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Auditing on Energy Consumption and Thermal Load Calculation of a Building and Optimized Duct Design to Attain Uniform Cooling

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Abstract: ***Heating ventilation and air conditioning (hvac) main goal is to provide thermal comfort and acceptable air quality inside rooms. In large buildings huge amount of energy is wasted due to its weak thermal performance and moderate hvac system. Heat load calculation is a basic step to be considered during designing a hvac system for a building. During heat load calculation weather conditions and occupants of a room are to be considered. Auditing is done on power consumption of a building when two different hvac system are used for distribution of conditioned air and also design a duct. In these paper fan coil unit and air handling unit are compared with each other and investigated how much power is consumed while using each system separately. When fan coil unit is connected with a duct the power consumed by a building is 32.75 kw/hr and when air handling unit is connected with a duct the power consumed is 41 kw/hr. Thus fan coil unit is preferred over air handling unit because it consumes less power and according to that duct is designed using designing tool to attain uniform cooling***.

Keywords: heating ventilation and air conditioning, power consumption, air handling unit, fan coil unit.

I. INTRODUCTION

Heating ventilation and air conditioning devices is used to maintain temperature, quality of air and humidity of buildings according to Conditions. To attain this devices need to transfer heat and moisture in and out of the air as Well to check level of air pollutants, Heating ventilation and air-conditioning apparatus are used to offer cooling or heating for a building such as residential, commercial and industrial buildings.

Heating ventilation and air conditioning Systems are used to provide fresh air inside rooms. There are many hvac systems are used to circulate fresh air and they are designed according

to thermal comfort. Ventilation Systems supply air to the space and Remove polluted air from it. Cooling is required to bring the temperature down in spaces where heat gains have arisen from people, apparatus or the sun and are causing worry from it. Cooling is required to bring the temperature down in spaces where heat gains have arisen from people, apparatus or the sun and are causing worry.Heating ventilation and air conditioning Systems are used to provide fresh air inside rooms. There are many hvac systems are used to circulate fresh air and they are designed according to thermal comfort. Ventilation Systems supply air to the space and Remove polluted air from it. Cooling is required to bring the temperature down in spaces where heat gains have arisen from people, apparatus or the sun and are causing worry.

Hani h.sail [1] has investigated thermal load of a building which is divided into three different zones then hand calculation and hap software calculations are compared with each other founds that two results are little differ from each other due to thermal resistance of wall, roof and windows. rutvik lathia et.al [2] has studied the energy waste of an auditorium by calculating cooling load by dividing into different parts such as heat gain through walls, peoples, windows, roof and from the results shows that by reducing the trunk for duct sizes it helps to decrease the energy waste and gives proper air flow. Mohamed elhelw [3] has analyzed energy running for a hvac system by comparing bin method with cltd, scl, and clf methods by dividing the day into occupied and unoccupied stages and the reports suggests that modified bin method is useful because it saves 45.57% compare to other methods which saves 33.42%. ali Alajm et.al [4] has investigated the energy audit in two levels and the reports shows that 52% of energy can be saved when all the damages are repaired, all the doors should be closed and roof columns should be isolated. luli et.al [5] and awanish kumar et.al [6] conducted energy audit of a building by Selecting light, equipment and shows that the energy can be saved by taking some effective measures. alessandra de angelis et.al [7] has investigated to maintain internal comfort in industrial building by considering internal gains, thermal load, and air flow and results are related in relations of energy savings as well as thermal comfort. pil brix purup et.al [8] has done simulation of different types of hvac system by comparing new procedure and standard calculation reports suggests that to select analytical procedure reasonably by selecting linear interpolation procedure.

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fujen wang et .al [9] has investigated size of chillers to be selected and to know size of chiller energy modeling tool is used. matteo dangellini et.al [10] has investigated the Energy audit of an industrial site by considering thermal load. Miklos Kassai et.al [11] has studied the Prediction of the HVAC energy demand and consumption of a single family house with different calculation methods. Mahmoud kassas et.al [12] has done a modeling and simulation for a residential building here the results which are obtained by actual outdoor temperature is compared with average outdoor temperature conditions of the similar day. The results which are compared are mostly equal with each other and used for to assess energy consumption.

