A

PROJECT REPORT

on

Cooling Load Estimation of SCE, Saharsa for Library and Computer Lab

Submitted by

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In the partial fulfillment of requirement for the degree of

Bachelor of Technology

in

MECHANICAL ENGINEERING

Under the guidance of

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CANDIDATE'S DECLARATION

We hereby declare that the work which is being presented in this project report entitled, "**Cooling Load Estimation of SCE, Saharsa for Library and Computer Lab"** in partial fulfillment of requirement for the award of the degree of **Bachelor of Technology** in **Mechanical Engineering**, submitted in the department of Mechanical Engineering, SCE Saharsa, is an authentic record of our own work carried out under the guidance of KUNDAN KUMAR**,** Assistant Professor, Department of MECHANICAL Engineering, SCE Saharsa.

The matter embodied in this report has not been submitted anywhere by us for the award of any other degree or diploma.

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CERTIFICATE

This is to certify that project report entitled "***Cooling Load Estimation for computer lab and Library office Room***" which is submitted by "**Nilesh Kumar-17102132046, Rajnish Kumar-17102132040, Raushan Kumar-17102132049, Tarun Dev-17102132027,**" in partial fulfilment of the requirement of project work for the degree of Bachelor of Technology in department of Mechanical Engineering of Saharsa College of Engineering, Saharsa is a record of the candidate own work carried out by them under my/our supervision. The matter embodied in this project report is original and has not been submitted anywhere for the award of any other degree or diploma.

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CHAPTER 1

INTRODUCTION

1.1. General

In present days the environmental problem is one of the most serious problems. Energy consumption by industries and buildings are responsible for this problem. About 72% of world energy is consumed by infrastructure, industry, commercial buildings, residential houses, and markets. In a large building or complex, which is air-conditioned, about 60% of the total energy requirement in the building is allocated for the air-conditioning plant installed to use the cooling purpose.

Exact prediction of the cooling and heating load, proper sizing of the heat ventilation air-conditioning (HVAC) system and optimal control of the HVAC systems are important to minimize energy consumption. Root factors that affect cooling loads are the external climates such as outdoor temperature, solar radiation and humidity. Local climatic conditions are important parameters for the energy efficiency of buildings. Because the energy consumption in buildings depends on the climatic conditions and the performance of heating ventilating and air conditioning (HVAC) systems changes with them as well, better design in building HVAC applications that take account of the right climatic conditions will result in better comfort and more energy efficient buildings.

Calculation of thermal load of building is very essential to find exact air-conditioning equipment and air handling unit, to achieve comfort operation and good air distribution in the air-conditioned zone.

This project ***Cooling load estimation for Library and Computer office building*** presents by using CLTD method

1.2. Terminology

Commonly used terms relative to cooling load calculation and heat transfer of the buildings according to the ASHRAE reference are given below.

a) **Refrigeration: -** the term 'Refrigeration' means process of removing heat from a substance or space under the controlled conditions. It also include the process of reducing and maintaining the temperature of a body below the surrounding temperature

b) **Unit of refrigeration: -** the practical unit of refrigeration is expressed in terms of 'tonne of refrigeration (TR)'. A tonne of refrigeration is defined as the amount of refrigeration effects produced by the melting of 1 ton of ice from and at 0 °C in 24 hours.

c) **Coefficient of performance (COP): -** the COP is defined as the ratio of heat extracted in the refrigerator to the work done on the refrigerant.

d) **Refrigerant: -** refrigerant is the fluid used for heat transfer in a refrigerating system that release heat during condensation at a region of higher temperature and pressure, and absorbs heat during evaporation at low temperature and pressure region.

e) **Air conditioning: -** controlling and maintaining environmental parameters such as temperature, humidity, cleanliness, air movement, sound level, pressure difference between condition space and surrounding within prescribed limit.

f) **CLTD: -** cooling load temperature difference is an equivalent temperature difference used for calculating the instantaneous external cooling load across the walls and roofs.

g) **Humidity: -** it is the mass of water vapour present in 1 kg of dry air, and is generally expressed in terms of gram per kg of dry air (g/kg of dry air). It is also called specific humidity or humidity ratio.

h) **Relative humidity (RH): -** it is a ratio of actual mass of water vapour in a given volume of moist air to the mass of water vapour in the same volume of saturated air at the same temperature and pressure.

i) **Dry bulb temperature (DBT): -** it is the temperature of air recorded by thermometer, when it is not affected by the moisture present in the air. The dry bulb temperature is generally denoted by t_d or t_{db}.

j) **Wet bulb temperature (WBT): -** it is the temperature of air recorded by a thermometer, when its bulb is surrounded by a wet cloth exposed to the air. The wet bulb temperature is generally denoted by t_w or t_{wb}.

k) **Dew point temperature (DPT): -** it is the temperature of the air recorded by the thermometer, when the moisture present it beings to condense.

l) **Heat transfer coefficient: -** it is the rate of heat transfer through a unit area of building envelope material, including its boundary films, per unit temperature difference between the outside and inside air.

m) **Thermal resistance: -** it is the reciprocal of the heat transfer coefficient and is expressed in m^2-K/W.

n) **Sensible heat gain: -** direct addition of heat to the enclosed space, without any change in its specific humidity, is known as sensible heat gain.

o) **Latent heat gain: -** heat gain of space through addition of moisture, without change in its dry bulb temperature, is known as latent heat gain.

p) **Space heat gain: -** it is the rate of heat gain, at which heat inter into and generated within the conditioned space.

q) **Space cooling load: -** it is the rate at which energy must be removed from a space to maintain a desired air temperature of space.

1.3 Objective

The objective of this paper is to calculate cooling load to find exact air-conditioning equipment and air handling unit, to achieve comfort operation and good air distribution in the air-conditioned zone.

1.3.1 HVAC system design

The main objectives of HVAC system design are as follows

i. Control of temperature, humidity, air purity and correct pressurization to avoid contamination.

ii. Provide comfort and healthy indoor environment of office buildings, educational buildings, cinemas, libraries, auditoriums, multiplex, shopping centers, hotel, public place,

iii. Provide special air filtration to remove bacteria, high indoor quality, avoid cross contamination.

1.3.2 Cooling load calculation

The objectives of cooling load calculation are as follows

i. To determine be the optimum rate at which heat needs to be removed from space to establish thermal equilibrium & maintain a pre-determined inside conditions
ii. To calculate peak design loads (cooling/heating).
iii. To estimate capacity or size of plant/equipment.
iv. To provide info for HVAC designs e.g. load profiles.
v. To form the basis for building energy analysis

1.4. Human comfort

Human comfort is the condition of mind, which expresses satisfaction with the thermal environment. Air conditioning of any building mainly concerns the comfort of people.

1.4.1. Heat exchange of human body with environment

A human body feels comfortable thermodynamically when the heat produced by the metabolism of human body is equal to the sum of the heat dissipated to the surrounding and the heat stored in the human body by raising the temperature of body tissues. The metabolic heat production depends upon the food consumption in the body.

Convection heat loss

The convective heat loss from the body is given by the Eqn. 1.2.

$$Q_C = UA\,(T_b - T_s) \quad \text{......} \quad (1.2)$$

Where

U = heat transfer coefficient on body surface.

A = body surface area.

T_b, T_s = temperature of the body and surrounding respectively.

1.4.1.1 Radiation heat loss

The radiation heat loss from body to the surrounding is given by the Eqn. 1.3.

$$Q_R = \sigma\,(T_b^4 - T_s^4) \quad \text{......} \quad (1.3)$$

σ is Stefan-Boltzmann constant.

1.5 Effective temperature

The degree of warmth or cold felt by a human body depends mainly on the following three factors

1. **Dry bulb temperature, 2. Relative humidity and 3. Air velocity.**

In order to evaluate the combined effects of the three factors is called effective temperature, It is defined as that index which correlate the combined effects of air temperature, relative humidity and air velocity on the human body.

The practical application of the concept of effective temperature is presented by the 'comfort chart' as shown in Fig 1.1. This chart is the result of research made in different kinds of people subjected to wide range of environmental temperature, relative humidity and air movement by the ASHRAE.

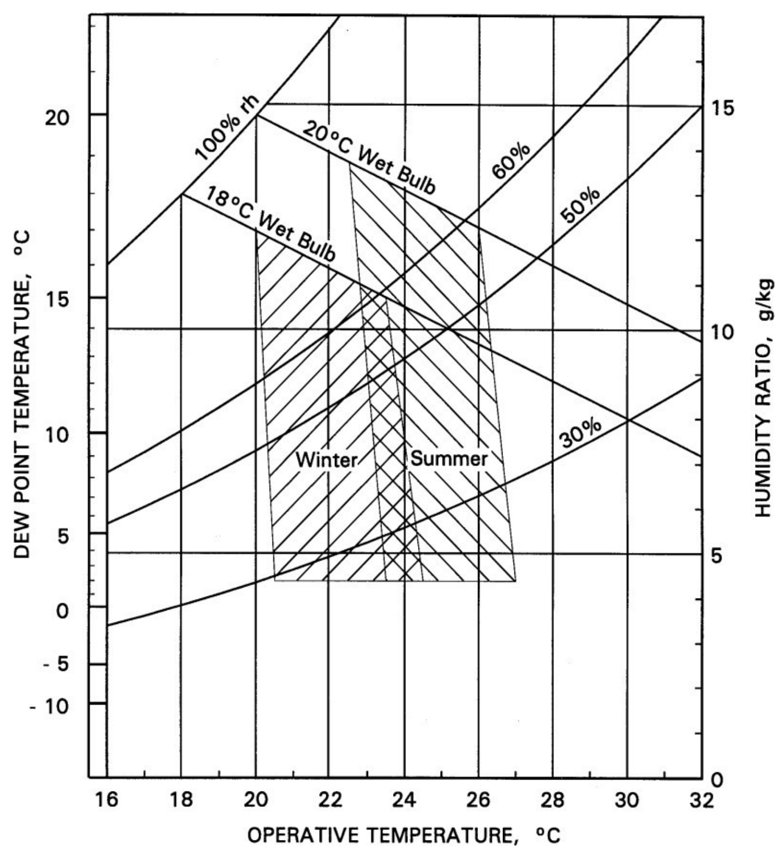


Fig 1.1 comfort chart

All men and women above 40 years of age prefer 0.5 ºC higher effective temperature than the person below 40 years of the age.

