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DESIGN OF AN ENERGY EFFICIENT HVAC SYSTEM FOR THE COMMERCIAL BUILDING

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ABSTRACT: The aim of a heating, ventilation, and air conditioning (HVAC) system is to meet the environmental requirements of occupant comfort and a mechanism. HVAC systems are widely used in a variety of structures, including manufacturing, commercial, domestic, and institutional structures. To manage the operation of a heating and/or air conditioning system, HVAC (Heating, Ventilation, and Air Conditioning) equipment requires a control system. Its effective design is arguably the most complex system installed in a building and is responsible for a substantial component of the total building energy use. A right size and design of HVAC system will provide the desired comfort and will run efficiently. This strategy guideline discusses the information needed to design an energy efficient HVAC system for a commercial building by providing results of Heat load calculations, the right choice of system selection and selection of proper materials. In this project we investigate and review the different Materials, Chiller choices, give a brief about HVAC, outline the process followed, which demonstrates its ability to improve the performance of HVAC systems to reduce energy consumption. The pros and cons of each system type specific to the building layout and climate zone will be discussed in this study. This research has a central theme which focuses on a peculiar project of a commercial building in Aurangabad, India along with its 3D design in Autodesk Revit 2021.

***Keywords**: HVAC, Heating, Ventilation, Air conditioning, Energy Efficient system, Energy consumption, Heat Load, Heat Load calculations, Chiller, Air Handling Units (AHUs), Climate conditions, location of building, Autodesk Revit.*

1. INTRODUCTION

1.1 Basics of HVAC System

HVAC stands for Heating, Ventilation and Air-Conditioning. Its goal is to provide the thermal comfort and good indoor air quality. HVAC system designing is the sub-disciple of mechanical engineering, based on the principles of thermodynamics, heat transfer, fluid mechanics and some of architectural. HVAC systems are more often used in several types of buildings such as commercial, residential, institutional and many more. The selection of HVAC systems for buildings will depend on the climate, age of building, the individual preferences of the owner of the buildings and the designer of the buildings, the project budget, and the architectural design of the building.

Many of the situations requiring mechanical ventilation also need a degree of air conditioning. To summarize, those situations most likely to require air conditioning are:

1. Rooms subject to high solar gains, such as south facing rooms especially those with large areas of glazing.

2. Rooms with high equipment densities such as computer rooms and offices which make extensive use of IT.

3. Rooms in which environment (temperature, dust, or humidity) sensitive work is being carried out such as operation theatre and microprocessor manufacturing units.

1.2 Project Objective

The main objective in this project is to design energy efficient HVAC system for a commercial building. This study will be focused on 3 parts:

1. Proper selection of efficient material
2. To minimize the Heat Load/Cooling Load
3. System selection based on Heat Load/Cooling Load

2. METHODOLOGY

2.1 Study of location and surrounding.

HVAC systems are of great importance to architectural design efforts for four main reasons. First, these systems often require substantial floor space and/or building volume for Equipment and distribution elements that must be accommodated during the design process. Second, HVAC systems constitute a major budget item for numerous common building types. Third, the success or failure of thermal comfort efforts is usually directly related to the success or failure of a building's HVAC systems. Last, maintaining appropriate thermal conditions through HVAC system operation is a major driver of building energy consumption.

As our building is located in Aurangabad, Maharashtra the co-ordinates for Aurangabad are N 19° 53' 47" – E 75° 23' 54". The city is surrounded by hills on all directions. Aurangabad features a semiarid climate under the Koppen climate classification.

2.2 Building Orientation

Form and orientation constitute two of the most important passive design strategies for reducing energy consumption and improving thermal comfort for occupants of a building. It affects the amount of sun falling on surfaces, day lighting, and direction of winds. Towards net zero energy goals, form and orientation have a significant impact on building's energy efficiency.

NORTH – Front Facing glass wall	EAST & WEST – Concrete side walls
SOUTH – Backside concrete wall	ROOF Orientation – Sloped

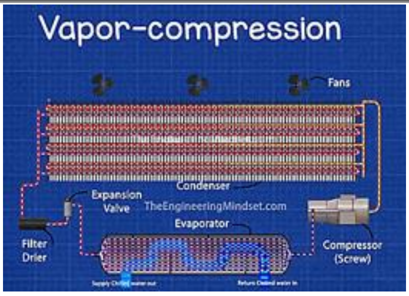
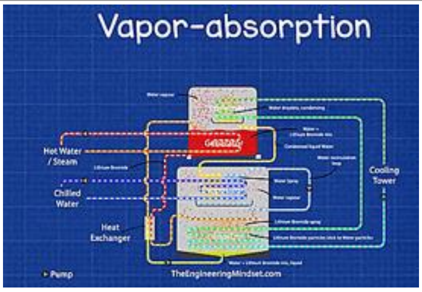
2.3 Heat Load