Michel Noussana et.al [13] has studied the performance of air handling unit and report shows that power which is consumed by the usage of air handling unit is same throughout the year. By cooling and heating usage it gives different variations by using air handling unit. Zheng Yang et.al [14] has investigated that how occupancy can be effects hvac system. Occupancy plays one of the most important factor in efficiency of hvac system. Here it is investigated that how and when heating and cooling can be effected by hvac system. These can be done by considering three outlooks of occupancy they are transitions, variations, and heterogeneity

Jia jun et.al [15] has studied the energy consumption of a typical office building here engaged the input and output survey to study its construction and operating energy consumption in detail. Reports of the building concludes that structure adds almost 80% of the construction energy consumption while the energy-efficient equipment and materials add a comparatively small percentage.

Based on the review proper energy audit should be done to minimize wastage of energy. In these study air handling unit and fan coil unit power consumption is compared with each other and selected a machine which consumes less power according to that a duct is designed to attain uniform cooling.

II. OVERVIEW OF AUDITED BUILDING

A. Location details

1. The location of site is at Hyderabad.
2. All four sides of the building are open to sun.
3. The front face of the building is towards north-west direction.
4. The office construction building has ground floor, first floor, second floor and roof.

Total area of ground floor is considered as non ac and in first floor and second floor toilets and corridors are considered as non ac. Hvac system depends on many factors for designing one of the most important factor to be considered is climatic conditions. In India mostly climatic condition is dry so here climate is chosen as summer for designing condition.

Table- I: Design conditions of climate

Climate conditions		
Conditions	***Ambient***	***Rooms***
DBT	106	76
WBT	78	63.5
RH	28	50

B. Building Plan

The location and plan of a building plays an important role for designing optimal duct to provide uniform cooling for a building.

C. Layouts

Ground floor area is used for parking's. First floor, second floor and of the building these are considered as ac zone, duct and pipe sizing is designed to these zones and at the roof chillers are placed.

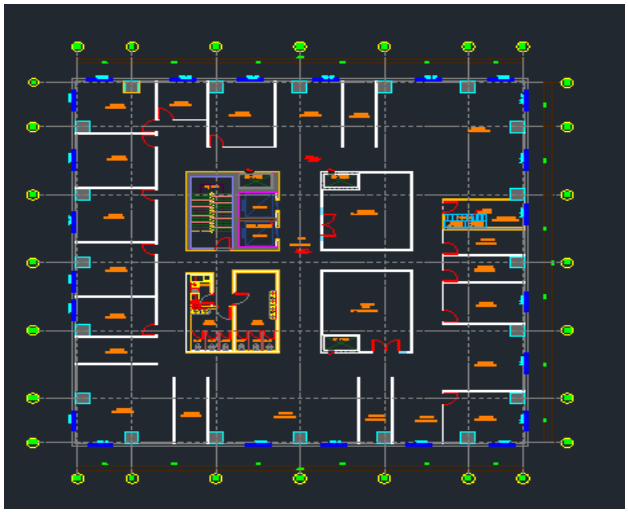

Fig 1. First floor drawing

Fig 2. Second floor drawing

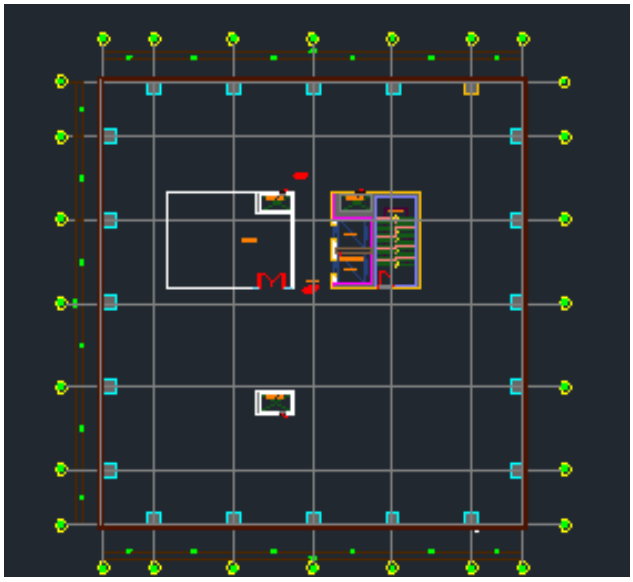

Fig 3. Roof drawing

D. Heat Load Calculation

First in designing hvac system is to select indoor and outdoor conditions according to climate. Heating load occurs due to transmission, ventilation and infiltration. In this paper two machines are selected i.e. fan coil unit and air handling unit and power consumption is compared with each other. Fcu has the capacity of 5TR and ahu has the capacity of 100TR.