1.5.1 Factor governing optimum effective temperature

The optimum effective temperature is affected by the following important factors.

a) **Climatic and seasonal difference:-** it is known fact that people living in colder climates feel comfortable at a lower effective temperature than those living in warmer regions. There is a relationship between the optimum indoor effective temperature and the optimum outdoor temperature, which change with seasons. It can be see from comfort chart that in winter, the optimum effective temperature is 19 ºC where in summer this temperature is 22 ºC.

b) **Clothing:-**it is another important factor which affects the optimum effective temperature. It may be noted that the person with light clothings need less optimum temperature than person with heavy clothings.

c) **Age and sex:-**we have already discussed that the women of all ages required higher effective temperature (about 0.5 ºC) than men. Similar is the case of old and young people. The children also need higher effective temperature than adult.

d) **Activity:-**when the activity of the person is heavy such as people working on the factory, dancing hall, then low effective temperature is needed than for the people sitting in cinema hall or auditorium.

e) **Latitude:** - the effective temperature is increases by about 0.5 . with every 5º reduction in latitude.

CHAPTER 2

LITERATURE REVIWE

Andersson et al. [1] designed heating and cooling loads for a sample residential building at different orientations, using a development version of the building energy analysis computer program BLAST. They identified that the total loads were found to be higher for north than south orientation except in extreme southern latitudes of the U.S.

Omar et al. [2] calculated the hourly cooling load due to different kinds of wall, roof and fenestration using transfer function method (TFM). The output of this method was compared with the well-known Carrier program and the results were acceptable. In the case of cooling load, when the results were compared with the ASHRAE examples, some differences were noticed due to wall and roof. They also studied the effects of changing the wall color on cooling load.

Adnan Shariah et al. [3] studied the effect of the absorptance of external surfaces of buildings on heating, cooling and total loads using the TRNSYS simulation program. Two types of construction materials, namely heavy weight concrete block and light weight concrete were used in the simulation. They also calculated the effects of the absorptance on energy loads for insulated buildings. They reported that, for uninsulated buildings, as the absorptance was changed from one to zero, the total energy load decreased by 32%, while for insulated buildings, it decreased by 26% in Amman. Whereas the decrease was about 47% for uninsulated and 32% for insulated buildings in Aqaba.

Kulkarni et al. [4] optimized cooling load for a lecture theatre in a composite climate in India. The lecture theatre had a dimension of 16m×8.4m×3.6m and was situated at Roorkee (28.58^{o}N, 77.20^{o}E) in the northern region of India. The monthly, annual cooling load and cooling capacity of air conditioning system was determined by a computer simulation program. They reported that the use of false celling, ceramic tiles on roof and floor, electro chromic reflective colored, 13mm air gap, clear glass gave the best possible retrofitting option.

Suziyana et al. [5] analyzed the heat gain and calculated cooling load of a Computer Laboratory and Excellent Centre Rooms in the Faculty of Mechanical Engineering, University Malaysia Pahang by using cooling load calculation method and cooling load factor method based on

ASHRAE 1997 fundamental handbook and then verified by data provided by contractor of building. From this calculation, it was found that the highest heat gain in the Computer Laboratory Room and in Excellent Centre Room is 20458.6 W and 33541.3 W respectively.

Hani H. Sait [6] estimated the thermal load for the engineering building located in Rabigh and compared the results by the outcomes from a HAP 4.2 program. It was reported that, there was a little difference among the two results due to defining the thermal resistance for the used materials of the wall, roof, and windows.

Yan Suqian et al [7] cooling load coefficient method and steady calculation method were used to estimate and compare cooling load of spinning workshop. They concluded that the results of two algorithms were little different and steady calculation method was more simple and efficient.

A. Fouda et al [8] predicted a modified method of calculating the cooling load for residential buildings. The outcome of this method were compared with the ASHRAE standards and they found that the results come from this method were more accurate and effective.

Lin Duanmu et al [9] predicted the hourly building cooling load for urban energy planning by using Hourly Cooling Load Factor Method (HCLFM) that can provide fast and fair estimate of building cooling load for a large-scale urban energy planning. This method was applied to an office building in Beijing, China. The calculated results showed that the dynamical trend of the cooling load was reasonable.

Christian et al. [10] the formulation of a new clear-sky solar radiation model suitable for algorithms calculating cooling loads in buildings were established. The main motive of formulating this model was to replace the ASHRAE clear sky model of 1967 to overcome the limitation of this model. The new model was derived in two steps. The first step consisted of finding a reference irradiance dataset from the REST2 model and the second step consisted of fits derived from a REST2-based reference irradiance dataset. The resulting models and its tabulated data were expected to be integrated in the 2009 ASHRAE Handbook of Fundamentals.

CHAPTER 3

DATA COLLECTION AND METHODOLOGY

3.1 Basic Information

Before estimating cooling load of any building there are some basic informations are necessary to design an exact HVAC systems, like building orientation, weather condition, building spacing, buildings materials etc. The more exact the information the more accurate will be the load estimated.

3.1.1 Building Location

The multi-story building considered in this study is situated in **Saharsa college of engineering** and located at **86° 36' 2.2464" E** longitude and **25° 53' 0.5820" N** latitude in Saharsa district of Bihar, India at an elevation of about **41 meters above mean sea level.**

3.1.2 Climate condition

Saharsa has a tropical and monsoon climate. During Southwest monsoon (June – September), it receives high rainfall and retreats Northeast monsoon (December – January). According to IMD'S annual rainfall report, Bihar receives 1027.6 mm rainfall in a normal monsoon year; the average annual rainfall through the year in all seasons is 1025.6 mm. The hot season lasts for 3.1 months, from March 24 to June 28, with an average daily high temperature above 92°F. The hottest day of the year is April 19, with an average high of 98°F and low of 73°F.. Table 3.1 gives the average high and low temperature of Saharsa.

Table 3.1 Average high and low temperature (in ºC) of **Saharsa** according to months

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high	25	29	35	39	39	38	34	34	34	32	30	26	32.91
Average low	14	16	22	26	28	29	28	28	27	24	20	17	23.25

Table 3.2 Average relative humidity according to months

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average RH %	78.6	66.4	52.3	55.2	64.4	65.2	77.0	83.7	82.7	76.2	71.2	70.0

3.1.3. Building Structures

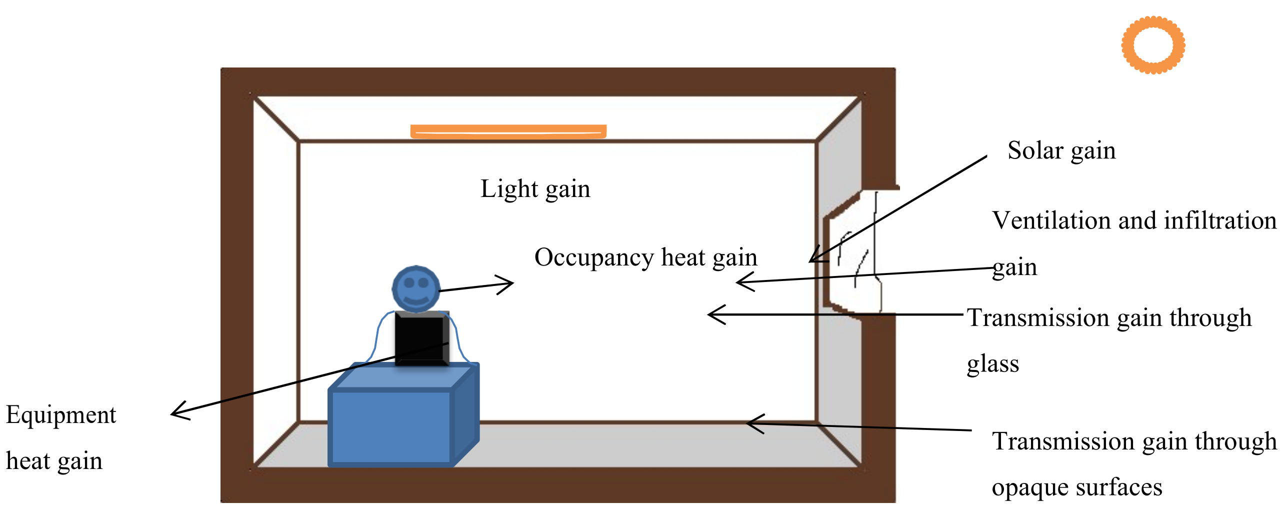
The dimension of the **Computer lab and Library** of Saharsa college of engineering which is to be air conditioned is, **17.73 x 11.63 x 3.51** m and **29.99 x 19.96 x 3.35** in size. It has located at first floors included the ground floor. The exterior walls of building consists of 230 mm common bricks + air space + 230 mm common bricks with 13 mm cement mortar and 26 mm (13 mm both side) sand cement plaster. The interior walls of building are consist of 230 mm common bricks with 26 (13 mm both side) inch sand cement plaster. The roofs consist of 152 mm concrete poured in a metal sheet with 13 mm plaster. The windows consist of single glass materials of 12.7mm thick with frame panel.

