in Rana era building by 9.5% to 16.1% with annual cooling energy input of 56057 kWh in modern building and 48567 kWh in Rana era building. These findings suggest that high thermal mass and lower effective heat transfer of building envelope considerably reduce cooling loads. This study provides a baseline for incorporating passive design concepts into modern engineering procedures and quantify the energy-efficiency observed in Rana era building.

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LIST OF ABBREVIATIONS

ACH	Air change per Hour
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BF	Ballast Factor
BTU	British Thermal Unit
CFM	Cubic Feet per Minute
CLF	Cooling Load Factor
CLTD	Cooling Load Temperature Difference
DHM	Department of Hydrology and Meteorology
DR	Daily Range
HAP	Hourly Analysis Program
HVAC	Heating, Ventilation, and Air Conditioning
IMC	International Mechanical Code
IOE	Institute of Engineering
LHG	Latent Heat Gain
MBH	Thousand BTUs per Hour
RTS	Radiant Time Series
SC	Shadding Coefficient
SCL	Solar cooling load
SHG	Sensible Heat Gain
SHGF	Solar Heat Gain Factor
TD	Temperature Difference
TF	Transfer Function
TR	Ton of Refrigeration

CHAPTER ONE: INTRODUCTION

1.1 Background

Buildings represent a significant portion of global energy demand, with approximately one-third of total energy produced being consumed by this sector (Zhou, Zhong , Liu, Han, & Peng , 2017). Of this, HVAC (Heating, Ventilation, and Air Conditioning) systems constitute 35-50% of a building's total energy use (Torres, Lombard, Coronel, Maestre, & Yan, 2022). Amid growing concerns for energy sustainability, exploring the thermal performance of historical architectural styles against contemporary ones is vital for creating energy-efficient designs.

The Rana Era in Nepal, which lasted from 1846 to 1951, marked a significant architectural shift characterized by the adoption of European styles. This period saw the construction of grand palaces that moved away from traditional Nepalese designs and instead embraced Neoclassical, Baroque, and Victorian aesthetics to reflect a sense of modernity and power. Rana architecture is distinguished by large-scale, white stucco palaces featuring Grecian columns, French windows, and expansive courtyards that blends Western designs with some local elements. Notable examples include the Singha Durbar, which now serves as the seat of Nepal's government, Ananda Niketan, which now serves as the Dean's Office of Institute of Engineering and other palaces that have been converted into hotels and public buildings. Following the end of the Rana dynasty, many of these residences were repurposed, though some have fallen into disrepair, standing as a testament to this unique period in Nepal's architectural history. Designed long before mechanical cooling and heating, these buildings relied on passive strategies—such as thermal mass, natural ventilation, and strategic orientation—to maintain comfortable indoor temperatures. In contrast, modern Nepalese buildings utilize industrially produced materials like concrete and lightweight bricks and depend heavily on mechanical HVAC systems.

Nepal's diverse climate zones make it an ideal setting for analyzing building envelope performance. While the passive design wisdom of Rana Era architecture is anecdotally acknowledged, there is a lack of quantitative studies comparing their cooling load requirements to those of modern buildings.

For this study, A-block building (Ananda Niketan) of Pulchowk campus have been taken due to availability of floor plan drawings and accessibility of the building.

The Administrative Building, A-Block, of IOE, Pulchowk Campus is distinct amongst other buildings of the Campus. It was built in a neoclassical style about 117 years ago. The building is believed to have been constructed in the first quarter of 20th century as a private palatial residence for Ananda SJB Rana, son of then Prime Minister of Nepal, Bir SJB Rana. Basic construction materials used are burnt bricks, mud, lime-surkhi, timber, steel I-beams. The building is 3-storey with attic roof and a central courtyard. It has decorative columns in lime-surkhi mortar. Lime-surkhi plaster is the basic element for outdoor plastering and most outdoor decorative parts were carved in the plastered surface. It has decorative windows and carvings at main hall walls, ceilings and mostly decorative ceilings in the lobby and major rooms (Report on Structural Condition Assessment and Retrofit of A-Block , 2019).

Situated at 27°4'N 85°21'E and 1,338 m elevation, Kathmandu Valley lies in the warm temperate zone (1,200-2,300 m). Average summer temperatures range from 28-30°C (82-86°F), while winter averages 10.1°C (50.2°F) across the valley (DHM, 2012). These temperature conditions yield roughly 8 months of summer (March-October) and 4 months of winter (November-February). So the cooling demands are higher than heating demand and therefore cooling load are mainly focused in the valley.

1.2 Statement of the Problem

The current trend in Nepalese construction favors modern architectural practices that often overlook the climate-responsive principles embedded in historical designs like those from the Rana Era. This has led to an increased dependence on energy-intensive HVAC systems.

While Rana Era buildings are known for their passive thermal regulation, there is insufficient quantitative data comparing their cooling load requirements against modern structures. This knowledge gap prevents architects, engineers, and policymakers from making informed decisions that could merge the time-tested principles of Rana architecture with modern technologies for optimal energy efficiency.

1.3 Research Objectives

Main Objective

To perform a detailed comparative analysis of the cooling load requirements of a Rana Era building and a modern building using energy simulation tool HAP.

Specific Objectives

- i. To calculate cooling load manually using CLTD method.
- ii. To create models in HAP (Hourly Analysis Program) for a building with two envelope configurations: one based on Rana Era construction and the other on modern practices.
- iii. To perform cooling load calculation and simulations in HAP under typical Nepalese climate conditions.
- iv. To quantify and compare cooling loads for both building types.

1.5 Significance/Rationale of the Study

This study will provide crucial insights into sustainable building design within the Nepalese context.

- i. **Academic Contribution:** It will add empirical data to the limited body of research on the cooling performance of Rana Era architecture compared to modern designs.
- ii. **Design Practice:** The findings will equip architects and engineers to make evidence-based decisions, potentially leading to hybrid designs that blend the high thermal mass of Rana buildings with modern insulation.
- iii. **Cultural Preservation:** By scientifically validating the engineering wisdom of Rana Era architecture, this research supports the preservation and adaptation of historical building techniques.

CHAPTER TWO: LITERATURE REVIEW

2.1 Related Work

Studies on historical building performance consistently highlight the advantages of traditional construction. (Yuksel, Arici, & Karabay, 2021) demonstrated that historical buildings with thick walls have longer thermal response times and greater thermal stability compared to modern structures, despite having higher U-values.

Research on vernacular architecture in warm-humid climates found that traditional mud houses achieve better thermal performance through passive design strategies including thermal mass, strategic orientation, and natural ventilation. A comparative study of laterite stone and rammed earth construction in coastal Karnataka by (P & Damle, 2024) showed that rammed earth achieved 10% cooling load reduction and 2°C surface temperature reduction compared to laterite stone.

A study by (Thapa & Jha, 2020) investigated methods to improve the energy efficiency of HVAC systems in a residential building in Bhaisepati, Lalitpur, Nepal. The research utilized Building Information Management (BIM) tools, specifically Autodesk Revit and Green Building Studio (GBS), to model a proposed residential building and simulate its energy performance. The study demonstrated that careful selection of building materials and systems can lead to substantial energy and cost savings for residential buildings in Nepal.

In Nepal, studies have often focused on indigenous Newari architecture. (Shrestha & Uprety, 2022) found that traditional buildings consumed less energy due to features like thick mud-brick walls and strategic space division. (Bajracharya S. B., 2014) investigated the aspects of thermal performance of traditional residential buildings in traditional settlements of Kathmandu valley and found traditional building also saves minimum 10-20% energy for either heating or cooling both in summer and winter than modern buildings of Kathmandu and concluded that, thermal performance of traditional residential building, adapted in various ways to the changing thermal regime for thermal comfort is better than that of contemporary buildings. While directly related studies on the thermal performance of Rana palaces are scarce, the principles of high thermal mass and passive design are

transferable. This research aims to fill that specific gap by focusing on Rana Era construction.

(Saragasan & Sies, 2021) compared cooling load calculations for a non-residential building (FPTV Blocks C&D at University Tun Hussein Onn Malaysia) using the manual Cooling Load Temperature Difference (CLTD) method and the Hourly Analysis Program (HAP) software employing the Transfer Function (TF) method. In the study, HAP estimated the peak cooling load at 3,275,100 BTU/hr (272.9 RT) across 23 air-conditioned spaces, 5.79% lower than CLTD's 3,464,094 BTU/hr, due to HAP's hourly scheduling of heat gains (e.g., computers, occupancy, lighting) and consistent material/weather databases.

(Mohammed, Abdullah, & Maree, 2016) compared manual hand calculations using the Cooling Load Temperature Difference (CLTD) method with Carrier's Hourly Analysis Program (HAP) for estimating total cooling loads in a two-story, 952 m² building at Erbil Polytechnic University, Iraq. In the study, Hand calculations yielded 95.7 TR total cooling load, while HAP produced 93.6 TR-a 2.1% difference attributed to precise material thermal resistances and ASHRAE transfer function modeling in HAP.

(Abir, 2019) compared hand calculations using the CLTD method with Carrier HAP software for total cooling load estimation of a bedroom in a one-story residential building in Sherpur, Bangladesh. In the study, both methods yielded nearly identical results: HAP showed 1.0 TR (11.8 MBH total, 10.2 MBH sensible coil load), while hand calculation gave 0.99 TR (11.85 MBH total, 10.755 MBH sensible), a maximum difference of 1.2%, validating HAP's ASHRAE transfer function accuracy against manual approaches

2.2 Related Theory

2.2.1 HVAC Load

HVAC stands for Heating, Ventilation and Air conditioning. HVAC load refers to the amount of heating or cooling energy a building requires to maintain desired indoor conditions like temperature and humidity. It encompasses heat gains (for cooling) and heat losses (for heating) from various sources, measured in BTUs or tons, and is essential for properly sizing HVAC equipment.

Heating load is the amount of heat energy required to be added to a building or space to maintain a desired indoor temperature during cold weather. It's calculated based on heat losses through the building envelope and ventilation, ensuring HVAC heating equipment is properly sized.

Some of the commonly used terms to describe aspects of heating and cooling loads are:

- a. Design load: a load that represents the highest reasonable heating or cooling load likely to be experienced by a building (or zone) based upon statistically significant climatic data. Design load is not the highest load that may or can occur, but, rather, the highest load it is reasonable to design for considering first cost of equipment and energy-efficient operations.
- b. Instantaneous load: a load that occurs during a defined time step/ period, usually one hour.
- c. Peak load: the largest load occurring in space, a zone, or an entire building.

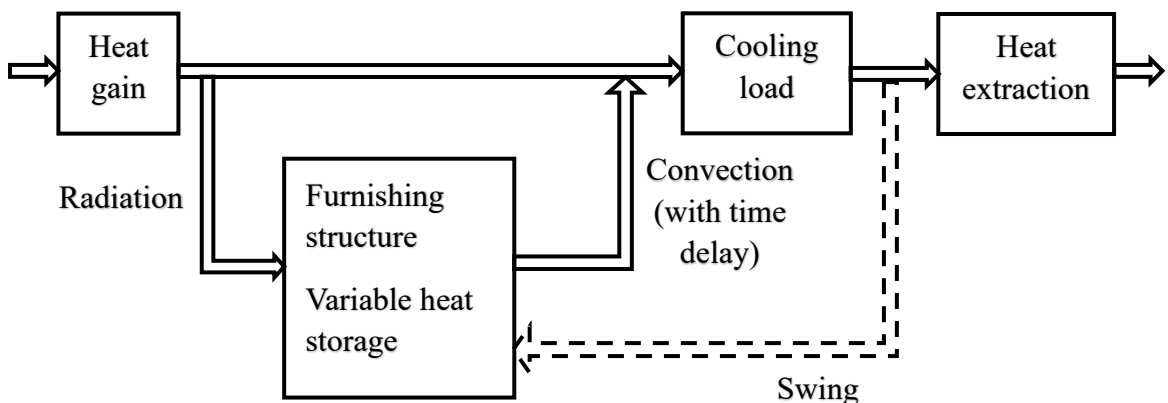


Figure 2. 1: Difference between the instantaneous heat gain and instantaneous cooling load due to thermal storage

The cooling load, the total heat that needs to be extracted, doesn't always match the heat entering a building at any specific moment. This discrepancy arises from heat storage and time lag phenomena. When heat enters, only part of it warms the indoor air right away; the rest (mainly radiant heat) gets absorbed by the building's structure, like walls, roof, floors, and furniture. This absorption creates the storage effect, and that held heat only later releases into the room air. There are different methods for calculating cooling load. They are:

- a. **Heat Balance (HB) Method:** Solves energy balance equations for each surface, tracking conduction, convection, radiation, and storage precisely. This method is used by commercial software like Carrier HAP 6 versions and EnergyPlus.
- b. **Radiant Time Series (RTS) Method:** A simplified HB derivative using hourly weighting factors for radiant/convective splits and time lags. This method is used by commercial software like Carrier HAP version 5 and earlier.
- c. **CLTD/CLF/SCL Method:** Uses tabulated Cooling Load Temperature Difference (CLTD) for envelopes, Cooling Load Factors (CLF) for internal gains, and solar cooling load (SCL) corrections; manual-friendly but conservative/outdated, often overestimates loads.

2.2.2 CLTD method

The CLTD method (Cooling Load Temperature Difference) is an ASHRAE-developed approach used in HVAC design to estimate building cooling loads by simplifying heat gain calculations through tabulated temperature differences. It is widely applied for walls, roofs, and fenestrations, making cooling load estimation more practical and standardized.

Cooling load calculations can be done using following formulas (Pita, 2002):

- i. **Conduction Through Exterior Structure (Roof, Walls, Glass)**

$$Q = U \times A \times CLTDc \dots \dots \dots (1.1)$$

Q: The cooling load resulting from heat gain through the roof, wall, or glass, measured in BTU/hr.

U: The overall heat transfer coefficient of the component, measured in BTU/hr.ft².°F.

A: The area of the roof, wall, or glass, measured in ft².

CLTDc: The corrected Cooling Load Temperature Difference, measured in °F.

$$\text{CLTDc} = \text{CLTD} + (78 - t_r) + (t_a - 85) \dots\dots\dots (1.2)$$

CLTDc: The corrected temperature difference value used in the cooling load equation, measured in °F.

CLTD: The base Cooling Load Temperature Difference found in standardized tables, which accounts for the time lag of heat traveling through the structure.

t_r: The designed indoor room temperature, measured in °F.

t_a: The average outside temperature on a design day, measured in °F.

$$t_a = t_o - (\text{DR} / 2) \dots\dots\dots (1.3)$$

t_a: The average outside temperature used to correct the CLTD, measured in °F.

t_o: The outside design dry bulb temperature, measured in °F.

DR: The daily temperature range, which is the difference between the maximum and minimum temperatures on the design day, measured in °F.

ii. Solar Radiation through glass

$$Q = \text{SHGF} \times A \times \text{SC} \times \text{CLF} \dots\dots\dots (1.4)$$

Q = solar radiation cooling load for glass in BTU/hr

SHGF = maximum solar heat gain factor in BTU/hr·ft²

SC = shading coefficient

CLF = cooling load factor for glass

A = area of the glass (ft²)

iii. Conduction Through Internal Structure

$$Q = U \times A \times \text{TD} \dots\dots\dots (1.5)$$

Q: The heat transfer through the building component, measured in BTU/hr.

U: The overall heat transfer coefficient of the material (e.g., wall, roof, glass), measured in BTU/hr.ft².°F.

A: The surface area of the component through which heat flows, measured in square feet (ft²).

TD: The design temperature difference between the inside air and the outside air, measured in °F.

iv. Cooling Load from people

$$Q_s = n \times SHG \times CLF \dots\dots\dots (1.6)$$

Q_s : Sensible cooling load from occupants, measured in BTU/hr.

n : Number of people in space.

SHG : Sensible Heat Gain per person (BTU/hr). This value changes based on the activity level (e.g., office work vs. gym).

CLF : Cooling Load Factor for people. This depends on how long the people have been in the space and the total hours the space is occupied.

$$Q_l = n \times LHG$$

Q_l : Latent cooling load from occupants, measured in BTU/hr.

n : Number of people in space.

LHG : Latent Heat Gain per person (BTU/hr), which also depends on the activity level.

v. Equipment cooling load

$$Q_s = n \times q_s \dots\dots\dots (1.7)$$

Q_s : Sensible cooling load from the equipment, measured in BTU/hr.

n : Number of identical equipment items.

q_s : Sensible heat generated by one piece of equipment (BTU/hr).

$$Q_l = n \times q_l \dots\dots\dots (1.8)$$

Q_l : Latent cooling load from the equipment, measured in BTU/hr.

q_l : Latent heat generated by the equipment (BTU/hr).

vi. Sensible Cooling Load from Lights

$$Q = W \times 3.41 \times BF \times CLF \dots\dots\dots (1.9)$$

Q : Sensible cooling load from lighting, measured in BTU/hr.

W : Total wattage of all lamps in the room.

3.41: The conversion factor to turn Watts into BTU/hr.

BF : Ballast Factor (or special allowance factor). For incandescent lights, this is 1.0. For fluorescent fixtures, it accounts for the heat generated by the ballast (typically 1.2 to 1.3).

CLF : Cooling Load Factor for lighting, which accounts for the building's thermal mass absorbing the radiant heat from the lights.

vii. Infiltration Cooling Load

$$Q_s = 1.1 \times \text{CFM} \times \text{TC} \dots\dots\dots (1.10)$$

Q_s : Sensible heat gain from infiltration, measured in BTU/hr.

CFM: Volume of outdoor air entering space, measured in cubic feet per minute.

TC: Temperature Change, which is the difference between the outdoor design dry-bulb temperature and the indoor design dry-bulb temperature (°F).

$$Q_l = 4840 \times \text{CFM} \times \Delta w \dots\dots\dots (1.11)$$

Q_l : Latent heat gain from infiltration, measured in BTU/hr.

CFM: Volume of outdoor air entering space (V), measured in cubic feet per minute.

$$\text{CFM} = \text{ACH} \times V/60 \dots\dots\dots (1.12)$$

Number of air changes per hour (ACH) in a room is caused by the infiltration.

One air change is defined as being equal to the room air volume.

Δw : The difference in the humidity ratio between the outdoor air and indoor air, measured in pounds of moisture per pound of dry air (lb/lb)

By adding the values, we obtain from equations 1.1, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, we get total cooling load in a space in BTU/hr, by dividing the cooling load by 12000 (12000 BTU/hr = 1Ton), gives the cooling load in tonnage.

2.2.3 Heat balance method

The Heat Balance Method explains how conduction, convection, radiation, and mass interact to determine cooling loads. A material can absorb energy in one form, such as radiation, while simultaneously releasing it in another, like convection. Because air is largely transparent, radiation does not directly affect the air in a room. Instead, radiation impacts surfaces, and those surfaces then transfer energy to the air through convection. In this way, mass becomes the medium that converts radiant energy into internal sensible loads.

The Heat Balance Method solves for a room cooling load by writing heat balance equations for every surface in the room. Those heat balance equations include every conduction, convection and radiation process associated with a surface. In addition, a heat balance is written for the room air mass. Because all these heat balance equations are interrelated, they

must be solved simultaneously to determine the temperatures and heat flows at each surface. That allows us to calculate the sensible load for the room. Explicitly calculating the radiation heat flows is one of the elements of the Heat Balance Method that is not present in the other simplified methods that have been used in the past. And that is one of reason why Heat Balance Method can provide results that are more faithful to building physis and can be more accurate.

Outside surface heat balance

$$q''_{sol} + q''_{LWR} + h_o(T_o - T_{so}) = q''_{cond} \dots \dots \dots (1.13)$$

Conduction through wall

$$q''_{cond,t} = \sum_{j=0}^n X_j T_{o,t-j} + \sum_{j=0}^n Y_j T_{i,t-j} + \sum_{j=1}^n Z_j q''_{cond,t-j} \dots \dots \dots (1.14)$$

Inside surface heat balance

$$q''_{cond} + q''_{SW} + q''_{LWX} = h_i(T_{si} - T_z) \dots \dots \dots (1.15)$$

Zone air Heat Balance

$$\sum h_i A_i (T_{si} - T_z) + \dot{m}_{sys} c_p (T_s - T_z) + \dot{m}_{inf} c_p (T_o - T_z) + Q_{int} = 0 \dots \dots (1.16)$$

Where,

- q_{sol}'' = absorbed solar radiation
- q_{LWR} = net long-wave radiation (sky + surroundings)
- h_o = outside convective heat transfer coefficient
- T_o = outdoor air temperature
- T_{so} = outside surface temperature
- q_{cond}'' = conduction heat flux into wall

•
 X_j, Y_j, Z_j = conduction transfer function coefficients

- T_o, T_i = outside and inside surface temperatures

- $t-j$ = previous time steps

- q_{sw}'' = absorbed short-wave radiation (solar inside)

- q''_{LWX} = long-wave radiation exchange with other surfaces

- h_i = inside convective heat transfer coefficient

- T_{si} = inside surface temperature

- T_z = zone air temperature

- A_i = surface area

- \dot{m}_{sys} = supply air mass flow rate

- T_s = supply air temperature

- \dot{m}_{inf} = infiltration air flow rate

- Q_{int} = internal heat gains (people, lights, equipment)

- c_p = specific heat of air

To use the Heat Balance Method, we should solve the equations 1.13 to 1.16 (U.S. Department of Energy, 2025) for the heat balance of the outside surface, the inside surface, and the zone air all at once. These equations use conduction (through conduction transfer functions), convection, and radiation heat transfer methods to figure out the heating and cooling loads of a building.

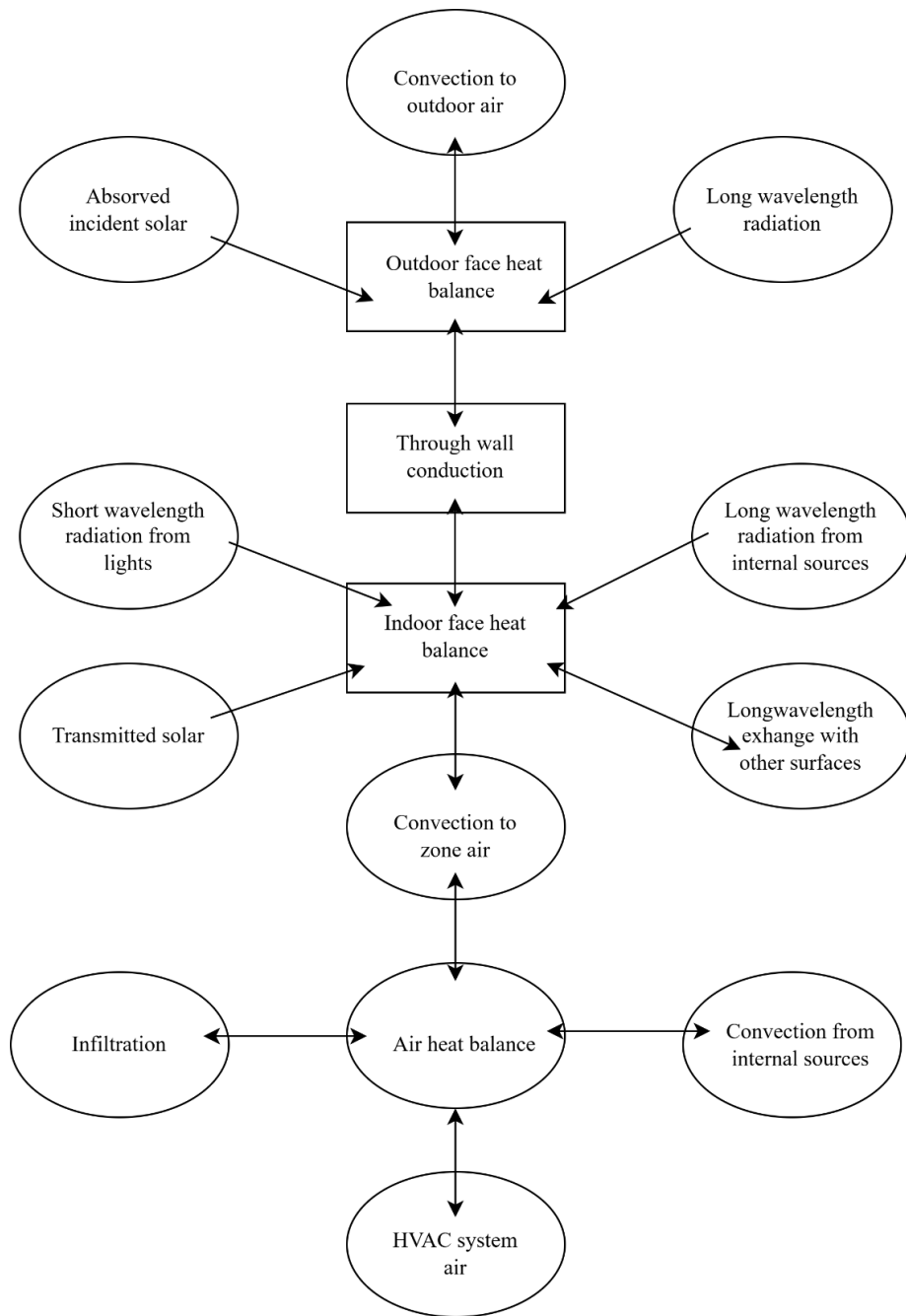


Figure 2. 2: Heat Balance method

As illustrated in Figure 2. 2, the schematic highlights the distinct pathways of energy movement. It shows that radiant loads and sensible loads are not simply added together to calculate the total load on the room air, as one might do in a basic spreadsheet. Instead, the method carefully distinguishes between these different forms of energy transfer to provide a more accurate representation of cooling load dynamics.