III. METHODS OF HVAC SYSTEMS

A. Fan Coil Unit

Fig 4. Fan coil unit

Fan coil unit is also known as fcu. It is device which consists of cooling and heating coils and fans. Fcu is a centrifugal kind it while starting it uses electric motor with a fan which is attached to its shaft. Fcu can be in both ways it may be ducted (or) it may be without ducted. The range of fcu is about 100-2000 cfm. Fcu is connected with a chilled water pipe which helps in cooling. The air passes through the coils and provide the required temperature these are placed in false ceiling as per spaces and supply air by diffusers.

B. Air Handling Unit

Fig 5.Air handling unit

Air handling unit is known as ahu. Ahu is a device which is used to circulate conditioned air through ducts. AHU contains of large metal box with a blower, dampers, filters and cooling and heating elements. Ahu is used in huge places and is bigger to a fan coil system.

IV. PROCEDURE OF DESIGNING

A. Duct Design

1. Before designing hvac system for a building air flow required for individual rooms and tonnage of room should be calculated. Indoor and outdoor conditions should be known. According to summer and winter heating (or) cooling capacity will be different. For designing branch duct there are two different ways such as reduce trunk method and reduce plenum method.
2. Designer should know about the ambient and room conditions of a building and should verify local customs, material availability before starting designing. Shape of ducts should be selected during designing there are three type's pf ducts can be considered but mostly rectangular duct is selected Because of it required less height and it is easy to fabricate.
3. The duct will be divided in many branches according to its air flow changes in other rooms. Size of branch duct should be calculated according to space available for installing. Supply air flow should be adjusted according to required air. Total pressure loss of the duct system should be calculated.
4. The supply flow rates of volume is adjusted according heat gain from outlet Diffusers should be

placed at center of room because it provides uniform conditioned air to the whole room.

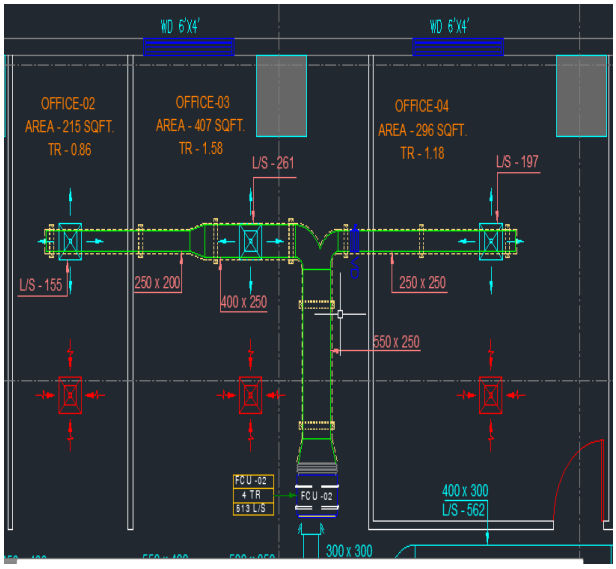

Fig 6. Duct designing

B. Pipe Sizing

Pipe sizing is done in hvac system it is a closed type. The system are consists of different components.

- A supply system
- A return system

The closed system is not effected by air but open system is effected by atmosphere air. The calculation

Of pipe sizing and thickness of a pipe use Hydraulic Design & Pressure Design. For HVAC Systems carrying lower or medium pressures then hydraulic design can be is used. If it carries higher pressures it requires more thickness so here Pressure design can be used based on ASME codes.

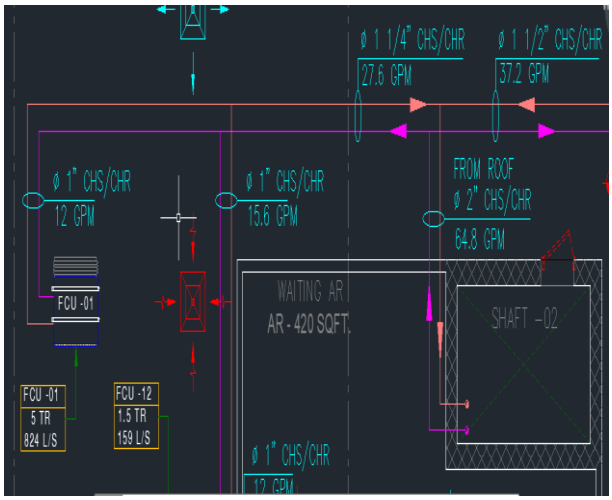

Fig 7. Pipe designing

Figure 6 and 7 shows the designing of duct and pipe by selecting fan coil unit and duct designing of 1st and 2nd floor complete drawing is done in cad designing tool.