3.2 Load Components

The total heat required to be removed from the space in order to bring it at the desired temperature (21-25) and relative humidity (50%) by the air conditioning equipment is known as cooling load or conditioned load. This load consists of external and internal loads.

3.2.1 External and Internal heat gains

External heat gains arrive from the transferred thermal energy from outside hot medium to the inside of the room. The heat transfer takes place from conduction through external walls, top roof and bottom ground, solar radiation through windows and doors, ventilation and infiltration. Other sources are internal heat gain like people, electric equipment and light. Fig 3.1 illustrates the load components.



3.2.1.1 Sensible Heat Gain through Opaque Surface

The heat gain through a building structure such as walls, floors, ceiling, doors and windows constitute the major portion of sensible heat load. The temperature difference across opaque surfaces causes heat transfer through these surfaces.

As shown in Fig. 3.2, heat from outside air is transferred mainly by convection to outer surface. The heat is then transferred by conduction through the structure to inside surface. The heat from inside surface is transferred by convection to the room air.

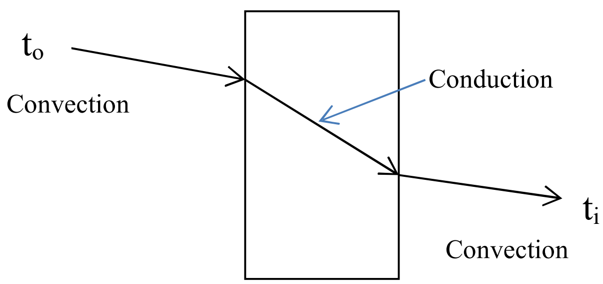


Fig 3.2 *Heat transfer through opaque surface*

The rate of heat transfer from outside air to inside air is calculated by the formula.

$$\boldsymbol{Q = UA(CLTD)_{corr}} \qquad \text{……………..} \ (3.1)$$

Where U = over all heat transfer coefficient (W/m^2-°C)

CLTD = cooling load temperature difference (°C)

A = surface area (m^2)

3.2.1.1.1 Overall heat transfer coefficient

When the wall, floor, or ceiling is made up of layer of different materials as shown in Fig 3.3, then the overall heat transfer coefficient 'U' can be calculated by the formula

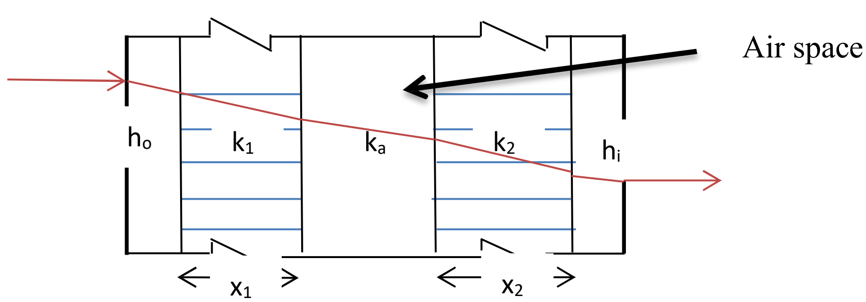


Fig 3.3 *Heat transfer through a composite wall with air space*

$$U = \frac{1}{\frac{1}{h_o} + \frac{x_1}{k_1} + \frac{1}{k_a} + \frac{x_2}{k_2} \ldots\ldots \frac{1}{h_i}} \qquad \ldots\ldots\ldots\ldots\ldots (3.2)$$

Commonly the building walls may consist of non-homogeneous materials for example hollow bricks, air gap and plaster. Heat transfer through these types of wall is quite complicated as it involves simultaneous heat transfer by conduction, convection and radiation as shown on Fig 3.3. All material has different kinds of thermo-physical properties; the thermo-physical properties of common building materials have been measured and presented in ASHRAE and other handbooks. Table 3.3 lists out thermo-physical properties of commonly used building materials.

Table 3.3 Thermo-physical properties of some common building and insulating materials

Material	**Description**	**Density**	**Specific heat**	**Thermal conductivity**	**Conductance**
		kg/m^3	kJ/kg.K	W/m.K	W/m^2.K
Bricks	Common	1600	0.84	0.77	-
	Face	2000	0.84	1.32	-
Masonry materials	Concrete	1920	0.88	1.73	-
	Plaster cement	1885	0.796	8.65	-
	Hollow clay tiles				
	10 cm	-	-	-	5.23
	20 cm	-	-	-	3.14
	30 cm	-	-	-	2.33
	Hollow concrete block	-			
	10 cm	-	-	-	8.14
	20 cm	-	-	-	5.23
	30 cm		-	-	4.54
Wood	Ply	544	-	0.1	-
	Hard	720	2.39	0.158	-
	Soft	512	2.72	0.1	-
Glass	Window	2700	0.84	0.78	-
	Coro silicate	2200	-	1.09	-
Insulating materials	Fiberglass board	64-144	0.7	0.038	-
	Core board	104-128	1.88	0.038	-
	Mineral or glass wool	24-64	0.67	0.038	-
	Magnesia	270	-	0.067	-
	Asbestos	470-570	0.82	0.154	-

Source: C.P. Arora

The heat transfer through outside air to outer surface of wall and inside surface to inside air is equivalent to the actual heat transfer by convection. So the air film coefficient depends upon air velocity, as convection heat transfer depends upon air movement the outside air film coefficient h_o is higher than inside air film coefficient h_i due to limited air movement in the room. The value of surface conductance for air film is given in Table 3.4.

Table 3.4 Surface or film conductance for air film

Air velocity	Surface position	**Direction of heat flow**	**Surface emissivity**		
			0.9	**0.7**	**0.5**
Still air	Horizontal	Up	9.4	5.2	4.4
Still air	Horizontal	Down	6.3	2.2	1.3
Still air	Vertical	Horizontal	8.5	4.3	3.5
25 kmph	Any position	Any	35	----	----
12 kmph	Any position	Any	23.3	----	----

Source: C.P. Arora

Table 3.5 gives the thermal conductance for air space of three widths with different orientations and at two different mean temperatures.

Table 3.5 Thermal conductance k_a of air space

Mean temperature	**Position**	**Direction of heat flow**	**Widths cm**	**Conductance W/m^2-^{o}C**
10 ^{o}C	Horizontal	Up	2.1	6.7
			11.6	6.2
		Down	2.1	5.7
			4.2	5.1
			11.6	4.8
	Vertical	Horizontal	2.1	5.8
			11.6	5.8
32 ^{o}C	Horizontal	Up	2.1	7.7
			11.6	7.2
		Down	2.1	7.0
			4.2	6.2
			11.6	5.8
	Vertical	Horizontal	2.1	7.0
			11.6	6.9

Source: C.P. Arora

3.2.1.1.2 Surface area

The area of wall is calculated after deducting the area of the opening for door and windows.

3.2.1.1.3 Cooling load temperature difference (CLTD)

CLTD is the effective temperature difference across a wall or ceiling, which accounts for the effect of radiant heat as well as the temperature difference. The ASHRAE has developed the CLTD values for exterior walls and roofs based on solar radiation variation typical of 40°N latitude on July 21 with a certain outside and inside air temperature conditions and based on building materials commonly used in North America. The accuracy of the CLTD values could be not accurate, when the location of the building is not at 40°N (especially below 24°N). The LM is correction factor for the locations other than 40°N latitude. As Saharsa is located on 25.88°N Latitude, the closest value of corrected factor is taken as latitude of 24.

3.2.1.2 Heat Gain through Glass

Heat is transmitted through glass due to solar radiation. The heat gain through glass areas constitutes a major portion of the load on the cooling apparatus. This could be direct in the form of sunrays or diffused radiation due to reflection from other objects outside. Heat transmitted through a glass depends on the wavelength of radiation and physical and chemical characteristics of glass. Part of the radiation is absorbed, part is reflected and the rest is transmitted. The heat transfer of glass takes place in the two ways, transmission heat gain and solar heat gain. The following equations are used to calculate heat gain from glass areas.

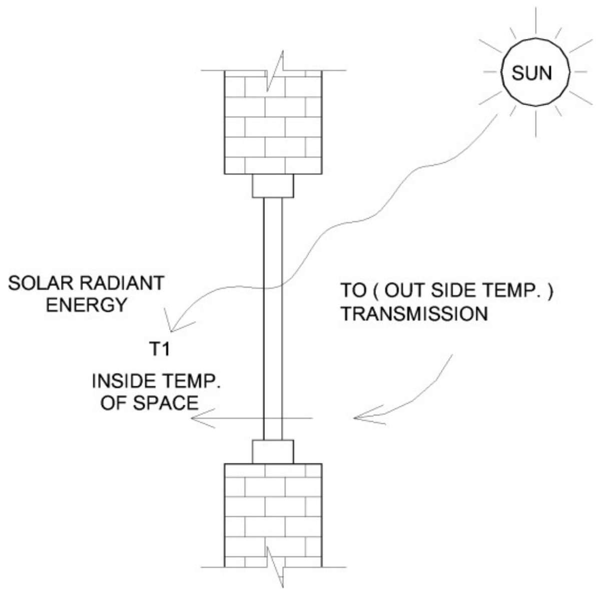


Fig 3.4 *heat gain through glass*

Transmission heat gain through glass:

$$Q = UA(CLTD)_{corr} \quad \text{………….. (3.4)}$$

By solar radiation:

$$Q = A \times SHGF_{max} \times SC \times CLF \quad \text{…………………. (3.5)}$$

$SHGF_{max}$ = maximum solar heat gain factor (W/m^2)

SC = shading coefficient depends on type of shading

CLF = cooling load factor

3.1.2.3 Heat Gain from Occupants

The human body in a cooled space constitute cooling load of sensible and latent heat. In an air conditioned room, sensible heat load given out is due to temperature different between body and room air. The heat gain from occupants is based on the average number of people that are expected to be present in a conditioned space. The heat load produced by each person depends upon the activity of the person. The value of heat gain increases with increase in activity of the human being.

