Design of an Air Distribution System for a Multi-Story Office Building

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***Abstract*— Earlier the use of air conditioning for comfort purpose was considered to be expensive, but now-a-day, it has been a necessity for all human beings. Window air conditioners, split air conditioners are used in small buildings, offices etc. But, when the cooling load required is very high such as big buildings, multiplex, multi-story buildings, hospitals etc. centralized unit (central air conditioners) used. The central AC's systems are installed away from building called central plant where water or air is to be cooled. This cooled air not directly supplied to the building rooms. When the cooled air cannot be supplied directly from the air conditioning equipment to the space to be cooled, then the ducts are provided. The duct systems carry the cooled air from the air conditioning equipment for the proper distribution to rooms and also carry the return air from the room back to the air conditioning equipment for recirculation. When ducts are not properly designed, then it will lead to problem such as frictional loss, higher installation cost, increased noise and power consumption, uneven cooling in the cooling space. For minimizing this problem, a proper design of duct is needed. Equal friction method is used to design the duct, which is simple method as compared with the other design methods. These work gives the combination of theoretical and software tool to provide a comparative analysis of the duct size. It also gives the comparison of pressure drop in rectangular duct and circular duct.**

Keywords – Equal friction method, friction loss, duct sizing

I. INTRODUCTION

There are many types of air conditioning system like window air conditioners, split air conditioners etc. but these AC's system are used in small room or office where cooling load required is low. When the cooling load required is very high like multiplex building, hospital etc. central AC's system are used. In central AC's system the cooled air is directly not distributed to the rooms. The cooled air from the air conditioning equipment must be properly distributed to rooms or spaces to be cold in order to provide comfort condition. When the cooled air cannot be supplied directly from the air conditioning equipment to the spaces to be cooled, then the ducts are installed. The duct systems convey the cold air from the air conditioning equipment to the proper air distribution point and also carry the return air from the room back to the air conditioning equipment for reconditioning and recirculation. In order to achieve required cooling load, proper method is required. Proper air distribution is achieved with proper duct design which leads minimum losses in the system, suitable selection of fan with high efficiency, optimum air velocity in duct, inlet and outlet of fan. Today some software's are available to estimate cooling load, to design the duct. CFD and ANSYS software can be used for analysis of air motion and also can predict fluid characteristics and pressure differentials to a very low level that are experimentally impossible during experimentation. Analysis of air flow in duct with static pressure and velocity pressure is made easier and faster in fluent software. Various researchers are having there contribution on the topic. Design for high velocity duct system is done by determining the pressure losses, calculating the noise level, determining the out of balance pressures &optimizing this against the total cost of the system [1]. VAV optimization procedure was applied to the three VAV duct systems to investigate the impact of varying airflow rates on the sizing of duct systems. For comparison purposes, other duct design methods, such as, equal friction, static regain, and the Method, were also applied to the duct systems [2]. Design optimization of industrial ducts is achieved with CFD. The CFD analysis has offered a comprehensive range of output including velocity distribution, pressure profiles and turbulence levels. [3]

Air may distribute in the room by air handling unit (AHU) or fan coil unit (FCU). The use of AHU and FCU is depends upon the cooling load required. In this work we decide that the FCU is used where cooling load required up to 5 tons and to use AHU above 5 tons. As we know that for FCU there is no duct is required. For calculating duct size first calculate the dehumidified air and there after duct dimension has to be calculated.

II. THEORY

The conditioned air (cooled or heated) from the air conditioning equipment must be properly distributed to rooms or spaces to be conditioned in order to provide comfort conditions. When the conditioned air cannot be supplied directly from the air conditioning equipment to the spaces to be conditioned, then the ducts are installed. The duct systems convey the conditioned air from air conditioning equipment to proper air distribution points or air supply outlets in the room and carry there turn air from the room back to the air conditioning equipment for reconditioning and recirculation. The conditioned air (cooled or heated) from the air conditioning equipment must be properly distributed to rooms or spaces to be conditioned in order to provide comfort conditions. It may be noted that duct system for proper distribution of conditioned air cost nearly 20 to 30 % of total cost of equipment required. Duct material is usually made from galvanized iron sheet metal, Al sheet metal or black steel. But now a day, the use of non-metal ducts has increased. There sin bonded glass fiber ducts are used because they are quite strong and easy to manufacture according to desired shape and size. They are used in low velocity applications less than 600m/min and for static pressures below 5mm of water gauge. Iz of static pressure, dynamic pressure &total pressure in duct is important. The pressure in duct is usually expressed in mm of water. The pressure is lost due to friction between the moving particles of fluid (i.e. air) and interior surface of duct. When the pressure loss occurs in a straight duct, it is usually termed as friction loss. The pressure is also lost dynamically at the changes of direction such as in bends, elbows etc. and the changes of cross section of duct; this type of pressure loss is usually termed as dynamic loss.

A. *General rules for duct design*

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

III. METHOD OF DUCT DESIGN

1) Equal friction method
2) Velocity reduction method
3) Static reduction method

In Equal Friction Method the frictional pressure dropper unit length of the duct is maintained constant throughout the duct system. Due to its simplicity, this method is used in the thesis to design the duct.

A. *Calculation for duct size/dimension*

1. First find out the air flow rate i.e. dehumidified air and cooling load.
2. Based on cooling load select AHU or FCU which is to be installed. For FCU there is no need to duct system. If AHU then calculate the duct dimension.
3. Select initial velocity (from CarrierHandbook)
4. Duct area = $\frac{\text{air flow rate}}{\text{velocity}}$
5. Based on duct area select duct size/dimension (From Carrier Handbook), also Equivalent duct diameter.