V. RESULTS AND DISCUSSION

A. Fan Coil Unit

In case 1 fan coil unit is selected to supply conditioned air through ducts Power consumption is calculated by considering air flow (l/s) of rooms.

Table-II: Calculations of 1st floor

Sl.no	Area reference	Tag no.	Tonnage TR	Air flow (L/S)	Kw
1	Office-1	fcu-1	5	824	1.1
2	Office-2	fcu-2	4	613	1.1
3	Office-3				
4	Office-4				
5	Office-5	fcu-3	4.5	821	1.1
6	Office-6				
7	Office-7				
8	Office-8	fcu-4	4.5	866	1.1
9	Office-9				
10	Office-10				
11	Office-11	fcu-5	4	722	1.1
12	Office-12				
13	Office-13				
14	Office-14	fcu-7	4	719	1.1
15	Office-15				
16	Office-16				
17	Office-17	fcu-8	4	711	1.1
18	Office-18				
19	Office-21				
20	Office-19	fcu-9	2.5	605	1.1
21	Data Room				
22	Office-20	fcu-6	4	619	1.1
23	Conference Room	fcu-10	4	464	1.1
24	Waiting Area	fcu-11	2.5	312	0.082
25	Lobby-1	fcu-12	1.5	159	1.1
25	Lobby-2	fcu-13	4	644	1.1
25	Lobby-3	fcu-14	3	479	0.10
	Total Floor		**51.5**	**8558**	**11**

Table-III: Calculations of 2nd floor

Sl. no	Area reference	Tag no.	Tonnage tr	Air flow (l/s)	Kw
1	Office-1	fcu-1	6.5	1380	2.2
2	Office-2	fcu-2	6	1354	2.2
3	Office-3				
4	Office-4				
5	Office-5	fcu-3	6	1420	1.5
6	Office-6				
7	Office-7				
8	Office-8	fcu-4	6.5	1520	2.2
9	Office-9				
10	Office-10				
11	Office-11	fcu-5	7	1611	2.2
12	Office-12				
13	Office-13				

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14	Office-14	fcu-7	6	1384	2.2
15	Office-15				
16	Office-16				
17	Office-17	fcu-8	6	1368	1.5
18	Office-18				
19	Office-21				
20	Office-19	fcu-9	3.5	883	1.1
21	Data Room				
22	Office-20	fcu-6	6	1376	1.5
23	Conference Room	fcu-10	5	800	1.5
24	Waiting Area	fcu-11	3.5	627	0.75
25	Lobby-1	fcu-12	2.5	460	0.75
25	Lobby-2	fcu-13	5.5	1144	1.5
25	Lobby-3	fcu-14	4.5	1040	1.5
	Total Floor		**74.5**	**16367**	**21.75**

B. Energy Consumption Details of Fcu

Table 2 describes that 51.5 tr and 8558 l/s flow is required for cooling of 1st floor and 11 kw power is consumed. Table 3 describes that 74.5 tr and 16367 l/s air flow is required for cooling of 2nd floor and 21.75 kw power is consumed.

C. Air Handling Unit

In case 2 air handling unit is selected for supplying conditioned air through ducts. Power consumption of a building is calculated

Table-IV: Calculations of 1st floor

Sl. no	Area reference	Tag no.	Tonnage tr	Air flow (l/s)	Kw
1	Office-1	Ahu-1	24.02	4177	7.5
2	Office-2				
3	Office-3				
4	Office-14				
5	Office-15				
6	Office-16				
7	Office-17				
8	Office-18				
9	Office-19				
10	Office-21				
11	Data room				
12	Conference hall				
13	Waiting room				
14	Office-14				

Table-V: Calculations of 1st floor

Sl. no	Area reference	Tag no.	Tonnage tr	Air flow (l/s)	Kw
1	Office-4	Ahu-2	24.85	4676	7.5
2	Office-5				
3	Office-6				
4	Office-7				
5	Office-8				
6	Office-9				
7	Office-10				
8	Office-11				
9	Office-12				
10	Office-13				
11	Office-20				
13	Lobby-1				
14	Lobby-2				
15	Lobby-3				