- ***Load Estimation:*** The importance of accurate load calculations for the air conditioning designs can never be over emphasized. In fact it the part which requires more precise work, and the designers does it very skillfully. The estimation of cooling load during summer and heating load during winter is the sole part performed by the designers.
- ***Solar Heat Gain Through Glass:*** Glass, which is transparent, it allows the sun-rays to pass through it. Which causes heat dissipation inside the room. The amount of heat dissipated depends upon the area of the glass exposed to sun,
- ***Solar Heat Gain Through Walls and Roofs****:* Heat gain through exterior construction (walls & roof) is normally calculated in the greatest heat flow. It is caused by the solar heat being absorbed by the exterior surfaces and by the temperature difference between the outdoor and indoor air. Q= U*A*ETD where Q is heat flow rate in (KJ/Sec)
- ***Transmission Heat Gain Through Glass:*** This is heat gain that is obtained due to the difference in outside and inside conditions. The amount of heat that is transmitted through the glass into the room depends upon the glass area, temperature difference and transmission coefficient of glass.
- ***Lighting****:* Lights generate sensible heat by the conversion of the electrical power input into light and heat. The heat is dissipated by radiation to the surrounding surfaces, by conduction into the adjacent materials and by convection to the surrounding air.
- ***Appliances****:* Most applications contribute both sensible and latent heat to a space. Electric appliances contribute latent heat, only by virtue of the function they perform that is, drying, cooking, etc., whereas gas burning appliances, contribute additional moisture as a product of combustion.
- ***Determination of U factor:*** The conduction heat transfer through the walls or roof will depend on its thickness and the thermal conductivity of the material used. In addition, there will be convection and radiation from both the outside and inside surfaces

3. System Selection

3.1 Basic Choice

A chiller is a machine that removes heat from a liquid via a vapor-compression or absorption refrigeration cycle. The first criteria of choice are whether to choose Compression or absorption technique for chillers.

Vapour Compression	Vapour absorption
This system employs an electrically driven mechanical compressor which forces the refrigerant around the system	**This system uses a heat source such as steam or hot water to move the refrigerant around the system.**
	
Electric motor driven chillers are rated in kilowatts of electricity per ton cooling.	Absorption chillers are rated in fuel consumption per ton cooling

Using the reference:

	Compression Chillers			Absorption Chillers	
Parameter	Reciprocating	Screw	Centrifugal	One-stage	Two-stage
Primary energy	Electric motor	Electric motor	Electric motor	Hot water, 149 to 176°F	Steam or fire, temperature > 338°F
Fluids	R-134a, HCFC, NH_3	R-134a, HCFC, NH_3	R-134a, HCFC, NH_3	H_2O with LiBr, NH_3 with H_2O	H_2O with LiBr, NH_3 with H_2O
COP	4 to 6	4 to 6	>7.0	0.6 to 0.75	1.2

The **Compression Chiller** is shortlisted, on basis of COP and Fluid range it provides with good refrigerants.

3.2 Compressor Chiller Choice

Furthermore, the compression Chillers are sub-divided by parameters such as the compressor types (Screw, centrifugal, or scroll compressors), fluids used (air-cooled or water-cooled), and the refrigerants one could employ or implement.

To choose the fluid we use the following tables from different standards and ASHRAE tables.

Chilled water side components are largely the same in air-cooled and water-cooled systems (differences may be number of chillers, pumps, piping configuration on primary)

3.3 EXPERIMENTAL RESULTS

Sr. No.	Floor	Zones/Area Served	OLD TR	NEW TR
1	Ground	Lounge Area 1	6.50	6.22
2		Lounge Area 2	5.60	5.30
3		Reception	21.01	20.23
4	First 1st	Cafeteria	22.39	21.61
5	Ground and First	Entrance Foyer	10.90	10.62
6	Second 2nd	Office 1	20.77	19.47
7		Office 2	20.27	18.99
8	Third 3rd	Office 1	13.61	13.61
9		Office 2	13.31	12.81
10	Fourth 4th	Office 1	16.70	15.59
11		Office 2	16.39	15.33
12	Fifth 5th	Office 1	9.91	9.52
13		Office 2	9.76	9.39
14	Sixth 6th	Office 1	13.32	12.29
15		Office 2	13.05	12.07
Total			213	203

3.4 Actual Table of Life Cost analysis

Using Tables of ASHRAE and other reference. Assuming to be screw type compressor driven.