Carrier's Hourly Analysis Program (HAP) is a comprehensive software tool designed to support HVAC engineers in the design and analysis of systems for commercial buildings. The heat balance and Radiant Time Series methods, the foundation of simulation tools like HAP, accounts for all heat transfer through building elements, including solar gains, internal gains, ventilation and infiltration. This method allows for a precise, dynamic analysis of how Rana Era and modern envelopes perform under identical climatic and operational conditions

HAP operates in two main modes: System Design and Energy Analysis.

1. System Design

In this mode, HAP calculates a building's heating and cooling requirements (loads) for each space and zone. It determines the necessary size for HVAC system components, such as air handlers, coils, and chillers, ensuring they are not oversized or undersized. This mode considers heat flow from all elements like walls, windows, roofs, people, and infiltration.

2. Energy Analysis

This function simulates the building's energy consumption over an entire year. It reuses the data from the system design phase to analyze the energy use of different HVAC system alternatives. The software tabulates hourly energy consumption from both HVAC components (like compressors and fans) and non-HVAC components (like lighting) to determine the building's total energy profile and associated costs.

CHAPTER THREE: METHODOLOGY

This study used a quantitative, comparative approach based on building energy simulation. A controlled virtual experiment will be conducted where a single building geometry is modeled with two different envelope systems: one Rana Era and one modern to isolate the impact of the envelope on HVAC loads. Figure 3. 1 shows the research flowchart of this study.

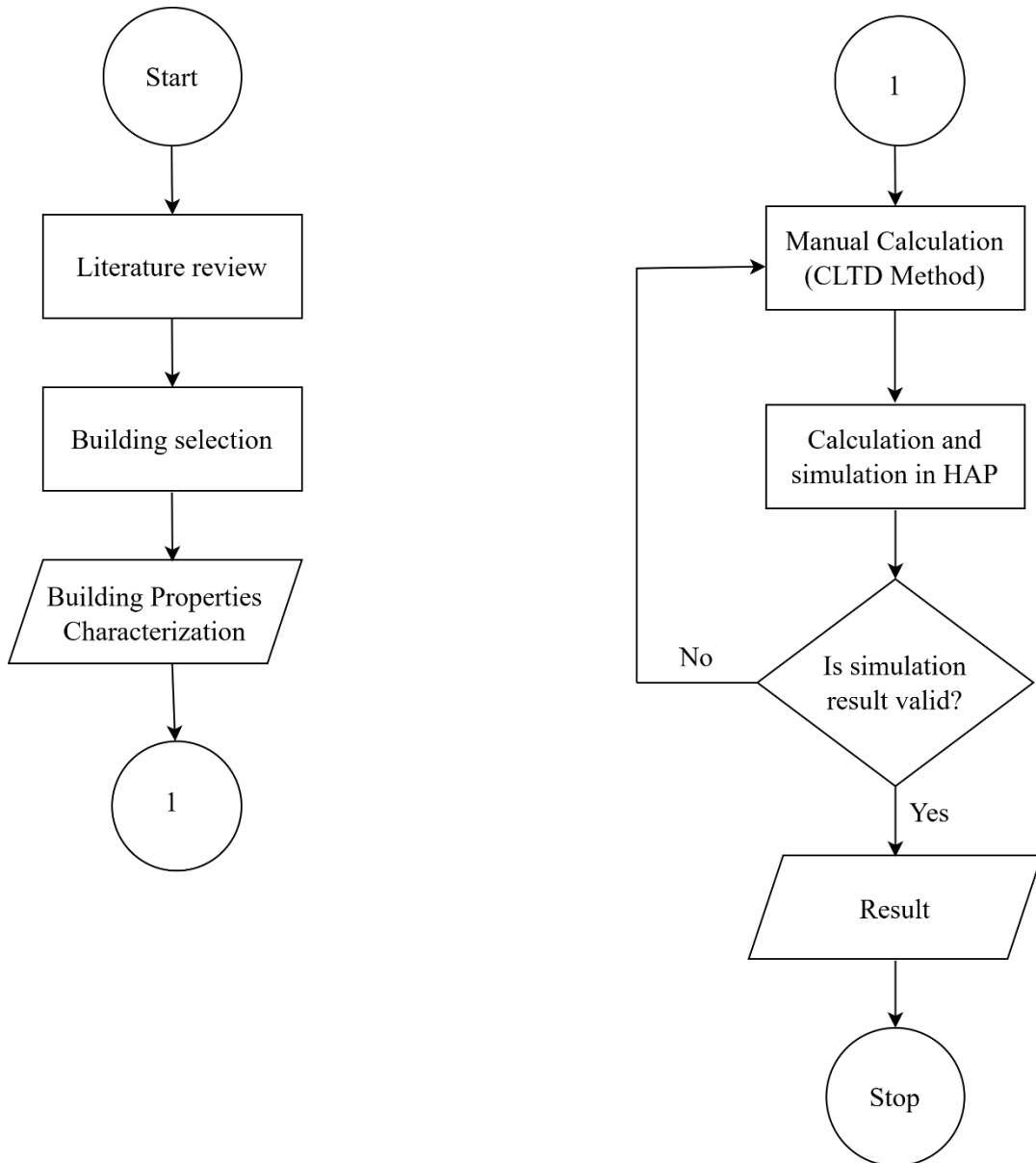


Figure 3. 1: Research flowchart

3.1 Literature review

During the literature review, various research articles related to cooling load calculations have been studied. Past literature suggests Carrier HAP can be used to study cooling load in a building.

3.2 Building Selection

Reference Building: A block building of Pulchowk campus was selected as a representative Rana Era building in Kathmandu due to the available documentation of floor plans and ease of accessibility of the building. Architectural drawings of the building were obtained from IOE consultancy. It was used to develop models in HAP.

3.3 Envelope Characterization

a. Rana Era Building:

The A block building is a load bearing structure with suspended ground floor, jack arch/timber/steel beams supported floors, timber truss supported CGI sheet roofing. Basic construction materials used are burnt bricks, mud, lime-surkhi, timber, steel I-beams. The building is 3-storey with attic roof and central courtyard. It has decorative columns in lime-surkhi mortar. Lime-surkhi plaster is the basic element for outdoor plastering and most outdoor decorative parts were carved in the plastered surface. It has decorative windows and carvings at main hall walls, ceilings and mostly decorative ceilings in the lobby and major rooms (Report on Structural Condition Assessment and Retrofit of A-Block , 2019). The wall thickness of the building varies from 960 mm - 410mm. The wall thickness data was obtained from the floor plan drawing that we obtained from IOE consultancy.

The material properties used in the buildings are as follows:

Walls: Brick with mud mortar/brick in lime-surkhi for arches

Plaster: Mud with rice husk on the inside surfaces and lime-surkhi at outer surfaces.

Beams: Timber (pine/sal-wood)

Floor finish: Telia tiles and mud/sal wood planks/marble

Roofing: Corrugated iron sheets in timber king-post trusses, wooden rafters and purlins

Door/Window: Wooden

b. Modern Building:

Modern buildings are structurally supported by columns and beams and walls are built for partitions only. Wall materials generally consist of bricks and cement plaster, floors and roofs consist of concrete. As per the Nepal Building Code, for a non-load bearing wall minimum outer wall of a building should be 230mm and internal wall should be 115mm (Department of Urban Development and Building Construction, 2081). These minimum thickness of walls were used in this study.

3.4 Manual Calculation

45 spaces (rooms) used as offices and halls of the A- block building have been used for this study. Most of the rooms were offices and few hall areas. Manual calculation of these spaces for cooling load using CLTD method was done in this study.

a. Design conditions

The design conditions were obtained from ASHARE handbook (American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc, 1980) and indoor humidity ratio was taken based on the comfort conditions required for occupants.

Indoor Temperature: 72 F

Outdoor Temperature: 89 F

Outdoor wet bulb temperature: 78 F

Indoor Humidity ratio: 50 %

Unconditioned Indoor temperature: 84 F

Humidity ratio required for infiltration calculation was obtained from psychrometric chart shown in Figure 3. 2.

Outdoor humidity ratio: 0.0228

Indoor humidity ratio: 0.0102

Determination of the expected number of air changes is based on experience and testing. Suggested values range from 0.5 ACH to 1.5 ACH for buildings ranging from "tight" to "loose" construction. (Pita, 2002)

For infiltration, ACH for Rana era building was used 1 and ACH for modern building was used 0.5.

In Kathmandu, as we can see in figure 3. 5, the maximum average dry bulb temperature which is about 76.5 F occurs in in the Month of July as summer peaks during this month and high solar radiation occurs, therefore July month was selected for the calculation and to observe the peak cooling load on the day, time of 15:00 was selected as the solar heat gain on building envelope, outdoor temperature, humidity and internal loads combinedly gives highest load around this time.

b. Material properties

For this study, wall, roof and floor materials were varied to study the load differences in rana era building and modern building.

Layer of materials in external walls of 960mm thickness in the Rana era building used for this study is shown in table. Wall type for the wall, with C4-4in common brick as primary material and stucco as secondary material and total resistance of 10.65 (ft².hr.°F)/ Btu, was used 5 as obtained from standard ASHRAE table (Appendix M).

Table 3.1: Layer of materials in 960 mm(external) wall in Rana era building

Wall layer	R-values
Outside surface resistance A0	0.33
1-in stucco	0.21
C9 -8 in common brick	1.59
C9 -8 in common brick	1.59
C9 -8 in common brick	1.59
C9 -8 in common brick	1.59
C4 – 4 in common brick	0.79
Rice husk (1 in)	2.60
Inside surface resistance E0	0.69
Total thermal resistance R, (ft ² .hr.°F)/ Btu	10.65
U-value (Btu/hr.ft ² .°F)	0.094

Layer of materials in internal wall of 900mm thickness in the Rana era building used for this study is shown in table 3.2.

Table 3.2: Layer of materials in 900 mm wall in Rana era building

Wall layer	R-value
Outside surface resistance A0	0.69
Rice husk (1 in)	2.6
C9 -8 in common brick	1.59
C9 -8 in common brick	1.59
C9 -8 in common brick	1.59
C4 -4 in common brick	0.79
C4 -4 in common brick	0.79
Rice husk (1 in)	2.60
Inside surface resistance E0	0.69
Thermal resistance, (ft ² .hr.°F)/ Btu	12.93
U-value (Btu/hr.ft ² .°F)	0.077

Layer of floor in the Rana era building used for this study is shown in table 3. 3

Table 3.3: Layer of materials in floor of the Rana era building

Floor layer		R-values	R-values
		Between framing	at framing
Bottom surface film		0.61	0.61
Wood Joist			9.06
Non reflective airspace		0.93	
Wood subfloor		0.94	0.94
Clay tile		1.11	1.11
Top surface film		0.61	0.61
		4.2	12.33
	U(=1/R)	0.24	0.08
With 10% framing		Ua	Ub
	$U_{av}=U_a*0.9+U_b*0.1$	0.22	

Table 3.4: Layer of materials in roof of the Rana era building

Roof materials	R-value
Outside surface resistance	0.17

22-gauge steel roof deck	0.00
4-in wood	3.77
Airspace	0.91
Acoustic ceiling	1.78
Inside surface resistance	0.61
Total resistance R, (ft ² .hr.°F)/ Btu	7.24
U-value (Btu/hr.ft ² .°F)	0.14

Layer of roof in the Rana era building used for this study is shown in table 3.4

Layer of materials in external wall of 230 mm thickness in the modern building used for this study is shown in table 3.5. Wall type for the wall, with C8-8in common brick as primary material and plaster as secondary material and total resistance of 3.25 (ft².hr.°F)/ Btu, is used 5 as obtained from standard ASHRAE table attached in appendix.

Table 3.5: Layer of materials in external wall (230 mm) of the modern building

Wall layer	R-value
Outside surface resistance A0	0.33
1/2-in gypsum plaster	0.32
C9 -8 in common brick	1.59
1/2-in gypsum plaster	0.32
Inside surface resistance E0	0.69
Total thermal resistance R, (ft ² .hr.°F)/ Btu	3.25
U-value (Btu/hr.ft ² .°F)	0.31

Layer of materials in internal wall of 115 mm thickness in the modern building used for this study is shown in table.

Table 3.6: Layer of materials in internal wall (115 mm) of modern building

Partition wall	
Wall layer	R-value
Outside surface resistance A0	0.69
1/2-in gypsum plaster	0.32
C4 -4 in common brick	0.79
1/2-in gypsum plaster	0.32
Inside surface resistance E0	0.69

Total thermal resistance R, (ft ² .hr.°F)/ Btu	2.81
U-value (Btu/hr.ft ² .°F)	0.36

Layer of floor in the modern building used for this study is shown in table

Table 3.7: Layer of floor material in modern building

Floor layer	R-value
Outside resistance	0.61
Carpet with rubber pad, R-1.23	1.23
4 in HW Concrete	0.29
Airspace	0.91
Gypsum board	0.32
Inside surface resistance	0.61
Total resistance, (ft ² .hr.°F)/ Btu	3.97
U – value (Btu/hr.ft ² .°F)	0.25

Layer of roof in the modern building used for this study is shown in table

Table 3.8: Layer of roof in modern building

Roof	R-value
Outside resistance	0.17
Built-up roofing	0.33
3/4-in HW stucco	0.08
4 in. HW concrete	0.29
Airspace	0.91
1/2-in gypsum board	0.45
Inside resistance	0.61
Total resistance, (ft ² .hr.°F)/ Btu	2.84
U – value (Btu/hr.ft ² .°F)	0.35

The R-values were obtained from standard ASHRAE tables present in appendix of this report.

U value of glass window used was 0.89 Btu/hr.ft².°F for wood frame single glazing glass window.

Shading Coefficient (SC) for window was used as 0.94

Cooling load factor (CLF) used for window was 0.24

For wooden door, U-value used was 0.47 Btu/hr.ft².°F

c. Internal load generating elements

People, lighting, and equipment are the internal loads that need to be accounted for cooling load calculations. Number of people, lights and equipment's numbers were obtained from field visit. Since the building is administrative building, the degree of activity of people was taken as seated, very light work, and data required for load calculations were obtained from standard tables from ASHRAE (attached in appendix).

Using the data available in appendix and formulas from equation 1-12, cooling load was calculated.

3.4 Load calculation and simulation in HAP

HAP software was used for calculating load requirements in space which consider heat flow from all elements of the building like walls, windows, roofs, people, infiltration, equipment, lighting elements and more. The software was also used for simulating building's energy consumption over an entire year. In this study we determined the instantaneous load at July 15:00 to compare the HAP result with manual CLTD method and simulate the buildings' energy consumption.

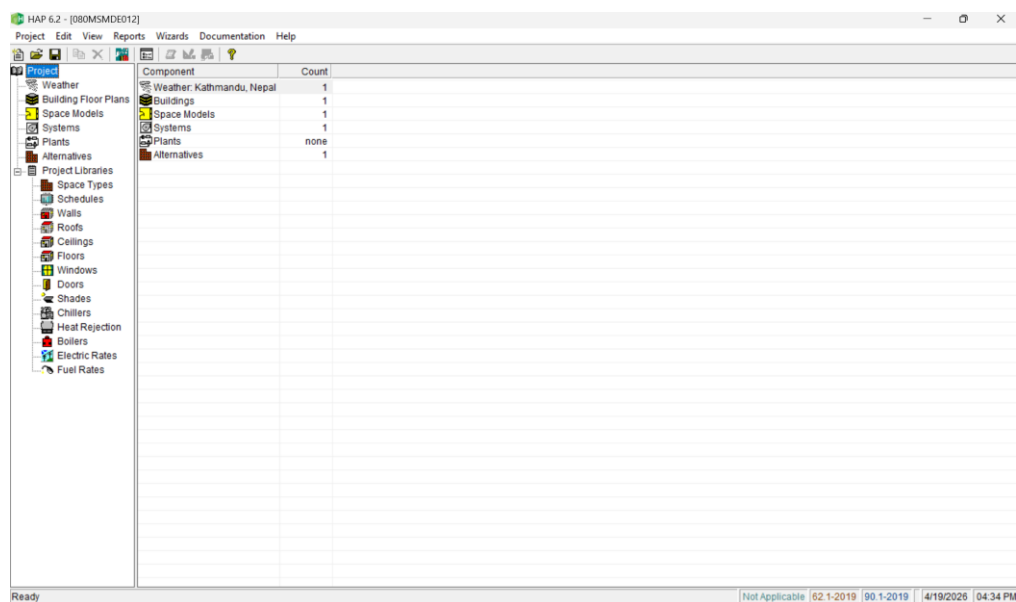


Figure 3. 3: HAP 6.2 Initial Interface

A. Load calculation

i. Weather Properties

HAP software inbuilt library does not have weather stations for any location in Nepal. So the design parameters were used as per standard design guidelines from ASHRAE handbook.

Also, the simulation weather data necessary for energy simulation was obtained from energy plus website (EnergyPlus, n.d.), and imported into the HAP file

The screenshot shows the 'Weather Properties - [Kathmandu, Nepal]' dialog box. It has four tabs: 'Design Parameters' (selected), 'Design Temperatures', 'Design Solar', and 'Simulation'. The 'Design Parameters' tab contains the following fields:

- Station: **Kathmandu, Nepal** (with a 'Select...' button)
- Latitude: **27.70** °N
- Elevation: **4388.0** ft
- Longitude: **85.30** °E
- Climate Zone: **5A - Cool Humid** (dropdown)
- Time Zone: **5.5** hrs E of GMT
- Data Source: **User Defined**
- Summer Condition: **User Defined** (dropdown)
- Outdoor Air CO2 Level: **420** ppm
- Summer Design DB: **89.0** F
- Average Ground Reflectance: **0.20**
- Summer Coincident WB: **78.0** F
- Soil Conductivity: **0.800** BTU/(hr ft F)
- Summer Daily Range: **25.0** F
- Design Clg Calculation Months: **Jan** to **Dec** (dropdowns)
- Winter Condition: **User Defined** (dropdown)
- Daylight Savings Time: Yes No
- Winter Design DB: **33.0** F
- DST Begins: **March** **4** (dropdown and text)
- Winter Coincident WB: **27.3** F
- DST Ends: **Nov** **1** (dropdown and text)

At the bottom, there are buttons for 'Save As Default Weather Data', 'OK', 'Cancel', and 'Help'.

Figure 3. 4: Design parameters used in HAP

Figure 3. 4 shows the design parameters used in HAP, for the comparison study these design parameters and the parameters used for manual calculations were kept same. Outdoor air CO₂ level, average ground reflectance, soil conductivity are the default values from HAP that were selected based on the location of the site.

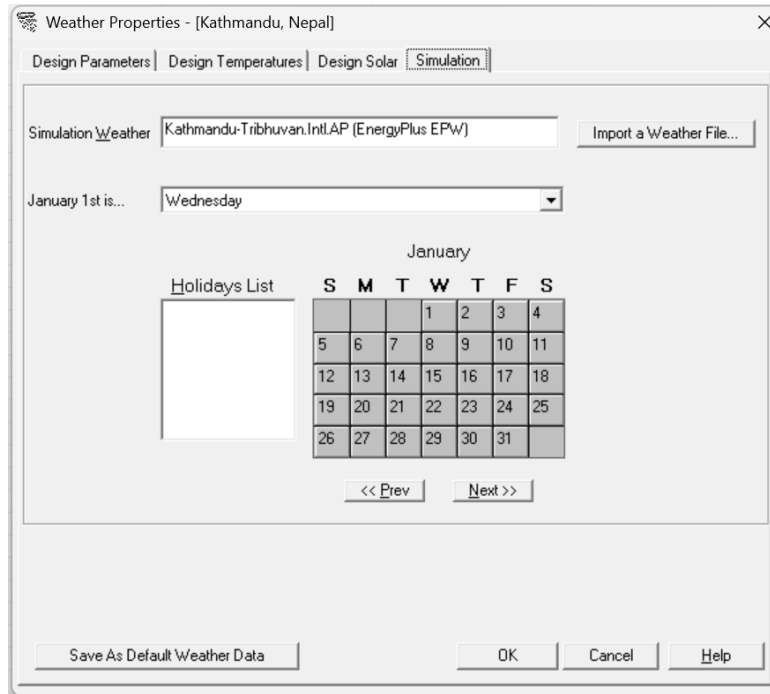


Figure 3. 5: Simulation panel on weather properties of HAP

The design temperature panel contains information about cooling design day temperature. The design solar panel summarizes the peak solar fluxes for cooling design days. Simulation panel shown in figure 3. 5 contains information about the weather data used in the project and was used to define the operating calendar for the energy model.

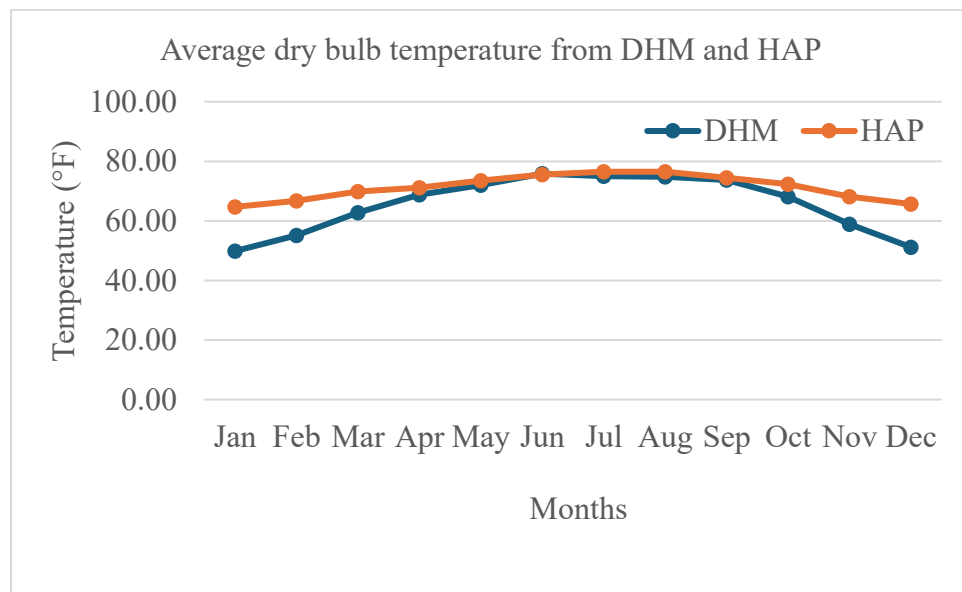


Figure 3. 6: Average dry bulb temperature from DHM and HAP

Figure 3. 6 shows the plot for average dry bulb temperatures from data in HAP and actual data obtained from Department of Hydrology and Metrology (DHM)

ii. Geometry model

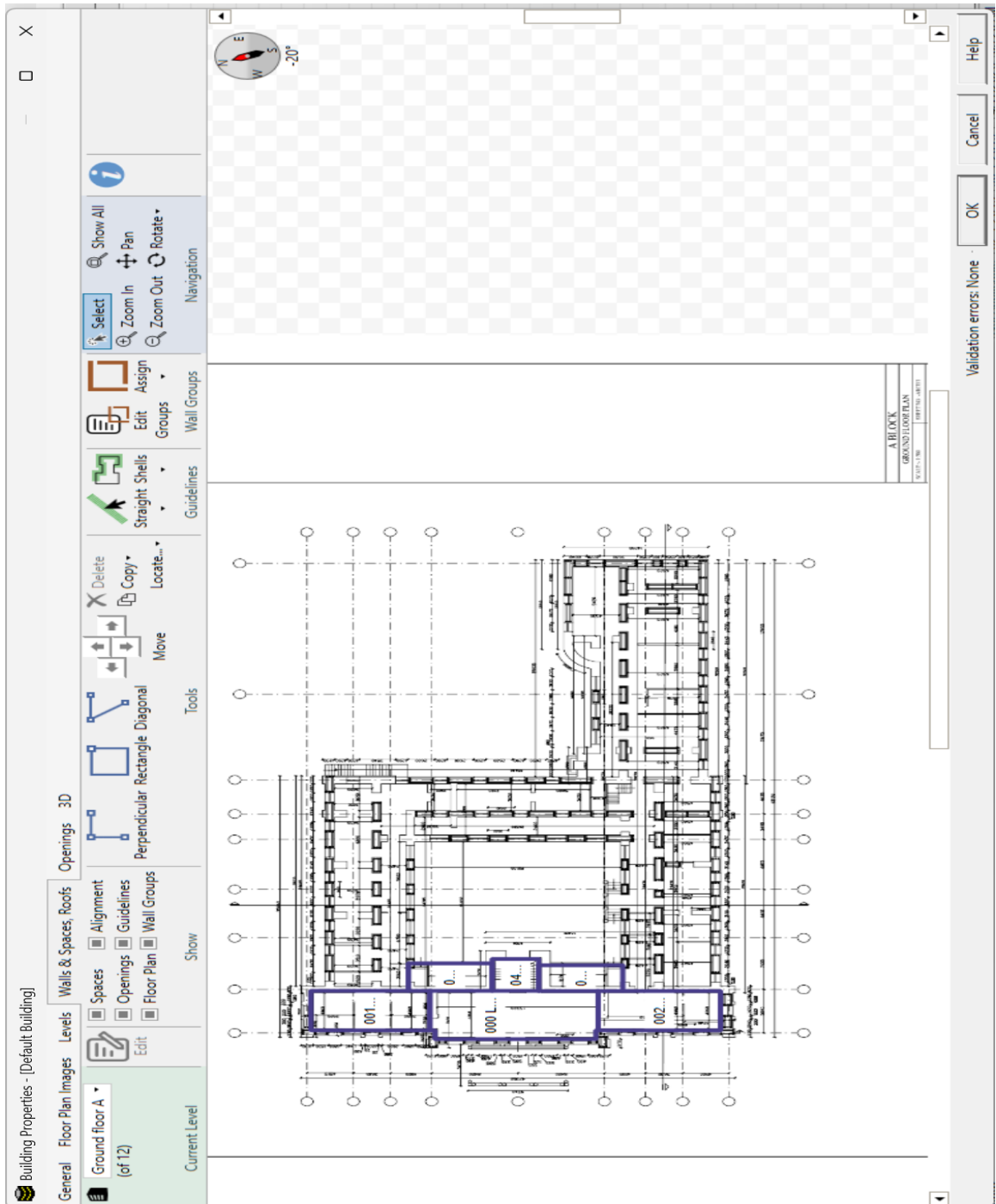


Figure 3. 7: Ground floor plan imported into HAP

Floor plan was imported into the HAP. Based on the floor plan building geometry was developed. Figure 3. 7 shows the floor plan in HAP used to draw the outline of wall. Floor plan drawings of the building are attached in the appendix. Internal area of both modern and rana era building were taken same for this study.