Then initial friction rate is determined by using friction chart, on the basis of air quantity and equivalent duct diameter or velocity of air.

B. *Calculation for dehumidified air quantity*

Room Rise = (1 – by pass factor)*(Room temp - ADP)

Dehumidified Air = RSH / (20.44 * dehumidified rise)

Where,

ADP = apparatus due point

RSH = room sensible heat

IV. RESULT

To design the duct for TIIR building calculation of cooling load and air flow rate is done. By taking some suitable velocity (from Table 1), considering noise factor main duct area is calculated. Based on these duct area, the duct size is find out for the rectangular duct as well as round duct. The cooling load, dehumidified air flow, duct size for all room is given in below:

TABLE-I COOLING LOAD AND DEHUMIDIFIED AIR FOR RESPECTIVE ROOM

S.N.	Room Name	Cooling Load (tons)	Dehumidified Air Flow (m^3/min)	Type of unit used (FCU/AHU)
1	120 seat Lecture Room 1	12.39	113	AHU
2	Direct TIIR	2.11	21	FCU
3	Admin Office	3.03	32	FCU
4	Placement Office	2.27	25	FCU
5	IPR Office	2.93	32	FCU
6	120 seat Lecture Room 2	12.39	113	AHU
7	Office Room	6.96	69	AHU
8	Meeting Room	6.77	66	AHU
9	Library	4.53	43	FCU
10	Dining	5.85	63	AHU
11	Alumini Relation	4.68	49	FCU
12	Alumini Visitor	7.55	74	AHU
13	Interview Room 1	2.95	31	FCU
14	Interview Room 2	4.69	44	FCU
15	Seminar Room	7.16	69	AHU
16	Central Design Office	24.69	247	AHU
17	Auditorium	50.14	422	AHU
18	Library Facility	5.57	48	AHU

Ansys 13.0 is used to observe the friction loss in rectangular duct as well as circular duct. For analysis we select only small portion of duct (3 m), also it can be applied

for all ducting in a building. It can be easily noticed that the friction loss in rectangular duct is greater than the circular duct.

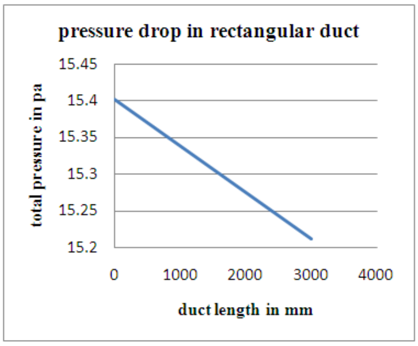

Figure-1 Pressure Variation along with Length in Rectangular Duct

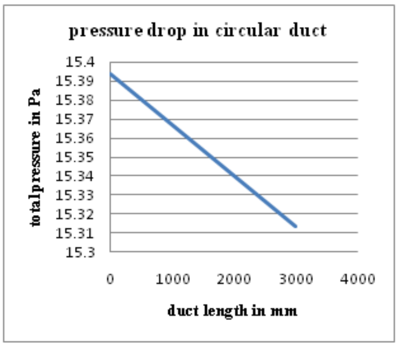

Figure-2 Pressure Variation along with Length in Circular Duct

V. CONCLUSION

1) The duct design for TIIR building is done, by using equal friction method. All values are comparable with the value find by duct software called ductulator.
2) The calculated value of frictional is less or near as calculated by software. Due to less value of friction drop, duct diameter is increased but loss in total pressure (i.e. static pressure, velocity pressure) can be avoided. Also use of damper may be decreased.
3) Ansys 13.0 software is used to analyze the pressure loss in circular and rectangular duct. After analysis we conclude that the circular duct has minimum friction loss, so it is better shape for ducting.
4) The circular duct can carry more air in less space, because of that, less duct material, less duct surface friction and less insulation is required.

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TABLE – II DUCT SIZE COMPARISON BETWEEN HAND CALCULATION AND DUCTULATOR SOFTWARE

S.N.	Room	Hand calculation			Using software (ductulator)		
		Rectangular duct (mm)	***Round duct (mm)***	***Friction drop***	***Rectangular duct (mm)***	***Round duct (mm)***	***Friction drop***
1	120 seat lecture room 1	650 * 600	680	0.0445	700 * 550	675	0.0487
2	Direct TIIR	FCU is used, no ducting is required					
3	Admin Office	FCU is used, no ducting is required					
4	Placement office	FCU is used, no ducting is required					
5	IPR Office	FCU is used, no ducting is required					
6	120 seat lecture room 2	650 * 600	680	0.0445	700 * 550	675	0.0487
7	Office Room	600 * 400	530	0.0600	550 * 450	525	0.0655
8	Meeting Room	500 * 450	520	0.0630	500 * 450	520	0.0674
9	Library	FCU is used, no ducting is required					
10	Dining	550 * 400	510	0.0663	500 * 450	500	0.0694
11	Alumini Relation	FCU is used, no ducting is required					
12	Alumini Visitor	550 * 500	570	0.0603	550 * 450	550	0.0627
13	Interview Room 1	FCU is used, no ducting is required					
14	Interview Room 2	FCU is used, no ducting is required					
15	Seminar Room	600 * 400	530	0.0623	550 * 450	530	0.0655
16	Central Design Office	950 * 900	1000	0.0295	1000 * 850	1000	0.0303
17	Auditorium	1200*1200	1300	0.0195	1250*1150	1300	0.0220
18	Library Facility	450 * 400	460	0.0792	450 * 400	460	0.0822