The heat gain from occupancy or people are calculated by following equations:

Sensible heat gain from occupants

$$Q_{s,\,person} = q_{s,\,person} \times N \times CLF \qquad \text{…………….. (3.6)}$$

Latent heat gain from occupants

$$Q_{l\,,\,person} = q_{l\,,\,person} \times N \qquad \text{……………….. (3.7)}$$

Where

$q_{s,\,person}$ = sensible heat gain/person (W)

$q_{l\,,\,person}$ = latent heat gain/person (W)

N = total number of people present in conditioned space

CLF = cooling load factor

Table 3.6 *Rate of heat gain from occupant at conditioned space (W)*

Degree of activity	Typical application	Total heat		Sensible heat	Latent heat
		Adult, Male	Adjusted		
Seated at Theater	Theater, matinee	115	95	65	30
Seated, very light work	Offices, hotels, apartments	130	115	70	45
Moderately active office work	Offices, hotels, apartments	140	130	75	55
Standing, light work; walking	Department store; retail store	160	130	75	55
Walking, standing	Drug store, bank	160	145	75	70
Sedentary work	Restaurants	145	160	80	80
Light bench work	Factory	235	220	80	140
Moderate dancing	Dance hall	265	250	90	160
Bowling	Bowling alley	440	425	170	255
Heavy work	Factory	440	425	170	255
Athletics	Gymnasium	585	525	210	315

3.1.2.4 Heat Gain from Lighting Equipments

Electric lights generate sensible heat equal to the amount of the electric power consumed. The heat gained from electric light depends upon the rating of light in watts, use factor and allowance factor. As a rough calculation, one may use the lighting load equal to 33.5 W/m^2 to produce a lighting standard of 540 $lumens/m^2$ in an office space. After the wattage is known the heat gain from electric light is given by Eqn. (3.8)

$$Q_{light} = \textit{Total wattage of light} \ X \ \textit{Use factor} \ X \ \textit{Allowance factor} \ldots\ldots\ldots\ldots (3.8)$$

The use factor is the ratio of actual wattage in use to installed wattage. Its value depends upon the type of use to which room is put. In case of residences, commercial stores and shops, its value is usually taken as unity, whereas for industrial workshops it is taken below 0.5. The allowance factor is generally used in the case of fluorescent light to allow for the power used by the ballast. Its value is taken as 1.25

Table 3.7 Typical lighting load

Description of rooms	Lighting power W/m^2
Office room	12
Conference/Meeting/Multipurpose	14
Classroom/Lecture/Training	15
Audience/Seating area	10
Dining area	10
Laboratory	15
Rest room	10
Electrical/mechanical room	16
Workshop	20
Library, reading area	13

3.1.2.5 Heat gain from electric equipments

The general electric equipments and appliances such as computers, printers, fax machines, TV, refrigerator and any other equipments of this type also adds heat in the air conditioning space and it is handled in a similar manner as lighting. The heat gain by the equipment is determined by the wattage of the equipment and is calculated by:

$$Q_{equipement} = \textit{Total wattage of equipment} \ X \ \textit{Use factor} \ X \ \textit{CLF} \ldots\ldots\ldots (3.9)$$

CLF = 1.0, if operation is 24 hours or of cooling is off at night or during weekends.

3.1.2.5.1 Heat gain from office equipments

General office equipments such as computers, printers, fax machines and copiers consume energy even when these are not in use. With the common use of desktop computers, printers and other devices also add heat in conditioned space. The Table 3.14 provides a sample of typical electrical power requirements for common office equipment. For details refer to *2001 ASHRAE Fundamentals Hand Book,*

Table 3.8 Heat gain rate for office equipments (Watts)

Appliance	Continuous	Average	Ideal
Computer -15” Monitor	110		20
-17” Monitor	125		25
-19” Monitor	135		30
printer-Desktop	130	100	10
-Small office	320	160	70
-Large office	550	275	125
Desktop Copier	400	85	20
Office Copier	1100	400	300

3.1.2.6 Heat gain due to Infiltration

Infiltration may be defined as the uncontrolled entry of untreated, outdoor air directly into the conditioned space in other words infiltration air is the air that enters a conditioned space through windows crack and opening and closing of doors. This is caused by pressure difference between the two sides of the windows and doors and it depends upon the wind velocity and its direction and difference in densities due to the temperature difference between the inside and outside air. For calculating the quantity of infiltration air generally air change method is use. According to this method, the amount of infiltrated air is calculated by equation

$$\textbf{Amount of infiltrated air } (V_{inf}) = \frac{\text{Valume of space} \times A_C}{60} \ \mathbf{m^3/min} \ldots\ldots\ldots \ \mathbf{(3.10)}$$

Where

A_C is number of air changes value/ hour

The total room infiltration air for an entire building is taken one-half of the above calculated value because infiltration takes place on the windward side of building. In multi- story buildings which are fully air conditioned, stack effect cause infiltration/exfiltration. In summer, due to cold air column inside, exfiltration may take place at lower floor and infiltration in upper floor. In winter the phenomenon is reversed.

Table 3.9 Number of air changes per hour.

Kind of room or building	Number of air changes per hour(A_C)
Room with no windows or outside doors	0.5 to 0.75
Room, one wall exposed	1
Room, two walls exposed	1.5
Room, three walls exposed	2
Room, four walls exposed	2
Entrance halls	2 to 3
Reception halls	2

3.1.2.7 Heat gain due to Ventilation

Human beings inside a space require freshness to air. It has been seen in studies by the ASHRAE, that, inadequate fresh air supply to a space leads to health problems for people inside it. This is called '*Sick building syndrome*'. The ventilation is provide to the conditioned space in order to minimize odor, concentration of smoke, carbon dioxide and other undesirable gases, so that freshness of air could be maintained.

The quantity of outside air used for ventilation should provide at least one-half air change per hours in building with normal ceiling height. Also, if the infiltration air quantity is larger than the ventilation quantity, then the latter should be decreased to at least equal to the infiltration air. The outside air adds sensible as well as latent heat.

Table 3.10 Required Ventilation rate per Person and per Area

Description	Default occupant density ppl/100m^2	Outdoor air m^3/min/person	Outdoor air m^3/min/m^2 area
Auditorium seating area	20	0.15	0.05
Classrooms (age 9 plus)	35	0.30	0.04
Computer lab	25	0.30	0.04
Lecture classroom	65	0.23	0.02
Library	10	0.15	0.04
Lobbies	150	0.15	0.02
Multi-purpose assembly	120	0.15	0.02
Office space	5	0.15	0.02
Reception area	30	0.15	0.02

3.3 Total Loads

The sum of total room sensible heat gain and total room latent heat gain is known as room total heat load.

$$\boldsymbol{RTH = RSH + RLH} \quad \text{...(3.13)}$$

3.3.1 Total Room Sensible Heat Gain

Room sensible heat gain is a combination of all type of sensible heat gain at a conditioned space i.e.

RSHG = Sensible heat gain through walls, floors and ceilings + Sensible heat gain through glasses + Sensible heat gain due to occupants + Sensible heat gain due to infiltration air + Sensible heat gain due to ventilation + Sensible heat gain due to lights and fans.

……………………… (3.14)

3.3.2 Total Room Latent Heat Gain

Room latent heat gain is a combination of all type of latent heat gain at a conditioned space i.e.

RLHG = Latent heat gain due to infiltration + Latent heat gain due to ventilations + Latent heat gain from persons + Latent heat gain due to appliances. ....(3.15)

3.3.3 Total Load in tons

Total heat gain obtained by all above modes is in Watts and we can convert this value from Watts to tons with help of Eqn (3.16)

$$Total\ load\ in\ tons = \frac{Total\ load\ in\ Watts}{35000} \quad \text{……………………...(3.16)}$$

CHAPTER 4

THERMAL LOAD CALCULATION FOR THE LIBRARY AND COMPUTER LAB BUILDING

4.1 Heat Transfer Analysis

In any building, heat is transmitted through external walls, top roof, floor of the ground floor, windows and doors. Heat transfer takes place by conduction, convection and radiation. The cooling load of the building is dependent on local climate, thermal characteristics of material and type of building.