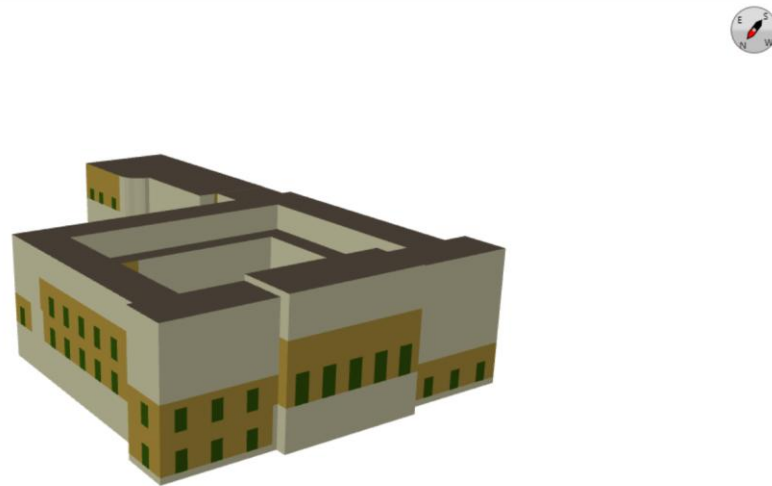


Figure 3. 8: 3D geometry for the Rana era building developed in HAP

Figure 3. 8 shows the 3D geometry developed for the Rana era building, the dimensions necessary were obtained from the architectural drawings. The grey area in the figure symbolizes the non-conditioned spaces in the model, where the load calculation are not done as the rooms do not lie in the category of offices and conference room area where air conditioning is necessary.

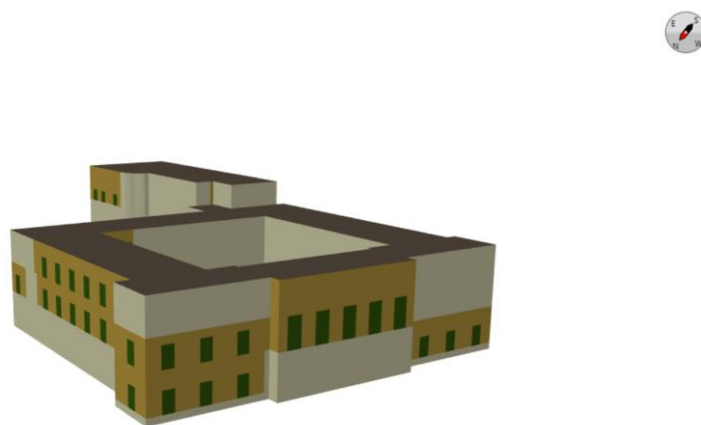


Figure 3. 9: 3D geometry for modern building developed in HAP

Figure 3. 9 shows 3D geometry for modern building developed in HAP. Attic floor was removed from the model based on the assumption that modern buildings do not have attic. The grey area in the figure symbolizes the non-conditioned spaces in the model, where the load calculation were not done as the rooms do not lie in the category of offices and conference room area where air conditioning is necessary.

iii. Defining material properties

Building properties like walls, windows, doors were defined in the project library.

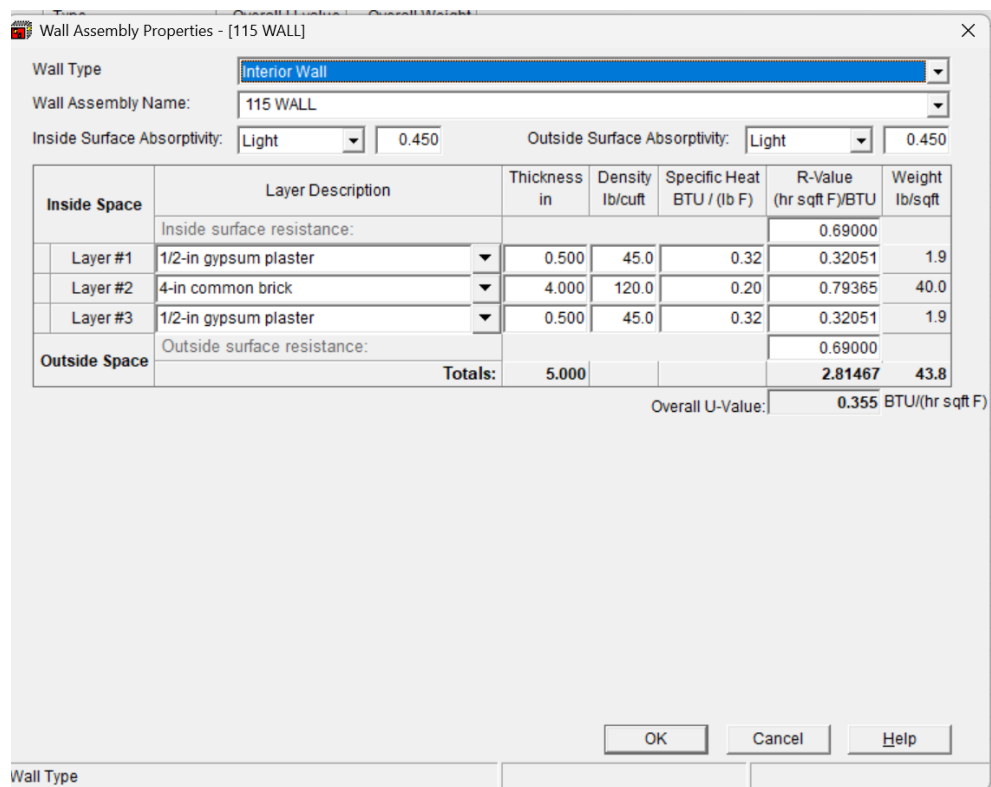


Figure 3. 10: Wall properties dialog box in HAP

Figure 3. 10 shows the wall properties dialog box in HAP. Here the different layers of wall were selected as per the building construction requirements and used in manual calculation. HAP calculates U-values based on the material layer we provide, which was also used for load calculations.

iv. Space Model Properties

Space generated in geometry model was provided with information such as purpose of space, lighting required in space, people present in space, equipment used in space.

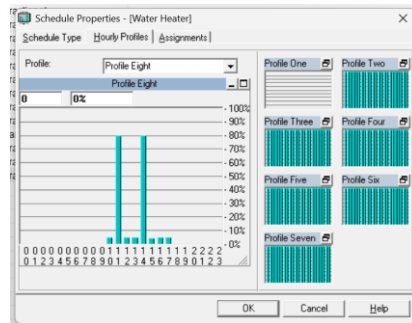


Figure 3. 11: Water heater schedule

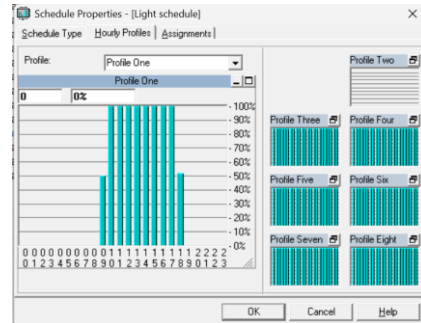


Figure 3. 12: Lighting schedule

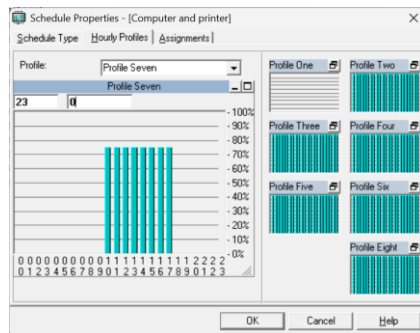


Figure 3. 13: Computer and printer schedule

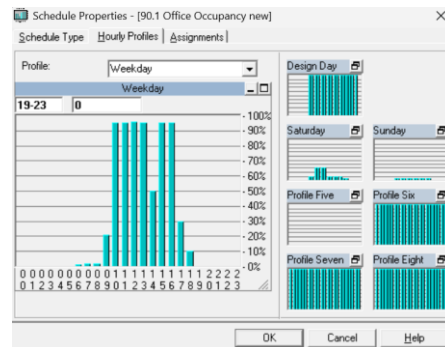


Figure 3. 14: People schedule

Figure 3. 10, 3. 11, 3. 12, 3. 13 shows the different schedules used in HAP for better information on actual condition of the building for cooling load requirements. The water heater was scheduled to run 80% at 11th and 14th hour, the lights were scheduled to operate at 50% for 9th and 18th hour and 100% for 10th -17th hours. The computers and printers were

scheduled to operate from 10-17th hours as the printers are not operated continuously, it was scheduled to operate at 75 % of its capacity.

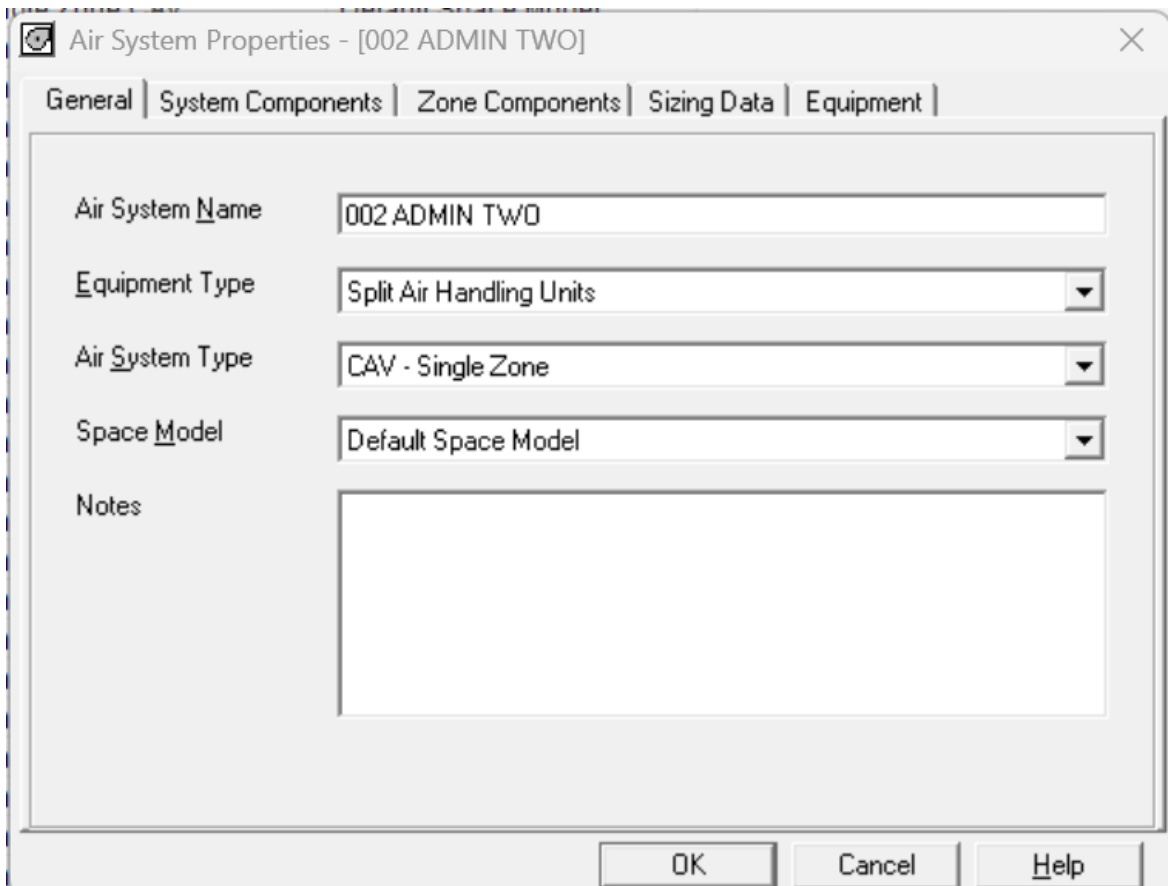


Figure 3. 15: System properties dialogue box in HAP

Figure 3. 15 shows the air system properties panel in HAP, here the air system type was defined. For this study we selected split air handling units as equipment type and single zone constant air volume air system type for energy modelling.

HAP program was run in the alternative section. And gave load output and energy modelling results.

Zone Heat Balance Summary for 008 ACADEMIC ADMIN 2 (In Alternative: Default Alternative)		
Project: 080MSMDE012		04/10/2026
Prepared by: 080MSMDE012		10:59 AM

Table 1. Heat Balance Loads for Zone 008 ACADEMIC UNIT 3

Zone Heat Balance Component	DESIGN COOLING - JULY 15:00			DESIGN HEATING		
	OA DB / WB 89.0 F / 78.0 F			OA DB / WB 33.0 F / 27.3 F		
	OCCUPIED T-STAT 72.0 F			OCCUPIED T-STAT 70.0 F		
	Details	Sensible [BTU/hr]	Latent [BTU/hr]	Details	Sensible [BTU/hr]	Latent [BTU/hr]
Exterior Wall Convection	133 sqft	538	-	133 sqft	894	-
Roof Convection	0 sqft	0	-	0 sqft	0	-
Window Convection	0 sqft	0	-	0 sqft	0	-
Skylight Convection	0 sqft	0	-	0 sqft	0	-
Door Convection	67 sqft	494	-	67 sqft	624	-
Floor Convection	225 sqft	638	-	225 sqft	339	-
Interior Wall Convection	386 sqft	1151	-	386 sqft	421	-
Ceiling Convection	225 sqft	837	-	225 sqft	645	-
Overhead Lighting Convection	0 W	0	-	0 W	0	-
Task Lighting Convection	80 W	120	-	0 W	0	-
Electric Equipment Convection	0 W	0	-	0 W	0	-
People Convection	4	294	820	0	0	0
Infiltration	16 CFM	252	594	18 CFM	616	0
Miscellaneous Equipment	-	1087	0	-	0	0
Air Internal Energy Change	-	0	-	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
		5409	1414		3539	0
Key:	Positive values are cooling loads Negative values are heating loads			Positive values are heating loads Negative values are cooling loads		

- Note 1:** Surface convection line items show the combined effects of conductive heat gain to the surface and radiative heat gains absorbed at the surface which are then convected to room air.
- Note 2:** Lighting, equipment, and people line items include only the direct convective heat gain from the heat source to the room air. The radiative portion of the heat gain is first absorbed by surfaces in the room and then later convected from the surface to the air. Therefore the effect of the radiative portion of the heat gain is found in the surface convection line items.
- Note 3:** Solar heat gain is absorbed by surfaces in the room, re-radiated to other surfaces, and finally convected from the surfaces to room air. Therefore, the effect of solar heat gain is found in the surface convection line items.

Figure 3. 16: Design zone heat balance result window in HAP

Figure 3. 16 shows the zone heat balance load result obtained from HAP. Here, we can see the heat balance summary for 008 Academic admin. The total sensible and latent design cooling load at July 15:00 is 5409 BTU/hr and 1414 BTU/hr respectively.

B. Simulation

In simulation section, HAP used the .epw simulation weather file and run simulation for energy consumption by the system designed.

3.5 Result

The simulation results generated by HAP and manual calculation for the two building models were systematically compared and analyzed.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Cooling load Obtained from CLTD method

Figure 4.1 shows the comparison between cooling loads in modern and Rana era building on the ground floor for data obtained from CLTD method. Total cooling load in ground floor in Rana era building is 13.19 Tons and that in modern building is 14.44 Tons which is 9.5 % higher than the load in Rana era building. The increase in cooling load can be observed across most of the spaces on the ground floor, suggesting that the modern building has generally greater heat gains. These differences are due to different heat transfer characteristics of walls and floors and infiltration in the buildings. Cooling load also depends on area of the space, so the larger area spaces have comparatively higher loads.

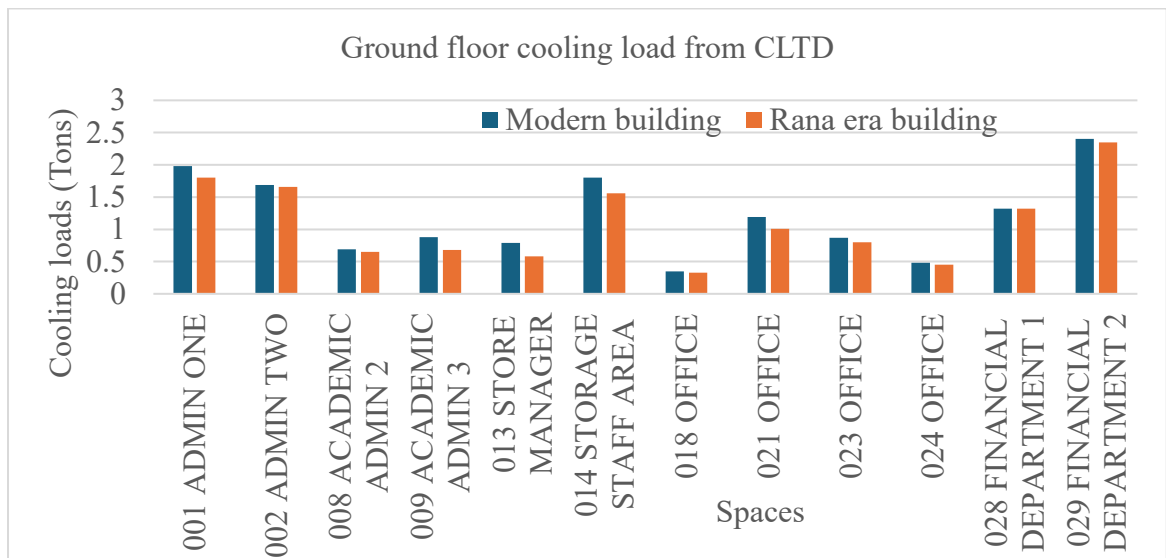


Figure 4. 1: Cooling load in ground floor of modern and Rana era building from CLTD

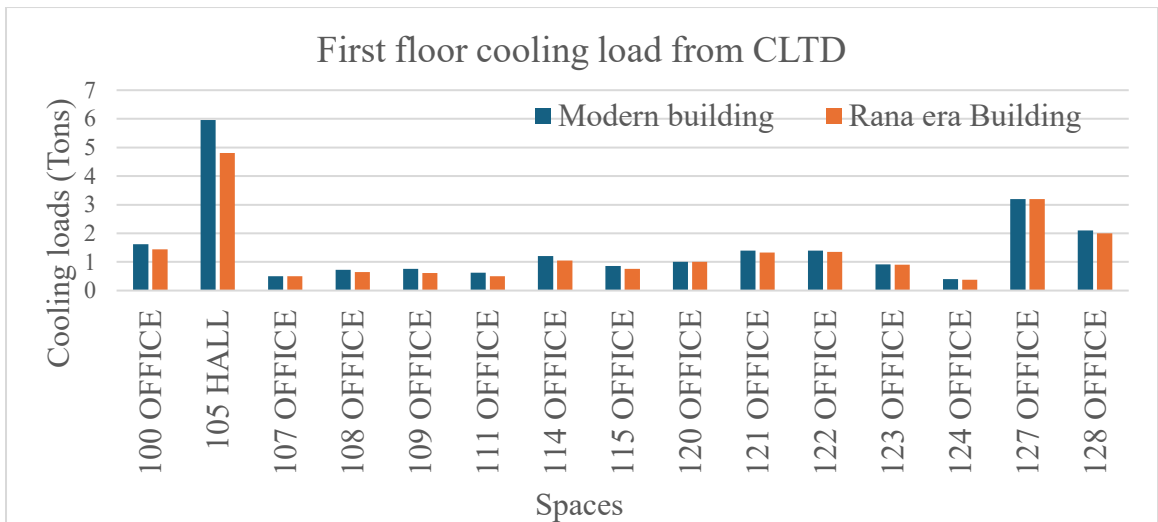


Figure 4. 2: Cooling load in first floor of modern and Rana era building from CLTD

Figure 4. 2 shows the comparison between cooling loads in Rana era and modern building on the first floor for data obtained from CLTD method. We can see that the cooling load is notably higher in modern building which is likely due to comparatively lower U- values of walls, floors and ceilings in rana era building. Total cooling load in first floor in Rana era building is 20.48 Tons and that in modern building is 22.66 Tons which is 10.6 % higher than the load in Rana era building. 105 HALL has higher cooling loads than others due to large room area, large external wall area, and higher number of people in the room.

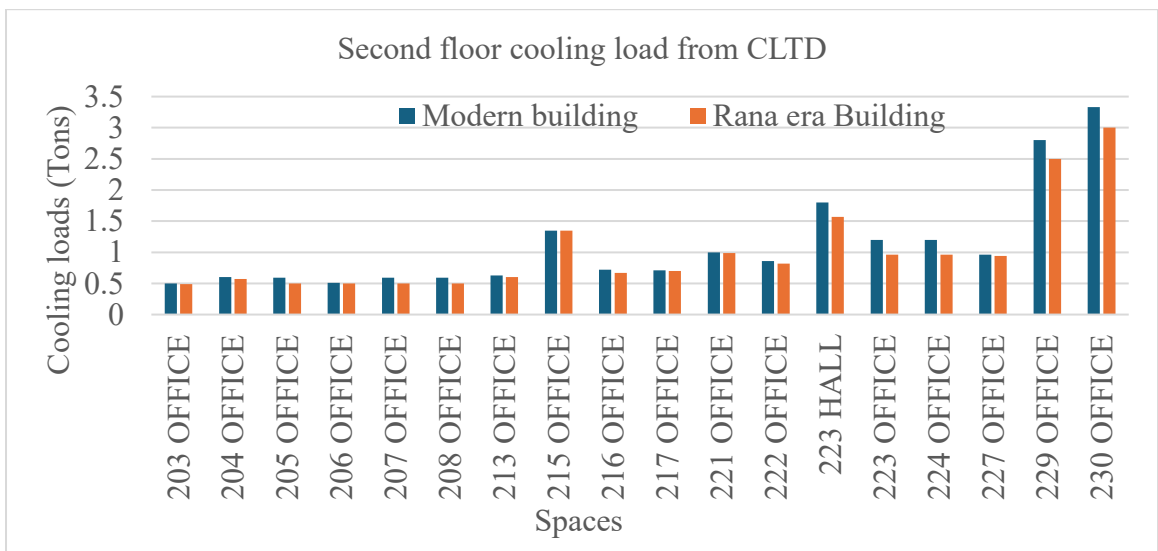


Figure 4. 3: Cooling load in second floor of Rana era and modern building from CLTD

Figure 4. 3 shows the comparison between cooling loads in Rana era and modern building on the second floor for data obtained from CLTD method. Total cooling load in second floor in Rana era building is 18.12 Tons and that in modern building is 19.94 Tons which is 10 % higher than the load in Rana era building. Cooling load also depends on area of the space, 229 office and 230 office having larger area in comparison have comparatively higher loads.