Table-VI: Calculations of 2nd floor

Sl. no	Area reference	Tag no.	Tonnage Tr	Air flow (l/s)	Kw
1	Office-1	Ahu-1	33.34	7357	11
2	Office-2				
3	Office-3				
4	Office-14				
5	Office-15				
6	Office-16				
8	Office-17				
8	Office-18				
9	Office-19				
10	Office-21				
11	Data room				
12	Conference hall				
13	Waiting room				
14	Office-14				

Table-VII: Calculations of 2nd floor

Sl. no	Area reference	Tag no.	Tonnage tr	Air flow (l/s)	Kw
1	Office-4	Ahu-2	42.66	9001	15
2	Office-5				
4	Office-6				
5	Office-7				
6	Office-8				
7	Office-9				
8	Office-10				
9	Office-11				
10	Office-12				
11	Office-13				
12	Office-20				
13	Lobby-1				
14	Lobby-2				
15	Lobby-3				

D. Energy Consumption Details of Ahu

Table 4 and 5 describes that two air handling unit is used for 1st floor and 48.87 tr and 8853 l/s air flow is required for cooling of 1st floor and 15 kw power is consumed. Table 6 and 7 describes that 76 tr and 16358 l/s air flow is required for cooling of 2nd floor and 26 kw power is consumed. After referring mc Quay air conditioning product catalogue power consumption values are taken according to air flow of rooms. Here case I and case 2 details are listed below i.e.

in case 1 fcu is connected with a duct and power consumed per hour is shown and in case 2 ahu is connected with a duct and power consumed per hour is shown in tables:

Table-VIII: Power Consumed By Selecting Fan Coil Unit

Tag	L/s	Kw
First floor	4177	11
Second floor	4676	21.75
Total	8853	32.75 kw

Table-IX: Power Consumed By Selecting Air Handling Unit

Tag	L/s	Kw
First floor	8558	15
Second floor	16359	26
Total	24917	41kw

Table-X: Details of Chillers

Area reference	Tag no.	Tonnage tr	Status
Roof	Chiller 1	60	On duty
	Chiller-2	80	On duty
	Chiller-3	80	Standby

Note: total tonnage obtained by an office building is 126TR. So on the roof 140TR chiller should be placed.

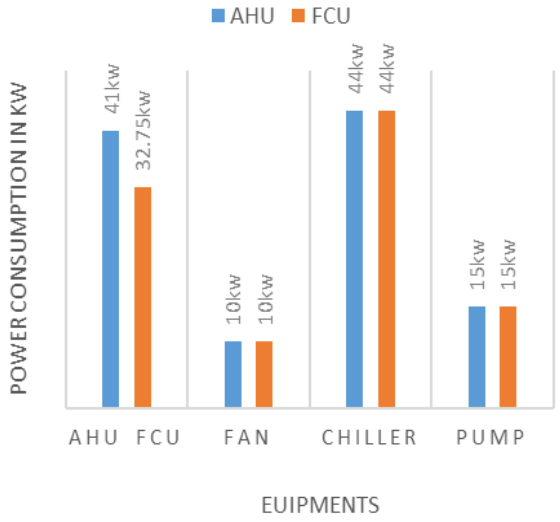

Fig 8. Variation of power consumption

From the above chart one can see that when air handling unit is consider its power consumption is higher and when fan coil unit is consider for supplying conditioned air its power consumed is less. Other equipment's which is used are fan, chiller, and pump its power consumption is same in both air handling unit and fan coil unit. For fan power consumed is 10kw, for chiller power consumed is 44kw, and for pump power consumed is 15kw.so better to consider fan coil unit because it consumes less power and for duct designing its cost and maintenance is also low when compared to air handling unit.

VI. CONCLUSION

Investigation is done on energy consumption of a building and heat load calculation is performed by considering weather conditions and occupants of rooms. Air handling unit and fan coil unit are compared with each other and the energy saved by using fan coil unit is higher than air handling unit.

The report refers the significance of proper duct design of a Centralized Air Conditioning System for the Corporate Office building. The paper concludes that:

- Heat load calculation is performed for every office room separately to get the required air flow of a room and attained uniform cooling.
- Optimized Duct sizing and pipe sizing design is done by using cad designing tool.
- After comparing the power consumption usage by using air handling unit and fan coil unit the results we obtained while using air handling unit the power consumed by an office building is 41kw/hr. and while using fan coil unit the power consumed by an office building is 32.75kw/hr.

Thus the report identifies the requirements of project, so fan coil unit is used for designing a duct using designing tool to attain uniform cooling because its power consumption is less compare to air handling unit.

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