The general step by step procedures for calculating the total heat load are as follows

i. Select inside design condition (Temperature, relative humidity).
ii. Select outside design condition (Temperature, relative humidity).
iii. Determine the overall heat transfer coefficient U_o for wall, ceiling, floor, door, windows, below grade.
iv. Calculate area of wall, ceiling, floor, door, windows.
v. Calculate heat gain from transmission.
vi. Calculate solar heat gain
vii. Calculate sensible and latent heat gain from ventilation, infiltration and occupants.
viii. Calculate lighting heat gain
ix. Calculate total heat gain and
x. Calculate TR

4.2 Design condition

The amount of cooling that has to be accomplished to keep buildings comfortable in summer and winter depends on the desired indoor conditions and on the outdoor conditions on a given day. These conditions are, respectively, called the “indoor design condition” and the “outdoor design condition”.

For most of the comfort systems, the recommended indoor temperature and relative humidity are as follows

DBT – 22.78 ºC to 26.11 ºC, and RH – 50% for summer

DBT – 22.11 ºC to 22.22 ºC and RH – 20 to 30% for winter

The outdoor design conditions are determined from published data for the specific location, based on weather bureau or airport records. The outdoor design conditions of Saharsa is 43 ºC DBT and Relative Humidity 46% for summer (month of May) and 36 ºC DBT and 84 % RH for monsoon (month of July).

4.3 Overall heat transfer coefficient calculation

Commonly the building walls may consist of non-homogeneous materials for example hollow bricks, air gap and plaster. Heat transfer through these types of wall is quite complicated as it involves simultaneous heat transfer by conduction, convection and radiation as shown on Fig 3.3 in Chapter 3. All material has different kinds of thermo-physical properties; the thermo-physical properties of common building materials have been measured and presented in ASHRAE and other handbooks.

4.3.1 Calculation of overall heat transfer coefficient (U_o) for outer walls of Computer Lab building

The outer walls of the Computer Lab building consist of combinations of different layers are 230 mm common bricks + air space + 230 mm common bricks with 13 mm cement mortar and 26 mm

(13 mm both side) sand cement plaster, and thermal conductivities and thermal conductance

We know,

Thermal conductivity of brick (k_{brick}) = 0.77 W/m-K

Thermal conductivity of plaster ($k_{plaster}$) = 8.65 W/m-K

Thermal conductance of air gape = 5.8 W/m^2-K

Outside film coefficient = 23 W/m2-K

Inside film coefficient = 8.5 W/m2-K

Now overall heat transfer coefficient

$$U_{\exp osed\ walls} = \frac{1}{\frac{1}{23}+\frac{0.013}{8.65}+\frac{0.23}{0.77}+\frac{1}{5.8}+\frac{0.23}{0.77}+\frac{0.013}{8.65}+\frac{1}{8.5}} = 1.07 \text{ W/m}^2\text{-K} \quad \ldots\ldots\ldots\ldots\ldots\ldots(4.1)$$

4.3.2 Overall heat transfer coefficient for inner and partition walls

The interior walls of building are consist of 230 mm common bricks with 26 (13 mm both side) inch sand cement plaster.

$$U_{partition} = \frac{1}{\frac{1}{8.5}+\frac{0.013}{8.65}+\frac{0.23}{0.77}+\frac{0.013}{8.65}+\frac{1}{8.5}} = 1.86 \text{ W/m}^2\text{-K} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4.2)$$

4.3.3 Overall heat transfer coefficient of roof

The roofs consist of 152 mm concrete poured in metal sheet with 13 mm plaster

$$U_{ceiling} = \frac{1}{\frac{1}{9.4}+\frac{0.154}{1.73}+\frac{0.013}{8.65}+\frac{1}{6.3}} = 2.82 \text{ W/m}^2\text{-K} \quad \ldots\ldots\ldots\ldots\ldots\ldots(4.3)$$

4.3.4 Overall heat transfer coefficient of floor

$$U_{flloor} = \frac{1}{\frac{1}{9.4}+\frac{0.2}{1.73}} = 4.5 \text{ W/m}^2\text{-K} \quad \ldots\ldots\ldots\ldots\ldots\ldots(4.4)$$

4.3.5 Overall heat transfer coefficient of window glass

$$U_{glass} = \frac{1}{\frac{1}{23}+\frac{0.0127}{0.78}+\frac{1}{8.5}} = 5.6 \text{ W/m}^2\text{-K} \quad \ldots\ldots\ldots\ldots\ldots\ldots(4.5)$$

4.4 Calculation of Cooling Load Temperature Difference

The expose walls of the Computer Lab building are thermally heavier than the group A type wall due to added insulation .

4.5 Calculation of heat transfer area

The detailed of AC requirement area is given in Table 4.1

Table 4.1 AC Requirement areas in the Computer building

TIIR BUILDING						
GROUND FLOOR						
S.N.	**Room/ Hall**	**Width (m)**	**Length (m)**	**Area (m^2)**	**Celling Ht (m)**	**AC Requirement**
1	Library	19.96	24.99	498.80	3.35	498.80
2	Computer Lab	11.63	17.73	206.19	3.51	206.19

All dimension of the doors and windows are given in Table

Table 4.2 Dimension of doors and windows

S.No	Type Mark	Width	Height	Description
1	D1 (Com)	1.39	2.31	Bifold Door
2	D2 (Lib)	1.09	2.38	Bifold Door
3	W1(Com)	1.21	`1.37	UPVC Window
4	W2 (Lib)	1.21	1.37	UPVC Window

4.6 Total Cooling Load Calculations of Computer Lab

4.6.1 Cooling load calculation of 67- Seated Computer Lab

Length of the room = 17.73 m

Width of the room = 11.63 m

Height of the room = 3.51 m

Area of glass (W_1) =1.37×1.21 = 1.65 m^2

Area of the door (D_1) =2.31×1.39=3.21m^2

Total sun facing glass area = 1.65× 9 = 17.85 m^2

Outside wall area (WN) =17.73×3.51 – 14.85=47.23 m^2

Partition wall areas (NE, SW, SE) = 11.63×3.51 + 11.63x 3.51 + (17.73×3.51 – 2× 3.21) = 96.63 m^2

Now the amount of infiltrated air through windows and walls is

$$= \frac{17.73 \times 11.63 \times 3.51 \times 1}{60} = 12.06\ m^3/min$$

The details of cooling load calculations of the 67 seated lecture room 1 are given on the calculation sheet in Table 4.4

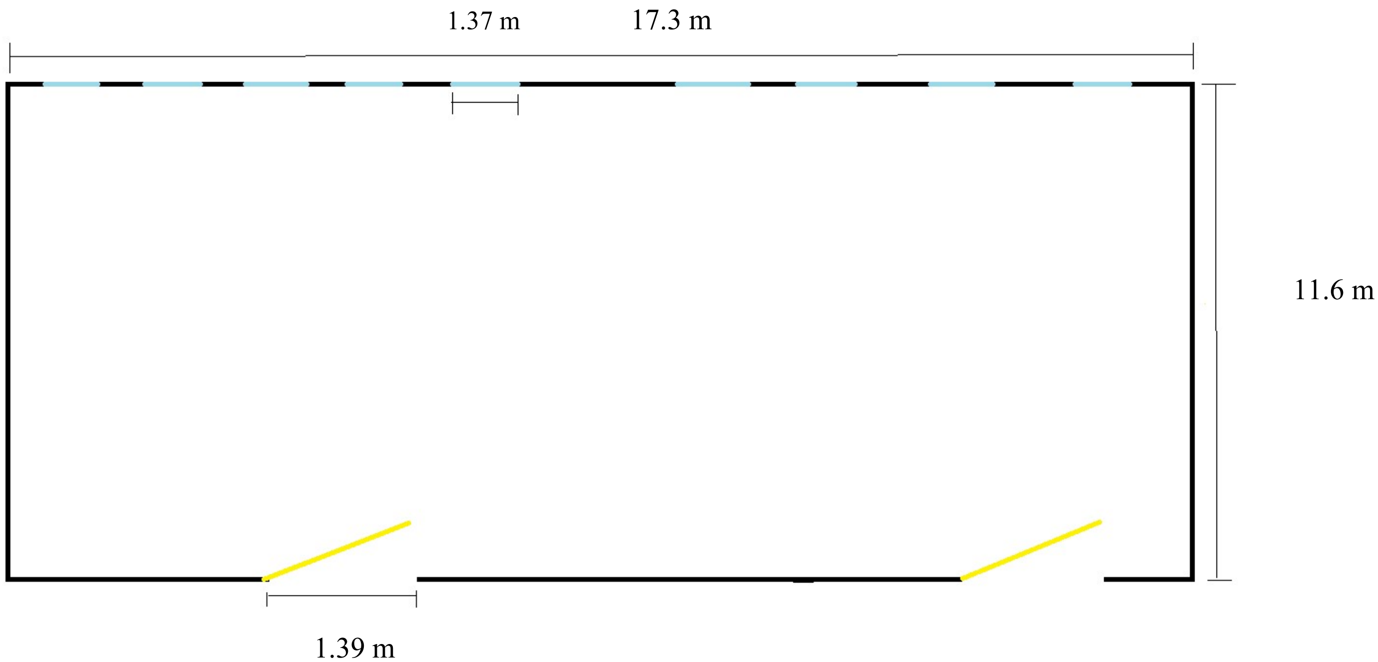


Fig 4.1. *Computer lab layout*

4.6.2 Calculate Area of All Side Wall

Area of South wall, A_S = (17.3 x 3.51) - (2.31 x 1.39) x 2

= (62.23 - 6.42)

= 55.81 m^2

Area of North Wall, A_N = (17.3 x 3.51) - (1.37 x 1.21) x 9

= (62.23-14.85)

= 47.23 m^2

Area of East Wall, A_E = (11.6 x 3.51)