4.2 Cooling load from Simulation (HAP)

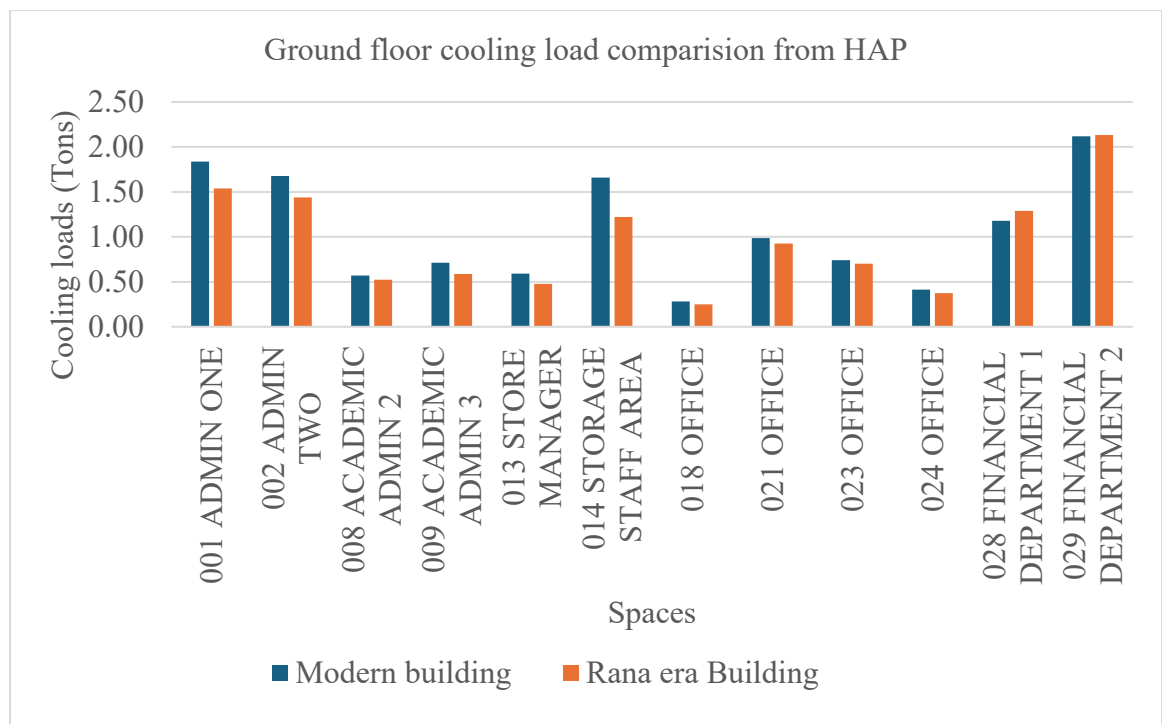


Figure 4. 4: Cooling load in ground floor of modern and Rana era building from HAP

Figure 4. 4 shows the comparison between cooling loads in modern and Rana era building at ground floor obtained from HAP. Total cooling load in ground floor in Rana era building is 11.46 Tons and that in modern wall is 12.77 Tons which is 11.4% higher than the load in Rana era building.

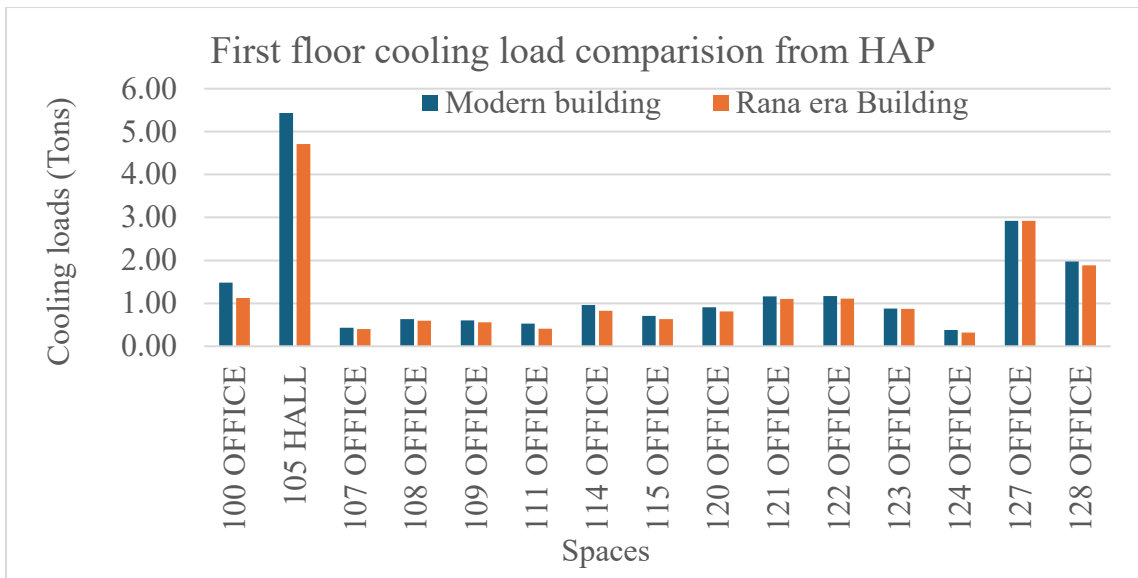


Figure 4. 5: Cooling load in first floor of Rana era and modern building from HAP

Figure 4. 5 shows the comparison between cooling loads in first floor in Rana era and modern building obtained from HAP. Total cooling load in first floor in Rana era building is 18.29 Tons and that in modern building is 20.19 Tons which is 10.4% higher than the load in Rana era building.

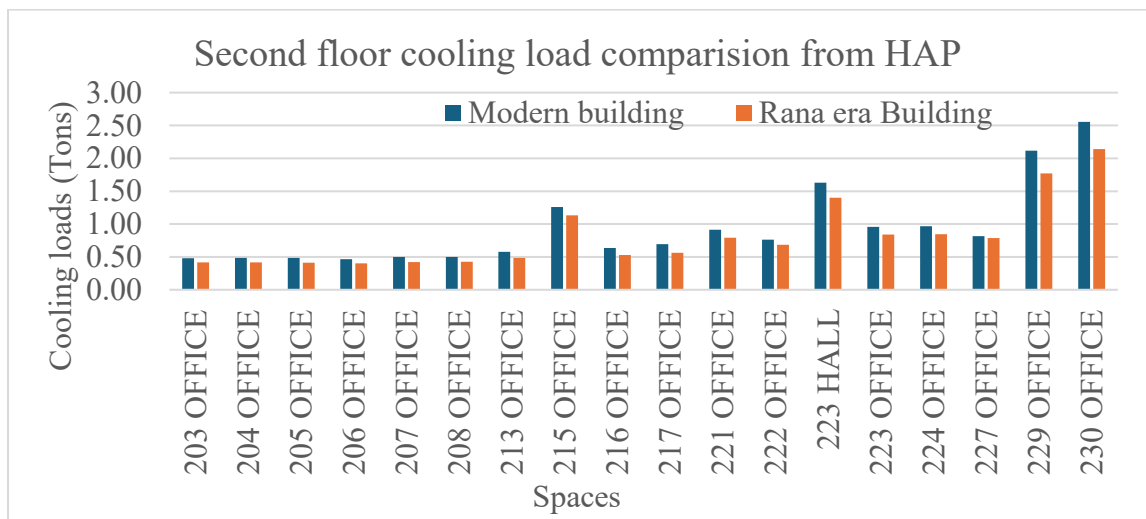


Figure 4. 6: Cooling load in second floor of Rana era and modern building from HAP

Figure 4. 6 shows the comparison between cooling loads at first floor in Rana era and modern building. Total cooling load in first floor of Rana era building is 14.46 Tons and that of modern building is 16.79 Tons which is 16.1 % higher than the load in Rana era

building. The second floor has higher percentage change than first and second floor due to the use of attic in Rana era building and direct exposure of rooms in second floor to roof.

4.2 Comparison of Result from CLTD method and HAP

4.2.1 Modern building

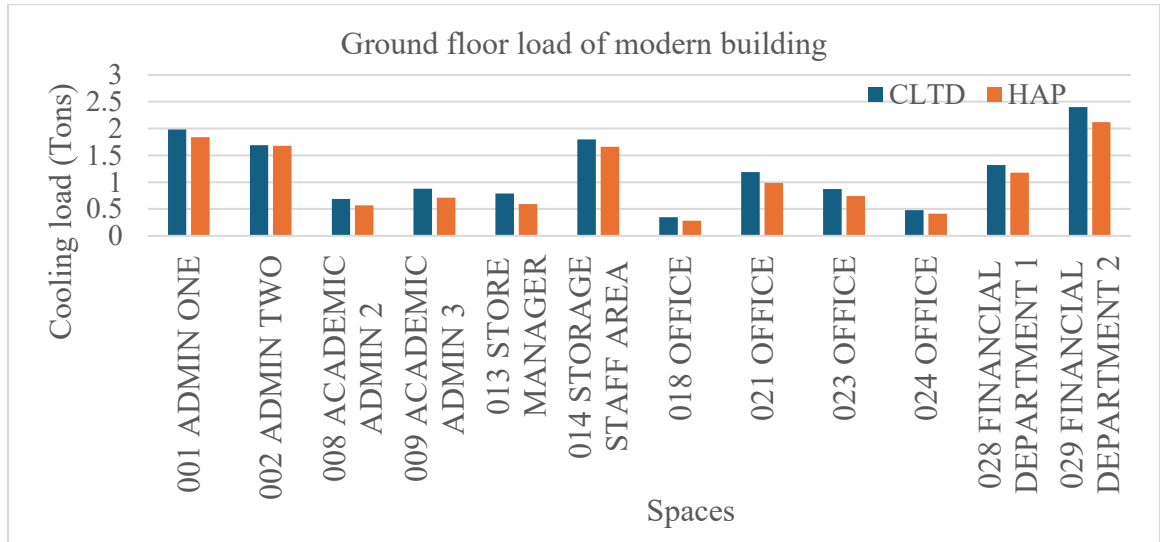


Figure 4. 7: Ground floor cooling load of modern building from CLTD and HAP

Figure 4. 7 compares the ground floor cooling loads calculated by CLTD and HAP. The results show that the two methods follow the same overall trend, although HAP (12.77 Tons) generally predicts slightly lower values than CLTD (14.44 Tons) which is about 11.6% lower.

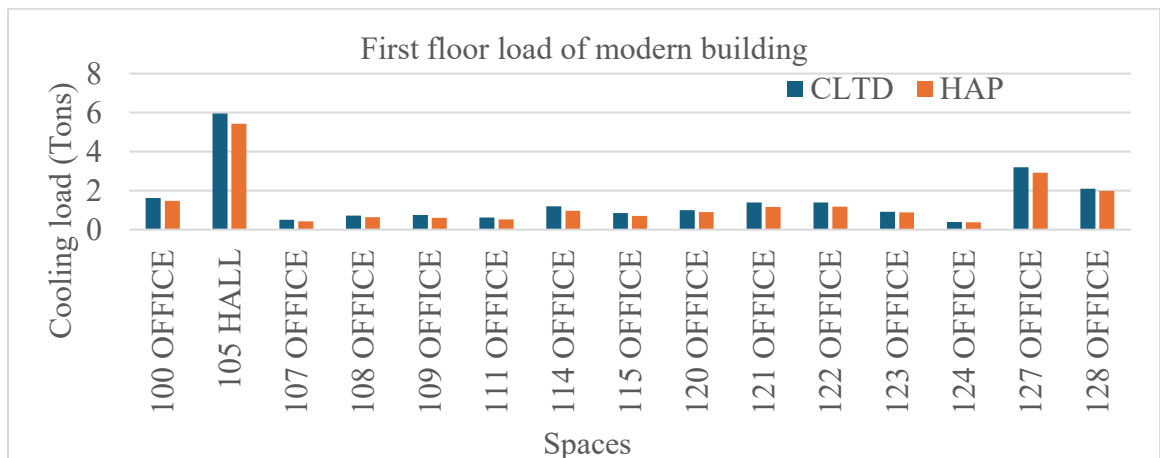


Figure 4. 8: First floor cooling load of modern building from CLTD and HAP

Figure 4. 8 compares the first-floor cooling loads of the modern building calculated by the CLTD and HAP methods. The results show that both methods produce similar trends. Here, HAP gives a total cooling load of 20.19 Tons which is 10.9% lower than CLTD gives which is 22.66 Tons.

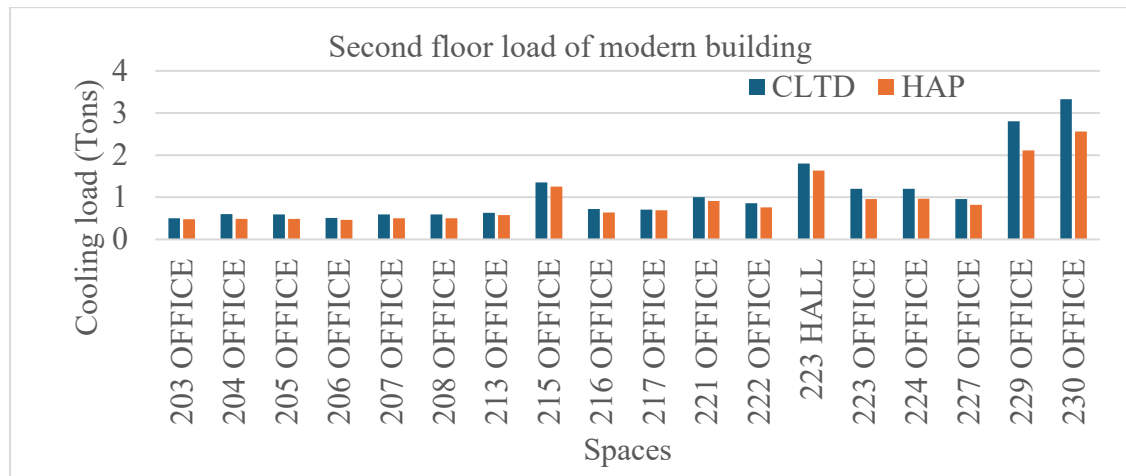


Figure 4. 9: Second floor cooling load of modern building from CLTD and HAP

Figure 4. 9 compares the second-floor cooling loads of the modern building calculated by the CLTD and HAP methods. The results show that both methods produce similar trends. Here, HAP gives a total cooling load of 16.9 Tons which is 15.8% lower than CLTD gives which is 19.94 Tons.

4.2.2 Rana era building

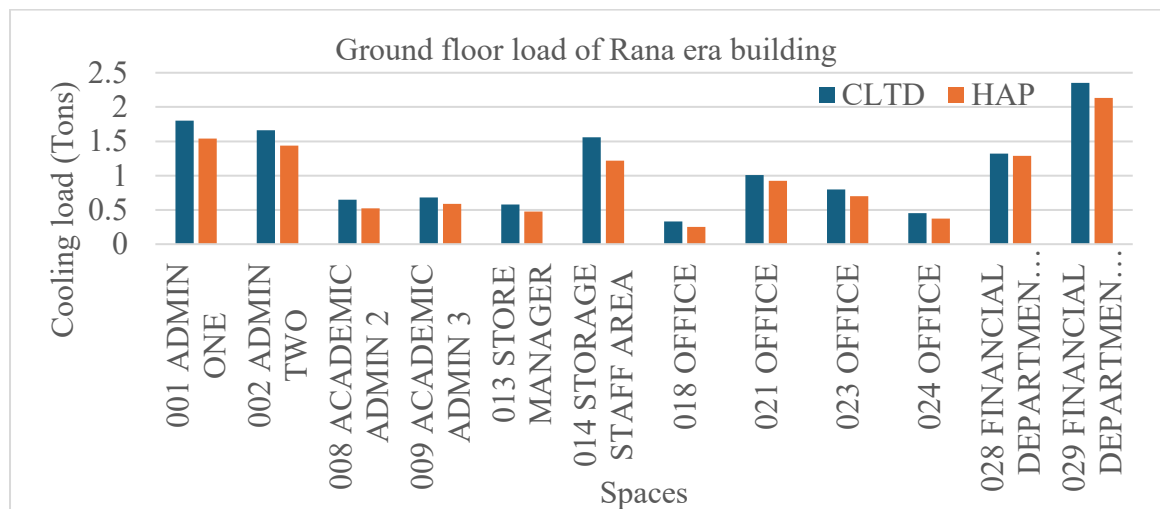


Figure 4. 10: Ground floor cooling load of Rana era building from CLTD and HAP

From figure 4. 10, we can see cooling load for Rana era building from both (CLTD and HAP) methods give similar results and follow the same trend, although CLTD values are slightly higher. The total cooling load of the ground floor is 13.19 tons by CLTD and 11.46 tons by HAP which is lower by 13% than by CLTD method, indicating that CLTD gives a more conservative estimate.

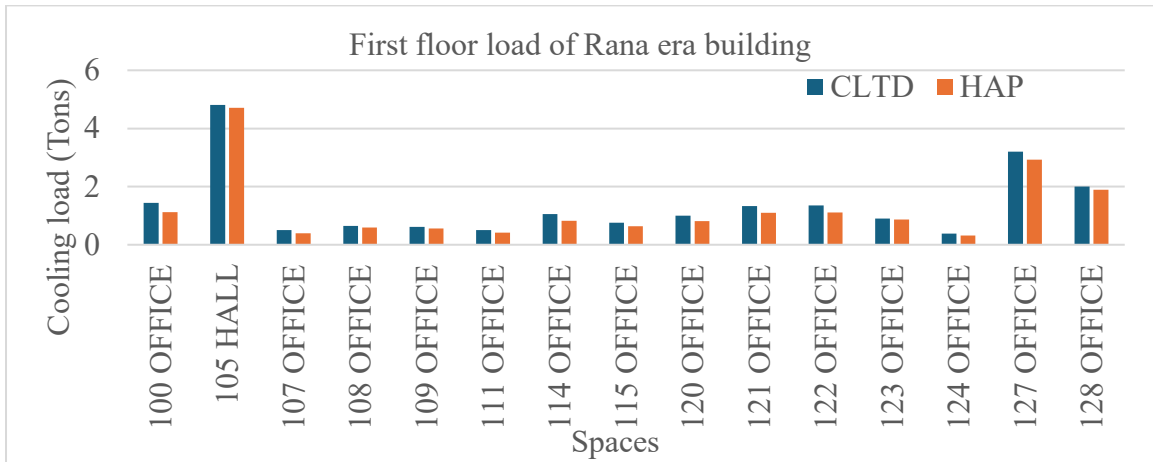


Figure 4. 11: First floor cooling load of Rana era building from CLTD and HAP

Figure 4. 11 compares the cooling load in spaces of first floor of the Rana era building calculated by CLTD and HAP. Overall, the two methods follow the same trend. The total cooling load in the floor is 20.48 by CLTD and 18.29 tons by HAP which is about 10.7% lower than from CLTD.

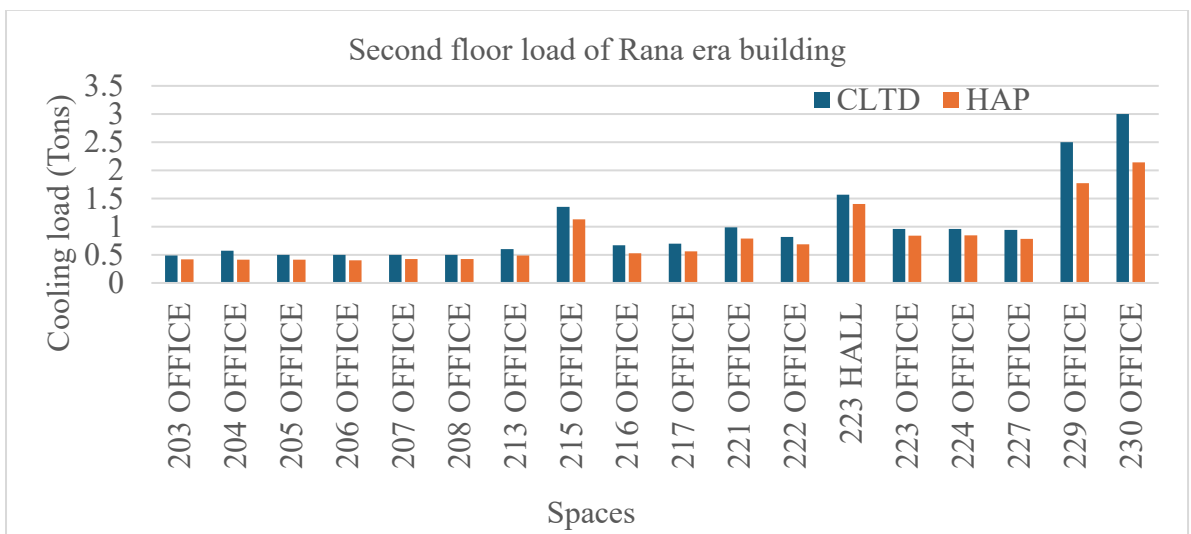


Figure 4. 12: Second floor cooling load of Rana era building from CLTD and HAP

Figure 4. 12 compares the cooling load in spaces of second floor of the Rana era building calculated by CLTD and HAP. The total cooling load on the second floor is 18.12 tons by CLTD and 14.47 tons by HAP, so the load from HAP is lower by 20.2%.

The cooling load results obtained from HAP are comparable to those calculated using the CLTD method, with 10-20% variations observed between the two approaches. The similarity in the overall trend and magnitude of the loads suggests that HAP is a reliable tool for cooling load estimation. In addition, HAP is suitable for load studies and energy analysis because it accounts for hourly variations and building operating conditions, making it useful for more detailed cooling load assessment and design.

4.3 Results

4.3.1 Cooling Load components in Rana era building.

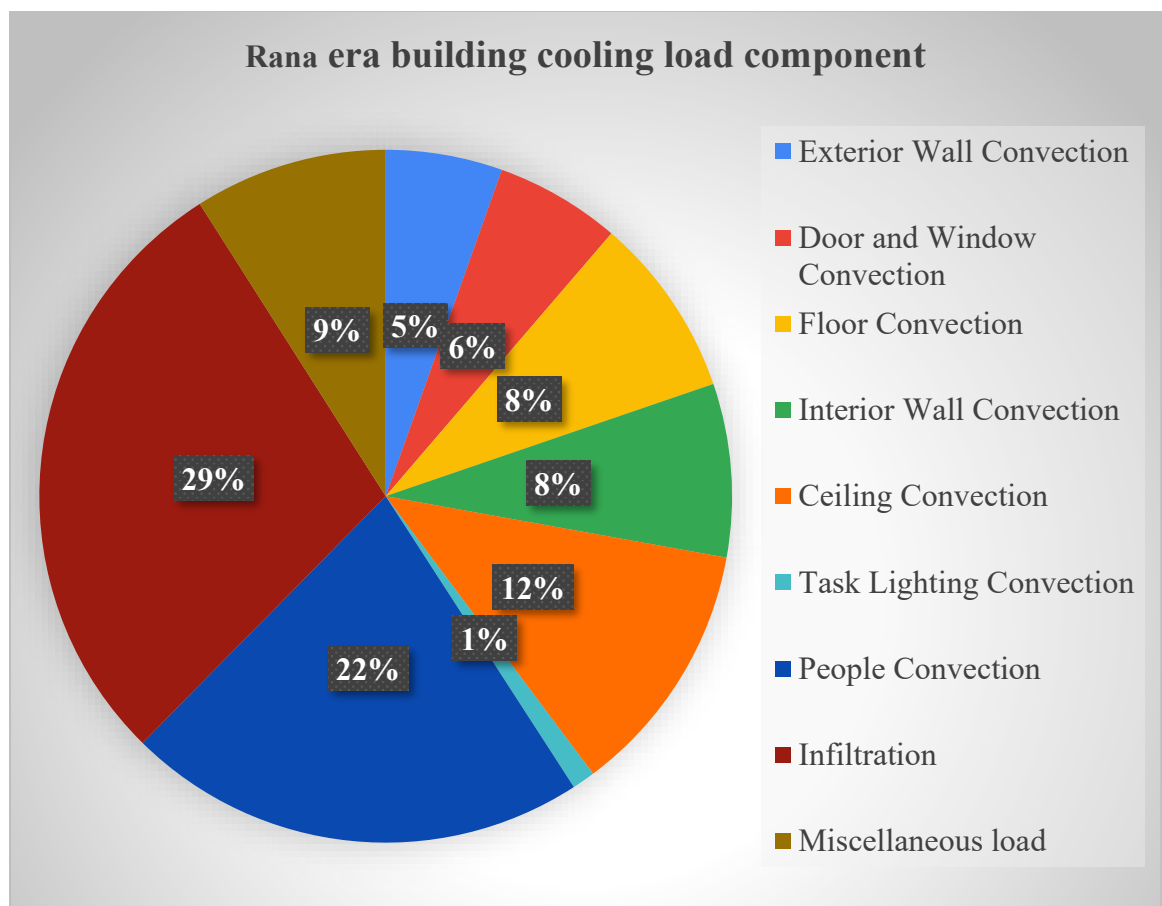


Figure 4. 13: Cooling load components in Rana era building

Figure 4. 13 shows the total cooling load distribution at selected cooling design hour in Rana era building which totals to 44.96 Tons. 29% of the load is contributed by infiltration, 9% by miscellaneous load (Computers, printer, water dispenser), 22% by people, 1% by lighting, 12% by ceiling, 8% by interior wall, 8% by floor, 6% by door and window and 5% by exterior wall.