Parameter	Water cooled	Air cooled
Chiller Energy use (Full Load) (kW/ton) ^2	0.6	1.225
Project Full Load (kW^2)	0.6*218=130.8	1.225*218=267.05
Chiller Energy use (IPLV) (kW/ton) ^2	0.4	0.941
Project IPLV (kW^2)	0.4*218=87.2	0.941*218=205.138
Space requirement	Chilled Water Plant Room At Utility Room In Basement, Cooling Tower At Roof Level Or In Open Yard	Chiller at Roof with Chilled water (CHW) systems
Redundancy (form of resilience that ensures system availability in the event of component failure)	Very Good	Very Good
System Life	18-22 years	13-16 years
System Capacity (Ton)	500	500
Average Capacity (Ton)	290	290
Condenser pump (HP)	30 HP or 22.37 kW	-
Condenser Pump Energy Usage (kW)		-

Filtration System Pump (HP)	3 HP or 2.23 kW	-
Filtration Pump Energy Usage		-
Cooling tower Fan (HP)	30 HP or 22.37 kW	-
Fan Energy Usage (kW)	5	-
Hours of Operation [Integrated Part Load value]	4380 hours or 182.5 days or half a year (assumed 12 hours a day operation)	4380 hours or 182.5 days or half a year (assumed 12 hours a day operation)
Peak Energy Demand (kW)	345	628
Chiller Energy Usage (kW)	116	273
Power Consumption per hour (KWh)	58	145
Daily energy consumption in kW (operating hours 12)	964.44	1740
Annual Energy Consumption (kWh for 4380 Hours of CT (cooling tower) operation)	**352020.6**	**635100**
Annual Energy Cost (365 days per annum & Rs.8/unit cost) or Energy charge in LACS	**₹ 28.16**	**₹ 50.81**
A water-cooled chiller thus, uses nearly half the amount of energy than the air-cooled system even after amounting the energy consumption of fan and pumps. The annual energy cost for water cooled chillers is also lesser than the air-cooled counter part		
Water costs		
Water consumption assumed	1400 LPH	-
Annual Water cost (4 COC [cycles of concentration]) in LACS	₹ 7.03	-
Annual Sewage Cost (4 COC) in LACS	₹ 3.22	-
Annual Chemical Treatment cost in LACS	₹ 2.96	-
Total Annual Water related cost (in LACS)	**₹ 13.21**	**-**
A water-cooled chiller thus, requires additional costs for it water and circulation units.		
Maintenance cost		
Maintenance cost of cooling tower/year in LACS	₹ 1.35	-
Total operating cost per year in LACS	**₹ 42.72**	**₹ 50.81**
Lifecycle cost for 15 years in LACS	**₹ 640.81**	**₹ 762.12**
Thus, water cooled chillers lead to saving of almost 8.2 lakhs every year which is nearly 16% savings on annual operating costs		
LIFE COST, assuming a 500-ton system		
Capital cost of chiller in LACS	₹ 46.25	₹ 30.00
Condenser water pump in LACS	₹ 22.00	-
Condenser water piping in LACS	₹ 18.00	-
Installation cost in LACS	₹ 50.00	₹ 75.00
Total One-time cost in LACS	**₹ 136.25**	**₹ 105.00**
Complete Cost		
Total cost (in LACS)	**₹ 178.97**	**₹**

		155.81
Additional cost or difference (in LACS)	**₹ 23.16**	**-**
Even though the cost of water-cooled chillers exceeds, in total, in the long run, much more efficiency is obtained along with quite less maintenance		

The above conclusions are self-explanatory and lay foundation regarding the firmness of our choice towards water-cooled chillers.

4. CONCLUSION

A commercial building can be made energy-efficient by using an appropriate system for heating and cooling when paired up with a traditional HVAC system.The very first procedure of our project is the study of location, surrounding and its orientation according to sun-path , due to this we are able to reduce the solar heat gain which directly affects the heat load calculation.

For material selection we compared different materials by using trial and error approach so we concluded that, if we select proper material there will be reduce in heat load capacity, by using trial and error method we got difference of 10 TR in total heat load. In order to make this building energy efficient the chiller system and its type selection plays a important role. According to the total tonnage of building, capacity of system is decided after comparison of various energy efficient system we decide that Air-Cooled type of chiller system will be best suited for our project.

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