= 40.82 m^2

Area of West Wall, A_W = 11.6 x 3.51

= 40.82 m^2

4.6.3 Calculate Area Of Door and Window

Area of Door = (2.31 x 1.39) x 2

$= 6.42\ m^2$

Area of window = $(1.37 \times 1.21) \times 9$

$= 14.85\ m^2$

4.6.4 Heat load through opaque surface by conduction

$Q_c = U_{wall} \times A \times (CLTD)$

From equation 4.1, Overall heat coefficient for outer walls= 1.07 W/m^2-K
From equation 4.2, Overall heat coefficient for inner and partition walls= 1.86 W/m^2-K

Total Overall heat coefficient for walls = 1.07 + 1.86 = 2.93 W/m^2-K

INDOOR TEMP- 24 C
OUTDOOR TEMP- 35 C

$Q_{South\ wall} = 2.93 \times A_s \times (CLTD)$

$= 2.93 \times 55.81 \times (35\text{-}24)$

$= 2.93 \times 55.81 \times 11$

= **1798.75 W**

$Q_{North\ wall} = 2.93 \times A_N \times (CLTD)$

$=2.93 \times 47.23 \times (35\text{-}24)$

$=2.93 \times 47.23 \times 11$

= **1522.22 W**

$Q_{East\ wall} = 2.93 \times A_s \times (CLTD)$

$=2.93 \times 40.82 \times (35\text{-}24)$

$=2.93 \times 40.82 \times 11$

=**1315.62 W**

$Q_{West\ wall} = 2.93 \times A_s \times (CLTD)$

$=2.93 \times 40.82 \times (35\text{-}24)$

=2.93 x 40.82 x 11

=**1315.62 W**

4.6.5 Heat load Through Window by Conduction

From equation 4.5, *Overall coefficient of Window = 5.6* W/m^2-K

$Q_c = U_{window}$ x A x (CLTD) x No of Window

= 5.6 x 14.85 x (35-24)

= **1247.4 W**

4.6.6 Heat load through door by conduction

Overall Coefficient for wood = 1.42

$Q_c = U_{wood}$ x A x (CLTD) x No. of Door

= 1.42 x 6.42 x (35-24) x 2

= 100.2 x 2

= **200.4 W**

4.6.7 Heat load Through Roof by Conduction

From equation 4.3, *Overall coefficient of Roof = 2.82* W/m^2-K

Q_{Florr} = *2.82* x A_s x (CLTD)

= *2.82* x (17.3 x11.6) x (35-24)

= *2.82* x 200.68 x 11

= **6225.09 W**

4.6.8 Heat load through opaque surface by Radiation

$$Q = \varepsilon\, \sigma\, (T_0^4 - T_i^4)\, A_h$$

Where,

Q = heat transfer per unit time (W)

ε = emissivity coefficient of the object

$\sigma = 5.6703 \times 10^{-8}$ (W/m^2K^4) - ***The Stefan-Boltzmann Constant***

T_o = hot body absolute temperature (K)

T_i = cold surroundings absolute temperature (K)

A_h = area of the hot object (m^2)

INDOOR TEMP- 24 C = 24 +273 = 297 K
OUTDOOR TEMP- 35 C = 35 + 273 = 308 K

Emissivity coefficient of the wall, ε = 0.93 (from below table)

Table- 4.3- Emissivity coefficient of different types of material.

Material	**Emissivity**
Asbestos paper	0.93
Asphalt (paving)	0.97
Brass (hard rolled-polished with lines)	0.04
(somewhat attacked)	0.04
Brick (red—rough)	0.93
Brick (silica—unglazed rough)	0.80
Carbon (T—carbon 0.9% ash)	0.81
Concrete	0.94
Copper (plate heavily oxidized)	0.78
Frozen soil	0.93
Glass (smooth)	0.94
Gold (pure highly polished)	0.02
Granite (polished)	0.85
Ice	0.97
Marble (light gray polished)	0.93
Paper (black tar)	0.93
Paper (white)	0.95
Plaster (white)	0.91
Plywood	0.96

$Q_{South\ wall} = \varepsilon\ \sigma\ (T_0^4 – T_i^4)\ A_{south\ wall}$

$= 0.93 \times (5.6703 \times 10^{-8}) \times (308^4 – 297^4) \times 55.81$

$= 64.24 \times 55.81$

= **3585.69 W**

$Q_{North\ wall} = \varepsilon\ \sigma\ (T_0^4 – T_i^4)\ A_{North\ wall}$

$= 0.93 \times (5.6703 \times 10^{-8}) \times (308^4 – 297^4) \times 47.23$

$= 64.24 \times 47.23$

= **3033.583 W**

$Q_{East\ wall} = \varepsilon\ \sigma\ (T_0^4 – T_i^4)\ A_{East\ wall}$

$= 0.93 \times (5.6703 \times 10^{-8}) \times (308^4 – 297^4) \times 40.82$

$= 64.24 \times 40.82$

= **2622.2768 W**

$Q_{West\ wall} = = \varepsilon\ \sigma\ (T_0^4 – T_i^4)\ A_{West\ wall}$

$= 0.93 \times (5.6703 \times 10^{-8}) \times (308^4 – 297^4) \times 40.82$

$= 64.24 \times 40.82$

= **2622.2768 W**

4.6.9 Heat load Through Window by Radiation

INDOOR TEMP- 24 C = 24 +273 = 297 K
OUTDOOR TEMP- 35 C = 35 + 273 = 308 K
Emissivity coefficient of Glass, ε = 0.94 (from table)

$\mathbf{Q_c = \varepsilon\ \sigma\ (T_0^4 – T_i^4)\ A_{Window}}$

$= 0.94 \times (5.6703 \times 10^{-8}) \times (308^4 – 297^4) \times 14.85$

$= 64.94 \times 14.85$

= **964.345 W**

4.6.10 Heat load through door by Radiation

INDOOR TEMP- 24 C = 24 +273 = 297 K
OUTDOOR TEMP- 35 C = 35 + 273 = 308 K
Emissivity coefficient of Plywood, ε = 0.96 (from below table)

$Q_c = \varepsilon\ \sigma\ (T_0^4 - T_i^4)\ A_{Door}$

$= 0.96 \times (5.6703 \times 10^{-8}) \times (308^4 - 297^4) \times 6.42$

$= 64.94 \times 6.42$

= **416.914 W**

4.6.11 Heat load Through Roof by Radiation

INDOOR TEMP- 24 C = 24 +273 = 297 K
OUTDOOR TEMP- 35 C = 35 + 273 = 308 K
emissivity coefficient of the concrete roof, ε = 0.94 (from table)

$Q_c = \varepsilon\ \sigma\ (T_0^4 - T_i^4)\ A_{Door}$

$= 0.96 \times (5.6703 \times 10^{-8}) \times (308^4 - 297^4) \times 200.68$

$= 64.94 \times 200.68$

= **13032.1592 W**

4.6.12 HEAT GAIN DUE TO INFILATRATION

AIR FLOW RATE = (Volume x Ac) /60

= ((Length x Width x Height) X Ac) /60

Where,

Ac= Number of Air Changes per hour

From table,

Ac =1; Room with one wall exposer

AIR FLOW RATE = ((17.3 x 11.6 x 3.51) x 1) / 60

=11.739 m^3/min

CFM = AIR FLOW RATE /2

=11.739 /2

=5.869 m^3/min

i) $Q_{sensible}$ =1.08 x CFM x (To-Ti)

=1.08 x 5.869 x (35 -24)

=**69.723 W**

ii) Q_{latent} = 4840 x CFM x (Wo-Wi)

Where,

CFM- Infiltration air flow rate
To,Ti- Outside/inside dry bulb temp
Wo,Wi- Outside/inside humidity ratio

W= Mv/Ma = 0.622 P_v/ (P_t -P_v) *kg/kg of dry air*

Where,

W= Specific humidity /humidity ratio/ absolute humidity

Wo = 0.622 P_v/ (P_t -P_v)

= 0.622 x 0.85 x 0.051/ (1.055 -0.051)

=0.0268/0.031

Wi = 0.622 x .60 x 0.025/ (1.15 -0.025)

= 0.012

Q_{latent} = 4840 x CFM X (Wo – Wi)

= 4840 x 5.869 x (0.031 -0.012)

Q_{latent} = **539.71 W**

4.6.13 HEAT GAIN DUE TO VENTILATION

Table 4.4- Air Flow Rate per person

APPLICATION	**SMOOKING**	**M^3/MIN /PERSON**
APARTMENT	SOME	0.6
OFFICES	NONE	0.45
BARS	CONSIDERABLE	0.9
HOSPITAL	NONE	0.9

$Q_{sensible}$ =1.08 x CFM x (To- Ti)

AIR FLOW RATE = (No. of People).(AFR/Person)

= PERSON X 0.45

=67 X 0.45

=30.15 m^3/min

CFM = AIR FLOW RATE /2

= 30.15 /2

= 15.075 m^3/min

$Q_{sensible}$ = 1.08 x CFM X (To -Ti)

= 1.08 x15.075 x (35-24)

= **179.091 W**

Q_{latent} = 4840 x CFM x (Wo-Wi)

= 4840x 15.075 x (0.031-0.021)

= **1386.297 W**

4.6.14 HEAT LOAD OF OCCUPANTS

$Q_{sensible}$ = (No of people) x (sensible heat gain/person)

Q_{latent} = (No of people) x (latent heat/person)