4.3.2 Cooling Load components in Modern building

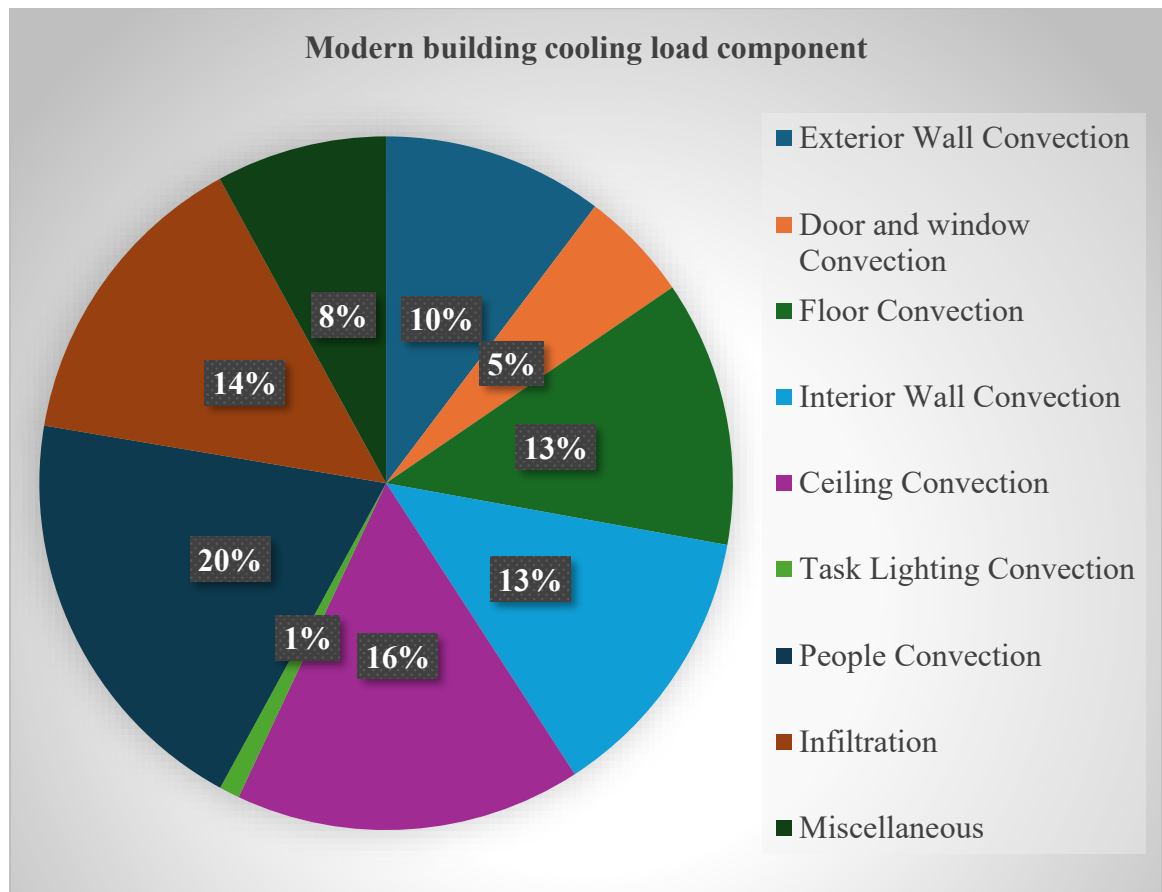


Figure 4. 14: Cooling load components in modern building

Figure 4. 14 shows the total cooling load distribution at the design condition in modern building which totals to 50.76 Tons. 14% of the load is contributed by infiltration, 8% miscellaneous load (Computers, printer, water dispenser), 10% by exterior wall, 5% by door and window, 13% by interior wall, 13% by floor, 16% by ceiling, 1% by lighting and 20% by people.

4.3.3 Comparison between cooling loads components in between Modern and Rana era buildings

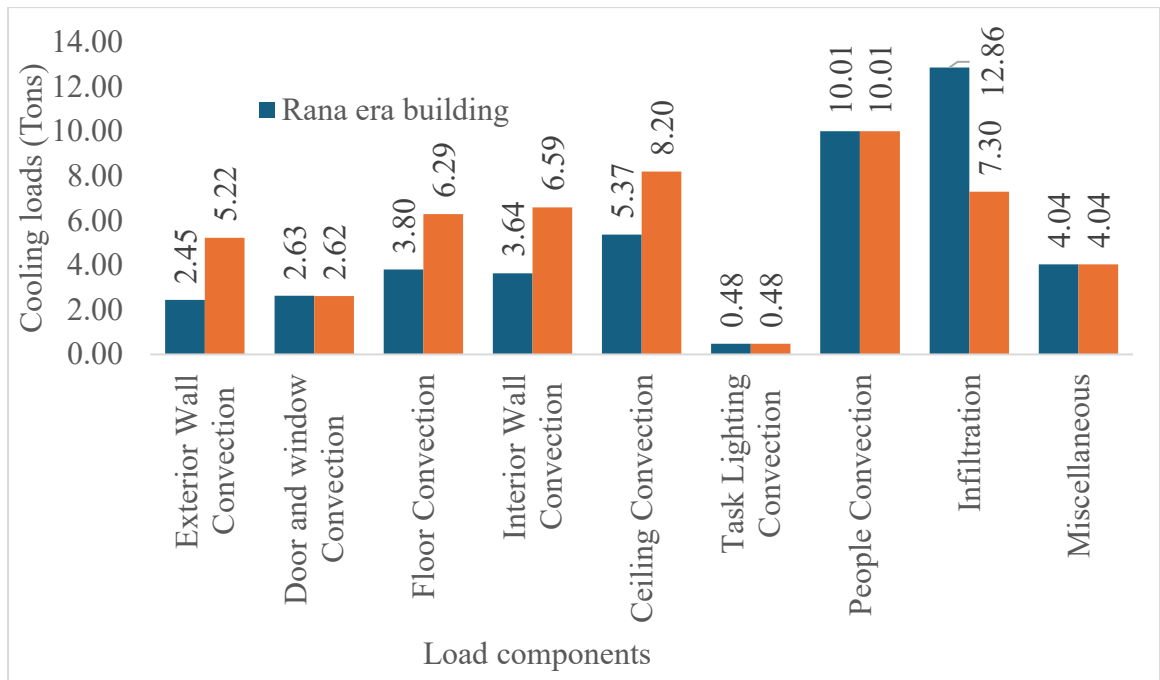


Figure 4. 15: Comparison of components of cooling load in between Rana era and modern building

Figure 4. 15 shows the comparison of components of cooling load in Rana era and modern building. Total cooling load in the modern building, 50.76 Tons is higher than the load in Rana era building, 44.96 Tons, by 12.88 %. The door and window convection, task lighting convection, people convection and miscellaneous are constant for both types of building as these were kept constant in both the buildings. Exterior wall convection is lower in Rana era building because the walls of the building are thicker which results in lower U-value and higher thermal mass and thermal time lag effect than the walls in modern building. Floor, interior wall and ceiling convection are lower in Rana era building as wall and roofs have lower U-value resulting slow release of heat from these components than in modern building. Modern buildings have lower infiltration load as the airtightness is higher in modern building. Although the infiltration load is higher in Rana era building, the combined effect of exterior wall, floor, interior wall and ceiling load overcomes the infiltration load and causes the Rana era building to have lower cooling load than the modern building.

4.3.4 Hourly Cooling Input

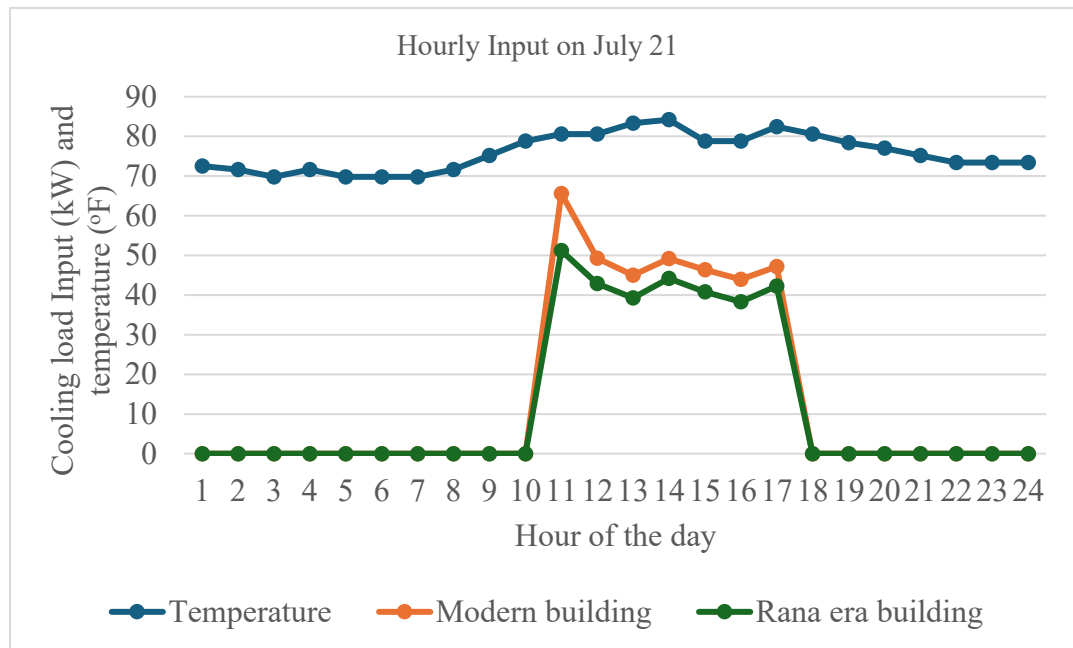


Figure 4. 16: Comparison of hourly cooling input in July 21 (kW)

Figure 4.16 shows that the dry-bulb temperature rises through the day and reaches its highest value in the early afternoon, while cooling input occurs only during the warmest hours. In the data taken from July 21, the modern building consistently needs more cooling coil power than the Rana era building, which indicates a higher cooling load. For both cases, cooling input is zero from hours 1 to 10 and again from hour 18 onward because cooling requirement is present only when occupants are present in the building. The modern building shows consistently larger cooling coil power than the Rana era building, with a maximum value of 65.602 kW compared with 51.195 kW. This indicates that the modern building experiences a higher cooling load during peak daytime conditions.

4.3.5 Daily Cooling Input

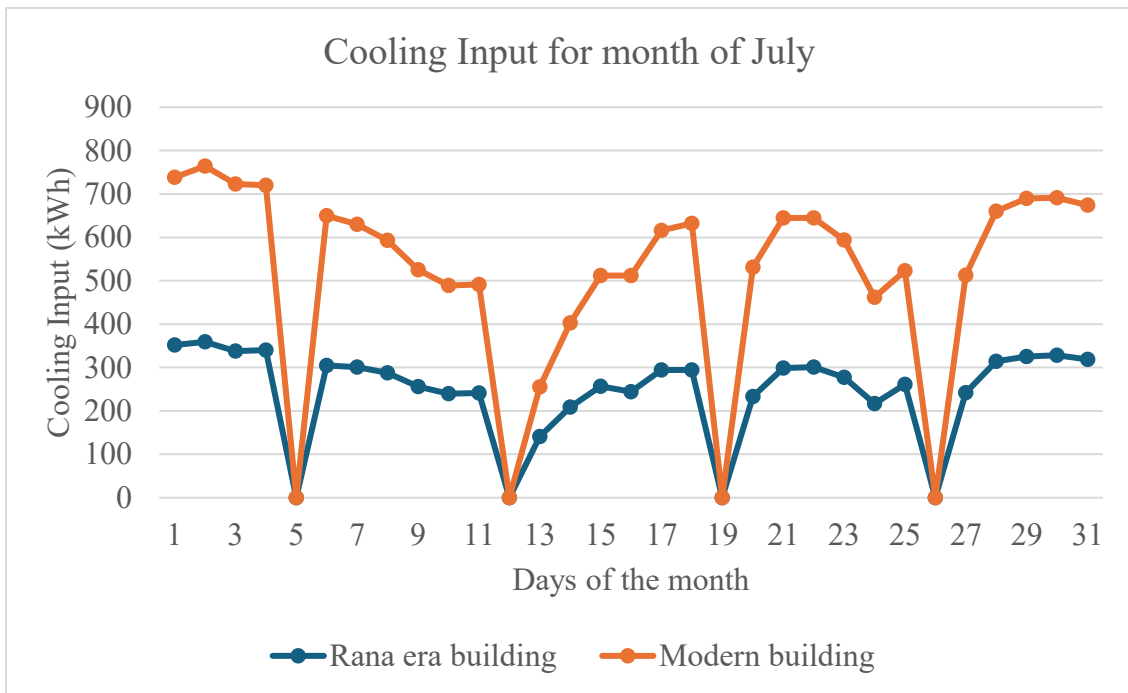


Figure 4. 17: Comparison of daily cooling input in month of July(kWh)

Figure 4. 17 shows the daily cooling input for July for the modern building and the Rana era building. The Rana era building has consistently lower cooling coil input (with 7575kWh month total) than the modern building throughout the month (with month total of 8308kWh), even though the modern building has a higher U-value but lower infiltration rate. Both buildings show a similar daily fluctuation pattern, with peaks on occupied days and drops to zero on Saturdays.

5, 12, 19 and 26th days were Saturday, when the cooling load is not required and system is off, so no load is observed on the day. Input variations on other days is due to the change in temperature and solar gains in the respective days. From the cyclic pattern we can see that internal load like people, light, equipment are the primary component of the cooling demand and the Rana era design seem to have lower energy footprint during peak occupied days than the modern building.

4.3.5 Monthly Cooling Input

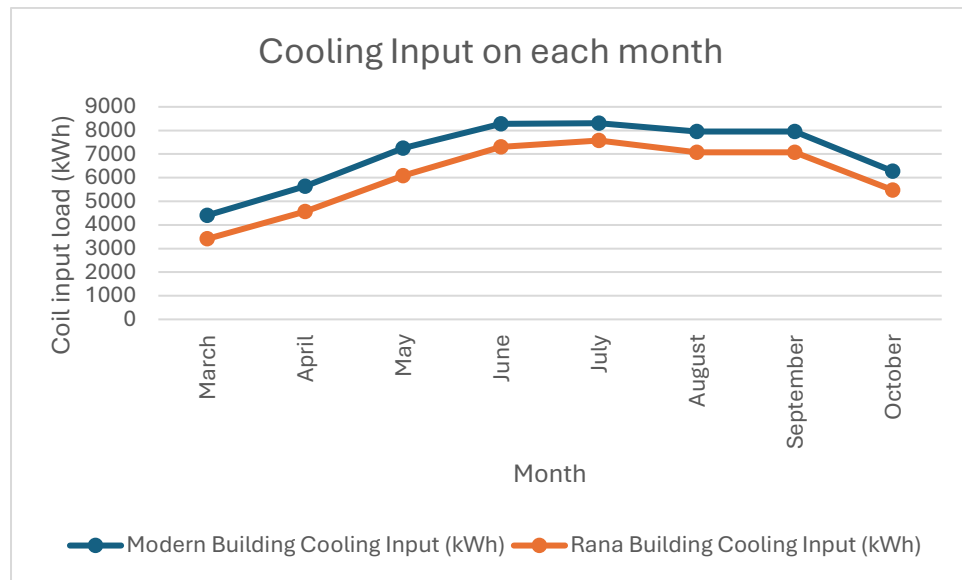


Figure 4. 18: Comparison of monthly cooling input load (kWh)

In figure 4. 18, presents the monthly cooling input load for the modern and Rana era building. The two curves follow the same trend and indicate peaking input in the month of June, July, August when the local climate has typically high temperature and humidity level. The modern building cooling input power shows consistently higher values than the Rana era building cooling input power. This shows that the modern building requires greater cooling energy input (56057 kWh total), which is 15.42% higher than the cooling energy input required in Rana era building (48567 kWh).

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

Under this comparative study, influence of building parameters such as wall, floors, roof and infiltration has been observed in cooling load requirement of Rana era and modern building. The modern building produces higher cooling load than the Rana era building on all floor with increase range from 9.5% to 16.1%. The difference is due to the thicker walls in Rana era building that have high thermal mass and slower heat release phenomenon which help dampen and delay heat transfer whereas the thinner modern walls allow faster heat transfer.

Cooling loads obtained from HAP were 10.7 % to 20.2% lower than that obtained from manual calculations. This might be because HAP considers hourly heat-balance effects, schedules, and how the building materials respond to changes. The close agreement in direction between the two methods supports the comparison.

Annual simulation shows that the modern building needs 15.42% more energy for cooling, 56057 kWh compared to 48567 kWh for Rana era building. The findings validate the engineering logic of Rana-era architecture and show passive strategies can effectively diminish the cooling energy requirement in the building.

Although the study provides comparative evidence, there had been made specific modeling assumptions, such as predefined occupancy schedules, standardized internal load values and idealized material properties for both types of building. Therefore, these findings should be interpreted as comparative performance trend instead of absolute values as the actual real-world performance would vary based on site specific climatic conditions, actual occupant behavior, and maintenance practices.

Economic analysis of this study could be done in future. Designers could use quantified data (keeping the assumptions in thought) to include the thick walls and higher thermal mass materials in their design to reduce the cooling load in the building and support sustainable building practices.

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Appendix A: Cooling load from CLTD method for ground floor

Ground floor space	Modern building load (tons)	Rana era building load (tons)
001 ADMIN UNIT	1.98	1.8
002 ADMIN UNIT	1.69	1.66
008 ACADEMIC UNIT	0.69	0.65
009 ACADEMIC UNIT	0.88	0.68
013 STORE MANAGER	0.79	0.58
014 STORE STAFF AREA	1.8	1.56
018 OFFICE	0.35	0.33
021 OFFICE	1.19	1.01
023 OFFICE	0.87	0.8
024 OFFICE	0.48	0.45
028 FINANCE DEPARTMENT 2	1.32	1.32
028 FINANCE DEPARTMENT 1	2.4	2.35
Total	14.44	13.19

Appendix B: Cooling load from CLTD method for first floor

First floor space	Modern building load (tons)	Rana era building load (tons)
100 OFFICE	1.62	1.44
105 HALL	5.96	4.81
107 OFFICE	0.5	0.5
108 OFFICE	0.72	0.65
109 OFFICE	0.76	0.61
111 OFFICE	0.62	0.5
114 OFFICE	1.2	1.05
115 OFFICE	0.86	0.76
120 OFFICE	1	1
121 OFFICE	1.4	1.33
122 OFFICE	1.4	1.35
123 OFFICE	0.92	0.9
124 OFFICE	0.4	0.38
127 OFFICE	3.2	3.2
128 OFFICE	2.1	2
Total	22.66	20.48

Appendix C: Cooling load from CLTD for second floor

Spaces	Modern building load (tons)	Rana era building load (tons)
203 OFFICE	0.5	0.49
204 OFFICE	0.6	0.57
205 OFFICE	0.59	0.5
206 OFFICE	0.51	0.5
207 OFFICE	0.59	0.5
208 OFFICE	0.59	0.5
210 OFFICE	0.63	0.6
213 OFFICE	1.35	1.35
215 OFFICE	0.72	0.67
216 OFFICE	0.71	0.7
217 OFFICE	1	0.99
221 OFFICE	0.86	0.82
222 OFFICE	1.8	1.57
223 OFFICE	1.2	0.96
223 HALL	1.2	0.96
224 OFFICE	0.96	0.94
227 OFFICE	2.8	2.5
230 OFFICE	3.33	3
Total	19.94	18.12

Appendix D: Cooling load from HAP for ground floor

Spaces	Modern building load (tons)	Rana era building load (tons)
001 ADMIN UNIT	1.84	1.54
002 ADMIN UNIT	1.68	1.44
008 ACADEMIC UNIT	0.57	0.52
009 ACADEMIC UNIT	0.71	0.59
013 STORE MANAGER	0.59	0.48
014 STORAGE STAFF AREA	1.66	1.22
018 OFFICE	0.28	0.25
021 OFFICE	0.99	0.93
023 OFFICE	0.74	0.70
024 OFFICE	0.41	0.37
028 FINANCIAL DEPARTMENT 2	1.18	1.29

028 FINANCIAL DEPARTMENT 1	2.12	2.13
Total	12.769	11.45

Appendix E: Cooling load from HAP for first floor

Spaces	Modern building load (tons)	Rana era building load (tons)
100 OFFICE	1.48	1.12
105 HALL	5.43	4.71
107 OFFICE	0.43	0.40
108 OFFICE	0.63	0.60
109 OFFICE	0.61	0.56
111 OFFICE	0.53	0.41
114 OFFICE	0.96	0.83
115 OFFICE	0.71	0.63
120 OFFICE	0.91	0.81
121 OFFICE	1.17	1.10
122 OFFICE	1.17	1.11
124 OFFICE	0.88	0.87
123 OFFICE	0.38	0.32
127 OFFICE	2.92	2.92
128 OFFICE	1.98	1.89
Total	20.19	18.28

Appendix F: Cooling load from HAP for second floor

Spaces	Modern building load (tons)	Rana era building load (tons)
203 OFFICE	0.48	0.42
204 OFFICE	0.49	0.42
205 OFFICE	0.48	0.41
206 OFFICE	0.47	0.40
207 OFFICE	0.50	0.42
208 OFFICE	0.50	0.42
210 OFFICE	0.58	0.49
213 OFFICE	1.26	1.13
215 OFFICE	0.64	0.53
216 OFFICE	0.69	0.56
217 OFFICE	0.91	0.79
221 OFFICE	0.76	0.68
222 OFFICE	1.63	1.40
223 OFFICE	0.96	0.84
223 HALL	0.96	0.85
224 OFFICE	0.82	0.79
227 OFFICE	2.12	1.77
230 OFFICE	2.56	2.14
Total	16.79	14.46

Appendix G: Relative Thermal Resistances of Building Materials

Material Description	Material Density lb/ft ³	Material Thickness in.	Resistance for Thickness Listed °F-ft ² -h/Btu	Material Description	Material Density lb/ft ³	Material Thickness in.	Resistance for Thickness Listed °F-ft ² -h/Btu
Building paper	...	...	0.06	Concrete block, 3 core, sand-gravel aggregate	...	8	1.11
Gypsum plaster, sand aggregate	105	½	0.09	Acoustical tile, wood or cane fiber	...	½	1.19
Structural glass	...	...	0.10	Fir, pine, and similar soft-woods	32	1	1.25
Air surface, 15 mph wind, outside surface	...	...	0.17	Insulation board, impregnated	20	½	1.32
Gypsum or plaster board	50	⅝	0.32	Concrete, lightweight aggregate	80	4	1.50
Stone, lime, or sand	...	4	0.32	Air space, vertical, bounded by reflective material	...	¼ to 4	1.70
Concrete, sand-gravel aggregate	140	4	0.32	Concrete block, 3 core, cinder aggregate	...	8	1.72
Built-up roofing	70	⅝	0.33	Concrete block, 3 core, lightweight aggregate	...	8	2.00
Brick, face	130	4	0.44	Vermiculite, expanded	7	1	2.08
Still air surface, horiz., ordinary materials, heat flow up	...	...	0.61	Carpet and fibrous pad	...	...	2.08
Aluminum, steel, or vinyl over sheathing, hollow backed	...	...	0.61	Cellular glass insulation board	9	1	2.50
Plywood	34	½	0.63	Roof insulation, preformed for above deck	...	1	2.78
Still air surface, vertical, ordinary mtrls, horiz. heat flow	...	...	0.68	Mineral wool, loose fill, from slag glass or rock	2-5	1	3.33
Wood siding, bevel, ½ in 8 in lapped	...	...	0.81	Wood fiber, loose fill, hemlock, fir or redwood	2-3.5	1	3.33
Wood shingle siding, 16 in, 7 ½ in exposure	...	...	0.87	Plastic, foamed	1.62	1	3.45
Oak, maple, and similar hardwoods	45	1	0.91	Macerated paper or pulp	2-3.5	1	3.57
Air space, vertical, ordinary materials, horiz. heat flow	...	¼ to 4	0.97	Corkboard, without added binder	6.5-8	1	3.70
Clay tile, one cell deep	...	4	1.11	Batt and Blankets Bounded by Nonreflective Materials			
Wood fiber, multilayer, stitched expanded	1.5-2	1	3.70	Mineral wool, fibrous form, rock, slag, or glass	1.5-4	1	3.70
Cotton fiber	0.8-2	1	3.85	Wood fiber, multilayer, stitched expanded	1.5-2	1	3.70
Wood Fiber	3.2-3.6	1	4.00	Cotton fiber	0.8-2	1	3.85
				Wood fiber	3.2-3.6	1	4.00

Appendix H: Thermal Properties and Code Numbers of Layers for Walls and Roofs

Code Number	Description	Thickness and Thermal Properties ^a					
		<i>L</i>	<i>k</i>	<i>ρ</i>	<i>c_p</i>	<i>R</i>	Mass
A0	Outside surface resistance	0.0	0.0	0.0	0.0	0.33	0.0
A1	1-in. stucco	0.0833	0.4	116.0	0.20	0.21	9.7
A2	4-in. face brick	0.333	0.77	125.0	0.22	0.43	41.7
A3	Steel siding	0.005	26.0	480.0	0.10	0.00	2.4
A4	$\frac{1}{2}$ -in. slag	0.0417	0.11	70.0	0.40	0.38	2.2
A5	Outside surface resistance	0.0	0.0	0.0	0.0	0.33	0.0
A6	Finish	0.0417	0.24	78.0	0.26	0.17	3.3
A7	4-in. face brick	0.333	0.77	125.0	0.22	0.43	41.7
B1	Airspace resistance	0.0	0.0	0.0	0.0	0.91	0.0
B2	1-in. insulation	0.083	0.025	2.0	0.2	3.33	0.2
B3	2-in. insulation	0.167	0.025	2.0	0.2	3.33	0.3
B4	3-in. insulation	0.25	0.025	2.0	0.2	10.00	0.5
B5	1-in. insulation	0.0833	0.025	5.7	0.2	3.33	0.5
B6	2-in. insulation	0.167	0.025	5.7	0.2	6.67	1.0
B7	1-in. wood	0.0833	0.07	37.0	0.6	10.00	3.1
B8	2.5-in. wood	0.2083	0.07	37.0	0.6	2.98	7.7
B9	4-in. wood	0.333	0.07	37.0	0.6	4.76	12.3
B10	2-in. wood	0.167	0.07	37.0	0.6	2.39	6.2
B11	3-in. wood	0.25	0.07	37.0	0.6	3.57	9.3
B12	3-in. insulation	0.25	0.025	5.7	0.2	10.00	1.4
B13	4-in. insulation	0.333	0.025	5.7	0.2	13.33	1.9
B14	5-in. insulation	0.417	0.025	5.7	0.2	16.67	2.4
B15	6-in. insulation	0.500	0.025	5.7	0.2	20.00	2.9
B16	0.15-in. insulation	0.0126	0.025	5.7	0.2	0.50	0.1
B17	0.3-in. insulation	0.0252	0.025	5.7	0.2	1.00	0.1
B18	0.45-in. insulation	0.0379	0.025	5.7	0.2	1.50	0.2
B19	0.61-in. insulation	0.0505	0.025	5.7	0.2	2.00	0.3
B20	0.76-in. insulation	0.0631	0.025	5.7	0.2	2.50	0.4
B21	1.36-in. insulation	0.1136	0.025	5.7	0.2	4.50	0.6
B22	1.67-in. insulation	0.1388	0.025	5.7	0.2	5.50	0.8
B23	2.42-in. insulation	0.2019	0.025	5.7	0.2	8.00	1.2
B24	2.73-in. insulation	0.2272	0.025	5.7	0.2	9.00	1.3
B25	3.33-in. insulation	0.2777	0.025	5.7	0.2	11.00	1.6
B26	3.64-in. insulation	0.3029	0.025	5.7	0.2	12.00	1.7
B27	4.54-in. insulation	0.3786	0.025	5.7	0.2	15.00	2.2
C1	4-in. clay tile	0.333	0.33	70.0	0.2	1.01	23.3
C2	4-in. lightweight concrete block	0.333	0.22	38.0	0.2	1.51	12.7
C3	4-in. heavyweight concrete block	0.333	0.47	61.0	0.2	0.71	20.3
C4	4-in. common brick	0.333	0.42	120.0	0.2	0.79	40.0
C5	4-in. heavyweight concrete	0.333	1.0	140.0	0.2	0.33	46.7
C6	8-in. clay tile	0.667	0.33	70.0	0.2	2.00	46.7
C7	8-in. lightweight concrete block	0.667	0.33	38.0	0.2	2.00	25.3
C8	8-in. heavyweight concrete block	0.667	0.6	61.0	0.2	1.11	40.7
C9	8-in. common brick	0.667	0.42	120.0	0.2	1.59	80.0
C10	8-in. heavyweight concrete	0.667	1.0	140.0	0.2	0.67	93.4
C11	12-in. heavyweight concrete	1.0	1.0	140.0	0.2	1.00	140.0
C12	2-in. heavyweight concrete	0.167	1.0	140.0	0.2	0.17	23.3
C13	6-in. heavyweight concrete	0.5	1.0	140.0	0.2	0.50	70.0
C14	4-in. lightweight concrete	0.333	0.1	40.0	0.2	3.33	13.3
C15	6-in. lightweight concrete	0.5	0.1	40.0	0.2	5.00	20.0
C16	8-in. lightweight concrete	0.667	0.1	40.0	0.2	6.67	26.7

Appendix H Thermal Properties and Code Numbers of Layers for Walls and Roofs
(continued)

Code Number	Description	Thickness and Thermal Properties ^a					
		<i>L</i>	<i>k</i>	ρ	c_p	<i>R</i>	Mass
C17	8-in. lightweight conc. block (filled)	0.667	0.08	18.0	0.2	8.34	12.0
C18	8-in. heavyweight conc. block (filled)	0.667	0.34	53.0	0.2	1.96	35.4
C19	12-in. lightweight conc. block (filled)	1.000	0.08	19.0	0.2	12.50	19.0
C20	12-in. heavyweight conc. block (filled)	1.000	0.39	56.0	0.2	2.56	56.4
E0	Inside surface resistance	0.0	0.0	0.0	0.0	0.69	0.0
E1	$\frac{3}{4}$ -in. plaster or gypsum	0.0625	0.42	100.0	0.2	0.15	6.3
E2	$\frac{1}{2}$ -in. slag or stone	0.0417	0.83	11.0	0.40	0.05	2.3
E3	$\frac{3}{8}$ -in. felt and membrane	0.0313	0.11	70.0	0.40	0.29	2.2
E4	Ceiling air space	0.0	0.0	0.0	0.0	1.00	0.0
E5	Acoustic tile	0.0625	0.035	30.0	0.2	1.79	1.9

^a*L* = thickness, ft; *k* = thermal conductivity, Btu/(hr-ft²-F); ρ = density, lb/ft³; c_p = specific heat, Btu/(lb-F); *R* = thermal resistance, (ft²-hr-F)/Btu; Mass = unit mass, lb/ft². See inside front cover for conversion factors to SI units.

Appendix I: Shading coefficients for glass

Type of Glazing	Nominal Thickness, in (Each light)	Without Shading	With Interior Shading				
			Venetian Blinds		Roller Shades		
			Medium	Light	Dark	Light	Translucent
Single glass							
Clear	$\frac{1}{4}$	0.94	0.74	0.67	0.81	0.39	0.44
Heat absorbing	$\frac{1}{4}$	0.69	0.57	0.53	0.45	0.30	0.36
Double glass							
Clear	$\frac{1}{4}$	0.81	0.62	0.58	0.71	0.35	0.40
Heat absorbing	$\frac{1}{4}$	0.55	0.39	0.36	0.40	0.22	0.30

Appendix J: Maximum solar heat gain factor (SHGF) for sunlit glass

20° N. Lat											36° N. Lat										
	N	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SSW	S	HOR	N (Shade)	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SSW	S	HOR	
Jan.	29	29	48	138	201	243	253	233	214	232	22	22	24	90	166	219	247	252	252	155	
Feb.	31	31	88	173	226	244	238	201	174	263	26	26	57	139	195	239	248	239	232	199	
Mar.	34	49	132	200	237	236	206	152	115	284	30	33	99	176	223	238	232	206	192	238	
Apr.	38	92	166	213	228	208	158	91	58	287	35	76	144	196	225	221	196	156	135	262	
May	47	123	184	217	217	184	124	54	42	283	38	107	168	204	220	204	165	116	93	272	
June	59	135	189	216	210	173	108	45	42	279	47	118	175	205	215	194	150	99	77	273	
July	48	124	182	213	212	179	119	53	43	278	39	107	165	201	216	199	161	113	90	268	
Aug.	40	91	162	206	220	200	152	88	57	280	36	75	138	190	218	212	189	151	131	257	
Sep.	36	46	127	191	225	225	199	148	114	275	31	31	95	167	210	228	223	200	187	230	
Oct.	32	32	87	167	217	236	231	196	170	258	27	27	56	133	187	230	239	231	225	195	
Nov.	29	29	48	136	197	239	249	229	211	230	22	22	24	87	163	215	243	248	248	154	
Dec.	27	27	35	122	187	238	254	241	226	217	20	20	20	69	151	204	241	253	254	136	

24° N. Lat											40° N. Lat										
	N	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SSW	S	HOR	N (Shade)	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SSW	S	HOR	
Jan.	27	27	41	128	190	240	253	241	227	214	20	20	20	74	154	205	241	252	254	133	
Feb.	30	30	80	165	220	244	243	213	192	249	24	24	50	129	186	234	246	244	241	180	
Mar.	34	45	124	195	234	237	214	168	137	275	29	29	93	169	218	238	236	216	206	223	
Apr.	37	88	159	209	228	212	169	107	75	283	34	71	140	190	224	223	205	170	154	252	
May	43	117	178	214	218	190	132	67	46	282	37	102	165	202	220	208	175	133	113	265	
June	55	127	184	214	212	179	117	55	43	279	48	113	172	205	216	199	161	116	95	267	
July	45	116	176	210	213	185	129	65	46	278	38	102	163	198	216	203	170	129	109	262	
Aug.	38	87	156	203	220	204	162	103	72	277	35	71	135	185	216	214	196	165	149	247	
Sep.	35	42	119	185	222	225	206	163	134	266	30	30	87	160	203	227	226	209	200	215	
Oct.	31	31	79	159	211	237	235	207	187	244	25	25	49	123	180	225	238	236	234	177	
Nov.	27	27	42	126	187	236	249	237	234	213	20	20	20	73	151	201	237	248	250	132	
Dec.	26	26	29	112	180	234	247	247	237	199	18	18	18	60	135	188	232	249	253	113	

28° N. Lat											44° N. Lat										
	N (Shade)	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SSW	S	HOR	N (Shade)	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SSW	S	HOR	
Jan.	25	25	35	117	183	235	251	247	238	196	17	17	17	64	138	189	232	248	252	109	
Feb.	29	29	72	157	213	244	246	224	207	234	22	22	43	117	178	227	246	248	247	160	
Mar.	33	41	116	189	231	237	221	182	157	265	27	27	87	162	211	236	238	224	218	206	
Apr.	36	84	151	205	228	216	178	124	94	278	33	66	136	185	221	224	210	183	171	240	
May	40	115	172	211	219	195	144	83	58	280	36	96	162	201	219	211	183	148	132	257	
June	51	125	178	211	213	184	128	68	49	278	47	108	169	205	215	203	171	132	115	261	
July	41	114	170	208	215	190	140	80	57	276	37	96	159	198	215	206	179	144	128	254	
Aug.	38	83	149	199	220	207	172	120	91	272	34	66	132	180	214	215	202	177	165	236	
Sep.	34	38	111	179	219	226	213	177	154	256	28	28	80	152	198	226	227	216	211	199	
Oct.	30	30	71	151	204	236	238	217	202	229	23	23	42	111	171	217	237	240	239	157	
Nov.	26	26	35	115	181	232	247	243	235	195	18	18	18	64	135	186	227	244	248	109	
Dec.	24	24	24	99	172	227	248	251	246	179	15	15	15	49	115	175	217	240	246	89	

32° N. Lat											48° N. Lat										
	N (Shade)	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SSW	S	HOR	N (Shade)	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SSW	S	HOR	
Jan.	24	24	29	105	175	229	249	250	246	176	15	15	15	53	118	175	216	239	245	85	
Feb.	27	27	65	149	205	242	248	232	221	217	20	20	36	103	168	216	242	249	250	138	
Mar.	32	37	107	183	227	237	227	195	176	252	26	26	80	154	204	234	239	232	228	188	
Apr.	36	80	146	200	227	219	187	141	115	271	31	61	132	180	219	225	215	194	186	226	
May	38	111	170	208	220	199	155	99	74	277	35	97	158	200	218	214	192	163	150	247	
June	44	122	176	208	214	189	139	83	60	276	46	110	165	204	215	206	180	148	134	252	
July	40	111	167	204	215	194	150	96	72	273	37	96	156	196	214	209	187	158	146	244	
Aug.	37	79	141	195	219	210	181	136	111	265	33	61	128	174	211	216	208	188	180	223	
Sep.	33	35	103	173	215	227	218	189	171	244	27	27	72	144	191	223	228	223	220	182	
Oct.	28	28	63	143	195	234	239	225	215	213	21	21	35	96	161	207	233	241	242	136	
Nov.	24	24	29	103	173	225	245	246	243	175	15	15	15	52	115	172	212	234	240	85	
Dec.	22	22	22	84	162	218	246	252	252	158	13	13	13	36	91	156	195	225	233	65	

Appendix K: July cooling load temperature differences (CLTDs) for calculating cooling load from Sunlit Walls 32° North Latitude

Wall Facing	Solar Time, hr																								Wall Facing
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
WALL NO 1																									
N	1	0	-1	-2	-3	-2	6	12	14	15	18	22	25	28	29	29	30	31	27	17	11	7	5	3	N
NE	1	0	-1	-2	-3	1	21	41	49	48	41	33	29	29	30	29	28	24	19	14	10	7	5	3	NE
E	1	0	-1	-2	-3	1	23	48	61	64	59	48	36	32	31	30	28	24	19	14	10	7	5	3	E
SE	1	0	-1	-2	-3	-1	12	29	42	50	52	49	42	35	32	30	28	24	19	14	10	7	5	3	SE
S	1	0	-1	-2	-3	-3	0	4	8	16	25	34	40	42	41	36	30	25	19	13	10	7	5	3	S
SW	2	0	-1	-2	-2	-2	0	4	8	13	17	23	34	47	58	65	64	57	41	22	13	8	5	3	SW
W	2	1	-1	-2	-2	-2	0	4	8	13	17	22	27	42	59	73	80	77	58	30	15	9	6	3	W
NW	2	0	-1	-2	-2	-2	0	4	8	13	17	21	26	32	43	56	65	66	52	27	14	8	5	3	NW
WALL NO 2																									
N	5	3	2	0	-1	-2	-1	3	7	10	13	15	18	22	25	27	28	29	30	28	23	17	12	8	N
NE	5	3	2	0	-1	-2	1	11	25	37	42	42	38	34	32	31	30	29	26	23	18	14	10	7	NE
E	5	3	2	0	-1	-2	1	13	30	45	54	56	52	45	38	35	32	30	27	23	18	14	11	8	E
SE	5	3	2	0	-1	-2	0	6	17	29	39	45	47	44	40	36	33	30	27	23	18	14	10	8	SE
S	5	3	2	0	-1	-2	-2	-1	1	5	11	18	26	33	37	39	37	34	29	24	19	14	10	7	S
SW	7	4	2	1	-1	-2	-2	-1	2	5	9	13	18	26	37	47	56	60	58	49	36	25	16	11	SW
W	8	5	3	1	0	-1	-2	-1	2	5	9	13	17	23	33	46	59	69	72	64	48	32	20	13	W
NW	7	4	2	1	-1	-2	-2	-1	2	5	9	13	17	22	27	36	46	55	60	55	42	29	19	12	NW
WALL NO 3																									
N	8	5	3	2	1	0	2	5	7	9	12	15	18	21	23	25	26	28	28	25	21	17	13	10	N
NE	7	5	3	2	1	0	6	16	26	33	35	35	33	32	31	31	30	28	26	22	18	15	12	9	NE
E	7	5	4	2	1	0	7	19	31	41	46	47	44	40	37	35	33	31	27	23	19	16	13	10	E
SE	7	5	3	2	1	0	3	10	20	29	35	39	40	39	36	35	33	30	27	23	19	16	13	10	SE
S	7	5	3	2	0	0	-1	1	3	6	12	18	25	30	33	34	33	30	27	23	19	16	12	10	S
SW	11	8	5	3	2	0	0	1	3	6	9	13	19	27	36	44	50	53	49	41	33	25	20	15	SW
W	13	10	7	4	2	0	1	2	4	6	9	13	17	24	34	45	56	62	62	52	41	32	24	18	W
NW	12	9	6	4	2	1	0	1	3	6	9	13	16	21	27	35	44	51	52	45	35	28	21	16	NW
WALL NO 4																									
N	11	8	6	4	2	0	0	0	3	6	8	11	14	17	20	22	25	26	28	28	27	23	19	15	N
NE	10	7	5	3	2	0	0	3	11	21	29	34	36	35	34	33	32	31	29	27	24	20	16	13	NE
E	10	8	5	4	2	1	0	4	13	25	36	44	48	47	44	40	37	34	32	29	25	21	17	13	E
SE	10	8	5	3	2	0	0	2	7	15	24	32	38	41	41	39	37	34	32	29	25	21	17	13	SE
S	10	8	5	3	2	0	-1	1	0	2	5	9	15	22	28	32	34	34	33	30	26	21	17	14	S
SW	17	12	8	5	3	1	0	0	0	2	4	7	11	17	24	32	41	48	53	52	47	38	30	23	SW
W	21	15	10	6	4	2	0	0	0	2	4	8	11	15	21	30	41	52	60	63	58	49	38	28	W
NW	18	13	9	6	4	2	0	0	0	2	4	7	11	15	19	25	32	41	48	52	49	42	33	25	NW
WALL NO 5																									
N	13	11	8	6	5	3	2	3	5	7	8	10	12	15	18	20	22	24	25	25	24	21	18	16	N
NE	13	10	8	6	5	3	3	7	13	20	26	29	30	30	30	30	30	29	28	26	24	21	18	15	NE
E	14	11	9	7	5	4	3	7	15	24	32	38	40	39	38	37	35	34	32	29	26	23	20	17	E
SE	13	11	9	7	5	3	3	5	9	16	23	28	33	35	35	34	33	32	31	28	25	22	19	16	SE
S	13	10	8	6	5	3	2	2	2	3	6	10	14	20	24	27	29	29	28	27	24	21	18	15	S
SW	20	16	13	10	8	6	4	3	3	4	6	8	11	16	22	29	36	42	45	44	40	35	29	24	SW
W	24	20	16	12	9	7	5	4	4	5	6	9	11	15	20	28	37	46	52	53	49	42	36	29	W
NW	21	17	14	11	8	6	4	3	3	4	6	8	11	14	18	23	29	37	42	44	41	36	31	25	NW
WALL NO 6																									
N	14	12	10	8	6	5	4	5	6	7	9	10	12	14	17	19	20	22	23	23	22	20	18	16	N
NE	14	12	10	8	7	5	6	9	15	20	24	26	27	28	28	28	28	28	27	26	24	21	19	16	NE
E	16	13	11	9	7	6	6	10	17	24	30	34	36	36	35	34	34	32	31	29	26	23	21	18	E
SE	15	13	11	9	7	6	5	7	11	16	22	26	30	31	32	32	31	31	29	27	25	22	20	17	SE
S	14	12	10	8	6	5	4	3	4	5	7	10	14	18	22	25	26	27	26	25	23	20	18	16	S
SW	21	18	15	12	10	8	7	6	6	6	7	9	12	16	22	28	34	38	40	39	36	32	28	25	SW
W	25	21	18	15	12	10	8	7	7	7	8	10	12	15	20	27	35	42	47	47	44	39	34	29	W
NW	22	18	15	13	10	8	7	6	6	6	8	9	11	14	17	22	28	34	39	39	37	33	29	25	NW
WALL NO 7																									
N	13	12	10	9	8	7	7	7	8	9	10	11	13	14	16	18	19	20	21	21	20	18	17	15	N
NE	15	13	12	10	9	8	9	13	17	21	23	24	25	25	26	26	26	26	25	24	22	21	19	17	NE
E	17	15	13	12	10	9	10	15	20	25	29	31	32	32	32	31	31	30	29	27	25	23	21	19	E
SE	16	14	12	11	9	8	8	11	14	19	22	25	27	28	28	29	28	28	27	25	24	22	20	18	SE
S	14	12	11	9	8	7	6	6	6	7	9	12	15	18	21	23	23	23	23	22	20	19	17	16	S
SW	21	18	16	14	12	11	9	9	9	9	10	11	14	18	22	27	32	35	35	34	31	28	26	23	SW
W	24	22	19	17	15	13	11	10	10	10	11	12	14	17	22	28	34	39	41	40	37	34	30	27	W
NW	21	19	16	14	12	11	9	9	9	9	10	11	13	15	18	23	28	32	35	34	31	29	26	23	NW
WALL NO 9																									
N	18	15	13	11	9	7	5	4	4	4	6	7	9	11	13	15	17	20	21	23	24	22	20	18	N
NE	18	16	13	11	9	7	5	5	6	10	15	21	25	27	28	29	29	29	29	29	27	25	23	21	NE
E	20	17	14	12	10	8	6	5	7	11	18	25	31	35	37	37	36	36	34	33	31	28	26	23	E
SE	19	16	14	11	9	7	6	5	5	8	12	17	23	27	31	32	33	33	32	31	30	27	25	22	SE
S	18	15	13	11	9	7	5	4	3	3	3	5	7	11	15	20	23	26	27	28	27	25	23	20	S
SW	28	24	20	17	14	11	9	7	5	5	5	6	7	9	13	18	23	30	35	40	41	40	37	33	SW
W	34	29	24	20	16	13	10	8	6	6	6	6	8	10	12	17	22	30	37	44	48	48	44	39	W
NW	29	25	21	17	14	11	9	7	5	5	5	6	7	9	12	15	19	24	30	36	39	40	37	34	NW

Appendix L: July cooling load temperature differences (CLTDs) for calculating cooling load from Sunlit Walls 24° North Latitude