		Total heat,	W*		
Degree of activity	**Typical application**	**Adult male**	**Adjusted M/F/C¹**	**Sensible heat, W***	**Latent heat, W***
Seated at theater	Theater-matinee	115	95	65	30
Seated at theater, night	Theater-evening	115	105	70	35
Seated, very light work	Offices, hotels, apartments	130	115	70	45
Moderately active office work	Offices, hotels, apartments	140	130	75	55
Standing, light work; walking	Department or retail store	160	130	75	55
Walking, standing	Drug store, bank	160	145	75	70
Sedentary work	Restaurant2	145	160	80	80
Light bench work	Factory	235	220	80	80
Moderate dancing	Dance hall	265	250	90	90
Walking 4.8 km/h (3 mph);					
light machine work	Factory	295	295	110	110
Bowling³	Bowling alley	440	425	170	255
Heavy work	Factory	440	425	170	255
Heavy machine work; lifting	Factory	470	470	185	285
Athletics	Gymnasium	585	525	210	315

Table 4.5 – Heat gain from people in conditioned spaces

From table,

Sensible heat gain from Moderately active office work/Person = 75

$Q_{sensible}$ = (No of people) x (sensible heat gain/person)

= 67 x 75

= **5025 W**

From table,

Latent heat gain from Moderately active office work/Person = 55

Q_{latent} = (No of people) x (latent heat/person)

= 67 x 55

= 67 x 55

= **3685 W**

4.6.15 HEAT GAIN FROM LIGHT

Q_{light} = (Wattage x Use Factor x Allowance Factor x No of Light)

= (20 x 1 x 1.25 x 40 tubelight)

=**1000 W**

4.6.16 HEAT GAIN FROM COMPUTER

According to ASHRAE JOURNAL the average value of heat gain from computer are 55 for Continuous for conservative value is 65.

Table 4.6- Heat gain from one computer

	Continuous (Watts)	**Energy Saver (Watts)**
Average Value	55	20
Conservative value	65	25
Highly Conservative value	75	30

Typical heat gain from computers according to ASHRAE Journal

$Q_{computer}$ = (Highly Conservative value/Computer) x No. Of Computer

= 75 x 60

= **4500 watt**

4.7 Cooling load calculation of Library Room

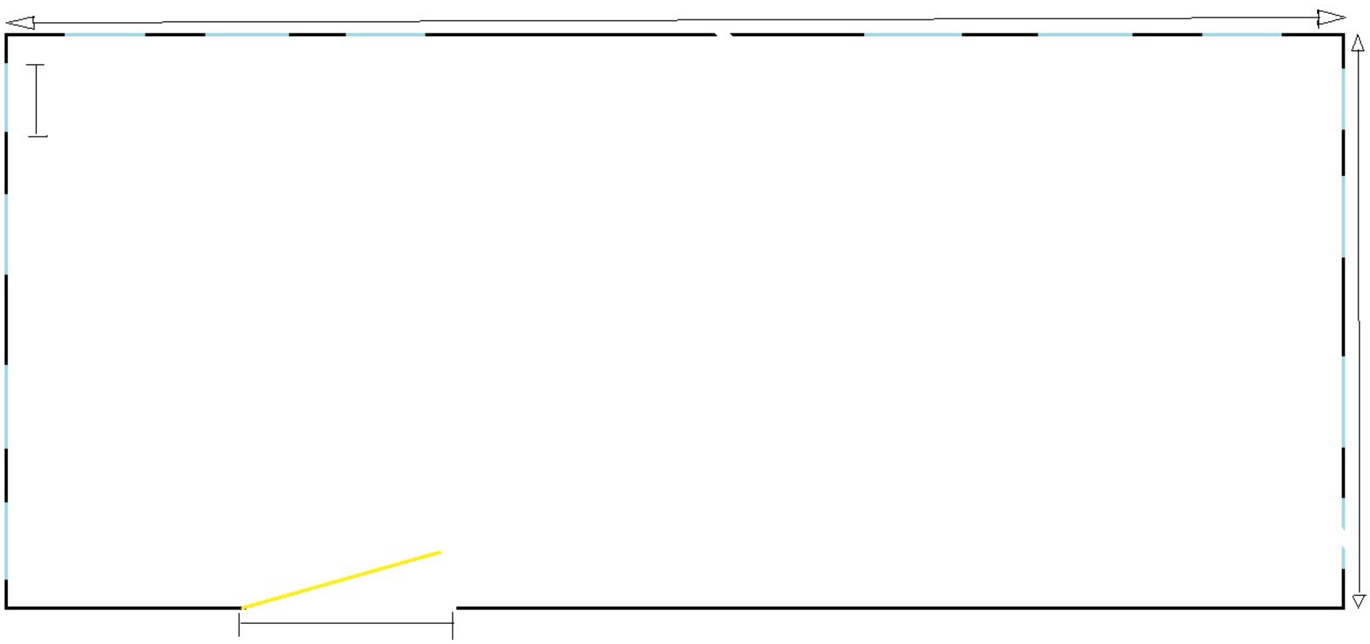
Length of room= 24.99 m

Width of room = 19.96 m

Height of room = 3.35 m

Area of glass= 1.21 x 1.37 = 6.63 m^2

Area of the door $= 2.38 \times 1.09 = 2.59\,\mathrm{m}^2$



4.7.1 Calculate Area of All Side Wall

Area of South wall = (24.99 x3.35) -2.38 x1.09) x 1

= 83.72 -2.59

= 81.13 m^2

Area of North Wall= (24.99 X3.35) – (1.21 X 1.37) X6

= 83.72-9.95

= 73.77 m^2

Area of East Wall = (19.96)-(1.2 X 1.37) X 4

= 60.23 m^2

Area of West Wall = (19.96 x3.35)-(1.21 x1.37) x4

= 66.86 -6.63

= 60.23 m^2

4.7.2 Calculate Area Of Door and Window

Area of Door = 2.38 x 1.09

= 2.59 m^2

Area of window = (1.37 x 1.21) x 18

= 29.88 m^2

4.7.3 Heat load through opaque surface by conduction

$Q_c = U_{wall}$ x A x (CLTD)

From equation 4.1, Overall heat coefficient for outer walls= 1.07 W/m^2-K
From equation 4.2, Overall heat coefficient for inner and partition walls= 1.86 W/m^2-K

Total Overall heat coefficient for walls = 1.07 + 1.86 = 2.93 W/m^2-K

INDOOR TEMP- 24 C
OUTDOOR TEMP- 35 C

$Q_{South\ wall}$ = 2.93x A_s x (CLTD)

= 2.93x 81.13 x (35-24)

= 2.93x 81.13 x 11

= **2614.82 W**

$Q_{North\ wall}$ = 2.93x A_N x (CLTD)

=2.93 X 73.77 X 11

= **2377.607 W**

$Q_{East\ wall}$ = 2.93x A_s x (CLTD)

$=2.93 \times 40.82 \times (35\text{-}24)$

$=2.93 \times 40.82 \times 11$

$=$**1315.62 W**

$Q_{West\ wall} = 2.93 \times A_s \times (CLTD)$

$=2.93 \times 60.23 \times 11$

$=$**1941.21 W**

4.7.4 Heat load Through Roof by Conduction

From equation 4.3, *Overall coefficient of Roof = 2.82* W/m^2-K

$Q_{Florr} = 2.82 \times A_s \times (CLTD)$

$= 2.82 \times (24.99 \times 19.96) \times (35\text{-}24)$

$= 2.82 \times 498.8 \times 11$

$=$ **15472.776 W**

4.7.5 Heat load Through Window by conduction

Thermal conductance of air = 8.375 W/m'C
Thermal conductivity of glass, k = 1.73 W/m'C

From equation 4.5, Overall coefficient of Window = 5.6 W/m C

$Q_c = U_{window} \times A \times (CLTD)$

$= 5.6 \times 29.83 \times (35\text{-}24) \times 18$

$=$ **1838.057 W**

4.7.6 Heat load through door by conduction

Thermal conductivity of wood , k = 0.96 w/mc
Overall Coefficient for wood = 1.42

$Q_c = U_{wood} \times A \times (CLTD)$

$= 1.42 \times (2.38 \times 1.09) \times (35\text{-}24)$

$=$ **40.52 W**

4.7.7 Heat load through opaque surface by Radiation

$Q = \varepsilon\ \sigma\ (T_0^4 - T_i^4)\ A_h$

Where

Q = heat transfer per unit time (W)

ε = emissivity coefficient of the object

$\sigma = 5.6703 \times 10^{-8}$ (W/m^2K^4) - ***The Stefan-Boltzmann Constant***

T_o = hot body absolute temperature (K)

T_i = cold surroundings absolute temperature (K)

A_h = area of the hot object (m^2)

INDOOR TEMP- 24 C = 24 +273 = 297 K
OUTDOOR TEMP- 35 C = 35 + 273 = 308 K
emissivity coefficient of the wall, ε = 0.93

$Q_{\text{South wall}} = \varepsilon\ \sigma\ (T_0^4 - T_i^4)\ A_{\text{south wall}}$

$= 0.93 \times (5.6703 \times 10^{-8}) \times (308^4 - 297^4) \times 81.13$

$= 64.24 \times 81.13$

= **5211.79 W**

$Q_{\text{North wall}} = \varepsilon\ \sigma\ (T_0^4 - T_i^4)\ A_{\text{North wall}}$

$= 0.93 \times (5.6703 \times 10^{-8}) \times (308^4 - 297^4) \times 73.77$

$= 64.24 \times 73.77$

= **4738.98 W**

$Q_{\text{East wall}} = \varepsilon\ \sigma\ (T_0^4 - T_i^4)\ A_{\text{East wall}}$