Wall Facing	Solar Time, hr																								Wall Facing
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
WALL NO 1																									
N	1	0	-1	-2	-3	-2	5	13	17	18	19	22	26	28	30	32	34	34	27	17	11	7	5	3	N
NE	1	0	-1	-2	-3	0	17	39	51	53	48	39	32	30	30	30	28	24	18	13	10	7	5	3	NE
E	1	0	-1	-2	-3	0	18	44	59	63	59	48	36	32	31	30	28	24	19	13	10	7	5	3	E
SE	1	0	-1	-2	-3	-2	8	25	38	44	45	42	35	32	31	30	27	24	18	13	10	7	5	3	SE
S	1	0	-1	-2	-3	-3	-1	3	8	12	18	24	29	31	31	30	27	23	18	13	9	7	4	3	S
SW	1	0	-1	-2	-3	-3	-1	3	8	13	17	22	29	40	51	58	59	52	36	20	12	8	5	3	SW
W	2	0	-1	-2	-2	-3	-1	3	8	13	17	22	27	42	59	73	80	75	52	27	14	9	5	3	W
NW	2	0	-1	-2	-2	-3	-1	3	8	13	17	22	27	37	50	62	69	67	48	25	13	8	5	3	NW
WALL NO 2																									
N	5	3	2	0	-1	-2	-1	2	7	12	15	18	20	23	25	28	30	32	32	29	23	17	12	8	N
NE	5	3	2	0	-1	-2	0	9	23	36	44	46	43	38	34	32	31	29	26	22	18	14	10	7	NE
E	5	3	2	0	-1	-2	0	10	26	42	52	55	52	44	38	35	32	30	27	23	18	14	10	8	E
SE	5	3	2	0	-1	-2	-1	4	14	26	35	40	41	38	35	33	31	29	26	22	18	14	10	7	SE
S	5	3	1	0	-1	-2	-2	-1	1	4	8	13	19	24	27	29	29	28	26	22	17	13	10	7	S
SW	6	4	2	1	-1	-2	-2	-1	1	5	9	13	18	24	32	42	50	54	52	44	33	22	15	10	SW
W	8	5	2	1	0	-1	-2	-1	1	5	9	13	17	23	33	46	59	69	71	61	45	30	19	12	W
NW	7	4	2	1	-1	-2	-2	-1	1	5	9	13	17	22	30	40	51	60	62	55	41	28	18	12	NW
WALL NO 3																									
N	8	5	4	2	1	0	1	5	8	11	14	16	19	21	24	26	29	30	30	26	21	17	13	10	N
NE	7	5	3	2	1	0	4	14	25	34	38	38	36	35	33	32	31	29	26	22	19	15	12	9	NE
E	7	5	3	2	1	0	5	16	29	39	45	46	43	30	37	35	33	30	27	23	19	16	12	10	E
SE	7	5	3	2	0	0	2	8	17	25	31	34	35	34	33	32	31	29	26	22	18	15	12	9	SE
S	7	5	3	1	0	-1	-1	0	2	5	9	13	18	22	25	26	26	26	23	20	17	14	11	9	S
SW	10	7	5	3	1	0	0	1	3	6	9	13	17	24	32	40	46	48	45	37	30	23	18	14	SW
W	13	9	6	4	2	1	0	1	3	6	9	13	17	24	34	46	56	62	59	50	39	30	23	17	W
NW	12	8	6	4	2	1	0	1	3	6	9	13	17	22	30	39	48	54	53	45	35	27	21	16	NW
WALL NO 4																									
N	12	8	6	4	2	1	0	0	3	6	10	13	15	18	21	23	26	28	30	30	28	24	20	15	N
NE	10	7	5	3	2	0	0	3	10	20	29	36	39	39	37	35	34	32	30	27	24	20	16	13	NE
E	10	8	5	3	2	1	0	3	11	22	34	43	47	46	43	40	37	34	32	28	25	21	17	13	E
SE	10	7	5	3	2	0	0	1	5	13	21	28	33	35	35	33	32	30	27	24	20	16	13	10	SE
S	10	7	5	3	2	0	-1	-1	-1	1	4	7	11	16	20	24	26	27	27	25	22	19	16	12	S
SW	15	11	7	5	3	1	0	-1	0	1	4	7	11	15	21	29	37	43	47	47	42	35	27	21	SW
W	20	14	9	6	4	2	0	0	2	4	7	11	15	21	30	41	52	60	61	56	46	36	27	21	W
NW	18	13	9	6	3	1	0	0	0	2	4	7	11	15	20	27	36	45	52	54	50	42	33	25	NW
WALL NO 5																									
N	13	11	9	7	5	3	2	3	5	7	10	12	14	16	19	21	23	25	27	27	25	22	19	16	N
NE	13	11	8	7	5	3	3	6	12	20	26	31	33	33	32	32	31	31	29	27	24	21	18	16	NE
E	14	11	9	7	5	4	3	6	13	22	31	36	39	39	37	36	35	33	31	29	26	22	19	16	E
SE	13	10	8	6	5	3	2	4	8	14	20	25	28	30	30	30	30	30	28	26	24	21	18	15	SE
S	11	9	7	6	4	3	2	1	1	3	5	7	11	14	18	20	22	23	23	22	20	18	16	14	S
SW	18	15	12	9	7	5	3	3	3	4	5	8	11	14	20	26	32	38	41	40	36	31	27	22	SW
W	25	19	15	12	9	7	5	4	4	4	6	8	11	15	20	28	37	45	51	51	47	41	34	28	W
NW	21	17	14	11	8	6	4	3	3	4	6	8	11	14	19	25	32	40	45	46	42	37	31	26	NW
WALL NO 6																									
N	14	12	10	8	7	5	4	5	6	8	10	11	13	15	17	20	22	24	25	25	23	21	19	16	N
NE	14	12	10	8	7	5	5	8	14	20	25	28	29	30	30	30	30	29	28	26	24	22	19	17	NE
E	15	13	11	9	7	6	6	9	15	22	29	33	35	35	34	34	33	32	30	28	26	23	20	18	E
SE	14	12	10	8	7	5	4	6	10	14	19	23	26	27	28	28	28	28	27	25	23	21	19	16	SE
S	12	10	8	7	5	4	3	3	3	4	5	8	11	14	16	19	20	21	21	21	19	17	16	14	S
SW	19	16	14	11	9	7	6	5	5	6	7	9	11	15	19	25	30	34	36	36	33	29	26	22	SW
W	24	21	17	14	12	9	8	7	6	7	8	10	12	15	20	27	35	42	46	46	42	37	33	28	W
NW	22	19	16	13	11	8	7	6	6	6	7	9	11	14	18	24	31	37	41	41	38	34	29	25	NW
WALL NO 7																									
N	14	12	11	9	8	7	7	7	9	10	11	12	14	15	17	19	20	22	23	22	21	19	17	16	N
NE	16	14	12	11	9	8	9	12	17	21	24	26	26	27	27	28	28	27	26	25	23	21	19	17	NE
E	17	15	13	11	10	9	9	13	19	24	28	30	31	31	31	31	30	30	28	27	25	23	21	19	E
SE	15	13	12	10	9	7	7	9	13	16	20	22	24	25	25	26	26	26	25	23	22	20	18	17	SE
S	12	10	9	8	7	6	5	5	5	6	7	9	11	14	16	17	18	19	19	18	17	16	15	13	S
SW	19	17	15	13	11	10	8	8	8	8	9	11	13	16	20	24	28	31	32	30	28	26	23	21	SW
W	24	21	19	16	14	12	11	10	10	10	11	12	14	17	22	28	34	39	40	39	36	32	29	26	W
NW	21	19	17	15	13	11	10	9	9	9	10	11	13	16	20	24	30	34	36	35	32	29	26	24	NW
WALL NO 9																									
N	19	16	14	11	9	7	5	4	4	5	6	8	10	12	14	16	18	21	23	25	26	25	23	21	N
NE	18	16	13	11	9	7	5	4	6	9	15	20	25	29	30	31	31	31	31	30	28	26	24	21	NE
E	19	17	14	12	9	7	6	5	6	10	17	24	30	34	36	36	36	35	34	32	30	28	25	22	E
SE	18	15	13	11	9	7	5	4	4	6	10	15	20	24	27	28	29	29	29	29	27	25	23	21	SE
S	15	13	11	9	8	6	4	3	2	2	3	4	6	8	11	14	17	20	21	22	22	21	19	18	S
SW	26	22	18	15	12	10	8	6	4	4	4	5	7	9	12	16	21	27	32	36	37	36	33	30	SW
W	35	28	23	19	16	13	10	8	6	5	5	6	7	9	12	16	22	30	37	44	47	46	43	38	W
NW	30	25	21	18	14	11	9	7	5	5	5	6	7	9	12	15	20	26	33	38	41	41	38	34	NW

Appendix M: Wall types, mass located outside insulation

Secondary Material	R-Factor, (hr-ft ² -F)/Btu	Principal Wall Material ^a														
		A1	A2	B7	B10	B9	C1	C2	C3	C4	C5	C6	C7	C8	C17	C18
Stucco and/or plaster	0.0-2.0	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b
	2.0-2.5	b	3	b	b	b	b	b	2	3	5	b	b	b	b	b
	2.5-3.0	b	3	b	b	b	2	b	2	4	5	b	b	5	b	b
	3.0-3.5	b	3	b	b	b	2	2	2	5	5	b	b	5	b	b
	3.5-4.0	b	3	b	b	b	2	2	2	5	5	10	4	6	b	5
	4.0-4.75	b	4	b	b	b	4	2	2	5	5	10	4	6	b	9
	4.75-5.5	b	4	b	b	b	4	2	2	5	6	11	5	10	b	10
	5.5-6.5	b	5	b	b	b	4	2	2	5	6	11	5	10	b	10
	6.5-7.75	b	5	b	b	b	4	2	2	5	6	11	5	10	b	10
	7.75-9.0	b	5	b	b	b	5	2	4	5	6	16	10	10	b	10
	9.0-10.75	b	5	b	b	b	5	4	4	5	6	16	10	10	4	11
	10.75-12.75	b	5	b	b	b	5	4	4	10	6	16	10	10	9	11
	12.75-15.0	b	5	b	b	b	5	4	4	10	10	10	10	11	9	11
	15.0-17.5	b	5	b	b	b	5	4	4	10	10	b	10	11	10	16
	17.5-20.0	b	5	b	b	b	9	4	4	10	10	b	10	15	10	16
	20.0-23.0	b	9	b	b	b	9	9	9	15	10	b	10	15	15	16
	23.0-27.0	b	b	b	b	b	b	b	b	b	b	b	15	b	15	16

Appendix N: Wall types, mass evenly distributed

Secondary Material	R-Factor, (hr-ft ² -F)/Btu	Principal Wall Material ^a														
		A1	A2	B7	B10	B9	C1	C2	C3	C4	C5	C6	C7	C8	C17	C18
Stucco and/or plaster	0.0-2.0	1	3	b	b	b	b	b	1	3	3	b	b	b	b	b
	2.0-2.5	1	3	1	b	b	2	b	2	4	4	b	b	5	b	b
	2.5-3.0	1	4	1	b	b	2	2	2	4	4	b	b	5	b	b
	3.0-3.5	1	b	1	b	b	2	2	b	b	b	10	4	5	b	4
	3.5-4.0	1	b	1	2	b	b	4	b	b	b	10	4	b	b	4
	4.0-4.75	1	b	1	2	b	b	b	b	b	b	10	4	b	b	4
	4.75-5.5	1	b	1	2	b	b	b	b	b	b	b	b	b	b	b
	5.5-6.5	1	b	2	4	10	b	b	b	b	b	b	b	b	b	b
	6.5-7.75	1	b	2	4	11	b	b	b	b	b	b	b	b	b	b
	7.75-9.0	1	b	2	4	16	b	b	b	b	b	b	b	b	b	b
	9.0-10.75	1	b	2	4	16	b	b	b	b	b	b	b	b	4	b
	10.75-12.75	1	b	2	5	b	b	b	b	b	b	b	b	b	4	b
	12.75-15.0	2	b	2	5	b	b	b	b	b	b	b	b	b	b	b
	15.0-17.5	2	b	2	5	b	b	b	b	b	b	b	b	b	b	b
	17.5-20.0	2	b	2	9	b	b	b	b	b	b	b	b	b	b	b
	20.0-23.0	2	b	4	9	b	b	b	b	b	b	b	b	b	b	b
	23.0-27.0	b	b	b	9	b	b	b	b	b	b	b	b	b	b	b

Appendix O: Wall types, mass located inside insulation

Secondary Material	R-Factor, (hr-ft ² -F)/Btu	Principal Wall Material ^a														
		A1	A2	B7	B10	B9	C1	C2	C3	C4	C5	C6	C7	C8	C17	C18
Stucco and/or plaster	0.0-2.0	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b
	2.0-2.5	b	5	b	b	b	b	b	b	5	b	b	b	b	b	b
	2.5-3.0	b	5	b	b	b	3	b	2	5	6	b	b	5	b	b
	3.0-3.5	b	5	b	b	b	4	2	2	5	6	b	b	6	b	b
	3.5-4.0	b	5	b	b	b	4	2	3	6	6	10	4	6	b	5
	4.0-4.75	b	6	b	b	b	5	2	4	6	6	11	5	10	b	10
	4.75-5.5	b	6	b	b	b	5	2	4	6	6	11	5	10	b	10
	5.5-6.5	b	6	b	b	b	5	2	5	10	7	12	5	11	b	10
	6.5-7.75	b	6	b	b	b	5	4	5	11	7	16	10	11	b	11
	7.75-9.0	b	6	b	b	b	5	4	5	11	7	b	10	11	b	11
	9.0-10.75	b	6	b	b	b	5	4	5	11	7	b	10	11	4	11
	10.75-12.75	b	6	b	b	b	5	4	5	11	11	b	10	11	4	11
	12.75-15.0	b	10	b	b	b	10	4	5	11	11	b	10	11	9	12
	15.0-17.5	b	10	b	b	b	10	5	5	11	11	b	11	12	10	16
	17.5-20.0	b	11	b	b	b	10	5	9	11	11	b	15	16	10	16
	20.0-23.0	b	11	b	b	b	10	9	9	16	11	b	15	16	10	16
	23.0-27.0	b	b	b	b	b	b	b	b	b	b	b	16	b	15	b

Appendix P: Climatic conditions

Col. 1 Country and Station	Col. 2 Latitude and Longitude	Col. 3 Elevation, Ft	Winter			Summer								
			Col. 4			Col. 5 Design Dry-Bulb			Col. 6 Out-door Daily Range F deg	Col. 7 Design Wet-Bulb				
			Mean of Annual Ex-tremes	99%	97½%	1%	2½%	5%		1%	2½%	5%		
IRAN														
Abadan	30 21N/48 16E	7	32	39	41	116	113	110	32	82	81	81		
Meshed	36 17N/59 36E	3104	3	10	14	99	96	93	29	68	67	66		
Tehran	35 41N/51 25E	4002	15	20	24	102	100	98	27	75	74	73		
IRAQ														
Baghdad	33 20N/44 24E	111	27	32	35	113	111	108	34	73	72	72		
Mosul	36 19N/43 09E	730	23	29	32	114	112	110	40	73	72	72		
IRELAND														
Dublin	53 22N/6 21W	155	19	24	27	74	72	70	16	65	64	62		
Shannon	52 41N/8 55W	8	19	25	28	76	73	71	14	65	64	63		
ISRAEL														
Jerusalem	31 47N/35 13E	2485	31	36	38	95	94	92	24	70	69	69		
Tel Aviv	32 06N/34 47E	36	33	39	41	96	93	91	16	74	73	72		
ITALY														
Milan	45 27N/09 17E	341	12	18	22	80	87	84	20	76	75	74		
Naples	40 53N/14 18E	220	28	34	36	91	88	86	19	74	73	72		
Rome	41 48N/12 36E	377	25	30	33	94	92	89	24	74	73	72		
IVORY COAST														
Abidjan	5 19N/4 01W	65	64	67	69	91	90	88	15	83	82	81		
JAPAN														
Fukuoka	33 35N/130 27E	22	26	29	31	92	90	89	20	82	80	79		
Sapporo	43 04N/141 21E	56	- 7	1	5	86	83	80	20	76	74	72		
Tokyo	35 41N/139 46E	19	21	26	28	91	89	87	14	81	80	79		
JORDAN														
Amman	31 57N/35 57E	2548	29	33	36	97	94	92	25	70	69	68		
KENYA														
Nairobi	1 16S/36 48E	5971	45	48	50	81	80	78	24	66	65	65		
KOREA														
Pyongyang	39 02N/125 41E	186	-10	- 2	3	80	87	85	21	77	76	76		
Seoul	37 34N/126 58E	285	- 1	7	9	91	89	87	16	81	79	78		
LEBANON														
Beirut	33 54N/35 28E	111	40	42	45	93	91	90	15	78	77	76		
LIBERIA														
Monrovia	6 18N/10 48W	75	64	68	69	90	89	88	19	82	82	81		
LIBYA														
Bengasi	32 06N/20 04E	82	41	46	48	97	94	91	13	77	76	75		
MADAGASCAR														
Tananarive	18 55S/47 33E	4531	39	43	46	86	84	83	23	73	72	71		
MALAYSIA														
Kuala Lumpur	3 07N/101 42E	127	67	70	71	94	93	92	20	82	82	81		
Penang	5 25N/100 19E	17	69	72	73	93	93	92	18	82	81	80		
Singapore	1 18N/103 50E	33	69	71	72	92	91	90	14	82	81	80		
MARTINIQUE														
Fort de France	14 37N/61 05W	13	62	64	66	90	89	88	14	81	81	80		
MEXICO														
Guadalajara	20 41N/103 20W	5105	35	39	42	93	91	89	29	68	67	66		
Mérida	20 58N/89 38W	72	56	59	61	97	95	94	21	80	79	77		
Mexico City	19 24N/99 12W	7575	33	37	39	83	81	79	25	61	60	59		
Monterrey	25 40N/100 18W	1732	31	38	41	98	95	93	20	79	78	77		
Vera Cruz	19 12N/96 08W	184	55	60	62	91	89	88	12	83	83	82		
MOROCCO														
Casablanca	33 35N/7 39W	164	36	40	42	94	90	86	50	73	72	70		
NEPAL														
Katmandu	27 42N/85 12E	4388	30	33	35	89	87	86	25	78	77	76		
NETHERLANDS														
Amsterdam	52 23N/4 55E	5	17	20	23	79	76	73	10	65	64	63		
NEW GUINEA														
Manokwari	0 52S/134 05E	62	70	71	72	89	88	87	12	82	81	81		
Point Moresby	9 29S/147 09E	126	62	67	69	92	91	90	14	80	80	79		
NEW ZEALAND														
Auckland	36 51S/174 46E	140	37	40	42	78	77	76	14	67	66	65		
Christ Church	43 32S/172 37E	32	25	28	31	82	79	76	17	68	67	66		
Wellington	41 17S/174 46E	394	32	35	37	76	74	72	14	66	65	64		
NICARAGUA														
Managua	12 10N/86 15W	135	62	65	67	94	93	92	21	81	80	79		
NIGERIA														
Lagos	6 27N/3 24E	10	67	70	71	92	91	90	12	82	82	81		
NORWAY														
Bergen	60 24N/5 19E	141	14	17	20	75	74	73	21	67	66	65		
Oslo	59 56N/10 44E	308	- 2	0	4	79	77	74	17	67	66	64		

Appendix Q: Roof classification

Mass Location ^a	Suspended Ceiling	R-Factor, (ft ² -hr-F)/Btu	B7, Wood 1 in.	C12, HW Concrete 2 in.	A3, Steel Deck	Attic-Ceiling Combination
Mass inside the insulation	Without	0 to 5	<i>b</i>	2	<i>b</i>	<i>b</i>
		5 to 10	<i>b</i>	2	<i>b</i>	<i>b</i>
		10 to 15	<i>b</i>	4	<i>b</i>	<i>b</i>
		15 to 20	<i>b</i>	4	<i>b</i>	<i>b</i>
		20 to 25	<i>b</i>	5	<i>b</i>	<i>b</i>
		25 to 30	<i>b</i>	<i>b</i>	<i>b</i>	<i>b</i>
	With	0 to 5	<i>b</i>	5	<i>b</i>	<i>b</i>
		5 to 10	<i>b</i>	8	<i>b</i>	<i>b</i>
		10 to 15	<i>b</i>	13	<i>b</i>	<i>b</i>
		15 to 20	<i>b</i>	13	<i>b</i>	<i>b</i>
		20 to 25	<i>b</i>	14	<i>b</i>	<i>b</i>
		25 to 30	<i>b</i>	<i>b</i>	<i>b</i>	<i>b</i>
Mass evenly placed	Without	0 to 5	1	2	1	1
		5 to 10	2	<i>b</i>	1	2
		10 to 15	2	<i>b</i>	1	2
		15 to 20	4	<i>b</i>	2	2
		20 to 25	4	<i>b</i>	2	4
		25 to 30	<i>b</i>	<i>b</i>	<i>b</i>	<i>b</i>
	With	0 to 5	<i>b</i>	3	1	<i>b</i>
		5 to 10	4	<i>b</i>	1	<i>b</i>
		10 to 15	5	<i>b</i>	2	<i>b</i>
		15 to 20	9	<i>b</i>	2	<i>b</i>
		20 to 25	10	<i>b</i>	4	<i>b</i>
		25 to 30	10	<i>b</i>	<i>b</i>	<i>b</i>
Mass outside the insulation	Without	0 to 5	<i>b</i>	2	<i>b</i>	<i>b</i>
		5 to 10	<i>b</i>	3	<i>b</i>	<i>b</i>
		10 to 15	<i>b</i>	4	<i>b</i>	<i>b</i>
		15 to 20	<i>b</i>	5	<i>b</i>	<i>b</i>
		20 to 25	<i>b</i>	5	<i>b</i>	<i>b</i>
		25 to 30	<i>b</i>	<i>b</i>	<i>b</i>	<i>b</i>
	With	0 to 5	<i>b</i>	3	<i>b</i>	<i>b</i>
		5 to 10	<i>b</i>	3	<i>b</i>	<i>b</i>
		10 to 15	<i>b</i>	4	<i>b</i>	<i>b</i>
		15 to 20	<i>b</i>	5	<i>b</i>	<i>b</i>
		20 to 25	<i>b</i>	<i>b</i>	<i>b</i>	<i>b</i>
		25 to 30	<i>b</i>	<i>b</i>	<i>b</i>	<i>b</i>

Appendix R: July cooling load temperature differences (CLTDs) for roofs

Roof No.	Solar Time, hr																								Roof No.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
Flat Roofs 24° North Latitude																									
1	0	-2	-4	-5	-6	-6	-3	9	26	44	62	76	87	92	92	86	74	58	39	23	14	8	4	2	1
2	2	0	-2	-4	-5	-6	-5	1	14	30	48	64	77	86	90	89	82	70	53	36	23	14	8	5	2
3	12	8	5	2	0	-2	-2	3	11	22	35	47	59	68	74	77	74	68	58	47	37	29	22	16	3
4	16	11	6	3	0	-2	-3	-4	-1	5	15	27	41	55	67	75	80	80	76	67	55	43	32	23	4
5	21	16	12	8	5	3	1	1	4	10	19	30	42	52	61	68	71	70	66	59	50	41	33	27	5
8	28	24	20	17	14	11	9	9	10	14	20	27	35	43	49	54	58	58	56	52	47	42	37	32	8
9	31	25	20	16	12	9	6	4	3	5	10	17	26	36	46	54	61	65	66	63	58	51	44	37	9
10	36	31	27	22	19	15	12	9	8	8	11	16	22	30	37	45	52	56	59	59	56	52	47	41	10
14	34	32	30	27	25	23	21	19	19	19	21	24	27	32	36	40	43	45	46	45	44	42	39	37	14
Flat Roofs 32° North Latitude																									
1	0	-2	-4	-5	-6	-6	-1	11	27	45	62	76	86	91	91	85	75	59	41	25	15	9	5	2	1
2	2	0	-2	-4	-5	-6	-4	3	16	32	48	64	76	85	89	88	82	70	55	38	24	15	9	5	2
3	12	8	5	2	0	-2	-1	4	12	23	35	48	59	68	74	76	74	68	59	48	38	29	22	17	3
4	17	11	7	3	1	-1	-3	-3	0	6	16	28	42	55	66	75	79	80	76	67	56	44	33	24	4
5	21	16	12	8	5	3	1	1	5	12	21	31	42	52	61	67	71	70	66	59	51	42	34	27	5
8	29	25	21	17	14	12	10	9	11	15	21	28	35	43	49	54	57	58	57	53	48	43	38	33	8
9	32	26	21	16	12	9	6	4	4	6	11	18	27	37	46	54	61	65	66	64	59	52	45	38	9
10	37	32	27	23	19	15	12	10	9	9	12	16	23	30	38	45	52	56	59	59	56	52	47	42	10
14	35	32	30	28	25	23	21	20	19	20	22	24	28	32	36	40	43	45	46	46	44	42	40	37	14
Flat Roofs 40° North Latitude																									
1	0	-2	-4	-5	-6	-6	0	13	29	45	60	73	83	88	88	83	73	60	43	26	15	9	5	2	1
2	2	0	-2	-4	-5	-6	-4	4	17	32	48	62	74	82	86	85	80	70	56	39	25	15	9	5	2
3	12	8	5	2	0	-2	0	5	13	24	35	47	57	66	72	74	73	67	59	48	38	30	23	17	3
4	17	11	7	3	1	-1	-3	-3	0	7	17	29	42	54	65	73	77	78	74	67	56	45	34	24	4
5	21	16	12	8	5	3	1	2	6	12	21	31	41	51	60	66	69	69	65	59	51	42	34	27	5
8	28	24	21	17	14	12	10	10	12	16	21	28	35	42	48	53	56	57	56	52	48	43	38	33	8
9	32	26	21	16	13	9	6	4	4	7	12	19	27	36	45	53	59	63	64	63	58	52	45	38	9
10	37	32	27	23	19	15	12	10	9	10	12	17	23	30	37	44	50	55	57	58	56	52	47	42	10
14	35	32	30	27	25	23	21	20	19	20	22	24	28	32	36	39	42	44	45	45	44	42	40	37	14
Flat Roofs 48° North Latitude																									
1	0	-2	-4	-5	-6	-5	3	15	29	44	58	69	78	83	83	79	71	59	44	29	17	9	5	2	1
2	2	0	-2	-4	-5	-5	-2	6	19	32	47	60	70	78	82	81	76	68	55	41	27	16	10	5	2
3	12	8	5	2	0	-1	1	6	14	24	35	45	55	63	68	71	70	65	58	48	38	30	23	17	3
4	17	12	7	3	1	-1	-3	-2	2	8	18	29	40	52	62	69	73	74	71	65	55	45	34	25	4
5	21	16	12	8	5	3	2	3	7	13	21	31	40	49	57	63	66	66	63	58	50	42	34	27	5
8	28	24	20	17	14	11	10	10	12	16	21	27	34	40	46	51	54	55	54	51	47	42	37	32	8
9	31	26	21	16	12	9	6	5	5	8	12	19	27	35	43	51	57	60	62	61	57	51	44	38	9
10	36	31	27	22	19	15	12	10	9	10	13	17	23	29	36	43	48	53	55	56	54	51	46	41	10
14	34	32	29	27	25	23	21	20	19	20	22	24	27	31	35	38	41	43	44	44	43	41	39	36	14