$= 0.93 \times (5.6703 \times 10^{-8}) \times (308^4 - 297^4) \times 60.23$

$= 64.24 \times 60.23$

= **3869.17 W**

$Q_{West\ wall} = = \varepsilon\ \sigma\ (T_0^4 - T_i^4)\ A_{West\ wall}$

$= 0.93 \times (5.6703 \times 10^{-8}) \times (308^4 - 297^4) \times 60.23$

$= 64.24 \times 60.23$

= **3869.17 W**

4.7.8 Heat load Through Window by Radiation

INDOOR TEMP- 24 C = 24 +273 = 297 K
OUTDOOR TEMP- 35 C = 35 + 273 = 308 K
emissivity coefficient of Glass, ε = 0.94 (from below table)

$Q_c = \varepsilon\ \sigma\ (T_0^4 - T_i^4)\ A_{Window}$

$= 0.94 \times (5.6703 \times 10^{-8}) \times (308^4 - 297^4) \times 29.88$

$= 64.94 \times 29.88$

= **1940.40 W**

4.7.9 Heat load through door by Radiation

INDOOR TEMP- 24 C = 24 +273 = 297 K
OUTDOOR TEMP- 35 C = 35 + 273 = 308 K
emissivity coefficient of Plywood, ε = 0.96 (from below table)

$Q_c = \varepsilon\ \sigma\ (T_0^4 - T_i^4)\ A_{Door}$

$= 0.96 \times (5.6703 \times 10^{-8}) \times (308^4 - 297^4) \times 2.59$

$= 64.94 \times 2.59$

= **168.19 W**

4.7.10 Heat load Through Roof by Radiation

INDOOR TEMP- 24 C = 24 +273 = 297 K
OUTDOOR TEMP- 35 C = 35 + 273 = 308 K
emissivity coefficient of the concrete roof, ε = 0.94 (from below table)

$Q_c = \varepsilon\ \sigma\ (T_0^4 - T_i^4)\ A_{Door}$

$= 0.96 \times (5.6703 \times 10^{-8}) \times (308^4 - 297^4) \times (24.99 \times 19.96)$

$= 64.94 \times 498.8$

= **32392.09 W**

4.7.11 HEAT GAIN DUE TO INFILATRATION

AIR FLOW RATE = (Volume x Ac) /60

= ((Length x Width x Height) X Ac) /60

Where,

Ac= Number of Air Changes per hour

From table,

Ac =1; Room with one wall exposer

AIR FLOW RATE = 24.99 x 19.99 x 3.35 x1 / 60

= 1670.98/ 60 m^2/min

= 27.85 m^2/min

CFM = AIR FLOW RATE /2

= 27.85 /2

= 13.93

i) $Q_{sensible}$ = 1.08 x CFM x (To-Ti)

= 1.08 X 13.93 X (35-24)

= 1.08 X 13.93 X 11

= **165.49 W**

ii) Q_{latent} = 4840 x CFM x (Wo-Wi)

Where,

CFM- Infiltration air flow rate
To,Ti- Outside/inside dry bulb temp
Wo,Wi- Outside/inside humidity ratio

W= Mv/Ma = 0.622 P_v/ (P_t -P_v) *kg/kg of dry air*

Where,

W= Specific humidity /humidity ratio/ absolute humidity

$Wo = 0.622\ P_v / (P_t - P_v)$

$= 0.622 \times 0.85 \times 0.051 / (1.055 - 0.051)$

$= 0.0268/0.031$

$Wi = 0.622 \times .60 \times 0.025 / (1.15 - 0.025)$

$= 0.012$

$Q_{latent} = 4840 \times CFM \times (Wo - Wi)$

$= 4840 \times 13.93 \times (0.031 - 0.012)$

$= 4840 \times 13.93 \times 0.019$

= **1281.00 W**

4.7.12 HEAT GAIN DUE TO VENTILATION

From table 4.4 AFR/person = 0.45

$Q_{sensible} = 1.08 \times CFM \times (To - Ti)$

AIR FLOW RATE = (No. of People).(AFR/ person)

= PERSON X 0.45

=31 X 0.45

$= 13.95\ m^3/min$

CFM = AIR FLOW RATE /2

= 13.95 /2

$= 6.98\ m^3/min$

$Q_{sensible} = 1.08 \times CFM \times (To - Ti)$

$= 1.08 \times 6.98 \times (35-24)$

= **82.92 W**

$Q_{latent} = 4840 \times CFM \times (Wo - Wi)$

$= 4840 \times 6.98 \times (0.031 - 0.021)$

= **641.88 W**

4.7.13 HEAT LOAD OF OCCUPANTS

$Q_{sensible}$ = (No of people) x (sensible heat gain/person)

Q_{latent} = (No of people) x (latent heat/person)

From table,

Sensible heat gain from Moderately active office work/Person = 75

$Q_{sensible}$ = (No of people) x (sensible heat gain/person)

= 80 x 75

= **6000 W**

Q_{latent} = (No of people) x (latent heat/person)

= 80 x 55

= **4400 W**

4.7.14 HEAT GAIN FROM LIGHT

Q_{light} = (Wattage x Use Factor x Allowance Factor x No of Light)

= (20 x 1 x 1.25 x 69 tubelight)

=**1725 W**

4.7.15 HEAT GAIN FROM COMPUTER

According to ASHRAE JOURNAL the average value of heat gain from computer are 55 for Continuous for conservative value is 65.

	Continuous (Watts)	**Energy Saver (Watts)**
Average Value	55	20
Conservative value	65	25
Highly Conservative value	75	30

Typical heat gain from computers according to ASHRAE Journal

$Q_{computer}$ = (Highly Conservative value/Computer) x No. Of Computer

= 75 x 1 = **75 watt**

CHAPTER 5

Result and Discussion

The maximum cooling loads of Computer and Library are calculated and summarized in below table

5.1 Total cooling loads for Computer lab building

Table 5.1 Total cooling loads for Computer lab building.

S.No	Heat Generated due to	Heat Generated (Watt)
1.	South wall- Conduction	**1798.75**
2.	North wall- Conduction	**1522.22**
3.	East wall- Conduction	**1315.62**
4.	West wall- Conduction	**1315.62**
5.	Window- Conduction	**1247.4**
6.	Door – Conduction	**200.4**
7.	Roof- Conduction	**6225.09**
8.	South wall- Radiation	**3585.69**
9.	North wall- Radiation	**3033.583**
10.	East wall- Radiation	**2622.2768**
11.	West wall Radiation	**2622.2768**
12.	Window- Radiation	**964.345**
13.	Roof- Radiation	**13032.1592**
14.	Door – Radiation	**416.914**
15.	infiltration – Sensible	**69.723**
16.	Infiltration – Latent	**539.71**
17.	Ventilation- Sensible	**179.091**
18.	Ventilation- Latent	**1386.297**
19.	Occupants- Sensible	**5025**
20.	Occupants- Latent	**3685**
21.	Light	**1000**
22.	Computer	**4500**
	Total Load	**56287.17 Watt**

Total Heat generated in Computer Lab in Watt = **56287.17W**

Lets convert it into Ton.

Total heat generated in computer Lab in KiloWatt = **56287.17**/1000

= 56.287 KW

= 56.287/3.517 TON

= 16.004 TON

<u>Result:-</u>

For maintaining the cooling in computer lab we need total 16 Tons of refrigeration.

5.2 Total cooling loads for Library Room

Table 5.2 Total cooling loads for Library Room.

Heat Generated due to	Heat Generated (Watt)
South wall- Conduction	**2614.82**
North wall- Conduction	**2377.607**
East wall- Conduction	**1315.62**
West wall- Conduction	**1941.21**
Roof- Conduction	**15472.776**
Window- Conduction	**1838.057**
Door – Conduction	**40.52**
South wall- Radiation	**5211.79**
North wall- Radiation	**4738.98**
East wall- Radiation	**3869.17**
West wall Radiation	**3869.17**
Window- Radiation	**1940.40**
Roof- Radiation	**32392.09**
Door – Radiation	**168.19**
Infilatration – Sensible	**165.49**
Infilatration – Latent	**1281.00**
Ventilation- Sensible	**82.92**
Ventilation- Latent	**641.88**
Occupants- Sensible	**6000**

Occupants- Latent	**4400**
Light	**1725**
Computer	**75**
Total Load	**92161.69 Watt**

Total Heat generated in Computer Lab in Watt = **92161.69 W**

Lets convert it into TON.

Total heat generated in computer Lab in KiloWatt =**92161.69** /1000

= 92.161 KW

= 92.161 / 3.517 TON

= 26.20 TON

<u>Result:-</u>

For maintaining the cooling in Library we need t otal 26.20 TON of refrigeration.

CHAPTER 6

CONCLUSION

In this study, a Computer and Library building an integrated part of Saharsa College of Engineering located in Saharsa was considered for calculating cooling loads. Cooling load temperature difference (CLTD) method was used to find the cooling load.

Cooling load items such as, people, light, infiltration and ventilation can easily be putted to the MS-Excel program. The program can also be used to calculate cooling load due to walls and roofs.

- The results show that the total cooling load for the AC required Computer lab rooms is 13.83 Tons.
- The results show that the total cooling load for the AC required Libraray rooms is 21.98 Tons.
- Load of Library Room is more than load of Computer Room.

These all factors show that the cooling load calculation of building is satisfactory.

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