Appendix S: Rates of heat gain from occupants

Degree of Activity	Location	Total Heat Btu/hr		Sensible Heat, Btu/hr	Latent Heat, Btu/hr	% Sensible Heat that is Radiant	
		Adult Male	Adjusted, M/F ^a			Low V	High V
Seated at theater	Theater, matinee	390	330	225	105	60	27
Seated at theater, night	Theater, night	390	350	245	105		
Seated, very light work	Offices, hotels, apartments	450	400	245	155		
Moderately active office work	Offices, hotels, apartments	475	450	250	200	58	38
Standing, light work; walking	Department store; retail store	550	450	250	200		
Walking, standing	Drug store, bank	550	500	250	250		
Sedentary work	Restaurant ^b	490	550	275	275		
Light bench work	Factory	800	750	275	475	49	35
Moderate dancing	Dance hall	900	850	305	545		
Walking 3 mph; light machine work	Factory	1000	1000	375	625		
Bowling ^c	Bowling alley	1500	1450	580	870	54	19
Heavy work	Factory	1500	1450	580	870		
Heavy machine work; lifting	Factory	1600	1600	635	965		
Athletics	Gymnasium	2000	1800	710	1090		

Appendix T: Hourly cooling input(kW) for July 21

Hour	Dry-Bulb Temp (F)	Modern building Cooling Input (kW)	Rana era building Cooling Input (kW)
1	72.5	0	0
2	71.6	0	0
3	69.8	0	0
4	71.6	0	0
5	69.8	0	0
6	69.8	0	0
7	69.8	0	0
8	71.6	0	0
9	75.2	0	0
10	78.8	0	0
11	80.6	65.602	51.195
12	80.6	49.243	42.865
13	83.3	44.986	39.248
14	84.2	49.172	44.153
15	78.8	46.388	40.796
16	78.8	43.917	38.307
17	82.4	47.184	42.273
18	80.6	0	0
19	78.4	0	0
20	77	0	0
21	75.2	0	0
22	73.4	0	0
23	73.4	0	0
24	73.4	0	0

Appendix U: Daily cooling input(kW) for July

Day	Modern building Cooling Input (kWh)	Rana era building Cooling Input (kWh)
1	386	352
2	405	359
3	385	338
4	380	340
5	0	0
6	345	305
7	329	301
8	305	288
9	269	256
10	249	240
11	250	241
12	0	0
13	114	141
14	194	209
15	255	257
16	268	244
17	322	294
18	338	294
19	0	0
20	298	233
21	346	299
22	344	301
23	317	277
24	245	217
25	262	261
26	0	0
27	271	242
28	346	314
29	365	325
30	363	328
31	355	319
Total	8308	7575

Appendix V: Monthly cooling input (kWh)

Month	Modern Building Cooling Input (kWh)	Rana era Building Cooling Input (kWh)
March	4406	3410
April	5644	4567

May	7244	6088
June	8280	7307
July	8308	7575
August	7953	7077
September	7950	7071
October	6272	5472
Total	56057	48567

Appendix W: Monthly temperature pattern for Kathmandu Valley (°F) from HAP

Month	Max DBT	Min DBT	Max WBT	Min WBT
Jan	77.2	52.2	70.6	51.7
Feb	79.2	54.2	71.6	53.7
Mar	82.4	57.4	74.8	56.9
Apr	83.6	58.6	75.0	58.1
May	86.0	61.0	76.0	60.5
Jun	88.0	63.0	78.0	62.5
Jul	89.0	64.0	78.0	63.5
Aug	89.0	64.0	78.0	63.5
Sep	87.0	62.0	77.0	61.5
Oct	84.8	59.8	75.8	59.3
Nov	80.6	55.6	73.8	55.1
Dec	78.2	53.2	71.8	52.7

Appendix X: Monthly temperature pattern for Kathmandu Valley (°F) from DHM

Month	Average BDT
Jan	49.87
Feb	55.10
Mar	62.72
Apr	68.83
May	72.03
Jun	75.85
Jul	75.00
Aug	74.81
Sep	73.67
Oct	68.15
Nov	58.94
Dec	51.21

Appendix Y: Monthly temperature pattern for Kathmandu Valley (°F)

Typical Heat Gain from Medical Equipment

Typical Equipment	Medical Nameplate, W	Equipment Peak, W	Average, W
Anesthesia system	250	177	166
Blanket warmer	500	504	221
Blood pressure meter	180	33	29
Blood warmer	360	204	114
ECG/RESP	1440	54	50
Electro surgery	1000	147	109
Endoscope	1688	605	596
Harmonical scalpel	230	60	59
Hysteroscopic pump	180	35	34
Laser sonics	1200	256	229
Optical microscope	330	65	63
Pulse oximeter	72	21	20
Stress treadmill	N/A	198	173
Ultrasound system	1800	1063	1050
Vacuum suction	621	337	302
X-ray system	968	...	82
X-ray system	1725	534	480
X-ray system	2070	...	18

Recommended Heat Gain from Typical Laboratory Equipment

Typical Equipment	Nameplate, W	Peak, W	Average, W
Analytical balance	7	7	7
Centrifuge	138	89	87
Centrifuge	288	136	132
Centrifuge	5500	1176	730
Electrochemical analyzer	50	45	44
Electrochemical analyzer	100	85	84
Flame photometer	180	107	105
Fluorescent microscope	150	144	143
Fluorescent microscope	200	205	178
Function generator	58	29	29
Incubator	515	461	451
Incubator	600	479	264
Incubator	3125	1335	1222
Orbital shaker	100	16	16
Oscilloscope	72	38	38
Oscilloscope	345	99	97
Rotary evaporator	75	74	73
Rotary evaporator	94	29	28
Spectronics	36	31	31
Spectrophotometer	575	106	104
Spectrophotometer	200	122	121
Spectrophotometer	N/A	127	125
Spectro fluorometer	340	405	395
Thermocycler	1840	965	641
Thermocycler	N/A	233	198
Tissue culture	475	132	46
Tissue culture	2346	1178	1146

Recommended Heat Gain from Typical Computer Equipment

Computer Equipment	Continuous, W	Energy Saver Mode, W
Computers		
Average value	55	20
Conservative value	65	25

Computer Equipment	Continuous, W	Energy Saver Mode, W
Highly conservative value	75	30
Monitors Displaying Windows		
Small monitor (13 to 15 in.)	55	0
Medium monitor (16 to 18 in.)	70	0
Large monitor (19 to 20 in.)	80	0

Recommended Heat Gain from Typical Laser Printers and Copiers

	Continuous, W	1 page/min, W	Idle, W
Laser Printers			
Small desktop	130	75	10
Desktop	215	100	35
Small office	320	160	70
Large office	550	275	125
Copiers			
Desktop copier	400	85	20
Office copier	1,100	400	300

Recommended Heat Gain from Miscellaneous Office Equipment

Appliances	Maximum Input Rating, W	Recommended Rate of Heat Gain, W
Mail-processing equipment		
Folding machine	125	80
Inserting machine, 3,600 to 6,800 pieces/hr	600 to 3,300	390 to 2,150
Labeling machine, 1,500 to 30,000 pieces/hr	600 to 6,600	390 to 4,300
Postage meter	230	150
Vending machines		
Cigarette	72	72
Cold food/beverage	1,150 to 1,920	575 to 960
Hot beverage	1,725	862
Snack	240 to 275	240 to 275
Other		
Bar code printer	440	370
Cash registers	60	48
Check processing workstation, 12 pockets	4,800	2,470
Coffee maker, 10 cups	1,500	1050 W sensible, 1540 Btu/hr latent
Microfiche reader	85	85
Microfilm reader	520	520
Microfilm reader/printer	1,150	1150
Microwave oven, 1 ft ³	600	400
Paper shredder	250 to 3,000	200 to 2420
Water cooler, 32 qt/hr	700	350

Appendix Z: Space name, floor area, number of people, lights and equipment

Space	Floor Area (sqft)	Number of people	Number of Lights	Number of computers	Water Dispenser	Number of printers	Number of projector
001 ADMIN UNIT	673.0	11	8	3	1	3	0
002 ADMIN UNIT	688.3	10	8	2	0	2	0
008 ACADEMIC UNIT 3	224.6	4	4	1	0	1	0
009 ACADEMIC UNIT 4	342.7	4	4	1	0	1	0
013 STORE MANAGER	118.8	5	2	0	0	0	0
014 STORAGE STAFF AREA	498.7	5	6	1	1	1	0
018 OFFICE	111.1	3	1	1	0	1	0
021 OFFICE	544.0	10	6	2	0	2	0
023 OFFICE	349.7	6	4	2	1	2	0
024 OFFICE	206.5	3	2	1	0	1	0
028 FINANCE DEPARTMENT 1	465.7	7	2	4	0	4	0
029 FINANCE DEPARTMENT 2	1,475.8	15	10	1	1	1	0
100 OFFICE	702.6	7	4	1	0	1	0
105 HALL	1,019.2	56	30	0	0	0	1
107 OFFICE	187.2	4	4	1	0	1	0
108 OFFICE	312.2	6	4	1	0	1	0
109 OFFICE	380.6	4	4	1	0	1	0
111 OFFICE	196.0	4	4	1	0	1	0
114 OFFICE	387.4	9	4	1	0	1	0
115 OFFICE	197.0	9	3	1	0	1	0
120 OFFICE	542.5	6	4	1	0	1	0
121 OFFICE	347.5	10	4	2	1	2	0
122 OFFICE	357.8	10	4	2	1	2	0
123 OFFICE	342.3	7	2	2	1	1	0

124 OFFICE	147.8	3	2	1	0	1	0
127 OFFICE	1,479.9	25	8	2	0	2	0
128 OFFICE	570.6	19	8	1	1	1	0
203 OFFICE	172.3	5	1	1	0	1	0
204 OFFICE	168.6	5	1	1	0	1	0
205 OFFICE	166.4	5	1	1	0	1	0
206 OFFICE	149.2	5	1	1	0	1	0
207 OFFICE	183.1	5	1	1	0	1	0
208 OFFICE	185.7	5	1	1	0	1	0
213 OFFICE	120.6	5	1	0	0	0	0
215 OFFICE	198.6	9	2	1	0	1	0
216 OFFICE	168.0	7	2	1	0	1	0
217 OFFICE	205.3	7	2	1	0	1	0
221 OFFICE	330.0	9	4	2	1	2	0
222 OFFICE	206.6	9	4	2	1	2	0
223 HALL	519.2	18	6	0	0	0	1
223 OFFICE	351.8	9	4	2	1	2	0
224 OFFICE	359.4	9	4	2	1	2	0
227 OFFICE	315.1	9	4	2	0	2	0
229 OFFICE	1,000.2	15	4	3	0	3	0
230 OFFICE	1,050.2	19	4	4	0	4	0

Appendix AA: CLTD calculation sample

For the month of July at 15:00

002 ADMIN UNIT					
Area	586.42	sq ft			
Height	11.36	ft	Volume	6661.731	cu ft
Design Conditions					
Temperature	DB (F)	WB (F)	humidity ratio	DR (F)	w
Outdoor, to	89	78		25	0.0228
Indoor, ti	72			50	0.0102

Ambient temperature (F) Temperature of unconditioned space
76.5 84

Wall on NW and SW

Outside wall resistance	
Outside surface resistance A0	0.33
1/2-in gypsum plaster	0.32
C9-8 in common brick	1.59
1/2-in gypsum plaster	0.32
Inside surface resistance E0	0.69
Total thermal resistance R _t (ft ² ·h·ft ² ·oF)	3.25
U-value(Btu/hr.ft2.oF)	0.31

Wall type 5

Partition wall

Outside surface resistance A0	0.69
1/2-in gypsum plaster	0.32
C4-4 in common brick	0.79
1/2-in gypsum plaster	0.32
Inside surface resistance E0	0.69
Thermal resistance _t (ft ² ·h·ft ² ·oF)/ Btu	2.81
U-value (Btu/hr.ft2.oF)	0.36

Wall	Latitude		
Exposure	24	32	27.42
NE	0	0	0
NW	11	18	13.9925
SW	20	22	20.855
SE			0

Glass SHGF	Latitude		
Exposure	24	28	27.42
NE			
NW	176	170	170.87

CLTDc(F)=C 1 BTU/hr = 0.293071 W

Conduction	Direction	U (Btu/hr.ft2.oF)	Area (ft2)	CLTD(F)	CLTDc(F)	Cooling load (BTU/hr)	Cooling load (W)
Glass	NE	0.89		0	14	0.00	0.00
	SW	0.89		66.6	14	829.84	243.20
Wall	SW	0.31	171.901	20.855	18.355	971.81	284.81
	NW	0.31		0	13.9925	11.4925	0.00
Door	NE	0.47		26.87	31.145	393.33	115.27
	NW	0.47		26.87	13.9925	176.71	51.79
						Total	2371.69
							695.07
Solar	Direction	SC	Area (ft2)	CLF	SHGF(BTU/hr-ft ²)	Cooling load (BTU/hr)	Cooling load (W)
Glass	NE						
	NW	0.94	53.74	0.52	170.87	4488.432297	1315.43
						Total	4488.43
							1315.43

Internal

Wall	U (Btu/hr.ft2.oF)	Area (ft2)	dT	Cooling load (BTU/hr)	Cooling load (W)
Wall	0.356	472.1142	12	2016.15	590.87
Ceiling	0.250	586.42	12	1548.15	453.72
				Total	3564.29
					1044.59

People	n	q(BTU/hr)	CLF	Cooling load (BTU/hr)	Cooling load (W)
SHG	11	245	0.76	2048.2	600.27
LHG	11	155		1705	499.69
				Total	3753.20
					1099.95

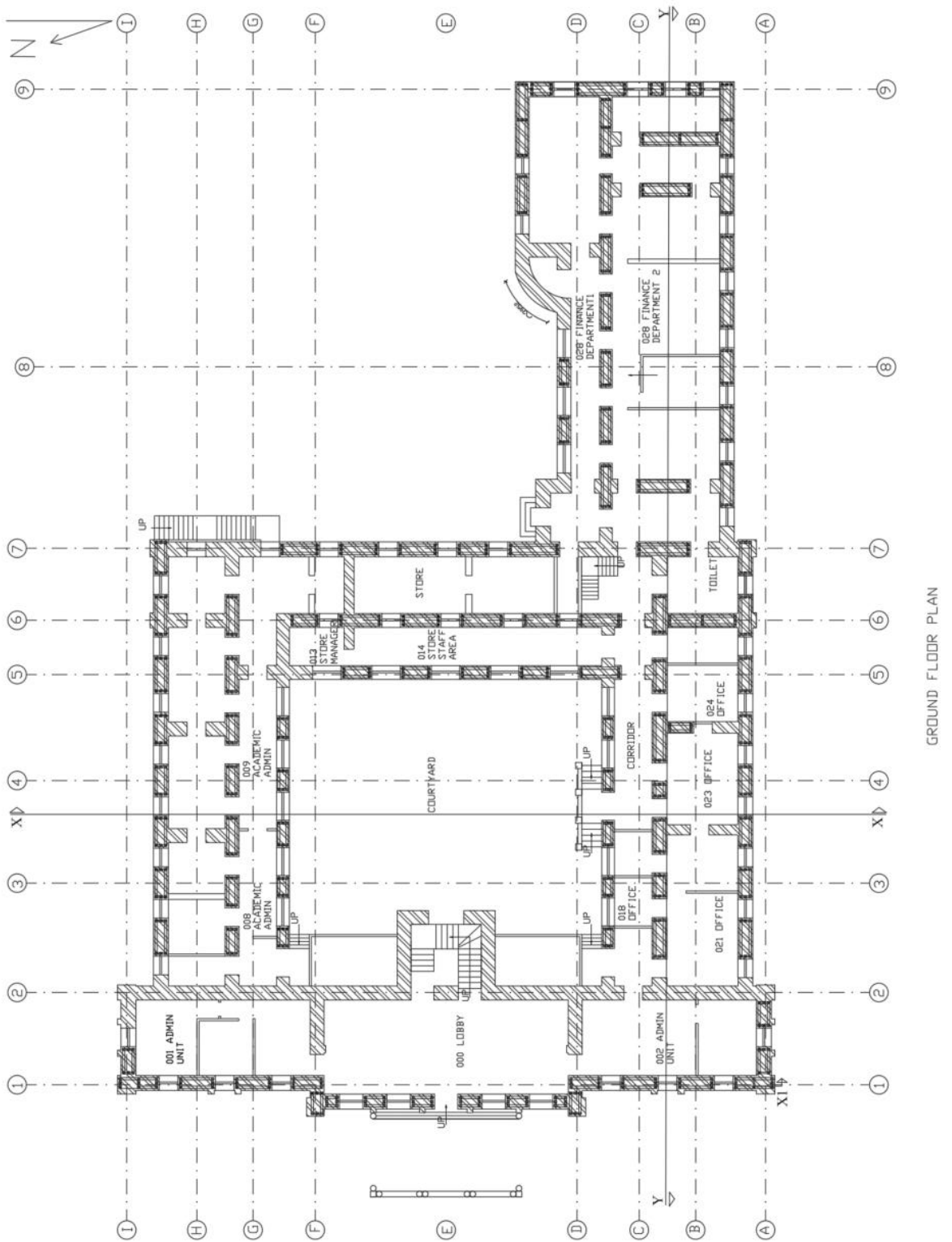
Equipment	n	q(BTU/hr)	q(BTU/hr)	Cooling load (BTU/hr)	Cooling load (W)
Computer	2	187.55		375.1	109.93
Water Dispenser	0	3580.5	1540	0	0.00
Printer	2	443.3		886.6	259.84
Photo copy machine					
				Total	1261.70
					369.77

Lighting	n	W	BF	CLF	Cooling load (BTU/hr)	Cooling load (W)
LED tubelight	8	20		1	545.6	159.90
					Total	545.6
						159.8995376

Infiltration	CFM(ft3/min)	TC(F)	(wo' - wi')	Cooling load (BTU/hr)	Cooling load (W)
SHG	55.51442667	17		1019.24	298.71
LHG	55.51442667	17	0.0126	3385.49	992.19
				Total	4404.74
					1290.90

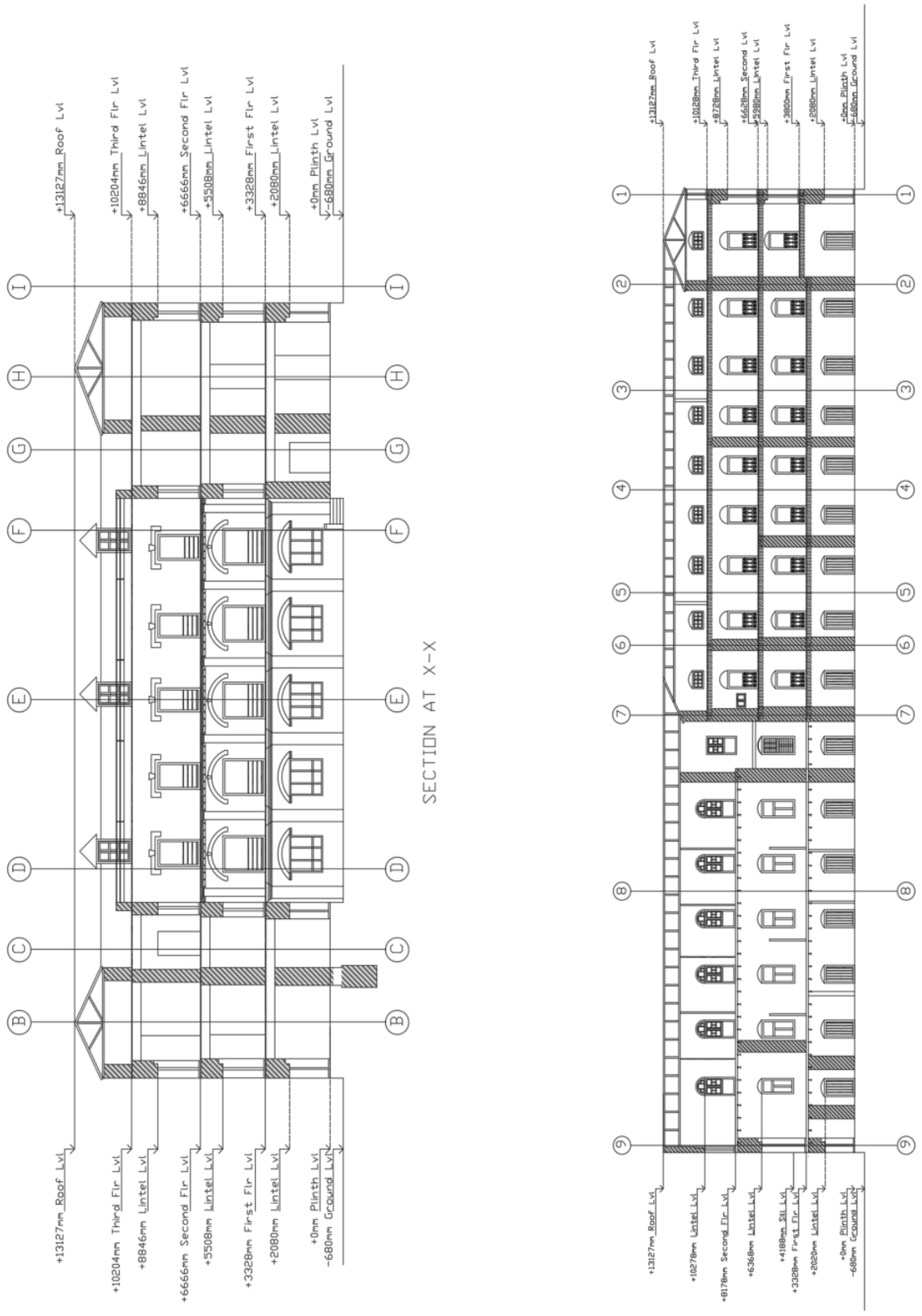
Grand Total 20389.652 5975.62
1.699 (Tonnage)

Appendix AB: Ground floor architectural plan



GROUND FLOOR PLAN

Appendix AE: Architectural sections





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Journal of Advanced College of Engineering and Management**

24th April, 2026

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Nirmala Kutuwo, Bishwo Prasanna Amatya, Laxman Motra

The Editorial Board of Journal of Advanced College of Engineering and Management (jacem) (ISSN No: 2392-4853), is pleased to inform you that your manuscript "**Comparative Study of Cooling Load Between a Rana Era and a Modern Building in Nepal**" has been reviewed by the referee and accepted for the publication. Your article will be published in the coming issue of Journal of Advanced College of Engineering and Management, Vol. 13.


We are delighted and thankful for considering this Journal as a venue of your valuable research work.

With Regards

Er. Ajaya Shrestha
Editor-in-Chief, jacem
Advanced College of Engineering and Management
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